COMPENDIUM

World Heritage Irrigation Structures

(2014–2022)

INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE

ICID•CIID

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International Commission on Irrigation and Drainage (ICID)

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International Commission on Irrigation and Drainage (ICID), established in 1950 is the leading scientific, technical, and not-for-profit Non-Governmental Organization (NGO). ICID, through its network of professionals spread across more than a hundred countries, has facilitated sharing of experiences and transfer of water management technology for over half-a-century. ICID supports capacity development, stimulates research and innovation, and strives to promote policies and programs to enhance sustainable development of irrigated agriculture through a comprehensive water management framework. The mission of ICID is to stimulate and promote the development and application of the arts, sciences and techniques of engineering, agriculture, economics, ecological and social sciences in managing water and land resources for irrigation, drainage, flood management, for achieving sustainable agriculture water management.

ISBN: 978-81-89610-42-5

International Commission on Irrigation and Drainage (ICID)

October 2023

Layout: ICID Central Office, New Delhi, India

Online Register URL: https://icid-ciid.org/award/his/44

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FOREWORD

Sustainability is an intrinsic characteristic of Heritage. Mainstreaming science heritage in our school education, policy and engineering designs, and community governance could be the best multi-disciplinary solution for our prevailing sustainability challenges. Heritage is not for the sake of heritage; it has important sustainability lessons for our future survival. It is generally said that we are the product of our heritage as it manifests itself in our very sense of being or identity, our aspirations, our designs, our creations, our possessions, our worldviews, and the list can easily be endless. We are basically living our heritage. However, most of us like to think that heritage is something that was in the past or it was some part of our distant history, which seems a very narrow conceptualization of the whole idea of heritage. In temporal terms, heritage is not a discrete concept, but a continuum of intellect-driven human evolution. It has no past, no present and hence no future. Whatever we create today for future is an incremental addition to what is there already, though maybe not in a very physically spatial sense, but definitely in terms of our thought processes. And, it only makes sense that it is simply impossible to completely drain all our accumulated thoughts or learnings and then let something new fill in the vacuum. Without going into any dictionary-type definition of heritage, let's try to look at it as an intangible force that guides us in future. This characterization holds true for all our aspects – physical and non-physical. So, when we talk about water heritage, we subtly mean how water was always there even before us, is there at present and will always be there even if we cease to exist or simply disappear.

Therefore, it is grossly erroneous to assume that historical water was something different than today's water or future water. Water is always water and it is infinite in many ways unless some cosmic events force it into unknown blackholes. It is a different matter how it always been contained in various natural earth formations, man-made structures or conduits, and vast atmospheric spaces.

Let's look at "sustainability" and then we try to establish a relationship between water heritage and sustainability, if any. Again, without taking any help of a dictionary, in very pure terms, sustainability could be thought of as a state of equilibrium that continuously balances the multiple opposing forces. These forces could either be living or non-living, or any combination of them, obviously subject to our current level of intellectual depth. Sometimes we can understand a concept that we are not able to comprehend by looking at a probable antonym of it. For sustainability, it would definitely be "chaos" i.e., dominance of one set of forces with nothing to balance them. So, in other words, sustainability is something which is basically resisting chaos, which many of us believe is the term for extinction of human species as we know them, if not all forms of biological life on earth. Non-living are not part of any of this as they were never created and can never be destroyed based on the law of conservation of mass or energy. To take the argument a little further, it would imply that sustainability is somehow our very basic instinct of survival or sustenance.

Now let's walk into the real world of today equipped with the above principles of "water heritage" and "sustainability." Water heritage is a continuum whether humans are around or not. In fact, water does not need humans at all as it can create biological life of its own choosing as it has done before, if again, we ignore the temporal aspect. It is the other way around that humans need water for their sustainability or survival. Unless they come to terms with these basic ugly truths, no holistic approach to development could be conceived. UN-SDGs breakdown sustainability into its various essential elements from human perspective or we can say SDGs are the physical spirituality necessary for future human survival. At given point of time individual elements could be vital to a specific stakeholder group; and if we do not want to leave anyone behind, then all stakeholders would need to come to the common recognition of these basic laws of science and apply them religiously in their own domain of influence. No individual stakeholder should be allowed to rock the boat and it is the existential responsibility of the rest of the stakeholders that the boat remains in a state of equilibrium. Development is a very subjective term that changes with time, contexts and assumed priorities. At some point of time in history it was like not dying from plague or eaten by a predator was development, today it may be the satisfaction that our future generations will have a content life in physical and emotional terms, and we really cannot know in future what animal would be called the development. Goals are just goals that keep us on our toes to make urgent efforts in the short run, but human life can be much more than just scoring some goals. It should be based on an eternal sense of harmonious living by all, including plant and animal kingdoms, within an environment that is empowered and capacitated to sustain us all.

It is not that the climate is changing for the first time; it is an eternal constant. At different times we have dealt with it appropriately depending on its nature and continued to thrive. This time it is no different; it only depends how intelligently we adapt considering the accelerated rate of change and surely by not feeding this monster at all so that it can consume us all.

This publication chronicles the heritage irrigation structures that document the tests of time that these structures have undergone over thousands of years and demonstrate important lessons for water security, food security, and sustainable agricultural water management in future.

Prof. Dr. Ragab Ragab
President, ICID

INTRODUCTION

Since the dawn of human civilization water has been an enabler of societal development so much so that we started believing "Water is Life," a common phrase in most languages. And, life is multi-dimensional involving not only a physical aspect but also economic, social, cultural, political, religious, and spiritual concepts. Early human settlements emerged around natural water availability and continued to do so for thousands of years. During civilization process the water bodies/scapes became integral parts of human communities and societies and their economic, social, cultural, political, religious, and spiritual activities. Historically, we have always assumed that water is not a limiting factor for human development, however, as our numbers grew from millions to billions, we started to see the finite dimension of water that we now term as "water scarcity" and once a life-critical natural resource becomes limiting our attention is diverted to its value, its use or misuse, its criticality to our survival and its conservation. We have started feeling constrained and questioning our early assumptions of infiniteness of water, and more importantly exploring ways to overcome this scarcity as climate change coupled with over-stretched carrying capacity of our ecosystem have exacerbated the human development situation.

Fortunately, water is now being discussed in many domains which have a diverse worldview of water. Water is not owned by just one discipline of human existence, its multi-dimensionality needs to be put in a holistic perspective facilitated by a dialogue among the stakeholders having asymmetric knowledge contexts, capacities, beliefs, socio-economic backgrounds, cultural and spiritual visions.

ICID's World Heritage Irrigation Structures (WHIS) program aims to do just that by bringing together on one platform all the stakeholders so that they can understand each other's viewpoints, positions, and arguments based on a common recognition of the physical, socio-economic, cultural and worldviews/constructs of water.

Er. A. B. Pandya
Secretary General, ICID

SCHEME FOR RECOGNITION OF WORLD HERITAGE IRRIGATION STRUCTURES (WHIS)

1. BACKGROUND

At the 63rd meeting of the International Executive Council (IEC) held in Adelaide, Australia, in 2012, President Gao Zhanyi suggested that a process for recognition of the historical irrigation structures on the lines of World Heritage Sites as recognised by UNESCO shall be initiated. Accordingly, a Task Team was set up to work out objectives, guidelines, and procedures to select the historical irrigation structures. The Scheme was discussed during the meeting of WG-HIST at the 65th IEC meeting. The members suggested changes in the scope of the Scheme, and the present Scheme has been revised and updated to include both the old operational irrigation structures and structures that have primarily archival value. The Management Board (MB), at its first virtual meeting of 2018 (MB-1/18) held in Kathmandu, Nepal, decided to prefix the word 'World' to HIS as the Scheme was conceptualised initially for recognising the individual structures forming an irrigation system, irrespective of its location.

2. OBJECTIVE

The "World Heritage Irrigation Structure" (WHIS) program aims to document the historical structures worldwide that have contributed to the evolution of irrigation and drainage in agriculture through history. The irrigation or drainage structures that fulfil the criterion in this document are, thereby, registered in the WHIS Register. As of 2020, a total of 106 systems have been recognised in the register. The main objectives of recognition as a "World Heritage Irrigation Structures" are:

- To trace the history and understand the evolution of irrigation in civilisations across the world,
- To select and collect information on historical irrigation structures from around the world, understand their significant achievements, and gather knowledge about the unique features that have sustained the project for such a long period;
- To learn the philosophy and wisdom on sustainable irrigation from these structures; and
- To protect/preserve these historical irrigation structures

3. SCOPE

3.1 The type of the structures or facilities to be considered for recognition as World Heritage Irrigation Structures shall fulfil the following criteria:

(a) The structure shall be more than 100 years old;

(b) The structures shall fall under one of the following categories:

- Dams (operational mainly for irrigation purposes),
- Water storage structures such as tanks for irrigation,
- Barrages and other water diversion structures,
- Canal Systems,
- Old waterwheels,
- Old shadouf,
- Agriculture drainage structures,
- Any site or structure functionally related to present or past agricultural water management activity.

4. CRITERION

The structure recognised as a World Heritage Irrigation Structure should fulfil one or more of the following criteria.

- The structure should represent a milestone/turning point in the development of irrigated agriculture and should bear exceptional testimony to the development of agriculture and increase in food production along with the improvement of the economic condition of farmers;
- The structure that was ahead of its times in terms of project formulation, engineering design, construction techniques, dimensions of the system itself, quantum of water diverted, and size of the command; [any one or more of these]
- The structure must have made an outstanding contribution to enhancing food production, livelihood opportunities, rural prosperity, and poverty alleviation in a region;

- The structure was innovative in its ideas at the time of its construction;
- The structure contributed to the evolution of efficient and contemporary engineering theories and practices;
- The structure is an example of attention to environmental aspects in its design and construction;
- The structure was an example of engineering marvel or excellence at the time of its construction;
- The structure was unique in some positive and constructive way;
- The structure bears the stamp of a cultural tradition or a civilisation of past the past;

The systems fulfilling the above-laid criterion are classified into two lists:

- List A would include those structures which are still operational and present an outstanding example of sustainable Operation & Management over a long period;
- List B would consist of those structures which essentially have archival value and are no more functional

5. SIGNIFICANCE

The process of documentation, recognition, and appropriate management of the World Heritage Irrigation Structures will benefit the irrigation and drainage fraternity as well as the society in general by providing:

(a) Understanding of the factors that make the heritage structures sustainable and learning lessons from there;

(b) Education opportunity for professionals, students, and the general public; and

For UNESCO World Heritage Sites, inclusion means maintaining the status quo forever. But it would be incorrect to stipulate the same for irrigation structures, as the people have the right to replace the older systems with more efficient ones for better water use efficiency. Recognition as a WHIS would be used to draw the attention of the concerned governments to provide sufficient resources to maintain the WHISs. ICID may provide small-scale technical guidance to the project authority through a team of experts from ICID for its further sustainability, conservation, and safety management as long as possible. ICID, through various kinds of published material (Coffee table publications, web pages, and so on), should bring these WHIS into the public knowledge and the role they have played in achieving food security.

6. PROCEDURE

Historical irrigation and drainage structure fulfilling the criterion laid under section 4, based on the recommendation of the Jury to be constituted following the guidelines, as presented below, will be approved by the International Executive Council to be recognised as World Heritage Irrigation Structure (WHIS) that will be included in an "ICID Register of World Heritage Irrigation Structures" and presenting a "World Heritage Irrigation Structure" Plaque citing the salient features of the WHIS. The Plaque will be awarded to the National Committees for onward transmission to the authorities responsible for the running and maintenance of the structure for displaying prominently on the body of the structure. The ICID Register of WHIS would be publicised through ICID media channels.

The National Committee should report the current status of the registered WHIS site to ICID after five years of registration.

Any National Committee/Committee of ICID can nominate or send a proposal for recognising historical irrigation structures meeting the criteria. The maximum entries per National Committee/Committee are limited to up to four (4) in a year. The NC shall obtain a letter of support from the relevant authorities.

The Jury or Panel of Judges is constituted by the President shall form a Panel of Judges, broadly following the composition below for adjudication with the objective to provide recognition to World Heritage Irrigation Structures:

- Chairman, PCSO - Chairman
- Chairman/Ex-Chair, WG-HIST - Member
- Nominees from 3 NCs of ICID - As Members
- Secretary-General, ICID - Member-Secretary

The nomination process for recognition of World Heritage Irrigation Structures is open-ended, and the National Committees desirous of submitting a nomination can fill in the required information in the Nomination Form available on the ICID website. The nomination forms received by 30th June every year will be processed together and presented to the following Executive Council meeting after due processing.

ACKNOWLEDGEMENTS

WG-HIST CHAIR AND MEMBERS

Sl. No.	Name	Country	Position
1	Dr. Kamran Emami	Iran	Chair
2	Mr. Charles L. Abernethy	United Kingdom	Member
3	Dr. Sinite YU	Chinese Taipei Committee	Member
4	Dr. Ahmed Adam Ibrahim	Sudan	Member
5	Prof. Dr. Yutaka MATSUNO	Japan	Member
6	Dr. Masaomi KIMURA	Japan	Member
7	Eng. Ahmed Awad Hag Abd-Elnabi	Egypt	Member
8	Dr. Dia El Din Ahmed El Quosy	Egypt	Member
9	Dr. Laszlo G. Hayde	Hungary	Member
10	Dr. Shivaji T. Sangle	India	Member
11	Dr. A. Hafied A. Gany	Indonesia	Member
12	Engr. Sirika Ahmad Abubakar	Nigeria	Member
13	Dr. Gerhard Backeberg	South Africa	Member
14	Mr. Chaiwat Prechawit	Thailand	Member
15	Mr. Ju Chang Kim	South Korea	Member
16	Mr. Wang Li	China	Provisional Member
17	Dr. (Ing.) Klaus Röttcher - Direct Member	Germany	Permanent Observer
18	Dr. (Mrs.) B. Dolfing	Netherlands	Permanent Observer
19	Dr. Ir. M. Ertsen (IWHA)	Netherlands	Permanent Observer

UNITS CONVERSION

Unit	Description	Approximate Conversion (if not standard)
acre		
BCM	Billion Cubic Meter	
cm	centimetre	
ds	desisiemens	
fed	feddan	Area (Egypt): After 1830, approximately 4,200.833 square meters (about 1.038 acres). Also romanized as faddan, and called feddan masri. When Egypt adopted the metric system, the feddan was the only old unit that remained legal. Currently taken as 0.42 hectares.
gal	gallon	
gm	gram	
ha	hectare	
h	hour	
hp	horsepower	
inch		
kg	kilogram	
kirat		Area (Egypt): 175 m^2
Kpa	kilo-pascal	
kW	kilo-watt	
kWh	kilo-watt-hour	
L	litre	
meska		Area (Egypt) ?
MCM	Million Cubic Meter	
mg	milligram	
Mha	Million Hectare	
mile		
ML	Megalitre or Million Litre (?)	
mm	millimetre	
Mpa	Megapascal	
MT	Metric Tonne	
mu		Chinese unit of land measurement
Q	Quintal	100 kg (India)
RMB		Currency (China)
s	second	
T or Ton	Tonne	

1 AUSTRALIA

1.1 BLEASDALE VINEYARDS FLOOD GATE

Name	Bleasdale Vineyards Flood Gate
Location	Langhorne Creek SA, Australia
Latitude	-35.3088
Longitude	139.0518
Category of Structure	Flood gate
Year of commissioning	1900 AD
River Basin	Murray-Darling Basin (Bremer River)
Irrigated/Drained Area	7011 ha

History

The Bremer River wooden irrigation diversion weirs are a series of levee banks and small wooden floodgates used to divert the floodwaters of the Bremer River into vineyards before discharging the water into adjacent Ramsar-listed Wetlands of international importance. Built in the 1890s on the Bleasdale property near Langhorne Creek in South Australia, the first of these diversion weirs (c. 15 feet wide by 12 feet deep) was constructed of four massive sawn Redgum logs embedded in masonry piers in the banks of the Bremer River sec-ured to a concrete platform.

The floodplains of the Angas and Bremer Rivers are part of the traditional homelands of the Ngarrindjeri people, who flourished on the abundant native foods of the area for many thousands of years before European settlement. Diverting the water of the Bremer River was essential for the European settlers to obtain productive food crops and stimulate the burgeoning economy of the region because of its semi-arid nature and unreliable rainfall.

Description

The floodgates are simple and robust, precisely shaped Redgum planks dropped into grooves in the stone piers. Individual logs can be removed or replaced to control the level and thus the volume of water entering the vineyard. They bear testament to the capacity of the settlers to utilise existing resources in a sustainable manner upon which has been built one of South-Eastern Australia's premier viticulture regions. Today, vineyard managers still use these structures to divert floodwaters for passive irrigation and prevent saline groundwater from upwelling into the irrigation area as the floods move through the district.

There is no proper management of the diversion process, which relies on communication between adjoining landholders to enable water to flow between irrigated blocks. Generational ownership of the properties has ensured the continuity of these traditional practices. Legislation in South Australia has acknowledged the outstanding contribution of these diversion weirs to modern productivity in an environmentally sustainable manner. Diversion weirs and levee banks have been mapped and licensed for contemporary use under the Water Allocation Plan for the Eastern Mt Lofty Ranges. Along with irrigation water, the diversion of floodwaters ensures that the aquifers are recharged, and the adjacent iconic Redgum swamps and Lake Alexandrina receive environmental water.

The Bleasdale Vineyards flood gate is still operational today, a testament to the structure's simple yet effective design and operation. Over the years, there have been incidences where upstream activities, including mining and urbanisation, have impacted the quality of received floodwaters. However, 'pollution' from upstream is not a recent phenomenon as captured in the Angas Bremer Regional History documents. While point source pollution caused by mining and industry is infrequent and now largely no longer an issue, upstream housing development has influenced the natural flooding regime. Anecdotally it is considered that peak flows now move more quickly through the Bremer River system due to a more rapid generation of runoff in the headwaters of the Bremer River near Mt Barker.

The Bremer River catchment also has a high density of farm dams to fill and spill before the water flows downstream. Regulation introduced through the Eastern Mt Lofty Ranges (EMLR) Water Allocation Plan assists in ensuring equitable sharing of the limited water resource and providing for critical flows on which the environment and water-dependent ecosystems are dependent.

Water Heritage

South Australia is the driest state in the driest inhabited continent on Earth. The semi-arid nature of the agricultural land and the lack of reliable rainfall has made sustainable irrigation a challenging enterprise since European settlement (1836).

Early structures focused on the standard practice of damming the Bremer River and its neighbouring Angas River to enable irrigation and better utilisation of the land. The residents concluded that dams were inappropriate infrastructure because of the need to keep the rivers running in their original courses across the relatively flat landscape, which was innovative thinking that retained the iconic Redgum swamps as natural resources for timber and helped the control of groundwater rise across the region.

Wooden diversion gates on the rivers and between properties were seen as fit-for-purpose, allowing everyone to share the water resource and collect the silt from the river to fill depressions and create suitable topography for establishing irrigated crops, including grapevines for wine and dried fruit. Diversion weirs instead of dams also enabled irrigators to harvest water of the best quality selectively, letting any pollution released from the new townships in the Adelaide hills bypass the vineyards.

The first diversion channel was built on the Bleasdale property in the 1860s to drain water from the Bremer River to a depression, irrigated and filled with silt to create flat land. The floodwaters were relatively uncontrolled through this channel. The debris carried with the water caused substantial infrastructure damage, resulting in the construction of the first wooden diversion weir that could be operated to regulate flow and control inputs.

The successful installation and operation of many of these diversion weirs embedded in levee banks over the next few decades was the foundation of viticulture in the region and facilitated the Langhorne Creek Grape Vendors' Association formation in 1929. Certainty of fruit supply enabled wineries to develop. In 'bad' years, currant grapes grown for drying could be sold for distillation at Bleasdale winery, thus providing secure income for the rural community.

The construction of such simple yet sound irrigation infrastructure in these wooden diversion weirs has sustained the region's environmental assets that would have been destroyed otherwise. Water that has been used for irrigation or is diverted away from crops drains into the Redgum swamps in the region and into Lake Alexandrina, which are part of the Ramsar-listed Coorong and Lakes Alexandrina and Albert Wetland of international importance.

During the Millennium Drought (2000-2010), the majority of the Redgums along the lower River Murray that also feeds into Lake Alexandrina were in poor health (75% in Health Class 1 or 2) due to the legacy of building large storages and over-extraction of water across the Murray-Darling Basin. By stark contrast, more than 80% of the Redgums in the Angas Bremer Irrigation Management Zone were in the top two health classes (Class 4 or 5), having been sustained by regular and appropriate flooding.

The redgums would likely have been lost or substantially degraded if the initial plans for damming the Angas and Bremer Rivers had been implemented in the 1800s. The development instead of a series of diversion weirs is a testament to the irrigation excellence and positive outcomes of using simple technology at Langhorne Creek for sustaining irrigation and environmental assets for more than 100 years.

The 2015/16 Irrigation Annual Report of the Angas Bremer Water Management Committee reported that the district had 7,011 ha of irrigated crops, of which 5,658 ha were wine grapes. The average district water use across all crop types was 2.99 ML/ha and 2.88 ML/ha for wine grapes.

1.2 DETHRIDGE OUTLET / WHEEL

Name	Dethridge Outlet/Wheel
Location	Various
Latitude	Various
Longitude	Various
Category of Structure	Waterwheel
Year of commissioning	1910 AD
River Basin	Through Australia and various other countries
Irrigated/Drained Area	Over 2 million ha

History

Constructed between 1887 and 1891, the Goulburn Weir is located on the Goulburn River, approximately 8 km north of Nagambie in Central Victoria, and was the first primary diversion structure built for irrigation in Australia. Considered very advanced, it appeared on the Australian half-sovereign and ten-shilling banknotes from 1913 until 1933.

Completed in 1891, Goulburn Weir was the first central diversion structure built for irrigation development in Australia. It enabled gravity diversion into Waranga Swamp via the National Channel (now Stuart Murray Canal). In 1905, the swamp was dammed to form Waranga Basin, the first significant storage built in the Goulburn system. The East Goulburn Main (EGM) Channel was constructed to supply the Shepparton District in 1910. Construction of the Waranga Western Main (WWM) Channel from Waranga Basin to the Serpentine Creek in 1912 provided the platform for a significant extension of irrigated agriculture in the Tragowel Plains District. Following the Eildon Reservoir expansion, the Stuart Murray Canal was duplicated from Goulburn Weir to Waranga Basin by the Cattanach Canal, and the EGM Channel was enlarged. These works enabled the diversion of approximately 10,000 ML/day from Goulburn Weir for irrigation.

The Goulburn Weir was considered a project of national significance when completed in 1891. In 1893, the Victorian Government funded the book “Goulburn Weir and its Dependant Systems of Works” by Stuart Murray, lead engineer of the weir’s construction. The book is still listed in some university library catalogues.

Description

Dethridge outlets/wheels have been used to distribute and measure water onto surface irrigation farms. This simple, robust measuring device has served the irrigation farmers and irrigation water providers of Australia and other countries since 1910. The Dethridge Outlet has generally now been superseded by newer digital technologies for measuring water volumes delivered onto farms and vineyards/orchards, but it played a significant role in the equitable sharing for irrigation of water resources in many countries. At its peak of use, the Victorian State Rivers and Water Supply Commission (SWRWC) estimated that 40,0001 Dethridge wheels were in operation in Australia and elsewhere.

Dethridge wheels have been used across Australia and many other parts of the world for over 100 years. The steel in the Dethridge wheel was protected by tar, epoxy paints, or galvanising but deteriorated over time and so was replaced by newer wheels. The concrete in the Dethridge Outlet emplacement was often 75 –100 mm thick and would have deteriorated and been replaced. Modernisation programs of irrigation infrastructure have seen these water wheels replaced.

The Dethridge outlet/wheel came in 3 sizes, with the largest of these being the most common. The standard size of the Dethridge outlets/wheel was 5 CFS (cubic feet per second). The second most common was the 2.5 CFS outlet, with both these size wheels used with broad area irrigation. The third size was 1.5 CFS capacity, almost exclusively used in horticulture systems where smaller delivery volumes were required. Farmers often ordered their water for delivery in ‘revs’, with delivery volumes determined by the wheel’s number of revolutions over a set time period.

Water Heritage

At the time of its introduction, the Dethridge outlet/wheel was innovative in that it could measure flow onto the paddock/field from the irrigation channel and hence the volume delivered over time. The flow rate was converted to a volume by counting the number of complete revolutions; the wheel undertook as counters attached to a wheel spoke and recorded every revolution. It was simple and robust yet accurate.

The volumetric measurement of water applied to the farm allowed for charges to be made on a volumetric basis of water use, not just the area irrigated. Accuracy was somewhat independent of flow rate, but generally, it was considered acceptably accurate. The Dethridge outlet/wheel with the volumetric measurement of water supplied to an irrigation farm enabled equitable sharing of limited water resources via volumetric entitlements of water to farms.

1.3 GOULBURN WEIR

Name	Goulburn Weir
Location	Nagambie, Central Victoria, Australia
Latitude	-36.71722°
Longitude	145.1700°
Category of Structure	Weir
Year of commissioning	1891 AD
River Basin	Goulburn River
Irrigated/Drained Area	1,130 ha; capacity (25,500 ML)

History

Constructed between 1887 and 1891, the Goulburn Weir is located on the Goulburn River, approximately 8 km north of Nagambie in Central Victoria, and was the first primary diversion structure built for irrigation in Australia. Considered very advanced, it appeared on the Australian half-sovereign and ten-shilling banknotes from 1913 until 1933.

Completed in 1891, Goulburn Weir was the first central diversion structure built for irrigation development in Australia. It enabled gravity diversion into Waranga Swamp via the National Channel (now Stuart Murray Canal). In 1905, the swamp was dammed to form Waranga Basin, the first significant storage built in the Goulburn system. The East Goulburn Main (EGM) Channel was constructed to supply the Shepparton District in 1910. Construction of the Waranga Western Main (WWM) Channel from Waranga Basin to the Serpentine Creek in 1912 provided the platform for a significant extension of irrigated agriculture in the Tragowel Plains District. Following the Eildon Reservoir expansion, the Stuart Murray Canal was duplicated from Goulburn Weir to Waranga Basin by the Cattanach Canal, and the EGM Channel was enlarged. These works enabled the diversion of approximately 10,000 ML/day from Goulburn Weir for irrigation.

The Goulburn Weir was considered a project of national significance when completed in 1891. In 1893, the Victorian Government funded the book "Goulburn Weir and its Dependant Systems of Works" by Stuart Murray, lead engineer of the weir's construction. The book is still listed in some university library catalogues.

Description

The 654 km Goulburn River is a highly regulated waterway with 41 tributaries along its course. It rises north of central Victoria's Great Dividing Range and joins the River Murray near Echuca. The river is recognised as a significant waterway under the Heritage Rivers Act 1992. Goulburn Weir is located downstream of Nagambie township. The weir regulates the river creating two major pools connected by the old river course. The northern pool is commonly called Goulburn Weir, while the southern pool is known as Lake Nagambie. At full storage level, the Goulburn Weir system has an area of 1,130 ha, a volume of 25,000 ML, and a maximum depth of 15 m. The upstream catchment area is 10,205 km^2, including the Lake Eildon catchment area of 4,000 km^2.

Goulburn weir is a concrete structure, 212 m long and 15 m high, founded on bedrock, and its downstream face stepped with granite blocks quarried from nearby Mount Black. The original superstructure included 21 cast and wrought iron gates mounted between cast-iron piers. Powered by water-driven turbines, the gates lowered into recesses in the weir crest to pass the river and flood flows. The weir is currently a fully operating water supply asset, diverting water down four major carriers (Stuart Murray Canal, Cattanach Canal, East Goulburn Main Channel, and the Goulburn River) to supply irrigation, urban and environmental water across Northern Victoria and mitigate flood events on the Goulburn River.

The weir was illuminated with electricity from one of the first hydroelectric turbines in the southern hemisphere. The electricity-powered five arc-lamps assist in weir gate operations and detect floating debris so that it was safely guided over the weir. Works to stabilise the deteriorating weir structure were completed in 1983, with a significant refurbishment in 1987, aided by advice on architectural and heritage matters from expert consultants and the engagement of specialist contractors.

Nine steel radial gates mounted between concrete piers replaced the main weir superstructure. Two original gates and their lifting gear were retained to preserve part of this unique piece of engineering history. The weir raises the level of the Goulburn River so water can be diverted by gravity along channels to supply irrigation water. The weir's gates can release up to 96,000 ML daily. Water travels via the Stuart Murray Canal, Cattanach Canal, and the East Goulburn Main Channel to supply the Central Goulburn and Shepparton Irrigation Areas and the Rochester and Pyramid Hill Irrigation Areas via Waranga Basin.

The weir also forms Lake Nagambie around which recreation, farming, and housing developments have grown. The lake covers 1,130 ha and, when full, holds 25,500 ML of water. The constant water level provided by the weir means locals and visitors can enjoy rowing, fishing, boating, water skiing, wakeboarding, and canoeing all year round.

The Goulburn Irrigation System supports some of Victoria's best-irrigated agriculture, including horticulture and dairy. Typically, 91 % of water released from Lake Eildon is diverted for irrigation purposes at Goulburn Weir, averaging 846,000 ML annually. The Goulburn Weir Complex is recognised by the National Trust of Australia (Victoria) as a place of state significance and high importance by Heritage Victoria.

Maintenance and upgrade works are consistently required to maintain the weir's functionality. In the past, GMW has implemented works to minimise the impact on the structure of flood events and earthquakes, including the installation of ground anchors between 1980-1987. A brief description of the works carried out since its inception is given below:

- **1890:** Original weir comprises a 210 m long concrete and masonry weir. Flow control was via 21 cast iron butterfly flood gates operated by an innovative water turbine arrangement.
- **1980-1987:** Significant foundation strengthening, including installing pier and toe plinth anchors—upgrading the operating gear and installing radial gates. Original cast-iron gates replaced with 9 No. X 12.87 m X 3.65 m high radial gates (two of the original gates retained for heritage reasons).
- **2007:** Replacement of compromised bar anchors with re-stressable strand anchors in four piers
- **2009-2010:** Installation of gate locking mechanisms on each of the main Spillway Gates: Installation of new full raised proximity sensors and end stops on each of the main Spillway Gates; Installation of new structural elements to strengthen the weir superstructure; Refurbishment of the hoist system on each of the main Spillway Gates, including the replacement of grease in the gearboxes and gearbox mounting plates; Upgrade of the existing Gate Control System to make it consistent with the new standards being implemented throughout G-MW; Installation of the new Gate Actuator Control Panels for each of the main Spillway Gates; Installation of new power supply cabling; Replacement of the existing Cathodic Protection cabling system on the Weir Structure: Installation of new gate position encoders.
- **2015:** Upgrade of a gantry crane to rectify non-compliance and other maintenance issues identified in the 25-year crane design review completed. The work included replacing the conductor rails, and hoist ropes, and installing new safety equipment (operation warning signs and anemometer (wind speed)).

Water Heritage

The Goulburn Irrigation System supports some of Victoria's best-irrigated agriculture, including horticulture and dairy. Recreation, farming and housing developments have also flourished around Lake Nagambie. Goulburn Weir is the central diversion point for water from the Goulburn River. Water is distributed west via the Cattanach and Stuart Murray Canals to Waranga Basin and east via the EGM Channel to supply the Shepparton Irrigation Area, recognised as one of the most highly productive regions within the nation. From Waranga Basin, the WWM Channel takes water as far as Boort and Pyramid Hill. The water diverted from Goulburn Weir is used for domestic and stock supplies and irrigation. It provides water to urban water authorities to supply potable water to numerous rural townships in northern Victoria. Over the last ten years, annual diversion for irrigation has averaged 846,000 ML, generating 25% of Victoria's total agricultural output.

Goulburn Weir is also a vital recreation site and tourist destination. Many water-based activities are conducted at Lake Nagambie, including rowing, water skiing, angling, duck hunting, and boating. Recreation provides the township of Nagambie with a valuable source of income. Visitors come from all over Victoria to marvel at the steady, bright electric light and floodlit water spray when the reservoir gates are operated at night.

Works to stabilise the deteriorating weir structure were completed in 1983, and in 1987 a major refurbishment was undertaken. Two of the original gates and lifting gear, mounted on the angled western abutment, were retained to preserve part of this unique piece of engineering history. In 1988, the refurbishment work received the Engineering Excellence Award, Public Works Section 'for stabilisation and reconstruction of a superstructure and retention of heritage value and charm' by the Institution of Engineers Australia (Victoria Division).

2 CHINA

2.1 36 WEIRS OF BAISHAXI STREAM

Name	36 Weirs of Baishaxi Stream
Location	Jinhua City, Zhejiang Province, China
Latitude	28.989
Longitude	119.482
Category of Structure	Weirs
Year of commissioning	27 AD
River Basin	Wujiang river basin
Irrigated/Drained Area	1.85 Mha

History

The 36 Weirs of Baishaxi Stream, located in the Jinhua City of Zhejiang Province, is an ancient weir complex for flood control, water storage, and the utilisation of water power.

In 27 AD, Lu Wentai, a general of the Eastern Han Dynasty, along with 36 of his sub-ordinates, decided to manage the frequent droughts and floods in Fucang (Wucheng District of Jinhua City in the Zhejiang Province). They built Baisha Weir in the Gaoru Village to facilitate irrigation, thereby starting the construction of the 36-weir complex along the Baishaxi Stream. Over the next hundred years, following Lu Wentai's technique and the success of the weir, the residents built other weirs, ultimately creating the Baisha Weir complex. From the upstream to the downstream, the 36 weirs cover a river section as long as 45 km and form a water level difference of 168 m. These weirs have ensured stable crop yields despite drought and excessive rain. Considering the regional topography of the Baishaxi Stream, including large vertical drops, rapid flow, and abundant deep pools, people built weirs at the pools and dug canals for irrigation. In this way, a water use system combining pools, weirs, ponds, wells, and springs was established, with a guaranteed water supply. During the infamous AD 238 drought, the Baishaxi Stream Basin registered a steady harvest thanks to the 36-weir irrigation water supply, while the peripheral areas suffered from total crop failure.

Description

Most of the 36 weirs are located in natural deep pools. Based on the theories of modern hydraulics, this not only improved their water storage and diversion capacity but also reduced the impact of water flow. Of the 36 weirs, 21 are still functioning. The bamboo cages filled with stones have been replaced by concrete and masonry. The building of two reservoirs further guaranteed water supply. Reservoirs, weirs, and canals have formed a complete irrigation system that has increased the irrigation area from 8,000 ha to 18,533 ha.

The establishment and renovations of the cascade weirs have fully tapped the local natural resources such as pines and bamboo, which were respectively made into reinforcing stakes and cages filled with stones. In addition, building low cascade weirs, relatively more straightforward and less risky, has reflected the ancient Chinese philosophies of water management and harmonious coexistence between man and nature.

The 36 ancient weirs are distributed as follows from the upstream to the downstream:

1. The Shafan Weir was located initially at Longzui Pool to the south of Shafan Village at Shafan Town in Wucheng District, Jinhua City. The water of Liyan Pool is channelled to irrigate 7.3 ha of farmland. Situated in a basin, Shafan uses water coming from the convergence of dozens of river branches flowing from mountains that collect rainwater over a distance of 131 km. Shafan Reservoir dam was built on Shafan Weir.

2. The Dafentou Weir (also known as the Qinglong Weir) is located at Lingjiao Village, Shafan Town. The weir measures 1 m high and 40 m long. Water from Dagongtan Pool is channelled into the Dafentou Weir, runs to the foot of the mountain ridge to the east of Baishaxi Stream and irrigates 1.3 ha of farmland. In 1999, the weir was rebuilt into a power plant weir of concrete structure combining the functions of both weir and bridge.

3. The Tingjiu Weir (also known as the Fucang Weir and colloquially called the Xinluxia Weir) is located at Tingjiu Village, Shafan Town. The water of Liugou Pool is channelled into a creek and runs for about 100 m until it flows into a weir canal and empties into the west of Baishaxi Stream, irrigating more than 33.3 ha of farmland.

4. The Sheji Weir, also known as Lingxia Weir, channelled water into Lingxia, or the tract of land under the mountain ridge. Water from the Weir irrigated 6.7 ha of farmland in Lingxia from 1689 to 1750. Later, a flood dyke was built, but the weir was discontinued following the destruction of the farms in the flood. The weir is now rebuilt into a hydropower station.

5. The Baisha Weir was the first weir initiated by Lu Wentai. Also known as Gaoru Weir, it is located at Gaoru Village, Shafan Town. The head of the weir was destroyed in the 1975 floods, and the weir was rebuilt and renamed the Xiaoxili Weir in 1978. The original weir measured 1.7 m high and 70 m long. The water of the Baisha Weir irrigates 46.7 ha of farmland at the villages of Tingjiu and Gaoru to the west of the Baisha Stream. It was rebuilt into a concrete weir in May 2012.

6. The Shangshui Weir is located to the south of Dongbian Village in Shafan Town. Water from the weir runs eastwards and irrigates 11.3 ha of farmland in four lower-reach villages of Dongbian, Gaoru, Lingjiao and Jiudian.

7. The Zhoucun Weir is located at the end of Hengshantou Pool in Tianning Temple at Zhoucun, Shafan Town. The water of the Zhoucun Weir runs eastward and irrigates the farmland at Damaitan and Zhou Village. The weir measures 1.2 m high and 80 m long. In May 2012, the Zhoucun Weir was rebuilt into a concrete weir.

8. The Huangtankengkou Weir is located near Huangtan Pit at Saifan Village in Shafan Town. It was initially a tiny tier, with its water running to the west of Baisha Stream and irrigating 1.3 ha of farmland. In 1951, a new channel was opened at Saifan Village to enlarge the weir. The temporarily enlarged weir, made of sand and stones and measures 1.5 m high and 80 m long, is used to irrigate 20 ha of farmland.

9. The Shangtang Weir, also known as Shangshuidui Weir, is located in front of Zhou Village in Shafan Town. Water from the Weir runs eastward and is mainly used to motivate the water-powered trip hammer to irrigate farmlands along the Baisha Stream Basin. The water-powered trip hammer was destroyed, and the Shangtang Weir was discontinued in 1953. The Shangtang Weir was rebuilt into a concrete weir in 2011.

10. The Xiatang Weir, also known as Xiashuidui Weir, is located near Zhou Village at Shafan Town and is separated from the Shangtang Weir by a pool. It was used to provide water to motivate the water-powered trip hammer and irrigate 0.3ha of farmland behind it. The riverbed changed its course during a flood in 1975; as a result, both the water-powered trip hammer and the Xiatang Wei were destroyed. The Xiatang Weir was rebuilt into a concrete weir in 2011.

11. The Peijia Weir is located to the south of Peijia Pool at Qingcao Village, Shafan Town. Water from the Weir irrigates 2.1 ha of farmland near the Qingcao Stream in the west of the Baisha Stream.

12. The Qingcao Weir is located to the south of the Qingcao Pool in Shafan Town. The weir measures 2 m high and 90 m long. Water from the Weir runs eastward to Qingcaofan and irrigates 4.5 ha of farmland there. The area of the farmland under irrigation increased to 7.4 ha after the founding of the People's Republic of China.

13. The Yatou Weir, also known as the Shetou Weir, is located north of Qingcao Village and south of Xiawu Pool in Shafan Town. Water from the Weir runs westward to Liaotou Village and irrigates 1.7ha of farmland.

14. The Zhutoutan Weir is located south of Zhutou Pool at Liaotou Village, Shafan Town, and is colloquially known as the Liaotouhui Weir. Water from the Weir runs to the west of Baisha Stream and irrigates 5ha of farmland. The weir was rebuilt into a concrete weir combining the functions of a bridge, road and weir.

15. The Shanjiao Weir was located along the stream to the south of Shanjiao Village at Shafan Town. The Shanjiao Weir was discontinued when a highway and a bridge were built at the mountain's foot in 1964.

16. The Chensi Weir is also known as the Chensiwutan Weir or the Big Weir. It is located to the west of Shanjiao Village at Shafan Town and south of Chensiwu Pool. The weir measures 1m high and 90m long, with its water running westward into villages like Zhongyangtan, Shanjiao, Zaoli and others a total of 8.7 ha of farmland.

17. The Zaoli Weir was initially located to the south of Zaoli, Lanbei Town, and Zaoli Pool. The water from the weir ran eastward and irrigated 0.7 ha of farmland at Renjiafan with a water-powered trip hammer. Both the Zaoli Weir and the trip hammer were inundated after the construction of Jinlan Reservoir was completed in 1960.

18. The Shanglanbei Weir was located at the original Zaolidiankou in Lanbei Town. The water had to be lifted by an ox-drawn water lift near the Li Village to irrigate 1.7 ha of farmland at the head of the stone bridge of Shanglanbei. Initially, there was a water-powered trip hammer. Both the Shanglanbei Weir and the trip hammer were inundated after the construction of Jinlan Reservoir was completed.

19. The Moshi Weir was located at the original Miaokangkou in Dayan Township. The water ran eastward to Moshifan and Shitangtou and irrigated nearly 6.7 ha of farmland. The weir was inundated after the construction of Jinlan Reservoir was completed.

20. The Zhucun Weir was located at the original Zhu Village, Dayan Town. The Zhucun Weir was inundated after the construction of the Jinlan Reservoir was completed.

21. The Xidong Weir and Shirenshan Weir were located north of Shitang and Tantoudian, respectively, in Dayan Township. The water ran eastward and irrigated 1.7 ha of farmland at Shangshishi and Xiashishi. Both the Weirs were inundated after the construction of the Jinlan Reservoir.

22. The First Weir is colloquially called Qiannian (Millenium) Weir. It was initially located at Shanhoujin Village in Langye Town and Qiannianjiao Pool between Yanshan Mountain and Wuguishan Mountain. The dam of Jinlan Reservoir is built on the original site of the First Weir. The weir measured 4 m high and more than 60 m long. The water ran westward and irrigated 1,600 ha of farmland in rural villages, including Yangtangxia, Zhili, Kaihua, Zekou and Xiayang. From March 1953 to July 1954, a double-hole water intake sluice was built, a new channel of 108 m long was opened, the general canal was deepened, and a sluice gate and a flood protection embankment were built, respectively. The renovated First Weir benefitted five townships and 22 villages. It can irrigate 2133.3ha of farmland and

turn 40ha of dry land into irrigated land. Following the construction of Jinlan Reservoir, the weir was rebuilt into an artificial lake with dry stones in November 1962. The weir measures 38m long and 1.2m high. The tailwater of a hydropower station is channelled into a water intake sluice and runs to Jiangtou where it is diverted into Majilong Reservoir. The water canal runs 6.9 km long from the mouth of the weir to Zhenggangshan Reservoir. After the First Weir was widened and deepened, the designed flow capacity of the upper reaches was 4 m3/sec, and the size of the area under gravity irrigation increased to more than 2,666.7 ha.

23. The Second Weir is located at the foot of Langfeng Mountain to the east of Langyexu Village, Langye Town. The water runs eastward to the farmland in the villages of Quankou and Changshan. The water is also channelled to Qingtang Reservoir to irrigate more than 2,000 ha of farmland.

24. The Third Weir, also known as Wentai Weir, was originally located south of Xindianxia Village, Langye Town. The water runs eastward to the villages of Houjin and Matandai. The Third Weir has inner and outer weirs, with a water lift from the outer weir to Gaocheng Village, located to the west of Baisha Stream. As the water level reduced in the inner weir, it was difficult to lift water, so the dragon-bone water lift or water pump was installed. The weir dyke made of pebble stones was built at Dongshan Pool in 1968.

25. The Fenglu Weir, known as the Changshu Weir in ancient times, is located to the south of Dongpu Village, Langye Town, benefiting Gufang and Linjiang and channelling water into the Zhililong Reservoir. Originally it was a temporary weir made with cages filled with stones and was destroyed and repaired from time to time. A stone weir made of concrete blocks was constructed from 1978 to 1979. The Fenglu Weir measures 115 m long, 1.3 m high, 1.3 m wide at its top and 2.3 m wide at its bottom. It has a double-hole water intake sluice and is made of dry-laid block stones, with cement mortar used to point the weir wall. It can protect a five km-long section of boundary paths of fields and the canal. The designed flow capacity is 4 m3/s. The Fenglu Weir can benefit more than 1,333 ha of farmland. The weir is expanded into a concrete weir functioning both as weir and road.

26. The Fourth Weir is located to the east of Lutou Village, Bailongqiao Town. The water runs westward to the villages of Gufang, Houdu and Xinchangqiao. In 2008, it was rebuilt as a concrete weir serving as a weir and road open to small motor vehicles. It benefits more than 93.3 ha of farmland.

27. The Huashan Weir, known as the Shigu Weir in ancient times, is located to the west of Youlanli and Gufang in Bailongqiao town. The water of the Huashan Weir is channelled from Huashan Pool and runs eastward, irrigating 16.7 ha of farmland in Youlanli and Gufang. It is a temporary weir made of sand and stones.

28. The Fifth Weir, a temporary weir made of sand and stones, is located east of Gufang Village at Bailongqiao Town. The water runs eastward and is channelled from Zhixian Temple and reaches Rangchang Town via Tianmu Hill, irrigating more than 66.7 ha of farmland. At the lower reaches, the water from the Fifth Weir, the Second Weir and the Hanlong Weir irrigates the same farmland. It measures 70 m long and 1m high.

29. The Dongshan Weir is located at the foot of Dongshan Hill, Xinchangqiao Village at Bailongqiao Town. A six-sided hollow Dongshan Pagoda of bricks and stones stands on the hill. With water channelled from Dongshan Pool, the inner weir measures 25 m long and 1 m high and is made of lime, clay, and sand. It irrigates 40 ha of farmland in the villages of Xinchangqiao and Daxu. The outer weir measures 1 m high and 40 m long and irrigates more than 53.3 ha of cropland in the villages of Gufang, Xinchangqiao and Daxu. The outer weir is a temporarily built weir made of sand and stones.

30. The Hanlong Weir, also known as the Anlong Weir, is located east of Xinchangqiao Village at Bailongqiao Town. The water runs eastward. In 1947, the Jinhuajiang Water Conservancy Section designed and built the weir along with seven flood control dykes and dams with cages filled with pebble stones. In the second design and rebuilding in 1963, the weir was made of dry-laid block stones, with cement mortar used to point the weir wall. The weir measures 140 m long and 1.4 m high. The water is channelled from Wazaotou, with one branch running to Dongli and Daxu and the other branch running to Rangchang Township, irrigating 200 ha of farmland. At the lower reaches, the water from Hanlong Weir and the Fifth Weir irrigate the same farmland. It was the longest weir in Jinhua County at that time.

31. The Matan Weir, also known as Wantan Weir, is located east of Xinchangqiao Village, Bailongqiao Town. It irrigated the villages of Dongli, Dayu,

Rangchang and Yedian. The weir disappeared after the water from Hanlong Weir was diverted to irrigate farmland in 1963.

32. The Yushan Weir is located at the foot of Yushan Park at Bailongqiao Village, Bailongqiao Town. It was renovated in 1533 and rebuilt into a concrete block weir in 1965. The weir measures 92 m long and 2 m high. It irrigates 200 ha of farmland in the villages of Bailongqiao, Yedian and Dongyu. The Stone Tablet of Yushan Weir, which was made in May 1733, is still housed in the ancestral temple of Dongyu Village.

33. The Shanghe Weir and Xiahe Weir are located in the southeast village of Bailongqiao Town. The Shanghe weir measures 50 m long and 0.5 m high. It irrigates 53.3 ha of farmland at Linjiangshangfan. The Xiahe Weir and the Shanghe Weir are the two parts of the same weir, with a distance of 20 m between the crests of weirs in the upper reaches and the lower reaches. The Xiahe Weir irrigates more than 40 ha of farmland at Linjiangxiafan.

34. The Zhongji Weir, located at Dongyu Village, Bailongqiao Town, irrigates more than 1.3 ha of farmland. It is the last one of the 36 weirs. In 1954, the water from the weir in the upper reaches was channelled for irrigation.

In the past two millennia, people and the government have joined hands to manage the weir complex and retain the community's wisdom and experience. The government laid down the general rules of weir management, clarifying water rights and repair responsibilities, coordinating the operation of the 36 weirs, and guaranteed equitable distribution in dry months. In addition, each weir has its water user association (WUA) responsible for weir management and related affairs. Inscriptions from Ming Dynasty also highlighted the community's role in the repair and maintenance work of the weirs since the beginning, especially in the cases of silting-up and destruction by flood. The 36 Weirs of Baishaxi Stream have consistently played an essential role in the region's social-economic development and ecological environment since ancient times.

Water Heritage

From the Shafan Weir on the upper reaches to Zhongji Weir on the lower reaches, the 36 Weirs are located on a belt extending 45 km with a drop of 168 m in elevation, exhibiting its ingenuity in terms of planning and construction scale. The weirs contributed to agricultural development and growth in food output. Historically, following the example of the weir complex, more than 6,000 water-diverting weirs were built for agricultural development. A water-powered machine trip-hammer, an advanced production tool for the time, was employed in the weir complex along the Baishaxi Stream. More than 150 water-powered trip-hammers were built in the 120 villages of the Baishaxi Stream Basin. The advanced grain-processing technology promoted liquor making, which later became the primary livelihood in the Tang and Song Dynasties. The machine trip-hammers were also used for crushing kaolin, the raw material of porcelain, supporting the development of local porcelain-making businesses.

It is one of the earliest weir irrigation projects in Zhejiang Province and even in China. Each weir was built and periodically renovated. The topographic feature of the region, such as deep terrace pools, was capitalised upon to build the structure. The weirs were built along the lower reaches of each deep pool to reduce the impact of water flow and to increase water storage of the weir in dry months. The principle of "dredging the pool thoroughly and keeping the weirs low" was practiced during the annual repairs of weirs for increasing water storage of deep pools, improving the water-diversion capacity of canals, increasing the energy dissipation effects of deep pools and ensuring the safety of weirs. It was constructed in a conducive way to preserve biodiversity and ecological restoration.

The construction of the weirs has boosted local cultural and economic development. Historically, more than 100 poems were composed to sing the praises of the 36 Weirs of the Baishaxi Stream. Nearly 100 Baisha Temples have been constructed in the region. The influences of Baisha Culture derived from these memorial structures are prevalent today.

2.2 CHANGQU (BAI QI) CANAL

Name	**Changqu (Bai Qi) Canal**
Location	**Hubei Province (Xiangyang City), China**
Latitude	**31.982032**
Longitude	**112.165078**
Category of Structure	**Canal System**
Year of commissioning	**279 BC**
River Basin	**Yangtze River (Sub Basin: Han River)**
Irrigated/Drained Area	**20200 ha**

History

Located in the city of Xiangyang in the northwest of the Hubei Province and the river basin of the Manhe River in the middle reach of the Han River, the Changqu (Bai Qi) Canal was first built in 279 BC. It is a "melons on vines" irrigation system with a history of over 2,200 years. The Xiangyang Plain has an average annual precipitation of 900 mm; however, the distribution of rain in a year or between the years is uneven. The construction of the Changqu (Bai Qi) Canal promoted agricultural development. It also boosted the economy of the Xiangyang-Yicheng Plains, turning it into a renowned grain production area in the middle reach of the Han River. At present, it covers an irrigated farmland (mainly rice fields) of 20,200 ha, which reached over 28,000 ha in earlier years. The Changqu (Bai Qi) Canal, named after its originator Bai Qi, is a paradigm of a sustained irrigation project.

The general of the Qin Kingdom, Bai Qi, constructed dams and canals in 276 BC as a warfare tool to flood the enemy troops. This project later became a critical irrigation system on the Xiangyang Plain. The name Changqu Canal ("long canal") was derived from the central canal, which ran about 50 km, in the Tang Dynasty (AD 618–907). The canal witnessed large- and small-scale engineering maintenance in different dynasties and ages. In particular, the Han (206 BC-AD 220) and Tang (AD 618–907) Dynasties witnessed many advancements. The project was renovated several times from the Qin and Han Dynasties (221 BC-AD 220) to the Southern and Northern Dynasties (AD 420–589). In the 12th century, the irrigation system was further refurbished to cater to garrison troops and peasants to reuse wasteland and grow food grain. Due to the unrest and weak upstream water transport, the structure was rebuilt in the middle of the 20th century.

Constructions were done to connect the Manshui River with the Changqu (Bai Qi) Canal, which increased the irrigation water supply and covered an area of 33,333 ha. The canal also promoted social stability and economic development in the Han River region. It brought higher grain production, the prosperity of silkworm breeding, mulberry planting, cotton planting and spinning, and the development of fishery and husbandry.

Description

The Changqu (Bai Qi) Canal Irrigation System consists of headworks, canal networks, and water regulation and storage projects. The headworks are located at the converging point of the mainstream of the Manhe River and its tributary Qinglianghe River near Wu'an Town in Nanzhang County. The project diverts water from one side of the weir. The weir is 120 m long and 3.4 m high. At present, the primary water source of the Changqu (Bai Qi) Canal is the Sandaohe Reservoir. The irrigation area covers the two counties (cities) of Nanzhang and Yicheng. The central canal is 49.25 km long with 38 main branch canals in the irrigation system, which connect many reservoirs, weirs, and ponds. There are ten medium- and small-sized melon-like reservoirs and 2,671 weirs and ponds in the irrigation district. The reservoirs are connected to the Changqu (Bai Qi) Canal through ditches and canals and are controlled by water gates.

The Changqu (Bai Qi) Canal has a history of over 2,200 years, from its construction during 770–476 BC to the present. The project has a detailed layout and ingenious design, and its hub projects retain the traditional engineering characterised by water storage with weirs, flood discharge, and water diversion from one side of the weir. The current canal layout is identical to that of ancient times. The system provides irrigation water to an extensive area of farmland in Xiangyang and Yicheng and plays an essential role in promoting regional social development and economic prosperity and managing natural disasters. The canal benefitted the economy, irrigation, flood control, drainage, and ecological agriculture. In over 2,000 years, it has contributed significantly to the agricultural and economic development of the Xiangyang-Yicheng Plains, making it a renowned grain production region. The canal plays an essential role in resisting natural disasters like drought and flood.

After the recent renovations, the canal has accumulated over 14 BCM of agricultural and industrial water to the two counties (cities) of Nanzhang and Yicheng. The annual total grain yield in the irrigation district reached 250 million kg. The Yicheng city in the central irrigation district is a rich agricultural county with high-yield fields and is one of the 484 counties in China that produce high-quality grain. It played a prominent role in making Xiangyang the first major city of grain production with a grain yield of over 5 billion kg in the Yangtze River Basin.

Water Heritage

The irrigation system and its management protocols can be traced back to the 11th and 12th centuries. Historical records and stone inscriptions from different periods prove the engineering aspects (water diversion structures and canal systems) found today in the Changqu (Bai Qi) Canal. The canal was a milestone in irrigation infrastructure in the Xiangyang-Yicheng region. Since the Northern and Southern Song dynasties (AD 960–1279), the canal watered over 10,000 ha of irrigated land in its peak time in history. At present, its irrigation area amounts to 20,200 ha, and the annual total grain yield in the area reaches 250,000 tons.

The Changqu (Bai Qi) Canal has contributed to water resource management, the planning of engineering projects and architectural technology. Its water storage and regulation projects have unique and sustainable features. Like melons on vines, ponds were connected with canals. In this way, water was diverted from multiple sources,. Water flowed downward from higher storage facilities which were joined together to form a network in which they supported each other as water sources. Watergates were used to control water diversion. The time-share rotation irrigation system adopted in the project has been used till today and experienced innovation and development.

The Changqu (Bai Qi) Canal facilitated irrigation, flood control, and drainage and fishery in the Han River region from time immemorial. It has contributed to the formation of "a land of fish and rice" and "the granary of all China" and the creation of rich and profound regional culture. The project still functions today, irrigating 20,200 ha of farmland and benefiting a population of 3.37 million in six townships and towns.

2.3 CHATAN WEIR IRRIGATION SYSTEM

Name	**Chatan Weir Irrigation System**
Location	**Jiangxi Province, China**
Latitude	**26.83288889**
Longitude	**114.24083333**
Category of Structure	**Irrigation System**
Year of commissioning	**937 AD**
River Basin	**Ganjiang River, the tributary of the Yangtze River**
Irrigated/Drained Area	**3,300 ha**

History

Located on Niuhou River (a tributary of Ganjiang River) in Taihe County of Jiangxi Province, Chatan Weir Irrigation System has provided for the local farmland and people for more than 1000 years. Taihe enjoys abundant precipitation (1434.2 mm/year) and excellent farmland fertility. In 937 AD, Zhou Ju built a weir with timber piles and bamboo battens upstream of the Niuhou River to overcome the drought problem in the area.

Initially, the weir was made of timber piles and bamboo battens. The wooden structure was replaced by stones in the 14th century and later by concrete. Initially, 36 canals irrigated more than 600 ha of farmland in Gaoxing and Luoxi townships. The weir has undergone significant repairs in later dynasties. However, the location of the weir and the main canal system stay unchanged. Today, it irrigates more than 3,300 ha of land.

Chatan Weir is a typical sustainable irrigation system with continuous operation and management. As a family project, it was passed down for 1,000+ years. The Zhou's had a well-established management and maintenance system for this project and designated family members to manage it with a dedicated budget. However, it wasn't monopolised: all residents in the area used the water for irrigation, reflecting the principle of "being broadly beneficial". With the vicissitude of time, the family's control weakened at the end of the Song Dynasty. The "Five Clans' Convention" was formulated in 1341 AD, specifying the members who could act as the project operator in turns. The five clans' official sponsorship and civilian management system effectively addressed the ever-worsening water shortage and improved the system's overall efficiency. In the 17th century, the main canal of Chatan Weir was 30+ km long and passed 100+ villages. With the aid of waterwheels, this project irrigated an area of 2,667 ha, serving several tens of villages.

For the reconstruction of Chatan Weir in 1938, Chatan Weir Reconstruction Committee was established upon the government's approval. Other than members of the five clans, other residents were also included as members of the committee. After maintenance, the Taihe County government adopted the proposal of local esquires. It approved the establishment of a nonprofit organisation, i.e. Chatan Weir Administration Committee, to ensure the smooth operation of the irrigation infrastructure. After 1949, the People's Government Taihe County reconstructed and expanded Chatan Weir and canals in 1952, 1956 and 1965. A siphon pipe was constructed on the northern trunk canal to divert water across the Niuhou River, expanding the irrigating area in southward and northward directions.

In 1983, the weir was further heightened and reinforced, and the southern main canal was developed so that higher lands could benefit from gravity irrigation. A hydropower station was also constructed on the trunk canal with an installed capacity of 125 KW and an annual generating capacity of 700 MWh. Today, the ancient project of Chatan Weir brings more benefits than ever.

Description

Chatan Weir irrigation system includes canal headwork, flood control works, canal systems, and regulation and storage projects. The Niuhou River flows out of the mountains and turns around at a steep angle; the weir guides the trunk river into the canal, ensuring discharge and reducing the pressure on the weir. Divided into the main and auxiliary sections, the weir was first built with wood. By the second half of the 14th century, the wooden structure was replaced by a stone one. Then the weir underwent multiple major repairs till 1983 when its body was solidified with concrete. The main section is 105 m long and 4 m tall, the auxiliary part is 177 m long and 4.1 m tall, and the top and the bottom are 7 m and 18 m wide, respectively. Both sections are equipped with a sand-flushing sluice to avoid silting up in front of the weir. Besides, the main section is also provided with a rafting path. 3.5 km downstream the Chatan Weir, a stone weir called Diaoshi was set up to divert the spring and summer floods back into the Niuhou River. In 1965, a new gate was installed at the intake of the main canal to control water diversion, and Diaoshi Weir was removed.

The canal system of Chatan Weir is divided into general main canals, main canals, branch canals, and distributing ditches. The general main canal starts from the intake and flows across a low-head hydropower station into the north main canal, irrigating the low-lying farmlands at Heshi and Luoxi townships. Before it passes the hydropower station, the general main canal bifurcates, and part of it flows into the south main canal, irrigating the high-lying farmland upstream by gravity. The main canals are 35 km long and are equipped with one inverted siphon, one tunnel, and 246 aqueducts. In addition, 17 distribution gates and three water release gates are built on various levels of canals. Meanwhile, many lakes and pools serve as storage and regulation project. The overall system has ensured a steady grain output during stable as well as dry periods.

Chatan Weir was initially a family project. It was ultimately managed by a joint committee of the community and the government. The weir survived all these years due to its scientific design and the participatory management style which still have reference value today. Currently, the weir is exposed above the water surface during the drought season when the residents, including their livestock and vehicles, use it as a passageway. With a catchment area of 1,070 km^2, the Weir experiences large water flow during the flood season, leading to severe erosion.

Water Heritage

Chatan Weir was constructed in 937 AD. The weir, canals, ponds, and flood prevention work constitute an integral irrigation system together. In terms of scale and design concept, the weir took a leading role among other works of the same era.

As one of the longest weirs in China in that era, it was designed to fully consider uneven water inflows and provide sufficient water during the drought period. Diaoshibei, an accessory flood control project, was constructed on the trunk canal 3.5 km downstream of Chatan Weir to effectively drain the excess flood into Niuhou River during the flood period and hence prevent the downstream farmlands from being flooded.

In the early days, Chatan weir was primarily an irrigation project irrigating 600 ha of land. After multiple renovations, maintenance and the reinforcement work in 1983, its water inflow and water level increased. A small-size hydropower station was constructed with an annual generating capacity of 700 MWh to cover the operating and management expenses. The lakes and ponds distributed within the irrigation zone work for irrigation and impounding purposes and are also used for aquatic breeding by residents.

The construction of the Chatan Weir irrigation project improved the local economy, promoted social and cultural development, and led to rapid immigration and the expansion of the local clans. It also became an important cultural bridge that linked the local clans together for the canal's management. It is a true emblem of local cultures and traditions. In honour of Zhou Ju, the founder of Chatan Weir, a memorial grave was built, which has become a protected national cultural relic. Zhou's village also preserves Zhou's Ancestral Temple which was constructed 300 years ago with the constructor's portrait inside. Each year, the villagers hold a sacrificial ceremony to memorise Zhou Ju and his contribution.

2.4 CHONGYI SHANGBAO TERRACES

Name	**Chongyi Shangbao Terraces**
Location	**Jiangxi Province, China**
Latitude	**N 25°24'~25°55'**
Longitude	**E 113°55'~114°38'**
Category of Structure	**Terrace**
Year of commissioning	**12th to 13th Century**
River Basin	**Zhangjiang River Basin under the Gangjiang River System, Yangtze River tributary**
Irrigated/Drained Area	**more than 3,400 ha**

History

According to the Classic of Mountains and Seas and other historical documents, the development of the Shangbao Terraces dates back to the pre-Qin period before 221 BC. Later in the Qin and Han dynasties, the terraces had gradually taken shape. After regular repairs and expansions in the later dynasties of Tang, Song, Yuan, Ming and Qing, the terraces eventually obtained their present magnificence. The remains of the stone dog preserved at the Chishui Village of Shangbao Township are proof of the terraces' early history.

Chongyi Shangbao Terraces began to form a full-scale in the Southern Song Dynasty more than 800 years ago. However, agricultural development in the region dates far back to the Qin and Han Dynasties. After China was unified in 221 BC, people from the north began to migrate to this region. A prefectural government was then established, and Chongyi County was within its jurisdiction. Later in the Tang Dynasty (618-907), the local ethnic minorities and migrants from the north (the Hakka people) gradually integrated, and the large scale development of terraces started. This process continued into the Song Dynasty (960-1279). At that time, the locals built terraces on gentler mountain slopes to expand arable land and constructed systems of mountain ponds, canals, ditches and bamboo pipes to utilize the abundant water resources and achieve gravity irrigation. In the later half of the Song Dynasty or the Southern Song Dynasty, the Terraces had reached a relatively large scale, which ensured local grain output and supported population growth. In the later Dynasties of Yuan (1271-1368) and Ming (1368-1644), the migration continued, and the following ballooning demand for food made it necessary to build more terraces. As a result, isolated terraces gradually became contiguous, spanning mountain after mountain. By 1552, 60 weirs had been built, irrigating more than 530 ha of land. At the early stage of the Qing Dynasty (1636-1912), the government adopted a series of policies to encourage migration and agricultural production. For instance, financial subsidies were offered for land reclamation. As a result, more and more people were driven to relocate to Chongyi County, leading to a surge in population and further expansion of terraces. It was during this period that Chongyi Shangbao Terraces attained its current scale. Also during this period, even more attention was given to the conservation of water and soil resources. By 1893, 77 weirs had been built, irrigating more than 780 ha of farmland.

After the foundation of the People's Republic of China in 1949, both the scale (3,400 ha) and the grain yield of the Terraces further expanded thanks to the construction and rehabilitation of infrastructures such as canals and weirs. In addition, the protection of the local ecosystem and cultural heritages has been gaining weight. In 2012, it was given the title "the largest Hakka Terrace in the World" by the Guinness Book of Records. In April 2018, it was listed as a "Globally Important Agricultural Heritage System" by FAO.

Description

Between the Luoxiao Mountains and the Zhuguang Mountains, at the source of the Zhangjiang River, a tributary of the Ganjiang River in the Yangtze River basin, there is a settlement of the Hakka people where the local mountains have been transformed into terraces. This is the Chongyi Shangbao Terraces, a marvel of the Hakka farming culture.

Located in the northwest of the mountainous Chongyi County of Jiangxi Province of China, the Terraces cover an area of about 3,400 ha distributed in 26 villages of the three townships of Shangbao, Fengzhou and Sishun. With a maximum altitude of 1,260 m and a minimum of 280 m, the terraces have a vertical drop as large as 1000 m, and the largest terrace has as many as 62 levels of ridges.

Shaped by the mountainous terrain, the Chongyi Shangbao Terraces flourish because of the water. The densely forested mountains help store abundant water resources; the granite mountain structure constitutes an impermeable reservoir so that rainwater harvested on the mountaintop can only seep out from the hillside slopes, creating a natural underground distribution and drainage network with reliable water supply to the terraces.

For thousands of years, local people have respected the laws of nature and built terraces with a water distribution system tailored to the local conditions. Connected to this irrigation network, each ridge serves as a small reservoir and soil preservation bed, preventing and controlling land erosion. This is indeed a good example of irrigation engineering created and perfected by the ancient Chinese people.

In general, the Chongyi Shangbao Terraces adopt gravity irrigation, and various irrigation methods are applied in different water demand scenarios such as isolated hills and seasonal and meteorological changes. The irrigation system of the terraces can be divided into three categories, namely the water storage structures, the canal network, and water flow regulation facilities. There are three ways of water storage: water directly seeping out of the mountain slopes, man-made water storage and distribution structures, and man-made filter and sedimentation facilities. Under the category of the canal network, there are several sub-categories: diverting water with weirs, delivering water through inverted siphons, using the small plots of farmland as canals, delivering water with aqueducts and bamboo tubes, and lifting water with waterwheels. For water flow regulation, water-distributing stones and pipeline valves are installed.

Today, the structure and layout of this gravity irrigation system are still intact. As a product of the sweat and wisdom of the ancient Chinese people, it has become an important part of the local agricultural economy. Combined with the development concept of modern agriculture, it is helping realize the value and functional potential of the terraces.

With the simplest engineering facilities and minimal maintenance, the Chongyi Shangbao Terraces have achieved sustainable and efficient gravity irrigation and thus strongly boosted land reclamation and agricultural production. Currently, the average grain yield has exceeded 7,500 kg/ha. Meanwhile, the ecological concepts and experience in construction and management accumulated over the past millennia could serve as a valuable reference for modern terrace management and soil and water conservation.

The Longsheng Terraces of Guangxi, the Yuanyang Terraces of Yunnan, and the Chongyi Shangbao Terraces are the three most scenic terrace systems in China. The Chongyi Shangbao Terraces also called the heavenly stairs, are spectacular throughout the year. In spring, the irrigated paddy fields are like strings of silver chains hanging in the mountains; in summer, the lush crops are like green waves pouring from the sky; the autumn is the season of gold, featuring the joy of harvest; in winter, the terraces are covered with pure snow, auguring another fruitful year.

Water Heritage

The building of the Terraces has improved irrigation conditions and thus enlarged the area of the paddy field. According to the Chronicles of Chongyi County, back in 1522, Chongyi County had about 4181 ha of arable land; in 1706, it grew to about 5235 ha; then, in 1765, it further increased to 5384 ha; by 1937, the arable land had expanded to around 9772 ha; after the foundation of the People's Republic of China in 1949, the figure was 10491 ha, of which 10280 ha were paddy field, and the growing trend has continued.

The development of the Terraces has also driven the formation of the local paddy-based agricultural structure. Within the long history of the Terraces, people have bred various strains of rice tailored to local water and soil conditions, including varieties of indica rice, japonica rice, early season rice and late rice, and formulated different cropping systems respectively. Irrigation and drainage facilities of the Terraces have greatly boosted local grain yield. According to the Chronicles of Chongyi County, by 1942, the grain yield per hectare had reached 3240 kg; currently, the figure is more than 7500 kg/ha. It is the sound irrigation and drainage system of the Terraces that has transformed the wild mountains into a land of fertility and prosperity.

The construction of the Terraces is a process of mountain development and population growth. The irrigation and drainage system, by bolstering land reclamation and agricultural production, has also helped the expansion of human settlements and population growth, which in turn further enhanced local economic and social development.

Currently, the Terraces supply 76.5% of food crops, various oil-bearing crops, vegetables and fruits for the local people. In 2015, the economic revenue of the proposed site was 1.357 billion yuan. The income from farming/agriculture contributed 87.8% to the total income of the rural households, while that from agriculture and forestry contributed 78.7%.

When building the terraces, the locals had fully considered the natural conditions of the mountains: the forest on the mountain top was preserved for water conservation; below the mountain top, villages were built; and below the villages lay the terraces. The canopy and soil of the forest above the terraces can greatly conserve water and effectively regulate the spatial and temporal distribution of rainwater. On rainy days, the forest ecosystem on the top part of the mountain can retain part of the rainwater, which will decrease the surface runoff and weaken the flood peak of rivers.

Meanwhile, in the dry season, the water conserved by the forest will infiltrate gradually into the terraces to meet the water demand of terrace crops. The soil of terraces can also conserve water to some extent and guarantee the water demand of varieties of plants in the ecosystem. Soil retention is also an important ecosystem function of these terraces. Covered by dense forests, terraces are rich in a variety of plants. Soil fixation character of vegetation roots is realized by the organic matter secreted by plants, which can therefore cement the soil and make them strong enough to resist soil erosion. The canopy of tall trees intercepts raindrops to undermine the erosion force of rain splashing directly on the soil, while the regulation of the ground vegetation and the litter layer on precipitation and runoff eliminates the erosion forces of rainfall from the top and runoff on the surface of the soil. Therefore, the terraces can help achieve better soil conservation, which is reflected in avoiding the waste of land, reducing sediment deposition and preventing the loss of soil nutrients. In this way, the elements of forests, villages and terraces are transformed into an integrated and eco-friendly agricultural system.

The building materials of the Terraces and the local farming practices have also reflected the respect and protection of nature. Built with locally produced soil, bamboo pipes and stones, the terraces fit perfectly into their surroundings, minimizing the impact on the local ecosystem. In addition, only organic fertilizers such as animal waste and plant-based compost are applied.

Besides, the design and scale of the terraces are based on the carrying capacity of local water resources. In ancient times, people drew insights and lessons from past experiences and formulated reclamation plans annually. If the hydrothermal condition was good, the plan would be more ambitious; if a drought was likely, they would reduce or even stop the work of reclamation. This principle of measured development has helped prevent the waste of human and material resources and the drastic change in the local ecosystem.

The Terraces are models of sustainable management of land and water resources in mountainous and hilly areas, providing important experiences for coping with global ecological problems like land degradation, extreme droughts and floods caused by climate change.

The history of Chongyi Shangbao Terraces dates back to the 12th-13th centuries. The Terraces are constituted by water storage structures, water diversion structures, canal systems, waterwheels and drainage structures. Its engineering form remains unchanged today. The gravity irrigation system of Chongyi Shangbao Terraces is an embodiment of the ancient Chinese philosophy of harmony between man and water, and man is an integral part of nature. In addition to the use of locally available building materials, the layout, engineering design and construction of weirs, water intakes and canals are all based on local terrain and resource availability, aiming at minimizing the possible impact on the local ecosystem.

Besides, the Terraces are home to various heritages of agricultural culture, including proverbs and calendars assisting farming and rituals and customs such as bull dance. In April 2018, the Terraces, under the name of “Jiangxi Chongyi Hakka Terraces”, were listed as a “Globally Important Agricultural Heritage System” by FAO as part of “Rice Terraces in Southern Mountainous and Hilly areas, China”.

2.5 DONGFENG WEIR

Name	**Dongfeng Weir**
Location	**Jiajiang County of Sichuan (Zhoucun City), China**
Latitude	**29.786**
Longitude	**103.499**
Category of Structure	**Diversion weir for irrigation**
Year of commissioning	**1662 AD**
River Basin	**Qingyijiang River, a tributary of the Yangtze River**
Irrigated/Drained Area	**5113 ha**

History

Built in 1662 during the Qing dynasty in southwestern China, the Dongfeng Weir is a masterpiece of historic irrigation development and the most incredible work of diversion irrigation without dams along the Qingyijiang River, the tier 3 tributary of Yangtze River. It is an outstanding example of sustainable operation and management, ecological conservation, and development in its command for more than 350 years. As a public infrastructure, the Dongfeng Weir, with its water distribution system, was initially built by the government of the Qing Dynasty in 1662. The local people took charge of annual repair outlay, labour expenditure, and construction supervision. This management mechanism continued until 1949.

Description

Dongfeng Weir is located in the Jiajiang County of Sichuan Province at the upper reach of the Qingyijiang River, where the river starts to enter the county. The premise enjoys the natural advantage of gravity water diversion. To divert water from the river, it is necessary to cut a water inlet in the first place.

As a water inlet, the Dongfeng weir was initially made of bamboo baskets filled with cobbles and earth-rock available in local mountains. In addition, the whole project consists of one 12 km main diversion canal, two secondary canals diverting into four by-canals, one tunnel, 11 aqueducts, 21 watergates and other supporting facilities. The main diversion canal connects ten previous micro canal systems, and the net of canals goes through Jiajiang County.

Since the completion of the project in 1662, its irrigated area has expanded over ten times from 467 ha to 5,113 ha, covering four towns and 48 villages. The local multiple cropping index has increased to 2.68 and the cultivated area to 13,367 ha. The weir serves combined functions of irrigation, drainage, urban flood control, and environmental water management. Two sub-canals throughout the county create an aesthetic and pleasant environment for the residents. The sufficient water supply through the weir helps in reducing pollution. Several changes to the site of the water intake ensured diverted surface water of Qingyijiang River with reduced sediment load and helped in ecological and water-soil conservation. Overall, the weir and canal system has contributed to irrigation farming, ecological conservation, and the economy. Before the Dongfeng Weir and Canal system, Jiajiang County was drought-prone. The Dongfeng weir and canal substantially promoted irrigation and economic development along the Qingyijiang River. Since its completion in 1662, a sufficient irrigation water supply has ensured agriculture stabilisation and social development.

The project has continuously been used for more than 350 years and underwent reconditioning twice to achieve an increased and sufficient water supply. In 2006, when the once-in-a-century drought attacked Sichuan Province and led to severe water shortage in many places, Jiajiang County was not affected. It achieved a good harvest thanks to Dongfeng Weir. Apart from playing a critical role in fighting drought, the water reserve of Dongfeng Weir also replenishes groundwater sources and improves the ecological balance.

As to the management of Dongfeng Weir, the local government manages the general canals and branch canals; the water user associations in villages are responsible for the sub-lateral canals. During the peak of irrigation, four other groups are set up to communicate among water users and between water users and project managers to coordinate water supply. The project provides sufficient, reliable, and sustainable irrigation water supply and is now performing the combined function of irrigation, drainage, urban flood control, and eco-environmental water supply.

Water Heritage

The design and construction of the weir exemplify the ancient Chinese philosophy of harmony with nature. According to the local geological and hydraulic conditions, in 1662, the county magistrate Wang Shikui led the construction of Dongfeng Weir. At that time, the Weir was made of bamboo baskets filled with cobbles and earth-rock from local mountains at that time.

As a cultural icon, the weir played an essential role in smoothly bringing together the community and the government. It has also saved the region from multiple droughts. The weir also provides the residents with a pleasant neighbourhood.

Dongfeng Weir is a waterworks built in the Qing Dynasty for sufficient, reliable and sustainable irrigation water supply. The whole site has remained in use continuously for 360 years. It has been reconditioned twice on large scale, and the water inlet has been moved three times for sufficient water supply. The several changes to the site of the water inlet has made sure that the surface water of the Qingyijiang River could be diverted efficiently. In this way, the water flow is increased, sediment reduced, and ecological and water-soil conservation achieved.

2.6 DUJIANGYAN JIANGYAN IRRIGATION SYSTEM

Name	**Dujiangyan Irrigation System**
Location	**Sichuan Province (Dujiangyan City), China**
Latitude	**31.008651**
Longitude	**103.606847**
Category of Structure	**Water diversion structures and canal systems**
Year of commissioning	**256 BC**
River Basin	**Minjiang River (a tributary of Yangtze River)**
Irrigated/Drained Area	**701,066.7 ha**

History

The Dujiangyan irrigation system was built in 256 BC. For over 2,200 years, it has played an imperative role in the economic and social development of the Sichuan province and left a rich water cultural heritage for future generations. The irrigation system provides an abundant water supply to the Chengdu Plain and offers benefits for irrigation, flood prevention and control, and water transport. It contributes to creating a land of abundance on the Chengdu Plain with an abundant water supply and no famine. Because of the irrigation system, the Chengdu Plain has been the granary of western China and the political, cultural, and economic centre of southwestern China since the 2nd century.

The Dujiangyan Irrigation System was continuously built and developed in different dynasties and ages. The period of creation and improvement began in 256 BC when the governor of the Shu Prefecture, Li Bing, constructed the Dujiangyan Irrigation System. The water of the Minjiang River was introduced into the heartland of the plain by building the Fish Mouth Levee and the Bottle Neck Canal. The project was mainly used for flood prevention and control, water transport and irrigation. In AD 662, the Flying Sand Weir was completed, which signified the formation of the distribution of the three major projects of the headworks of the Dujiangyan Irrigation System. During the Tang (AD 618–907) and Song (AD 960–1279) dynasties, prosperity and stability prevailed, expanding the irrigation area of the Dujiangyan project to cover 12 counties. By the end of the 1940s, the project provided irrigation water to 1,88,000 ha of farmland in 14 counties on the Chengdu Plain. From 1949, the system experienced large-scale transformations and development. Currently, the project provides irrigation water to 7,10,000 ha of farmland in 38 counties in 7 cities of the Sichuan Province.

Description

The Dujiangyan Irrigation System is built at the point where the Minjiang River enters the Chengdu Plain. The river is a first-level tributary of the Yangtze River with a total length of 711 km. Its middle reach within the Chengdu Plain runs 216 km long, accounting for 30% of its total length. Here, the river's gradient gradually drops from 10% to 1%, and its slope is around 8.2%. The left bank of the river is the ancient landslide belt of Er'wang Temple, and Mount Lidui is the product of geotectonic movement.

The Dujiangyan Irrigation System is an engineering system that consists of headwork, water-diverting channels at various levels in the irrigation district, ponds, weirs and farmlands. The project has created a water environment characterised by crisscrossing rivers and densely distributed ponds, lakes and swamps on the Chengdu Plain. The headwork system mainly consists of the three major parts of the Fish-Mouth Diverting Levee, Flying-Sand Weir (spillway) and Bottle Neck Canal, and the Baizhang Dike's auxiliary projects and the Renzi Dike. It is the water-diverting hub of the irrigation system where people fully utilise Minjiang River bed terrain and manage river water diversion, sediment flushing, inlet flow control and flood discharge, and achieved multiple benefits with minimal engineering facilities.

The headwork project has been renovated and improved many times for the sustained development of the Dujiangyan Irrigation System. Starting from the Fish Mouth Levee, the water flow is controlled by water diversion levees and overflow weirs made of bamboo cages and timber piles. Though no gate has been installed, the water of the Minjiang River could reach the farmland and the residential communities smoothly.

The system's management mechanism was characterized by a conjunctive workflow between the government and the community. Such arrangements ensured the sustained development of the irrigation district and provided a historical experience that people can draw from for present-day water resources projects. The management of the irrigation system involved a highly centralized administrative system with a decentralized approach. The water resources officials in provincial, prefectural and county governments carried the administrative management for headwork, channels and weirs at the main canal level, and while branch canal level, and rural water resources bodies, field ditches were managed by the community. Such an official and non-governmental management system allowed a mutually beneficial relationship.

The Dujiangyan Irrigation System has a super-large irrigation district, the first one with an irrigated area that exceeds 6,66,666.67 ha in China. At present, the project has already developed into a tremendous engineering system composed of headwork projects, water-diverting canals of various levels in the irrigation district, various kinds of engineering structures, large, medium and small-sized reservoirs, ponds and weirs. An engineering pattern characterized by the combination of water diversion, water storage and a weir system has been formed as the System's feature. There are now 111 main and sub-main canals in the irrigation district that run 3,664 km long, 260 branch canals that run 3,234 km long, each irrigating thousands of hectares of farmland, and field ditches below branch canals that run over 34,000 km. There are also three large reservoirs, 21 medium-sized reservoirs, small-sized reservoirs and other micro water storage facilities, all these providing a gross storage capacity of 2.471 BCM. At present, the irrigation system covers an area of 23,200 km2 and provides irrigation water to 710,000 ha of farmland.

In addition to guaranteeing agricultural water, the system also possesses multi-target comprehensive service functions such as providing urban industrial and domestic water, preventing and controlling floods, generating electricity, promoting the development of aquaculture and farmed animal industries, planting industry, and tourism, and supporting the environmental protection. It possesses a critical status and role in the national economy and social development of the Sichuan Province. The population benefited by the Dujiangyan Irrigation System accounts for 27.5% of the provincial total; the industrial output value and the gross national product of the Dujiangyan Irrigation District account for 44.6% and 44.3%, respectively.

The weirs or canals of the Dujiangyan Irrigation System as irrigation water supply channels, drainage channels and waterways reshaped the rivers on the Chengdu Plain. They provided for the city of Chengdu and the 14 county towns and market towns in water supply, water transport, environmental needs, and flood prevention and control. The System provided a high-quality landscape environment, habitat environment and ecological environment. The construction of the Dujiangyan Irrigation System radically improved the urban and rural ecological environment of the Chengdu Plain. The Mohechi Pond, the Jinshuihe River, the Yuhe River, the Fuhe River, the Modihe River, and the Qingshuihe River were built in different ages from the Tang Dynasty (AD 618–907), constituted the developed urban water system of the city of Chengdu. There are 192 bridges of various kinds in the city. The Dujiangyan Irrigation System nourished the land of the ancient Shu region. Vibrant woods and bamboo, crisscrossing rivers, and densely distributed lakes, weirs and ponds formed a beautiful landscape.

Water Heritage

The Dujiangyan Irrigation System is a dam-less water diversion project with the longest history in the world.

Its history exceeds 2200 years (dated back to 256 BC). The project's planning, design, and construction address the issues of irrigation, flood prevention and control, and water transport have been scientifically addressed. Its engineering form remains unchanged today.

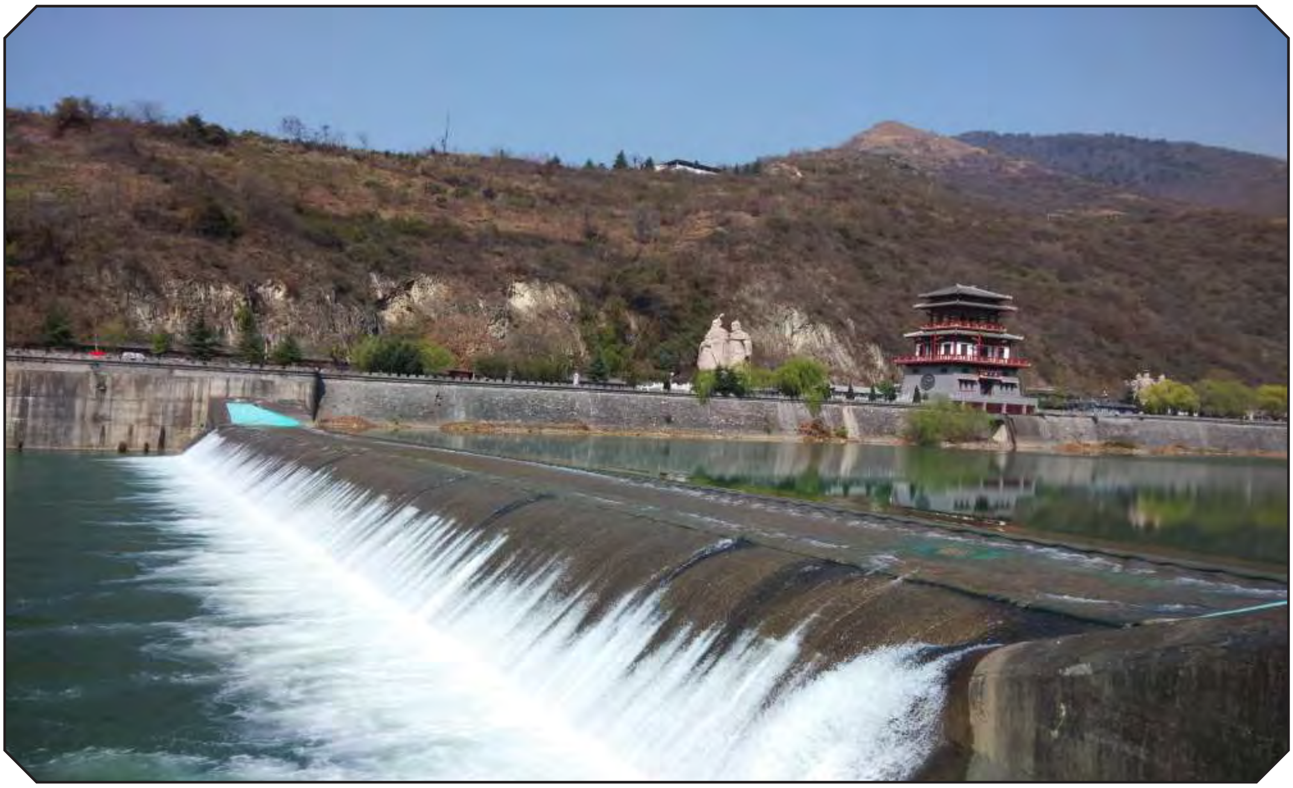
The headwork system mainly consists of the three major parts of the Fish-Mouth Diverting Levee, Flying-Sand Weir (spillway) and Bottle Neck Canal, and the Baizhang Dike's auxiliary projects and the Renzi Dike. It is the water-diverting hub of the irrigation system. The people adopted measures to build on the local geographical and climatic conditions. They fully utilized the terrain of the Minjiang River bed and scientifically resolved the issues of river water diversion, sediment flushing, water transport and flood discharge, materializing the development philosophy of the harmonious coexistence of man and nature. Weir engineering technology and annual maintenance system were formed with unique features. People summarized the water regulation principles and philosophy epitomized by "digging riverbed deep and building weirs low" and created the Dujiangyan water culture with great charm.

Built at the end of the Warring States Period (475 BC-221 BC), it laid a good foundation for developing water resources projects on the Minjiang River. Since the Western Han Dynasty (206 BC-AD 24), the irrigation district of the project saw rapid development. The headwork was gradually improved and perfected. Irrigation channels extended on the Chengdu Plain and formed a crisscrossing river network. The water channels in the irrigation district, similar to natural streams, provided irrigation water and the convenience of flood discharge and water transport. The developed regional economy made Chengdu Plain the political, cultural, and economic centre of southwestern China. From the Three Kingdoms (AD 220–280) to the Five Dynasties and Ten Kingdoms (AD 907–960) after the Tang Dynasty (AD 618–907), Chengdu remained the economic epicentre for a long time. In contrast to the Central Plains in turmoil at that time, the affluent Chengdu Plain was prosperous and stable and won the "Land of Abundance" reputation.

The Dujiangyan Irrigation District has become the heartland of the Sichuan Province with the most prosperous and developed economy. The Dujiangyan Irrigation System has played a critical role in the Sichuan region's grain safety, economic development, and social stability for over 2,200 years. Though the irrigation system accounts for less than 5% of the provincial total land area, the project covers 25.8% of the population and 20.7% of the province's effective irrigation area. It is both a water resources project with great historical relevance that has played a role in the unification of China and a construction that achieved harmony between man and nature.

2.7 HANZHONG ANCIENT WEIR IRRIGATION SYSTEM

Name	**Hanzhong Ancient Weir and Irrigation System**
Location	**Shaanxi Province (Hanzhong City), China**
Latitude	**35.394**
Longitude	**109.188**
Category of Structure	**Irrigation System**
Year of commissioning	**Early 10th Century**
River Basin	**Han River (a tributary of the Yangtze River)**
Irrigated/Drained Area	**14500 ha**



History

Hanzhong Ancient Weir Irrigation System (Shanhe Weir, Wumen Weir and Yangtian Weir) is located in Hanzhong Basin, southwestern part of Shaanxi Province. It is a typical irrigation system with weirs diverting water in the upper reaches of the Han River. Hanzhong Ancient Weir Irrigation System mainly refers to Shanhe Weir on the Baohe River, and Wumen Weir and Yangtian Weir on the Xushui River (both the Baohe River and Xushui River are tributaries of the Han River). The canal networks of the three weirs are interconnected with the irrigation area forming an organic whole. They irrigate the core area of the Hanzhong Basin, hence pushing forward the regional agricultural development.

By the 1st century AD, Hanzhong Basin had a large-scale irrigation system using water diverted through weirs. In the 11th century, the irrigation project of the Han River witnessed re-development. During the Jin–Song Wars (1125–1234), Hanzhong as the frontier base provided war expenses leading to its rapid development. During the Song Dynasty (AD 960–1279), the Hanzhong Ancient Weir Irrigation System, consisting of Shanhe Weir, Wumen Weir, and Yangtian Weir, took shape by and large. In the mid-12th century, the irrigation area of Shanhe Weir amounted to 15,333.3 ha. During the Yuan (1271–1368), the Ming (1368–1644) and the Qing (1644–1912) dynasties, the irrigation system underwent several renovations. Between the 14th century and 16th century, the government and the people rebuilt the five water intakes and expanded the stone canals at the irrigating gate of Wumen Weir successively. As a result, the irrigation area increased by 3,333.3 ha. At the end of the 16th century, the water intake sluice of Yangtian Weir was reconstructed on a large scale by modelling after Wumen Weir. By then, the irrigation area of Yangtian Weir totalled 1,667.7 ha.

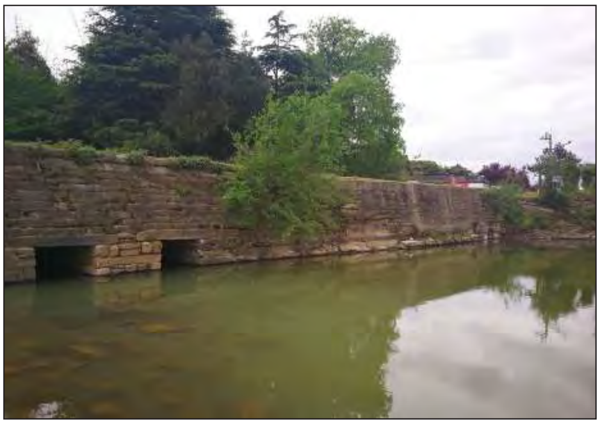
During the reign of Emperor Jiaqing (1796–1820), the irrigation water use and labour expenses of Yangtian Weir were shared proportionately between Chenggu County (30 %) and Yang County (70 %), respectively. Baohui Canal was constructed in 1942 and Xuhui Canal in 1948, replacing the original Shanhe Weir, Wumen Weir and Yangtian Weir. Later, due to the scanty water of the Xuhui Canal, the old Wumen Weir and Yangtian Weir were rebuilt in 1952, and the irrigation areas of both weirs increased to some extent. In 1975, with the reconstruction of the Shimen Reservoir, all the fields irrigated by the original Shanhe Weir were included in the irrigation district of the South Trunk Canal of Shimen Reservoir. In 2006, Wumen Weir was listed as an important heritage site under state protection by the State Council. Currently, the irrigation area of the three weirs totals 14,500 ha.

Description

Hanzhong Ancient Weir Irrigation System consists of three irrigation districts that interconnect and complement each other, jointly irrigating the core area of the Basin. The Irrigation System is mainly composed of canal headwork, irrigation and drainage canal network and control work.

Shanhe Weir dams the water of the Baohe River, which is a tributary of the Han River. The headwork of Shanhe Weir is at the mouth of the Baohe River Valley. During the Southern Song Dynasty (1127–1279), it had six weirs, unfortunately, destroyed by a water rush. During the Yuan, Ming and Qing periods, there were four weirs from north to south. Shanhe Weir I and Shanhe Weir II were built and managed by the government and are still the main irrigation facility of Shanhe Weir. The water intake is on the left bank of the Baohe River. The trunk canal winds eastward to Shibalipu where it turns southward into the Han River. Its overall length is 35 km, with over 60 branches. Shanhe Weir III is about 1 km away downstream of Weir II. Shanhe Weir IV, constructed in 1932, is 1.5 km away downstream of Weir III. Both weirs dam the water of the Baohe River at one of its branches on its east bank.

Wumen Weir is located along the Xushui River, 15 km north of Chenggu County. It mainly consists of a water-diversion weir, five water intakes, a water intake sluice and water outlet sluice, and an irrigation canal network. The water-diversion weir stretches over the Xushui River and shapes like a turning curve. Five water intakes located to the southeast of the barrage are the facility for irrigation diversion and water control. To ensure flood control safety of the canals, water intake sluice and water outlet sluice are constructed 300 m away downstream of the five water intakes. In case of excessive flooding, the water empties into the Xushui River via the water outlet sluice. Both sluices are still in use today. The trunk canal passes through the five water intakes and then bifurcates: one branch flows eastward and the other westward. The two branches flow for 550 m, performing the function of desilting, speed reduction and erosion prevention, and then reuniting again. The trunk canal is 22.8 km long.



Yangtian Weir, located at the middle reaches of Xushui River, about 10 km north of Chenggu County, consists of a water-diversion weir, water-control headwork, irrigation canal and excessive water outlet. The dam barrage is a masonry gravity dam that is 120 m long, 5 m wide and 2 m high. The trunk canal is 11 km long. 500 m away from the diversion dam is the relic of an ancient canal embankment that runs 900 m. The excessive water outlet, built during the Wanli period (1573–1620) of the Ming Dynasty, is 950 m away downstream of the headwork.

Hanzhong Ancient Weir Irrigation System, taking advantage of Han River tributaries, dams water with weirs. It takes advantage of the North-South gradient to deploy the irrigation canals and downflow weirs. With minimum engineering facilities and management, it performed multi-functions such as water diversion, irrigation and water volume control. The diversion canal begins in the east river valley of the Baohe River and ends at Shibalipu Town, Hanzhong City—a distance of 35 km. Yangtian Weir is located to the north of the Han River and covers Chenggu County and Yangxian County. It irrigates about 666.7 ha of farmland in this region. Today, most canals in Hanzhong Basin are included in Shimen Reservoir Irrigation Scheme or transformed into one part of modern irrigation districts: Baohui Canal and Xuhui Canal. Despite this, it maintains its ancient irrigation area and traditional management mode. Currently, the direct irrigation area of the three weirs totals 14,500 ha.

Hanzhong Ancient Weir Irrigation System contributed to increased agriculture production, the development of tourist economy, and a rich cultural heritage. Over the past 1,000 years and more, it has played a crucial role in developing the agricultural economy of Hanzhong Basin, the upper reaches of the Han River. Currently, Hanzhong Basin is a crucial rice-producing area of the Qinling-Daba Mountain area.

With social and economic development and an improved standard of living, people consider the irrigation system of a higher spiritual value. Since its inception, a significant number of natural and cultural relics have been left behind. Taking advantage of these relics, the management unit of the irrigation district promoted tourism, stimulating the development of the local tourist economy. Shimen Reservoir in Shanhe Weir was the site of the ancient Bao-Xie Plank Road, which has profound historical and cultural deposits concerning the Han Dynasty and the Three Kingdoms (Wei, Shu and Wu, AD 220–280). Specifically, Shimen Plank Road Scenic Area has been set up to develop its tourist industry. This not only increased the economic returns of the Department of Water Resources and stabilized the water management staff but also contributed to the economic development of Hanzhong. Moreover, the Goddess of Mercy Pavilion, Longmen Temple at Wumen Weir, Tomb of Yang Congyi beside Yangtian Weir, Orange Orchard Scenic Spot, Dou Mountain Taoism Center and Wetland Scenic Spot of Xushui River form the major scenic spots of ecological tourism of Hanzhong. The Museum of Hanzhong boasts a great number of water conservancy cultural relics, facilitating the tourist economy of the irrigation district.

Hanzhong Ancient Weir Irrigation System witnessed a sustainable management model--a joint governance model of the government and the common people. As of great military and strategic significance, it was jointly run by the government, the army and the civilians until the 12th century. Shanhe Weir was garrisoned by troops who opened up the wasteland, grew grain and built irrigation and drainage projects. After the Ming and Qing dynasties, Hanzhong Ancient Weir Irrigation System was mainly “superintended by the government and constructed by the common people”. Beneficiary peasant households undertook routine maintenance. In the case of overhaul or reconstruction, the local government would offer financial aid. Village regulations and agreements were carved on stone tablets by the government showing respect to the wisdom of the labouring people and standardising a joint management system. Currently, Hanzhong Ancient Weir Irrigation System is managed by the Hanzhong Bureau of Water Resources. They are in charge of monitoring and preserving Hanzhong Ancient Weir Irrigation System, guaranteeing the project’s safety and sustainable irrigation. Archaeological investigations are conducted, and the relics are preserved at the Museum of Hanzhong, which has an extensive collection of water conservancy inscriptions, irrigation tools, models, etc.

Water Heritage

Hanzhong Ancient Weir Irrigation System originated from the early period of the Northern Song Dynasty (AD 960–1127), and the project has a history of over 1,000 years. Hanzhong Ancient Weir Irrigation System played a significant role in the construction of Hanzhong, which was a cradle of the Han culture. It had a history of over 2,300 years since King Hui of the State of Qin established Hanzhong Prefecture in 312 BC. During the Three Kingdoms Period, Hanzhong was a strategic area of diplomatic importance and home to famous personalities like the warrior Zhu Geliang, Zhang Qian (pioneer of the opening of the Silk Road), and Cai Lun (inventor of papermaking technology, one of the four great inventions in Chinese history) was buried.

Historically, Hanzhong was the birthplace of the Han Dynasty (206 BC-AD 220) and successive dynasties. Since the construction of the Hanzhong Ancient Weir Irrigation System, cultural traditions with distinctive local features emerged. Yang Congyi (1092–1170), who contributed to weir construction, was worshipped and offered sacrifice every year.

The irrigation system is a cultural icon carrying forward the history of many generations. For the past 1,000 years and more, farmers in the irrigation district have benefited a lot from the three weirs of Hanzhong, hence holding a profound cultural identity. It represents water conservancy and cultural inheritance. Festivals and customs have been observed for thousands of years like the festival of opening canals to draw off water. Stone tablets also recorded the contributors and recognised them as water gods. The inscriptions showcase the history of the weirs, system, disputes over water conservancy, and local conditions and customs. These historical datasets are of vital significance to the history of the region and demonstrate a social perspective of Hanzhong.

Hanzhong Basin, located in a humid subtropical area, boasts an annual average rainfall of 846.6 mm, however uneven. The System capitalised on this rich water resource. Irrigation canals and overflow weirs were deployed by taking advantage of the North-South gradient. It performed multi-functions such as water diversion, irrigation and water volume control with limited engineering facilities and management. The production of grain crops such as rice and wheat increased, and cash crops including rape, maize, soybean, tea and oranges and tangerines gained popularity. This improved the livelihood of the farmers and promoted the prosperity of the countryside and reduced poverty. Gradually, it became a major grain-producing area, leading to grain production, higher incomes and sustainable development.

The Hanzhong Ancient Weir Irrigation System still maintains the ancient irrigation project’s water use method and irrigation area. The direct irrigation area of the three weirs reaches 14,500 ha. Currently, heritage signs have been set up at important sites of the irrigation district to increase the public’s awareness of cultural heritage and to facilitate protection and exhibition. For over 1,000 years, farmers in the irrigation district have benefited a lot from the system. People share a strong sense of cultural identity and pride in the System creating the social basis for its protection and inheritance.

2.8 HETAO IRRIGATION DISTRICT

Name	**Hetao Irrigation District**
Location	**Hetao Irrigation District of Inner Mongolia, China**
Latitude	**40.32 - 41.30**
Longitude	**105.02 - 109.32**
Category of Structure	**Irrigation System**
Year of commissioning	**2nd Century B.C.**
River Basin	**Yellow River Basin**
Irrigated/Drained Area	**67000 ha**

History

Situated in Bayannur City, Inner Mongolia Autonomous Region, the Hetao Irrigation District covers one of the most significant ancient irrigation areas in the Yellow River basin. The Hetao Plain is a flat and fertile region with favourable temperate arid and semi-arid climates and good precipitation levels, enabling the irrigation of the Yellow River to support the agricultural and economic development of the area. Therefore, the system is a witness to the conflicts and integration between nomadic and farming civilizations over the long history.

Irrigation activities in the Hetao region date back to the Qin dynasty and were recorded and documented since the Han dynasty. In 215 BC, Meng Tian, a famous general in the Qin dynasty, led people and promoted farming and settlements south of the Yellow River, including the Hetao Plain. Several historical records present the time and scale of irrigation in the region. After the unification of China in the Sui and Tang dynasty, farming and irrigation facilities were ramped up. There were three canals, namely Lingyang, Xianying, and Yongqing, during the Tang dynasty, and the total irrigation area covered was 32,000 ha, and annual grain production reached 400,000 hu. The landmark Shuibushi, or Water Administration Regulations, released by the Tang government, standardized the construction of irrigation structures and management at the national level, promoting further development of irrigation farming.

A growing population marked the end of the 18th century, and the public voluntarily initiated the construction of irrigation structures and used the river as the primary water supply source, before which the irrigation was limited, and the area was mainly used as a grazing field. In 1850, the Hetao section of the Yellow River was rechanneled from the Wula River in the north to the route in the south (the mainstream nowadays). The channel served as the new water supply of the Hetao Plain irrigation structures.

Later on, businessmen drove the expansion of the irrigation structure. In 1911, with over 40 canals diverting the water of the Yellow River, the system irrigated over 66,667 ha in the area, and the Hetao Irrigation District developed. After 1949, the system and the corresponding administrative regulations multiplied. The Sanshenggong diverting system, established in 1961, marked a new era for the irrigation system featuring advanced water supply and drainage systems and the integration of main structures and seven supporting systems for irrigation and drainage.

Description

The Yellow River originates in the Hetao Irrigation District at Sanshenggong headwork, and flows through the main canal, 13 branches and supporting channels to supply water for farms and lakes. The water then enters the drainage receiver in the Wuliangsu Sea through the Honggebu pumping station. It is returned into the Yellow River at the exit section of the central drainage system, completing an irrigation system with a single water intake. The system consists of 183,500 structures in total and covers an area of 600,000 ha. The heritage of Hetao Irrigation District includes eight major ancient canals, the original system before 1949, remains and historical sites of the abandoned structures, and those non-engineering items of historical and cultural values, including inscriptions and documents water-deities, worship temples and management facilities. The region experiences a temperate continental arid and semi-arid climate, with average annual precipitation of 169.4 mm, and average yearly evaporation of 1500 mm.

The management of the structure was passed through many dynasties, from the Qin Dynasty to the Tang Dynasty. After establishing the People's Republic of China in 1949, the government managed the construction and management of the irrigation system.

Throughout the 2,200 years of Hetao Irrigation District's history, the irrigated area continued to grow. Though not recorded before the Tang dynasty, from the 7th to the 8th century, it was nearly 32,000 ha, 66,667 in the early stage of the 20th century, 266,667 in the middle age of the 20th century, and 600,000 at present. The water availability also improved. With effective and efficient irrigation, grain output and population on the Hetao Plain kept growing. Grain produced during the 7th and 8th centuries was 25,000 tons, 150,000 tons in the middle age of the 20th century, and over 3 million at present. The number of people in the area grew from 50,000 in the Han dynasty (2nd century B.C.) to 400,000 in 1946 and 1 million in 1985. Crops of the irrigation area were mainly wheat, corn, soybeans and sorghum. Other than grain, Lycium barbarum and grape were also featured plants in the area. While Hetao Plain is now a significant grain base in northern China, it is the construction and development of the Irrigation Structure that facilitates the prosperity of agriculture and the economy of the place.

The Hetao Irrigation Structure located in the middle and upper reaches of the Yellow River mainly realizes irrigation and diversion without dams, which caused little influence on the environment, and managed to exist for over 2,000 years without rendering detriments. In addition, the professional planning of warping irrigation and crop rotation increased the fertility of the saline-alkali land. The irrigation system across the whole Hetao Plain realized the relatively even distribution of local water resources and generally improved the ecological conditions of the place. In conclusion, as a heritage irrigation structure, the Hetao Irrigation Structure greatly benefited the local environment.

At present, the irrigation structure is preserved the same as in the late stage of the Qing dynasty. The Sanshenggong irrigation structure built in 1961 integrated the existent scraps of channels and canals and unified diversion headworks. The irrigation and drainage system improved and thus increased irrigation coverage and water availability. The administration of the Hetao Irrigation District builds the Museum of the Yellow River Irrigation Culture to preserve the cultural items and heritage of the irrigation structure. At present, authorities in the irrigation area are formulating plans to protect and preserve the heritage structure. Once completed, the plans will serve as legal documents to systematically manage and preserve the structure and guarantee sustainable development.

Water Heritage

The Hetao Irrigation District is a classical large-scale irrigation project in Mongolian Plateau in China. The system's coverage reached over 32,000 ha in the Tang Dynasty and 66,667 ha in the Qing Dynasty. In 1940, the area irrigated was more than 266,667 ha, and the present coverage increased to more than 600,000 ha. Therefore, the irrigation area in the system had always been a representative exemplar of where techniques were very advanced for their time.

The establishment and development of the structure, that diverted the Yellow River in the Qin Dynasty and Han Dynasty, is the preclude for agricultural development in Hetao Plain. The construction of the supporting structures at the end of the Qing dynasty was a turning point and milestone ushering in an era when modern agriculture in the Hetao region embraced rapid development. In conclusion, the construction of the irrigation system laid the foundation for Hetao Irrigation District to become a major grain-producing base. The development of the

Hetao Irrigation District served as strong support for the nomadic civilization to transform into an agricultural civilization, which dramatically enhanced food production, increased agricultural output and local capacity for supporting the population, and improved economic benefits.

A large amount of mud and sand discharged into the river makes the Yellow River the most sediment-laden river globally, which determined that the irrigation structure was constructed without large barrages or dams. Such a system with a relevant small influence on the environment provided historical references for the construction theories and the evolution of technologies for modern hydropower engineering; hence it is of great academic value. The gradient of the irrigation area is small, resulting in poor drainage conditions and severe salinization problems. Referring to practices in the long history, local people summarized systematic methods and measures for crop screening, colmatage, drainage and cultivation practices, thus supporting modern theories and technologies for combatting salinization. The Hetao Irrigation District was constructed with diversion headwork without a dam and technologies for salinization prevention, so the whole system was flexible enough to accommodate after the rechannelling of the Yellow River. The ecology and environment were better preserved and guaranteed the essential condition for the irrigation system to develop, so the system is an exemplar of structures of its type in arid and semi-arid regions. During the district's evolution, engineers chose to apply the small-influence development mode that utilized the high-sediment river to irrigate salinized land and headwork with the dam.

The Hetao Irrigation District is where nomadic and agricultural civilisations meet, so it bears the records of civilizational conflicts and combinations and the political, economic, and cultural evolutions. The development of the irrigation area is closely linked to China's political situation, geopolitical landscape and the changes in population, society and economy. Therefore, the Hetao Irrigation District witnessed the development of the Chinese civilizations and bore traces of history. Through 2200 years, the operation and management system has been changing and adapting to developments, be it natural, social, economic, political, or even military situations, especially since the end of the Qing dynasty. In addition, the modest degree of development and the ecology-friendly planning enabled the area to enjoy sustainable development and thus become an exemplar of sustainable irrigation.

2.9 HUANG JU IRRIGATION SYSTEM

Name	**Huang Ju Irrigation System**
Location	**Fujian Province (Ningde Municipality), China**
Latitude	**26.8875**
Longitude	**119.475**
Category of Structure	**Irrigation System**
Year of commissioning	**Early 7th century**
River Basin	**Huotong River**
Irrigated/Drained Area	**1333.33 ha**

History

Huang Ju Irrigation System is located in the valley of the middle reaches of the Huotong River at Huotong Town in Jiaocheng District of Ningde City, Fujian Province. According to genealogical records and local historical data, the building of the Huang Ju Irrigation System began in the early 7th century. For more than 1,000 years, it played a significant role in promoting local economic, cultural, and social development. Even today, it plays an essential role in agricultural irrigation, domestic water supply, and hydraulic processing.

In the early 7th century, Huang Ju of the Sui Dynasty presided over the construction of a long weir for damming the water of Dashi Stream, a large tributary on the left bank of Huotong River, the digging of the Longyao Canal, and the digging of Pipa Culvert at Songanyang on the right bank of Huotong River for conducting water through the mountain. At first, Longyao Canal was used to irrigate about 66.7ha of fertile land at Shiqiao Village. The area of the irrigated land expanded to more than 1000 ha after the construction of Pipa Culvert was completed. The Huotong River changed its course due to floods in the Ming Dynasty, which led to significant changes in the local hydrologic environment. Despite this change of watercourse, the two water-diversion projects have been constantly improved and are in use today since the Sui and Tang dynasties.

Description

Huang Ju Irrigation System encompasses two irrigation projects. On the right bank of the river sits Longyao Canal, and on the left bank of the river sits Pipa Culvert. The trunk canal is about 10,000 m long, with an irrigated area of 1333.3 ha. The main crops planted in the irrigated area include paddy rice, tea tree and loquat. In Longyao Canal, the trunk canal is an open canal that is more than 5,000 m long, 1.51 to 2.72 m wide, and 0.95 to 3 m deep. A stone weir with a length of more than 20 m is built at the head of Longyao Canal. The water from the Dashi Stream—a large tributary of the Huotong River—is diverted into the channel of the open canal. The water bifurcates into two branches at a large banyan tree located along Longyao Canal's natural village. The water that runs along the terrain of one branch is used to irrigate farmlands at higher elevations while the water of the other is diverted into the village. The water in the village forms five cascades where water-powered huskers are built using the discrepancy in water levels to process agricultural and sideline products, grain, and oil. Then the water further bifurcates into two sub-branches. One sub-branch is used to irrigate more than 66.7ha of fertile land in Shiqiaoyang via Keshanliang, and the other is diverted into Sun Pond, Moon Pond, Star Pond, and other water-storage ponds. The latter sub-branch forms nine twists in Shiqiao Village. A stone toad is erected at the water's diversion. Its purpose is to block the swift currents to raise the water level. It also facilitates the management of the channel section by section and makes it convenient for villagers to use water for domestic use and as drought reserves. Thus, a water supply system characterized by three toads and nine twists is created.

The water from the canal is pooled for irrigating farmlands, and the Luoxing Pond in front of the Longshou Hall at the back of the village plays the role of water storage and adjustments. On the left bank of the Huotong River is Pipa Culvert. In the initial construction of Pipa Culvert, seven parts were dug at Song'an'yang for diverting water from Huotong River into Duping Lake via Pipa Culvert. Only five parts of the original Culvert remain today. Their total length is 77 m, average height is 2.41 m, and width is about one meter. The water diverted from Pipa Culvert mainly irrigates farmlands in the Hutouyang area. The Pipa Culvert and the head of the open canal in the lower reaches are dangerous and feature a remarkable discrepancy in elevation. On one side of the Culvert, sediment flushing outlets were dug for convenience in dredging and de-silting.

The extant canal network of Longyao Canal and Pipa Culvert maintains its original features. Huang Ju Irrigation System plays an irreplaceable role in promoting sustainable social development, ensuring economic prosperity and resisting natural disasters in Ningde City. Its irrigation area expanded from more than 1,000ha in its early days to the present1,333.3ha, covering many natural villages including Shiqiao Village, present Huotong Village, Pipadong Village (part of the land along Huotong River), and the original Huotong Village. Thanks to Huang Ju Irrigation System, advanced farming techniques and strains of crops were introduced from the Central Plain Areas of China. The area became the production base for loquat and tea leaves and is the home to late-maturing lychee in south China.

Water Heritage

According to genealogical records and local historical data, the Huang Ju Irrigation System building began in the early 7th century. Having been in use for more than 1,000 years on end, it is still delivering benefits today. The discrepancy of elevation was taken into consideration, and a scientific plan was designed. For example, the weir was built to block water, and the open canal and the culvert were constructed to divert water. A reasonable layout for water diversion, delivery, storage, irrigation, and drainage was thus formed. This layout ensures the irrigation system achieves various purposes. In the excavation of canals, an advanced water conservancy construction technique was introduced from the Central Plan Area to Fujian in preparing stone materials. Mountain stones were heated with fire to cause expansion and then cooled with water to force contraction. In this way, a reasonable cross-section of tunnels was also formed, increasing the canal's structural stability.

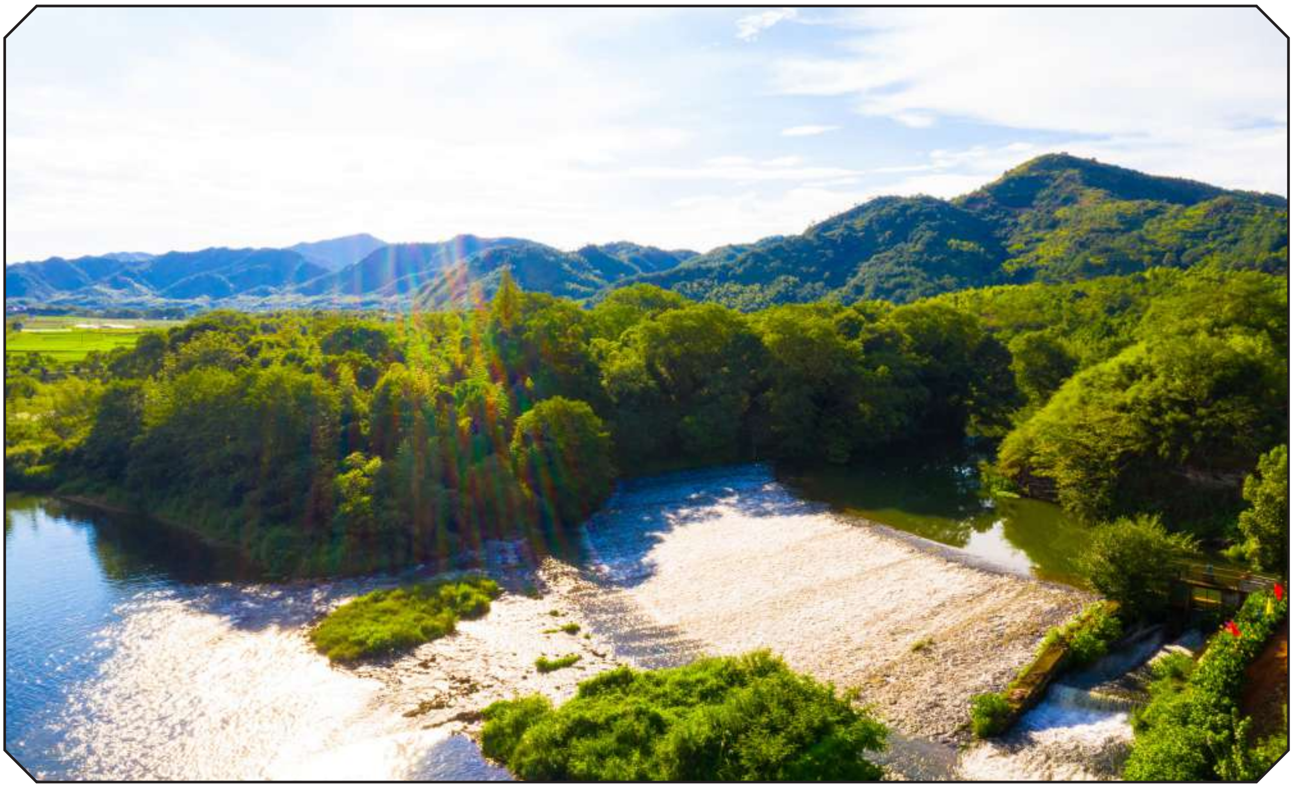
Before the construction of the irrigation system, the area nearby Huotong River was but a barren valley. The area was thick with weeds; there were very few pieces of fertile land, and people lived hard life. Later the project for diverting water from Longyao Canal and Pipa Culvert was completed. Advanced cultivation and seed-selecting techniques, fine strains of crops and farming techniques were introduced from the Central Plain Area into the valley of Huotong River. The soil conditions improved, the number of strains of crops increased, and the original barren valley turned into a piece of fertile land where loquat, tea leaves and rice are cultivated. By introducing water-powered mechanical equipment, farming techniques and new strains of crops, Huang Ju Irrigation System promoted economic development. The rich irrigation culture is also derived from the irrigation system.

The irrigation left an indelible imprint on the region's culture and history. At Huotong Town—where the irrigation system is located—the ancient buildings, streets, local customs and habits derived from the irrigation system remain today. As the founder of the irrigation system, Huang Ju is remembered as a guardian deity. The historically formed activities of honouring ancestors have crucial cultural significance in the maintenance and operations of the system until today.

For about one thousand years, under the joint management of the government, non-governmental sectors, and the community the Huang Ju Irrigation System has been protected and maintained as a valuable heritage. Today, the Water Resources Bureau of Jiaocheng District in Ningde City and the People's Government of Huotong Town under Jiaocheng District in Ningde City exercise joint management over the Huang Ju Irrigation System by taking charge of its daily maintenance. The irrigation system provided stable agricultural irrigation, domestic water supply, and hydraulic processing and enabled Ningde to become a highly livable city that boasts a sound ecological environment. Covering an effective irrigated area of 1333.3ha, Huang Ju Irrigation System guarantees that thousands of people living in Shiqiao and other villages nearby have access to safe water.

2.10 JIANGXIYAN IRRIGATION SYSTEM

Name	**Jiangxiyan Irrigation System**
Location	**Zhejiang Province (Longyou County), China**
Latitude	**29.031**
Longitude	**119.151**
Category of Structure	**Irrigation System**
Year of commissioning	**1330-1333 AD**
River Basin	**Yangtze River**
Irrigated/Drained Area	**2333 ha**



History

The Jiangxiyan Irrigation System is located in Jinqu Basin, west of Zhejiang Province. Longyou County of Zhejiang, situated in the moist subtropical monsoon climate region, boasts abundant rainfall, with annual average precipitation totalling 1761.9 mm. Jiangxiyan Irrigation System is the best preserved and the most representative part of the weir system of the Lingshangang River. The irrigation project of the Jiangxiyan Irrigation System makes full use of the terrain and its features. It takes the 5.33 ha of a sandbank in the riverway as the link, connecting Jiang Weir and Xi Weir, hence an angle-square-shaped retaining dam flowing from west to east with around 570 m, and a side-direction overflow weir, which realizes dam-less water diversion. Irrigating over 2,333 ha of farmland, the System is a model of mountain-river diversion projects constructed in ancient China.

In the 14th century, with the drastic increase in population in southern China, it was imperative to develop agriculture. Jiangxiyan Irrigation System was constructed from 1330 to 1333 under the supervision of a Mongolian official and is the only one of them built over 680 years ago, which is still in use today. The System faced many washouts, overhauls, and repairs and maintenance. The annual repair system, established in the Ming Dynasty (1368–1644), was passed on from generation to generation. The canal system of the Jiangxiyan Irrigation System, extending to the county town of Longyou, became a water conservancy project with comprehensive profits of irrigation, navigation and municipal water supply.

Since the 1950s, the headwork and the canal system of the Jiangxiyan Irrigation System have experienced several renovations. And the latest renovation was completed in 2014. It has maintained its original layout, structure, and weir building technology ever since its construction.

Description

The Jiangxiyan Irrigation System is composed of water-diversion headwork, irrigation, drainage canal network and control work. The water-diversion headwork includes Jiang Weir, Xi Wei, intake gate and scouring sluice. Jiang Weir and Xi Weir are also called the Upper Weir and the Lower Weir, respectively. Jiang Weir is located on the right side of the sandbank on the upper reaches of the Lingshangang River. It is 100 m long, and its bed is 32 m wide and 63.2 m high. Xi Weir is located on the left side of the end of the sandbank on the lower reaches. It is 50 m long, and its bed is 30 m wide and 63.1 m high. Xi Weir is arc-shaped, diverting water into the main irrigation canal through the intake gate. With the proper design of the weir crest elevation, Jiang Weir and Xi Weir regulate and control the water level, and the adequate volume of water is diverted. The weirs provide the water needed for irrigation, whereas the rest of the water runs downward when spilling over the weir crests. A scouring sluice has been built between Xi Weir and the intake gate for preventing sludge from accumulating at the river intake. The Lingshangang River was an important waterway historically. A raft sluice was specially built on the weir. It was closed when the water was diverted for irrigation and was opened for navigation the rest of the time. In light of the local geographical conditions, the headwork was constructed to divert water, drain flood, discharge sand, and create conditions for river traffic.

There were two main canals in the ancient Jiangxiyan Irrigation System: the East and West canals. According to a historical record, the irrigated area was more than 3,333 ha during Emperor Qianlong's reign of the Qing Dynasty. Jiangxiyan Irrigation System has been optimized since 1973. The system is composed of a general main canal, four main canals, namely the east canal, the west canal, the middle canal and the Guancun Canal, and 15 branch canals. The four main canals have a total length of 18.8 km. The 15 branch canals have a total length of 30.87 km. Twenty-four slices of different sizes are distributed on the canals. They regulate and distribute water and drain floodwater.

The whole system mainly irrigates 21 administrative villages under the jurisdiction of the Longzhou neighbourhood, Donghua neighbourhood and Zhanjia Township, with the irrigated area totalling 2,333 ha. Paddy rice is the main grain crop in the irrigation district. Vegetables, tea bushes, oranges and tangerines are the main cash crops. In 1955, double-cropping rice was popularized, which led to a dramatic increase in grain yields. As a result, Sihoufan was known as a barn and a genuine land of fish and rice. After the completion of the Jiangxiyan Irrigation System, its capacity for drought resistance was greatly enhanced. Water diverted from the Jiangxiyan Irrigation System is still in use in the downtown area of Longyou.

Presently, a special management organization is in charge of the maintenance and protection of the project and the heritages, guaranteeing engineering safety and the sustainable development of irrigation and facilitating the long-term protection and inheritance of the irrigation system scientifically. The local government conducts systematic surveys and protects the cultural relics. Now, hydraulic engineering inscriptions, irrigation tools and management records are well preserved in Longyou Museum.

Water Heritage

Jiangxiyan Irrigation System played a vital role in boosting agricultural and commercial development. It provided for irrigation, domestic supply, and ecological development. With increased water supply, irrigation techniques advanced. With the evolution of food processing methods, labour productivity significantly increased. The region flourished in other commercial activities like the handicraft industry. After its completion, Jiangxiyan Irrigation System has made full use of the headwaters of the Lingshangang River. It guarantees gravity irrigation, irrigating over 2,000 ha of farmland in the lower reaches. The largest irrigated area in history amounts to 3333.33 ha, intensely pushing forward the local agricultural development. Jiangxiyan Irrigation System makes full use of the natural conditions of the Lingshangang River flowing from the mountainous area to the plains. Based on the sandbank in the riverway, the weirs were built rationally and scientifically, featuring dynamic integration of the upper and lower weir.

Moreover, it takes full advantage of the water resources of the natural rivers to irrigate the farmland and improve people's survivability. In this sense, it is a model for respecting nature and attaching importance to sustainable development. According to historical records, there were 72 sub-weirs under Jiangxiyan Irrigation System in the 17th century. Water-powered devices such as water-powered trip hammers and scoop waterwheels were installed along the canals to help farmers process products and lift water to irrigate farmland. The ruins of water-powered trip hammers can still be found in some places, which are named after the trip hammers. A pinewood framework was embedded into the weir body to consolidate the weir structure. After a flood damaged the weirs, the mortar was used to consolidate the weir surface when the weirs were repaired.

Following the completion of the Jiangxiyan Irrigation System, a 300 m2 weir god temple was built at Shanlitou Village to commemorate the Mongolian official and the Jiang and Xi families who had contributed the most. Every year, rituals like closing the weir, discharging water and praying for rain in times of drought were held at this temple. It was also the site for the government officials and the villagers to discuss official business. The temple was a bond of communication between the government and the common people. Beside the temple, there is a camphor tree that has a history of over 360 years. Now, it is still thriving. It is called Weir God Tree by the local people.

The Jiangxiyan Irrigation System has successfully functioned for more than 680 years, owing to its effective management and operation system. Since its construction, it has been supervised by the local government and managed by the general public. Traditionally, county-level officials granted the management power and assigned specific tasks to the prestigious local gentry who would later distribute maintenance work to farmers benefiting from the irrigation system. Under the supervision of the prefectural and county governments, the local gentry was specifically responsible for repairing weirs and canals, managing relevant funds, and formulating relevant rules and regulations. This approach of integrating government supervision and private management is still in use today. It guarantees the sustainable operation of the Jiangxiyan Irrigation System.

2.11 LI CANAL-GAOYOU IRRIGATION DISTRICT

Name	**Li Canal-Gaoyou Irrigation District**
Location	**Gaoyou Irrigation District, Jiangsu, China**
Latitude	**N 32°38'~33°05'**
Longitude	**E 119°13'~119°50'**
Category of Structure	**Irrigation System**
Year of commissioning	**486 BC**
River Basin	**Huai River and Yangtze River**
Irrigated/Drained Area	**39,260 ha**

History

The history of the Gaoyou Irrigation District started with the famous Hangou Canal. The Master Zuo's Spring and Autumn Annals records in the ninth year during the reign of Duke Ai of Lu (486 BC): "In the Autumn, State Wu built Hangou Canal, which linked Jianghuai Area". In 486 BC, Fuchai, King of State Wu, fought for hegemony with the State Jin to defeat State Qi and become the lord in the north. At that time, there was no connecting waterway between the Yangtze River and the Huaihe River.

Fu Chai decided to excavate canals to connect the lakes between the two rivers, whereby forming a waterway connecting the two rivers and shortening the march route. Hangou Canal dug under the order of Fu Chai, the King of Wu, is very beneficial to the development of the local economy and has become one of the main water sources for local agricultural irrigation in the historical evolution.

It is because of the characteristics of Hangou Canal and the good irrigation function that the local economic, military and administrative status has become prominent. As a result, Yingzhou, the first emperor of China, built a high platform and a post office here in 223 BC, which is the origin of the name of Gaoyou ('Gao' means high in Chinese and 'you' means post). This reflected that the Gaoyou region had good irrigation agriculture at that time, which provided a solid economic foundation for the establishment of the Post Office of Qin. Three years later, Qin Shi Huang built a road to the seaside in Gaoyou, which can better reflect the local economy and agriculture.

Description

Building the Lake dyke: The formation of the irrigation network in the Sui and Tang Dynasties. During the Zhenguan period, thanks to the water conservancy function of the Hangou Canal (the precedent of Li Canal) dug in the Sui, the Gaoyou section of Hangou

Canal formed a water conservancy irrigation network managed by the central government officials under uniform planning.

According to the Six Codes of the Tang Dynasty, “When it comes to irrigation, it shall carry out average irrigation in the best season according to the amount of water”. Later, due to the fall of the water level of the canal that it was impossible to carry vessels, while the pond to the west of Li Canal had less water and also was not enough for water transport. Therefore, Governor Li Jifu built Pingjin Weir at the north entrance of Fanlianghu Lake to control the drainage of the canal, facilitate water transport and benefit the local agricultural irrigation.

During the Song and Yuan Dynasties, canal dyke and lake dyke were built. In the fifth year of the reign of Shaoxi (1194), Chen Shunzhi, the Governor of Huaidong, built a causeway from Jiangdu of Yangzhou to Huaiyin of Chuzhou, in a total of 360 li (1 li = 0.5 km). In this way, the lake water can be prevented from flowing to the periphery and the area of the lakes can be fixed, which is not only conducive to the stability of the water quantity of the canal but also promotes the growth of the lakes west to the canal and the development of agricultural irrigation water conservancy. Therefore, during this period, the canal was connected to the lake, which could provide water for the canal. As a result, with a stable water source, Gaoyou’s agriculture steadily improved at that time.

To solve the contradiction of water use between canals and farming, many water conservancy projects were built in Ming and Qing Dynasties, which improved the Gaoyou irrigation system gradually.

Building the dyke to separate the lake from the canal: In the early Ming Dynasty, there was no distinction between canal and lake on Li Canal, which was known as lake-canal. To reduce the potential safety hazard of the lake waves to shipping vessels, the large-scale construction of canal dykes was started by the Ming Dynasty to separate the Li Canal from the Gaoyou Lake.

Building water-reducing sluices and dams: To reduce the impact of floods upon the canal, the governments of the Ming and Qing Dynasties built water conservancy facilities such as water-reducing sluices and dams on the canal dyke of the Li Canal. By releasing water to the East, the water quantity of the canal can be controlled to ensure the smooth progress of water transport and irrigation.

To coordinate the contradictions between the parties, the government formulated the rules for the opening and releasing of the dam, which made the upstream dams of the canal have limits of releasing. Only when the water reached the fixed limit, could the sluice or dam be opened and released. For example, the water limits of the three dams, Nanguan, Wuli and Cheluo of Gaoyou, indicated that “the dam can only be opened when the water rises to more than three feet “. If the rule was broken, the related officials would either lose their jobs or even their lives.

After the founding of the People’s Republic of China, in 1953, large-scale construction of farmland water conservancy projects have been carried out to fight against drought and floods by water control, as well as excavation of trunk canals, construction of control buildings, and establishment of the gravity irrigation district. By 1958, 15 communes in the county had realized gravity irrigation, including five gravity irrigation districts of Cheluo, Nanguan, Touzha, Zhoushan and Ziying, with a gravity irrigation district of 36.8 km2; by 1965, the gravity irrigation district had developed into 55 km2, and the overall irrigation pattern of Gaoyou Irrigation District was formed.

Using the lake and canal for water storage, the gates, culverts, and dams for water distribution, and the main canal, branch canals and sub-lateral canals for water delivery, the heritage of the Li Canal and Gaoyou Irrigation District has formed a complete irrigation system that has achieved two dynamic balances: the balance of water levels during droughts and floods as well as the functional balance between water transport and irrigation.

Before the Ming Dynasty, the Li Canal was linked with many lakes. Starting from 1489 in the Ming Dynasty, the east and west embankments of the canal were gradually built to separate the Canal from the lakes, which not only protected the boats from winds and waves of the lakes but also transformed Gaoyou Lake into a water tank that regulates the water volume of the Canal and irrigation.

By 1921, nine gates, nine culverts and four overflow dams had been built on both sides of the Li Canal in Gaoyou, forming a sound irrigation and drainage system. Nanshuiguan Culvert (971), Ziying Gate (1596), Jieshou Gate (1653) Cheluo Gate (1740), and Pipa Culvert (1711) are all still in use today. Nanguan Dam, built in 1414, was in use till the founding of the People’s Republic of China. For hundreds of years, the canal water has nourished vast farmland through these time-honoured facilities.

In the Gaoyou Irrigation district, gravity irrigation is adopted by diverting water from the Li Canal. At present, the irrigation district has 8 water division culverts along the Grand Canal, with a total designed water diversion capacity of 150 m3/s, irrigating 39,260 ha of farmland of 10 towns and 135 administrative villages.

Water Heritage

Excavation of Li Canal provided a stable water source for regional irrigation, and irrigation reliability was further ensured by the lake-canal-gate dam-channel in the later period, which provided a strong guarantee for regional grain growth. During the Tang Dynasty, there was a saying that Yangzhou was No.1 and Yizhou (today's Chengdu) was No.2 in terms of agriculture production. Qin Guan, a poet in the Northern Song Dynasty, said: "According to Yugong-Shangshu, the farmland of Yangzhou only ranked ninth… but today, it is known for fertility. Why?" The ancient people constantly improved the land by building water conservancy facilities, which greatly enhanced land fertility.

According to the Records of Northern Tour written by Tan Qian in the Qing Dynasty; "It is agriculture that has made the locals rich." (Three Sequels of Annals of Gaoyou Prefecture written in the Republic of China period). The above extracts show that in the past, Gaoyou was a rich agricultural base because of the water conservancy projects.

Construction of Nanguan Dam is of great originality, and envelope heads in the north and south was built by laying boulder strips and a liquid obtained by mixing lime juice and sticky rice juice was applied between boulder strips for adhesion, with very small and nearly no stone gap. Streamlined dam base diverts the overflowing water and reduces the water resistance and erosion damage to the dam body, and is of great aesthetic feeling and ornamental value. The dam body has a very rigorous structure. The bottom layer is densely covered with many cedar piles, which have suffered floods and droughts for thousands of years.

This is to prevent the dam body from being destroyed due to the foundation collapsing. There is dense tabia between wood pile foundations, and there is a net of steel cable above the tabia. The grid is long and narrow, with iron-cast rectangular blocks at four corners. There are 90° grooves on both sides of the iron block only to be embedded by corners of the boulder strips, showing a smooth and perfect dam surface.

There is a gap of over 200 m between the north and south dam bodies, which are still solid after weathering the floods of over 200 years. This fully reflects the engineering technology used at that time was ahead of its time.

According to historical records, in the 22nd year of the Qianlong Period (1757), the Qing Government formally set up a "water gauge" at Gaoyou Imperial Wharf in Jiangsu (then known as Jiangnan Province), and carried out regular water level observation, which was the earliest formal water level gauging station set up in the Huaihe River Basin in China.

Gaoyou water level gauging station not only has an earlier set time but also has earlier continuous water level observation records. From the 19th year of the Qianlong Period (1754), the Qing Government began to formulate an opening system for Guihai dams, which was not allowed to be opened easily but only must be opened when a specified water level is reached to prevent the dike from bursting. It stipulated that the Cheluo Dam should be opened after the canal water level is 3 chi (1 chi = 1/3 m) above the ridge of Cheluo Dam, and then Nanguan Dam and other dams should be opened in turn when the water level of the canal is above 3 chi. In the 22nd year of Qianlong, marker pillars were set up at Gaoyou Imperial Wharf and other places, thus Gaoyou Water Level Gauging Station was constructed. Due to the marker pillar and setting of the water gauge at Gaoyou Imperial Wharf, not only overflow dams had an opening basis but also overflow dam ridge and gate bottom along the canal and culvert bottom had a height basis.

It has creatively realized the "separation of canal and lake", which not only avoids the risk of wind and waves when boating in the lake but also makes Gaoyou Lake a water tank regulating the water volume and level of Li Canal. "When the water rises in the canal, some water should be discharged into the lake; when there is little water in the canal, some water of the lake should be discharged into the canal. Various gates and dams are built and can be opened or closed on time." "During water rising in the canal, overflow water is stored in the lake; otherwise, water in the lake is discharged into the canal." That is, in case of a large amount of water in the canal, the water is discharged into the water tank through the sluice dam and other facilities; when water is less in the canal, the lake water is discharged into the canal. To prevent insufficiency of water and discharge more, as mentioned in the Annals of Gaoyou Prefecture: there are 11 gates from north to south. Except for Jinmen Gate, other gates are used to receive the water from the canal from north to south to irrigate millions of qing of farmland. When in drought, they are open together, and when in waterlogging, they are close firmly.

After long-term construction and development, Li Canal - Gaoyou Irrigation District has established a complete system of irrigation, drainage, blocking and lowering facilities, forming the irrigation system of trunk, branch and ditch and the interconnected drainage system of large, medium and small ditches.

Gaoyou has a long history and a lot of celebrities. For thousands of years, foreign and local historical celebrities made poems, saved the country or studied sciences. They have left many admired traces and poems in Gaoyou. According to the Annals of Gaoyou Prefecture in the Qing Dynasty, there were 33 officials at and above the prefecture level in Gaoyou in and before the Qing Dynasty, and 56 officials from Gaoyou Prefecture were recorded in biographies. Among others, they had made outstanding achievements in water control.

The Li Canal was listed on the World Cultural Heritage List by UNESCO as early as 2015. Many historical relics are also national cultural relics protection organizations with a perfect protection management system. In recent years, several project exhibition halls have been opened and an identification system has been set up on the canal to facilitate tourism.

2.12 LIAO RIVER IRRIGATION DISTRICT

Name	**Liao River Irrigation District**
Location	**Jiangxi, China**
Latitude	**N28°40′～28°54′21″**
Longitude	**E 115°14′38″～ 115°38′32″**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**AD 827-835**
River Basin	**Liao River (a tributary of Xiu River)**
Irrigated/Drained Area	**4333.3 ha**

History

Liao River Irrigation District is located in Fengxin County, Jing'an County of Yichun City, and Anyi County of Nanchang City, northwest of Jiangxi Province. It belongs to the Liao River Basin, a tributary of the Xiu River. Liao River is the largest tributary on the south bank of the lower reaches of the Xiu River. It is a mountain river in the Jiuling Mountain Range north of Yichun City, consisting of the South Liao River and the North Liao River. Liao River Irrigation District has been developed based on three weir water conservancy systems, namely, Pu Weir, Wushitan Weir and Xiang Weir. It is a large-scale irrigation district with the functions of flood control, drainage and soil and water conservation. It is also the earliest multi-dam gravity diversion irrigation district built in Jiangxi Province, with an irrigation area of 22,400 ha.

With a long history, the irrigation district originated in the Tang Dynasty, and then after a long period of evolution, gradually developed into the current pattern. According to the literature available, the Pu Weir project, located on the North Liao River beside Chexiachen Village, Xiangtian Township, Jing'an County, is a weir built of firewood and soil by local villagers in the Taihe Period (AD 827-835) of the Tang Dynasty. It has been in existence for more than 1,100 years, and is the earliest irrigation water conservancy project in the irrigation district; In the 12th year of the Chenghua Period in the Ming Dynasty (1476), people of Congshan Township (now Ganzhou Town) in Fengxin County built Wushitan Weir on the bank of Wushi Lijia Village, about 3 km upstream from the Pu Weir. They led the villagers to chisel the stone mountain spur, dredge the river, and divert the water in the pond to Yanghao Weir, about two li (1 li = 0.5 km) away, where they built the south and north ditches to channel water to irrigate the farmland of Fengxin and Jing'an counties; in addition, the local people in the Ming Dynasty built Xiang Weir on the bank of Macao Lake, Xiangjia Subdistrict outside the east gate of Jing'an County, about 1 km upstream from Wushitan Weir.

Description

All three weirs, namely Pu Weir, Wushitan Weir and Xiang Weir, are typical damming water diversion projects in hilly areas of South China. The ancients built dams for water diversion from the lower to the upper reaches based on the actual demand, reflecting the rationality of the development and utilization of water resources. All three ancient dams were located at the river bends, which could reduce the impact of water flow on the weirs while increasing the water storage area. Meanwhile, the dam foundation was built in the hard places of the riverbed. For Wushitan Weir, in particular, the dam was built directly using the boulders in the river. With less sediment deposition, desilting was unnecessary, and less harm was done to the dam foundation. All three ancient weirs are nonorthogonal, which enables the weirs to withhold smaller flow shear force under the same magnitude of the flood, thus reducing the interference of man-made engineering to nature.

After multiple times of renovations and reinforcement, the water conservancy projects of the three weirs have reached their current scale, capable of irrigating 3593 ha, 1040 ha and 1753 ha of farmland, respectively. Liao River Irrigation District was gradually developed and expanded based on the above three water conservancy systems. There are 7 trunk canals in the Liao River Irrigation District, with a total length of 152.0 km, 213 branch canals, with a total length of 540.1 km, and 853 structures in the main canal system. The multiple-cropping index of crops is 2.12 with the main crops in the irrigation district being rice, cotton and rape. There are 27 townships, towns and yards in Fengxin County and Jing'an County of Yichun City and Anyi County, Nanchang City benefiting from the irrigation.

Pu Weir

During the Taihe Period (AD 827-835) in the Tang Dynasty, local villagers built a weir with firewood and soil, named Pu Weir, in Chexiachen Village, Bailu Village, Xiangtian Township, Jing'an County, to divert river water for irrigation for the benefit of more than 66.7 ha of farmland. At that time, the earth dam was about 30 li (1 li = 0.5 km) long, with 16 water gates, which had the function of water storage and flood discharge; and a dike together with a sluice named "Zhakou" was also built to avoid the southward flow of water.

In the 52nd year of the Kangxi Period (1713), stone materials were used to rebuild Pu Weir. However, the rainfalls were heavy in spring and summer every year in the area, causing a sudden rise in water level and rushing currents, and the stone dike was thus destroyed again several years later. Therefore, the local people pegged out and fixed the foundation again, dug out the stone, piled up the soil, and prepared the "tabia" to paint the weir, so that the restored weir was firmer. The project was completed in the autumn of the fifth year of the Yongzheng Period (1727). Pu Weir was expanded in 1950, and then further reinforced five times to reach its current scale. Now the ruins of the weir can be seen, with numerous huge blocks and boulder strips.

Wushitan Weir

In the 12th year of the Chenghua Period in the Ming Dynasty (1476), Wushitan Weir was built. Villagers chiselled the stone mountain, dredged the river, and diverted the water in the pond along the channel to Yanghao Weir about two li away for storage and accumulation; and the south and north ditches were built for diverting water to Fengxin County and Jing'an County respectively, to irrigate more than 667ha of farmland.

To achieve equal water division, people of the south and north ditches agreed to place measuring wood in the north ditch to block water. With the coordination of the governments, the measuring wood was specified in the 16th year of the Qianlong Period (1754) as follows: "It should be 8.79m in length and 1.10m in circumference, with the crossbar, placed 21.38m away from the mouth of the ditch in Jing'an County, and 24 clamp nails installing on the pine pile". In the third year of the Daoguang Period of the Qing Dynasty (1823), Chen Dike was built at the mouth of the weir. Up to the old Wushitan Weir, the dike stretched more than 266.4m, and a 133m-plus transverse weir was built on the old weir, most of which was built with stone, wood and tabia. Wushitan Weir was expanded and reinforced in 1954. After several times of reconstruction, it has reached the current scale.

Xiang Weir

In the Ming Dynasty, in the area of Machao Lake, Xiangjia Subdistrict outside the east gate of Jing'an County, local farmers intercepted the streams from the Qingshan tributary of the North Liao River and built Xiang Weir with a length of 33.3m, which could irrigate 21.68ha of farmland.

In the 16th year of the Qianlong Period in the Qing Dynasty (1751), local people rebuilt Xiang Weir. The length of the dike was increased to 214.79m, consisting of the south and north ditches. The inlet of the north one was 2.44m wide, and that of the south one was 2.77m wide. The weir was built of firewood and soil, capable of irrigating about 133-200ha of farmland. In the third year of the Tongzhi Period (1864), stone on the mountain was chiselled to build a 666m-plus ditch, supplying water for 467ha of farmland. After the founding of the People's Republic of China, Xiang Weir was rebuilt and expanded many times. In 1999, the spillway dam was reinforced and a concrete apron was added downstream.

The Pu Weir, Wushitan Weir and Xiang Weir were initially characterized by firewood piles and earth dams. With the improvement of dam building techniques, plus the abundant stone in the river, the firewood-and-earth structure gradually gave way to a stone weir structure, reinforced by Tabia consisting of lime, clay and fine sand, which increased the strength and water resistance of the dam foundation and improved the stability of the weir.

Water Heritage

The project's site selection is scientific and reasonable. The three weirs, namely Pu Weir, Wushitan Weir and Xiang Weir, are all water diversion projects using weirs, typical in the southern hilly areas, and their planning and design are scientific, as the local water flow environment and actual conditions of irrigation of farmland were taken into full consideration. The three weirs were built at the river bends, with slow water flow, to reduce the impact on the weirs, thus ensuring the effective and consistent operation of the facilities. In addition, the weirs are located at the hard riverbed in the upper and middle reaches of the river, with a stable dam foundation and less sand sediment on the dam, so desilting is scarcely needed, and less damage will be caused to the dam foundation, to extend the service life.

The construction of Pu Weir, Wushitan Weir and Xiang Weir has improved the irrigation conditions of local farmland, promoted land reclamation and agricultural production, increased the grain output, and facilitated the formation of a production mode focusing on agriculture and supporting both agriculture and Confucian studies, promoting the local development of imperial examinations; the three weirs could also control and prevent floods to protect the local agricultural production and properties of local people, providing a safe and stable living environment for people within the area; in addition, they have promoted the flood prevention, navigation and reasonable utilization of resources in the irrigation district, providing the foundation for the development of traditional commodity economy.

The irrigation district has promoted local economic development, maintained social security and stability, and played an important role in flood prevention, irrigation, navigation, reasonable utilization of resources, etc., as well as an indispensable role in handling regional flood, drought, deterioration of water environment and other problems, contributing significantly to safeguarding the security of grain output, water use, ecological environment and sustainable development of agriculture in the area.

As the traditional medium/small size water conservancy facilities, the Pu Weir, Wushitan Weir and Xiang Weir are all nonorthogonal, so they don't intercept the water flow directly. According to modern technologies, such a weir can improve the water flow capacity, and increase the discharge capacity of the weir or decrease the water head at the upper reaches, to prevent floods and improve discharge.

When constructing Pu Weir, Wushitan Weir and Xiang Weir, the local environment and the characteristics of local water resources were taken into full consideration, and the weir height, site selection, irrigation, navigation, flood prevention and more were formulated following the principle of utilizing the natural conditions but not causing deterioration of the natural environment, which demonstrated the ecological concepts of adapting to local conditions, drawing on local resources and maintaining harmony between human and water, and perfectly interpreted the philosophy of harmonious co-existence of human and nature. It is a good example of ancient Chinese practising the theory of "harmony between man and nature", showing the ecological wisdom and concepts of the ancients.

Pu Weir, Wushitan Weir and Xiang Weir are located on the south branch of the North Liao River, with a controlled drainage area of 729 km2, and average annual precipitation of 1500-1800 mm, which is distributed unevenly in the year and mostly comes in the form of a rainstorm. The average annual flow of the south branch is 25.1 m3/s, and the designed peak flow for the approved flood standard (P=1%) is 2,368 m^3/s. Flood occurs nearly every year; therefore, it is very difficult to build weirs on a river under such conditions. However, ancient people built three weirs for water diversion from the lower to the upper reaches according to the actual demand, demonstrating excellent dam construction techniques and wisdom.

The site of Wushitan Weir was chosen by utilizing the natural geographic advantages of the deep pond and natural boulders in the river. The deep pond can effectively store floodwater, delay the flood peak, and reduce the water flow speed to some extent to make the flow state of water at the bottom of the pond more stable and reduce the impact on the weir, thus protecting the dam foundation and further ensuring its safety. The main dam was built based on boulders in the river, which effectively avoided impact from the water flow, and effectively leveraged the natural geographic conditions and hydromechanical principles.

The ancient weirs in the irrigation district are steeped in rich water conservancy culture, having a profound influence on the local communities. People in the Liao River Irrigation District created many water conservancy tales of varied contents during the long course of production and life, including tales of water division, land boundaries, case judgments, suits, water sources, etc. Among them, Xu Jingyang Killing Flood Dragon for Water Regulation, Origin of the Name of Ganzhou Town, Old Han Tactfully Building Yanghao Weir and Dragonfish Spraying Rain at Jiaoyuan Mountain are the top four tales which are widely spread.

There are abundant water conservancy heritage items in the irrigation district. They have rich contents and varied forms, serving as cultural remains and pieces of evidence of the traditional farming economy of the local area. In the long historical process, experience in agricultural production activities was summarized by people from different places, e.g., farming seasons and time, farmer's proverbs, etc., reflecting the traditional wisdom of labourers; and many rites and folk customs about farming production were formed, embodying the desires of ancient people for timely wind and rain, peaceful and happy life. Such farming culture survives till now, and it is an important part of the traditional folk culture.

In the project system of Pu Weir, Wushitan Weir and Xiang Weir, numerous ditches for water diversion were built, covering a large area of farmland at different elevations. Many relevant water-division methods and water-use rules were formed in the past, and the water-division method of Wushitan Weir was particularly unique. For Wushitan Weir, the south ditch and the north ditch were built, diverting water to irrigate the farmland in Fengxin County and Jing'an County respectively. Since the north ditch is lower than the south one, to prevent all the streams from flowing to the north ditch and allowing the south ditch to play an effective part in irrigation too, people of the two counties agreed upon the method of placing measuring wood in the north ditch to block water. With the coordination of the governments, the measuring wood was specified in the 16th year of the Qianlong Period (1754) as follows: "It should be 8.79 m in length and 1.10 m in circumference, with the crossbar, placed 21.38 m away from the mouth of the ditch in Jing'an County, and 24 clamp nails installing on the pine pile", to achieve the goal of the equal water division.

Having been in continuous operation for over one thousand years, the three weirs have promoted local agricultural production and substantially improved the livelihood of local people without causing a negative ecological effect on the local river courses and the irrigation district, demonstrating the harmonious development between the economy, society and ecological environment, and providing the best proof of the scientific water regulation concept of "human-water harmony" and the social development philosophy of "sustainable development".

Establishing Liao River Irrigation District Cultural Exhibition Hall: In the one-thousand-year development process, the water conservancy system of Liao River Irrigation District witnessed many changes in operation management, exerting important influence on the local ecological environment, population growth and governance system; and "water conservancy" communities were formed surrounding the water conservancy system in the irrigation district, leaving behind abundant historical materials in varied forms. The Irrigation District Administration has established the Liao River Irrigation District Cultural Exhibition Hall as the site for preserving and passing down the historical and cultural memories of the Liao River basin, offering a panoramic display of the scope, terrain, etc. of the irrigation district in the form of sand table, video or photo, to vividly and comprehensively depict the connotations of the water conservancy heritage items of the irrigation district. The construction of the exhibition hall can facilitate the tourism development of the water conservancy culture of the irrigation district, and serve as the base of the Administration for carrying forward the outstanding cultural heritage and promoting the joint development of rural tourism.

Building Water Conservancy Scenic Area: Liao River Irrigation District was listed as a water conservancy scenic area in Jiangxi Province in 2018. On this basis, such measures as building the 10-li Wushitan Weir Water Conservancy Cultural Corridor have been taken and satisfactory results have been achieved: Based on the distribution of water conservancy projects, integration of advantageous resources in the irrigation district, and the overall positioning of water culture landscape construction, establish the layout consisting of "One Belt, Two Corridors and Multiple Nodes", gradually develop ecological tourist resources along with the water system, protect the ecological environment, and link important water conservancy scenery nodes of the irrigation district, thus building a modern ecological water conservancy scenic area that integrates water conservancy, ecological, natural and cultural landscapes.

2.13 LINGQU CANAL

Name	**Lingqu Canal**
Location	**Guangxi Zhuang Autonomous Region (Xing an County), China**
Latitude	**25.570 - 25.726**
Longitude	**110.474 - 110.756**
Category of Structure	**Irrigation System**
Year of commissioning	**214 BC**
River Basin	**Yangtze River and Pearl River**
Irrigated/Drained Area	**4333.3 ha**

History

Lingqu Canal is one of the most famous water conservancy projects of ancient China. It was built in 214 BC and is a cross-basin water conservancy project connecting the Yangtze River and Pearl River. It delivers both water transport and irrigation benefits. There had been a clear record of the irrigation benefits of the Lingqu Canal in the 12th century. At present, it has an irrigation area of about 4,333 ha.

The Canal is a landmark project of the Qin Dynasty (221–206 BC) and China's unification, contributing significantly to the economic and cultural exchanges and national integration between the Lingnan area and the Central Plains for more than 2,000 years. It was initially used for military purposes, with several remnants still in existence reflecting the outstanding characteristics of the military culture of Lingqu Canal.

With the continuous increase of the population, the irrigation functions and benefits of the Lingqu Canal became increasingly prominent, making it a critical irrigation project in the region. In 1386, Yan Zhenzhi, the supervisory censor, presided over the significant repair work of the Lingqu Canal and built 24 irrigation culverts. In the Qing Dynasty (1644–1911), more attention was paid to the irrigation function of the Lingqu Canal. In the 18th century, the Huilong and Haiyang Dikes of the North Canal ensured irrigation efficiency. There was no detailed record of the irrigation system and scale of the Lingqu Canal in ancient times. Investigation and the Yangtze River Water Conservancy Commission Survey, 1938 showed that the irrigated area of the Lingqu Canal totalled about 567 ha.

The Lingqu Canal has been completely restored in modern times, branch canals have been maintained, expanded, or newly built, and some irrigation weirs have been repaired or reconstructed. Water turbine pumps have replaced the original scoop waterwheels. Zhiling Reservoir and others have been built to supplement the irrigation sources of the Lingqu Canal.

Description

The irrigation system of Lingqu Canal includes headworks, a main canal project, a flood control project, gravity and water lifting irrigation systems and others. It has scientific planning, a complete system, and distinctive features, forming together an organic whole, and bringing into play the comprehensive benefits of irrigation and water transport.

The headwork of the Lingqu Canal is located on the Xiang River. It consists of the Plow Beak, the large- and small-scale weirs, and the south gate and the north gate. The Plow Beak splits the Xiang River into two, which are then guided respectively into North Canal and South Canal through the large- and small-scale weirs. Rationally designed crest elevation of the large- and small-scale weirs ensures the volume of water needed for canal traffic and irrigation. During the flood season, it ensures that water spilt over the weir crest and runs into the old course of the Xiang River. The South and North Gates coordinate with the Plow Beak, jointly regulating water distribution in the South and North Canals.

The main canal of Lingqu includes the two sections of the North Canal and the South Canal. The length of the North Canal is 3.25 km, still guiding water downstream of the Xiang River. The South Canal crosses the watershed and flows into the Li River, and it is 33.15 km in length, including an artificial section of 4.1 km and a canalized section of the natural watercourse of 29.05 km. The gates on the canal were used to regulate the flow of water and facilitate canal traffic. There were 36 gates on the canal, and these gates performed their functions similar to those of ship locks today. To ensure flood prevention, five spillover weirs or overflow weirs were also built on the Canal. The embankment of the key canal segment—the Qin Dike—is 3.15 km.

Lingqu Canal irrigation mainly takes two forms: gravity irrigation and water-lifting irrigation. Gravity irrigation includes two types: culverts of water diversion without weirs and ones with weirs. Two are still in use of the 24 water culverts built in the early Ming Dynasty (1368–1644). Weirs are built at some sections of the canal to elevate the water level to regulate and direct water flow. On the one hand, these weirs could conserve and divert water for gravity irrigation or water-lifting irrigation; on the other hand, they could serve as the “gates” for boats. In places where the canal is lower than the farmland, waterwheels and turbine pumps are generally used.

Concerning the specific irrigation system and facility distribution, there was no concrete record in ancient times. According to 1938 statistics, there were 13 gravity irrigation canals, 31 weirs, and 205 scoop waterwheels on Lingqu Canal. Since 1949, the government has systematically repaired and expanded the irrigation system of increasing its efficiency. At present, 18 branch irrigation canals directly divert water from Lingqu Canal (4 branching off from the North Canal and 14 from the South Canal). Their total length is 129.7 km, and the total diversion flow reaches 14 m3/s, including seven diversion weirs for irrigation, two culverts and nine diversion gates. Nine water turbine pump stations (with an irrigation area of 49.67 ha) are reserved on the South Canal. The total irrigation area of Lingqu Canal is about 4,333 ha (about 294 ha of land irrigated by the North Canal and 4,039 ha by the South Canal).

Lingqu Canal is a water conservancy project comprehensively benefiting irrigation, water transport, ecology, flood control, etc. It has played an important role in inter-regional population, and economic and cultural exchanges. According to the records of the 18th century, the irrigation area of the Lingqu Canal was several hundred hectares. The survey and statistics by the Yangzi River Water Conservancy Commission in 1938 showed the irrigation area of Lingqu Canal reached 567 ha. After 1949, with the systematic rehabilitation of the Lingqu Canal and the continued construction and extension of the irrigation system, its irrigation area increased significantly. Currently, its irrigation area totals more than 4,333 ha, including about 2,689 ha of paddy fields and 1,645 ha of dry farmland, which mainly involves five townships in Xing’an County, covering a total of 186 natural villages, and benefiting 59,000 people. In addition to paddy rice, cash crops such as grapes, oranges, tangerines and strawberries are also planted in the irrigation district. The annual agricultural output value is about 1.3 billion RMB. Lingqu Irrigation District has become the main agricultural production area of Xing’an County.

The water transport function is one of the main water conservancy functions of the Lingqu Canal. After its completion, it laid the foundation for Qin’s unification of the Lingnan area and had an important impact on the historical course of China. It has played an important role in the political and social stability of the Lingnan area and inter-regional population, economic and cultural exchanges. The historical mission of Lingqu Canal as a cross-basin canal was not terminated until the Xianggui Railway was opened to traffic in the 1930s. Currently, there are still some sections of the Lingqu Canal serving as channels for water transport.

A strict management system has guaranteed the continued use of the Lingqu Canal for more than 2,000 years. Due to the important strategic position of the Lingqu Canal in ancient transportation, historically, it has been managed and maintained by the government as a state-level project. As for the irrigation facilities of Lingqu Canal, they were jointly managed by local governments and civil society. The weirs, culverts and main branch canals were generally built and maintained by the government. The field ditches, scoop waterwheels and other water lifting facilities were collectively constructed and maintained by farmers. At present, the irrigation of the Lingqu Canal still uses the management model of joint participation by both the government and the private sector.

Lingqu Water Conservancy Project is protected by relevant laws, regulations and unique protection plans. In 2014, the Measures for the Protection of Lingqu Canal in Guangxi Zhuang Autonomous Region were reviewed and approved by the Autonomous Regional Government and announced for implementation, further clarifying the protection requirements and protection measures for Lingqu Water Conservancy Project. A series of protection plans have carried out the specific deployment for relevant protection work of Lingqu Canal, which is being implemented in an orderly and planned manner.

Water Heritage

One of the earliest trans-basin water conservancy projects, it was constructed with its grand planning horizon, accurate elevation measurement and hydrological calculation, scientific headwork and canal route selection, and clever engineering system design using original engineering technology and traditional material techniques between complex and unique landforms. The connection between the Yangtze River Basin and the Pearl River Basin across the watershed was realized, and the water transport and irrigation benefits continued to be developed. Its engineering system and management system were also gradually developed.

Lingqu Canal is a water conservancy project comprehensively benefiting irrigation, water transport, ecology, flood control, etc. It has played an important role in inter-regional population, and economic and cultural exchanges. It has been a strategic channel of water transport for the exchanges between Lingnan and the Central Plains. The irrigation function of the Lingqu Canal has a long history, which has generated outstanding benefits. It has continuously improved, and the irrigated area has been constantly expanded, which has played a fundamental supporting role in regional agricultural development, population growth and social, economic and cultural development. Lingqu Canal has become the primary support for developing the agricultural economy and tourism service industry in Xing'an County.

Lingqu Canal has scientific and perfect system planning, which comprehensively uses the regional terrain and landform and water resource conditions. Thus, it has achieved the maximum water conservation benefits with the minimum amount of engineering and has continued to exert benefits for more than 2000 years. This provides knowledge for the planning, design, construction and operation of contemporary water conservancy projects.

Lingqu water conservancy project is a model of low-impact development. The planning and construction of the project fully embody the principle of having the least impact on the physical geographic environment. It has lasted more than 2,000 years, and at the same time maximized the benefits of water transport and irrigation; it not only had no negative effect on the physical geographic environment of the region but also further optimized regional water resource conditions and ecological environment and shaped the agro-ecological system of the irrigation district through the deployment of regional water resources.

Lingqu Canal is the product of Qin Shi Huang's (the first emperor of China) battle against Lingnan (the land south of the Nanling Mountains) and his unification of China. It was initially and primarily used for military purposes. The military fortress, the "Qincheng" site, which used to help guard Lingqu Canal, still exists. The descendants of the "gate army" which defended and managed the Lingqu Canal and their ancestral halls and villages are still in existence, all of which reflect the outstanding characteristics of the military culture of the Lingqu Canal. The planning and design of the Lingqu water conservancy project fully reflect the traditional Chinese philosophy of water control, which advocates harmony between man and nature.

Lingqu Canal has been operating for more than 2000 years. Although its irrigation system has been continuously improved, there has been no major change in the main project location, layout, and type. Its irrigation and water-transport benefits have constantly been exerted. With the development of the social economy, its water transport function has gradually degenerated, while its irrigation function has become more prominent, and the water conservancy project has become more vigorous, fully embodying its characteristics of advancing with the times and adapting to and serving the development of society. The Lingqu Canal's water conservancy function has been uninterrupted, and the scientific nature of the engineering system, the perfect management and maintenance guarantee the sustainable development of its water conservancy function.

2.14 LONGSHOU CANAL AND ANCIENT LUOHE RIVER IRRIGATION DISTRICT

Name	Longshou Canal and Ancient Luohe River Irrigation District
Location	Shanghai City, China
Latitude	35.07
Longitude	109.84
Category of Structure	Irrigation System
Year of commissioning	120 BC
River Basin	Luohe River of the Yellow River basin
Irrigated/Drained Area	49.5 Mha

History

The Longshou Canal and Ancient Luohe River Irrigation District of Shaanxi Province are located on the terraces of the Weihe River and Luohe River. This area is plagued by frequent drought. Therefore, diverting water from the Luohe River for irrigation has been essential to tackle water shortages.

Luohe River, as a secondary tributary of the Yellow River, originates from the southern slope of the Baiyun Mountain in Dingbian County. Flowing through three cities and eleven counties, it enters the Weihe River at Sanhekou. The barrier of Tielian Mountain makes it hard to develop and utilize the lower reaches of the Luohe River.

In 120 BC, Emperor Wu of the Han Dynasty constructed an irrigation canal at the Laozhuang Waterfall of the Luohe River in Chengcheng County. It took them more than ten years to complete this oldest gravity irrigation project in the Luohe River Basin. The construction of the canal was extremely difficult. For instance, a 3.5 km-long tunnel had to be built in Tielian Mountain for water diversion. The digging of the tunnel was divided into multiple sections. Shafts were dug at both ends of each section, and workers were sent to the bottom of the shafts to dig towards each other. And these sections naturally joined together upon completion to form the tunnel. The shafts served as exits and entrances for workers, pathways for muck disposal, and openings for ventilation and daylighting. In this way, the efficiency improved. During the tunnel's construction, dinosaur bones were unearthed, misunderstood as dragon bones, hence the name of Longshou Canal, or the canal of dragon head. When constructing the 20 km main canal, the ancient Chinese adopted the technology of intercept to cross rivers and streams. In addition, the open canals at the two ends of the tunnel of the Tielian Mountain are of proper gradient, which has been the result of excellent measuring techniques.

The canal faced many issues like loess subsiding in water, collapsed banks, blockages, quicksand and submerged springs. In addition, the area was plagued by frequent wars; thus, sustainability became difficult. Later generations reconstructed the canal and utilised the Ruohe River for irrigation. In 227, the Kingdom of Wei started to expand the irrigation district. The Linjin Weir was built downstream of the Longshou Canal. The improvement of the irrigation infrastructure turned this area into a granary, laying the expansion of the Kingdom of Wei.

In 561, Emperor Wu of the Northern Zhou Dynasty reconstructed the Longshou Canal, improving national strength. In 712, the local governor diverted water from the Luohe River through Tongling Weir for irrigation and the alleviation of soil salinization. As a result, crop yield surged, laying the economic foundation for the Kaiyuan Heyday of the Tang Dynasty. During Yuan, Ming and Qing Dynasties, many small water diversion projects were built along the Luohe River. Most of these projects irrigated farmland by diverting spring water from wells.

Fengtu Granary was built on the site of the Chengyi Granary of the Han Dynasty. Known as the first granary of China, it now serves as one of the state-owned grain reserves, demonstrating the affluence and prosperity of the irrigation district. In 1934, Li Yizhi, a famous Chinese hydraulic engineer, rehauled the Luohui Canal based on the Longshou Canal and Ancient Luohe River Irrigation District to manage frequent droughts and famine. He also named the water-diverting dam of the new canal Longshou Dam. The Luohui Canal, integrating different ancient Luohe River irrigation projects, took 14 years to complete. It has expanded the area of irrigation. Its scientific and efficient layout and management system are characteristically similar to the ancient Longshou Canal, proving the wisdom and superior skills of the ancient Chinese people.

Description

As a fine combination of Chinese and Western styles and technologies, the Luohui Canal has one dam, two aqueducts, and five tunnels. These hydraulic structures have added touches of modern technology to the ancient irrigation district, which embodies the mixed culture of the dragon, Han and water.

Today, Luohui Canal has evolved into a large irrigation district with a complete irrigation and drainage system. The irrigation district, divided into two systems by the Luohe River, comprises a dam, a canal network, and supporting facilities. Its 235 km canal network, with one general main canal, four main canals, and 13 branch canals, irrigates 49,500 ha of farmland of Chengcheng, Pucheng and Dali Counties, nourishing 6,90,000 people and generating remarkable biological, economic, and social benefits.

Within the Ancient Luohe River Irrigation District, the ruins of the shaft-tunnel construction and the Longshou Canal have been listed as officially protected cultural heritage sites. In 2018, the Implementation Plan of the Maintenance and Protection of Luohui Canal Heritages was approved by the Department of Water Resources of Shaanxi Province. In 2019, the irrigation district spent 2.88 million RMB (4,33,691 USD) on improving the surrounding environment of essential heritages such as the ruins of the Longshou Canal, the ruins of the shaft-tunnel construction, the Longshou Dam, the five tunnels, etc. The critical parts of the heritage have been guarded with a protective mesh. And the responsibilities of management and maintenance have been clarified and distributed.

Water Heritage

Since the construction of the Longshou Canal by Emperor Wu of the Han Dynasty, locals alleviated soil salinization using the water of the Luohe River, which is high in sand concentration. This approach of soil desalinization, which contributed to the improvement of soil quality and crop yield, is a milestone in developing irrigated agriculture.

The construction of the Longshou Canal was ahead of its times in terms of engineering design, construction techniques (measuring technique, the shaft-tunnel method, and the building materials), and dimensions (it took tens of thousands of soldiers more than ten years to complete this 20 km long canal, including a 3.5 km long tunnel). The layout of the Longshou Canal is the same as that of the Luohui Canal, which was planned and built with modern technologies. More than 2000 years ago, the famous Chinese historian Sima Qian commented in the Historical Records that the construction of the Longshou Canal was the earliest application of the shaft-tunnel method. This method, a new ground-breaking theory and practice of tunnel construction, has contributed significantly to the treasure trove of science and technology.

With the help of the Longshou Canal and the tunnel in the Tielian Mountain, locals diverted water from the Luohe

River at the point where the altitude is relatively high and managed to achieve gravity irrigation for the vast land south of the Tielan Mountain. Shafts were dug to facilitate the opening of the tunnel. With the shafts, it was easier to measure the direction and the elevation of the tunnel, and they were also used for ventilation and muck disposal. In this way, the working efficiency was improved. This shaft-tunnel construction approach was innovative at its times, contributing to the evolution of contemporary engineering theories and practices.

The Longshou Canal is a testimony to the highly developed agriculture and economic prosperity in the central Shaanxi Plain. The Chengyi Granary for Grain Shipping, the grain shipping culture of the Luohe River, serves as proof of the high crop yield in the region. The Fengtu Granary, built in the late Qing Dynasty, shows the region's prosperity and the foresight of the locals.

Since the construction of the Longshou Canal, the irrigation district has been using local materials for repairs, renovations and expansions. Meanwhile, water with high sand concentration has been employed for soil desalinization. These practices have improved the local ecosystem.

In the past two millennia, the Canal, having overcome many challenges, vividly reflects the unyielding national spirit of the Chinese--their belief in hard work and dogged perseverance. The culture of the Longshou Canal is the perfect combination of the cultures of the dragon, Han and water, and local customs, religions, and architectural style. For instance, the name Longshou means dragon head, reflecting the worship of the totem of a dragon, several villages in the irrigation district were formed in the Han Dynasty when the Canal was constructed. Stone inscriptions describe the management system of the irrigation district, including the irrigation order, organizational structure, and the handling of disputes. The Taibai Temple, the Quli Temple, and the Pinglu Temple, where the water god was worshipped, grew into major water-related affairs management sites. Today, these temples still serve as the management stations of the irrigation district.

2.15 LOUGANG IRRIGATION AND DRAINAGE SYSTEM OF TAIHU LAKE BASIN

Name	**Lougang Irrigation and Drainage System of Taihu Lake Basin**
Location	**Weinan City, Shaanxi Province, China**
Latitude	**31.128**
Longitude	**120.284**
Category of Structure	**Irrigation System**
Year of commissioning	**300-200 BC**
River Basin	**Taihu Lake basin**
Irrigated/Drained Area	**Irrigated-28000 ha; Drained- 44000 ha**

History

The development of Lougang polder lands dates back to about the 3rd century B.C. when people started to build embankments and cross ponds on the mudflats of Taihu Lake. The construction of such cross ponds led to the creation of a comparatively independent area of polder lands and their irrigation and drainage canal system. This system started to develop and flourish in the southern region of China in the Tang and Song Dynasties (from 800 to 1100 A.D.). Under population pressure, the Lougang system came into being around Taihu Lake and laid a solid foundation for regional agriculture development. In the Yuan, Ming and Qing Dynasties (from the 13th to 19th century), it became China's prominent grain and silk production base due to the well-established irrigation and drainage system here.

Description

Lougang is the unique irrigation and drainage system in the plain beside Taihu Lake in China. It comprises the canal system, the water gates, and the embankments for water drainage irrigation and waterway transport purposes. The multi-year mean rainfall in the region is 1,200 mm. This project was constructed 2500 years ago and started with the excavation of ditches for water drainage and the construction of embankments for farmland protection at the low-lying area close to Taihu Lake. With the continual constructions in the coming years, the canals were connected to natural rivers and ponds and controlled by sluice gates to constitute an irrigation system. Today, Huzhou is the only place with complete relics of Lougang in the Taihhu Plain. There are also 16 lakes between the cross ponds and longitudinal lougangs and gates, sluices, sluice gates and other control works, including 23 main control water gates on Lougang. Lakes are extensive water areas between cross ponds and longitudinal lougangs, and they are relevant to water catchments and ecological wetlands along Taihu Lake.

The Lougang system of Taihu Lake has a farmland irrigation area of about 28,000 mu and a drainage area of about 44,000 ha. It has a warm and humid climate here, and the crops have a long growing period. The farmlands use irrigation water from the Lougang system throughout the year. However, the Lougang system mainly works for flood drainage during the flood season from June to September each year. The excavation and maintenance of the Lougang system and the land improvement work promote each other so that the area where the Lougang system is located becomes a substantial growing base of paddy rice. People plant mulberries on the embankment-protected lands, and thus, large-scale silkworms multiplied other than grain production, turning this place into a production base of silk in China.

Water Heritage

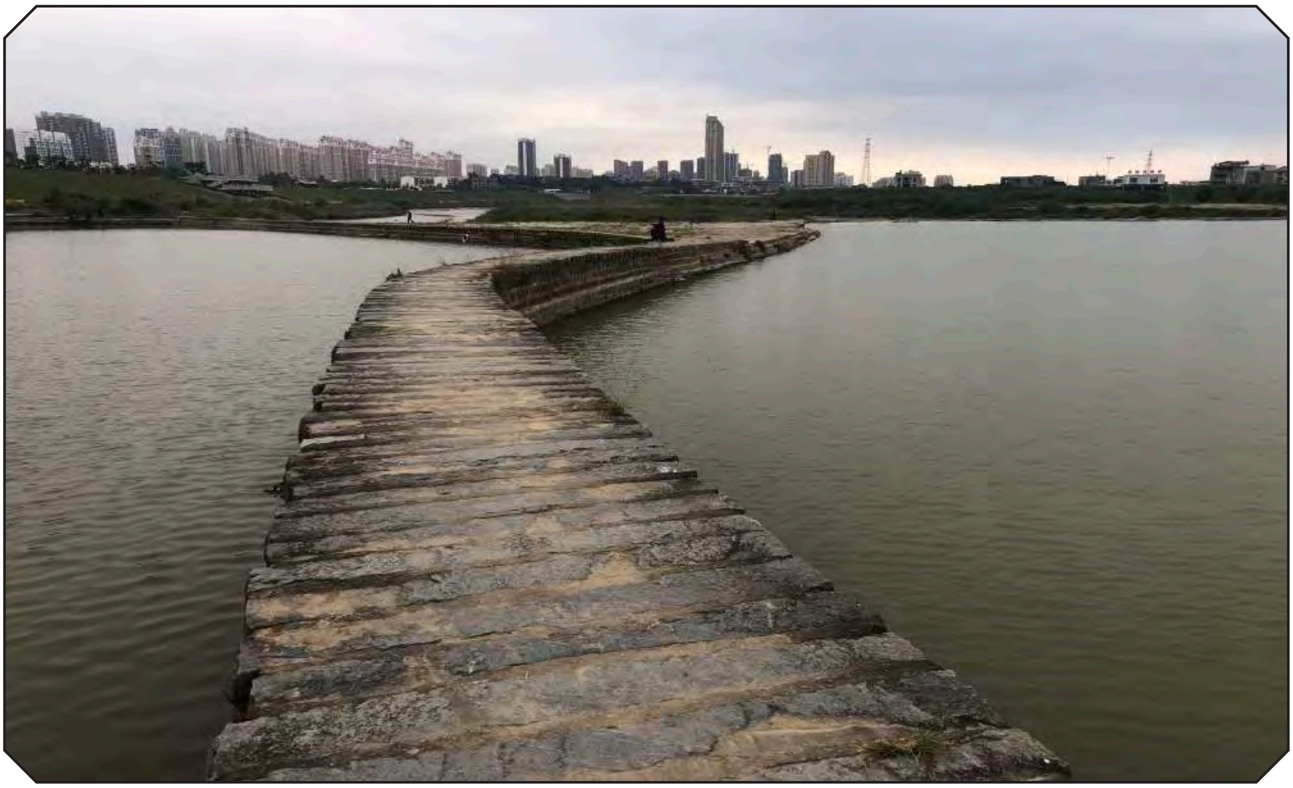
The system has adopted a sustainable operation and management model. From the 10th century, the local government participated in the administration of the Lougang system by raising operating funds for the project. In contrast, the local farmers contributed their labour and participated in waterway dredging and embankment maintenance under the government's organization. Such an administrative mode involving both government and residents has been preserved until today. Currently, there are three levels of administration for Lougang, including the provincial, municipal and county-level administration. The routine management and maintenance expenses are paid from the local treasury.

Passed over many dynasties, the system represents a rich cultural heritage. Taihu Lougang heritage comprises four parts: the Taihu embankment project, the Lougang pond system, the polder system and other relevant heritages, including the ancient bridges, banks and polders. The embankment of Taihu Lake is about 65 km long within Huzhou. There are three cross ponds and 73 Lougangs of historical value in this region. The system with cross ponds as the latitude and Lougang as the longitude is the principal part of this heritage. The irrigation area has paddy rice planting and silkworm raising as prominent industries. Other relevant irrigational heritages primarily include the ancient bridges on Lougang, the water god temples preserved near the sluice gates of various Lougangs and the sacrificial events relating to water affairs. Unique folk customs, festival celebration modes and water god worship events were also created.

Lougang is a paradigm of irrigation projects in China. It was constructed in the Spring and Autumn Periods and has remained in operation for 2,000+ years. It has a reasonable layout, and ingenious design and the ancient engineering structure has been preserved until today. It irrigates the vast sprawl of farmlands in the Taihu region and has played an irreplaceable role in promoting local social development, economic prosperity and resistance to natural disasters in Huzhou. Lougang has played an important role in irrigation through the civilian-government joint management mode. As a result, Huzhou has become a typical farming area with regional characteristics. The irrigation-based social organization, production and living mode and cultural traditions have been well preserved until today.

2.16 MULANBEI WATER CONSERVANCY PROJECT

Name	**Mulanbei Water Conservancy Project**
Location	**Fujian, China**
Latitude	**24.983**
Longitude	**118.450**
Category of Structure	**Water Conservation Project**
Year of commissioning	**1083**
River Basin	**Mulan River**
Irrigated/Drained Area	**9133 ha**



History

Located on the Mulan River in the Fujian Province in Southeast China, Mulanbei Water Conservation Project has served for nearly 1000 years and was ahead of its contemporaries in unique planning, design and construction techniques to retain fresh water and resist saline water intrusion. The structure, completed in 1083, during the Northern Song Dynasty, continues to be in operation, irrigating over 9,133 ha of farmland in the Putian Xinghua plains.

Mulanbei, a water conservancy project, was initiated by Qian Siniang, a young woman from a wealthy local family. The structure located at the Mulan River flew out of the mountain, with a narrow surface, steep slope and torrential flow. Due to flooding-caused destruction, the weir site was moved downwards to the Spring Mouth, with slower water flow and flatter terrain but was very near the coast. Soon after completion, the surging sea tides destroyed the weir once again. By 1073, Project Manager Li Hong and Monk Feng Zhiri built the weir premise between the last two sites beneath Mulan Mountain. Sandwiched between two mountains, this place was of slow and wide river flow and suitable for dam construction. In 1083, the Mulanbei water conservancy project was finally completed.

Description

Located on the weak riverbeds near the ocean, the headwork structures of the Mulanbei water conservancy project include an overflow weir, gravity dam, diversion dike, sluicing gate and diversion mouths at both banks. The gravity dam is 123.43 m long and 7.6 m high on the north bank of the river. The overflow dam is 95.7 m long on the south bank, with 28 water release gates and one scouring sluicing gate distributed above it. The Mulanbei project is a large masonry weir with a sluice foundation and a weir made of local granite. The maximum height of the weir is 7.25m. Up to now, the project has kept its fundamental form of engineering construction. The foundation of the weir adopted the raft foundation commonly seen in the bridge foundation, which effectively alleviates the pier pressure on the unit area. Gate walls or piers are built on the weir. At the same time, stone pillars (called general columns) are inserted through the walls or piers into the river-bed base rock, and the pig iron is melted to fill the gaps afterwards, and the pier stones of the weir and the gates are linked with shoe-shaped iron ingots. The weir/gate forms an integrated whole. Such structures integrating weirs and gates have been conducive to discharging floods and dredging silts.

The south water inlet, Huilan Qian, double holds 11 m3/s, controls the south main canal and irrigates 4,867 ha of farmland and flows through 70 villages. The north water inlet Wanjin Qiao, single hold, 5.5 m3/s, controls the north main canal, irrigates 4,267 ha of farmland, and flows through 63 villages. Hitherto, the structure has been in operation for nearly 1000 years, with the weir front virtually free of sedimentation and the two inlets still in normal function.

Water Heritage

Mulanbei Water Conservation Project was a visionary structure that capitalised on native wisdom and used the locally available material in the best way possible. It was scientifically designed to serve the purpose of water retention, tide prevention, flood discharge, sand removal and water diversion. The site of this weir was selected based on early experiences perfectly balancing the shock from the upstream flood and the downstream sea tide. The project has kept its primary form of engineering construction as it was in the historical period.

The multi-purpose irrigation project increased the irrigation area and the agricultural production capacity of the region and boosted the local economy. Before the construction of the Mulanbei project, no crops except cattail could grow in the south and north plains. The project ensured water supply for agriculture, industry and domestic life in the command area. At present, it irrigates a farmland area of 10,867 ha and benefits more than 500,000 people. Mulanbei project had wholly changed the plain to the prominent grain and sugarcane production area in Putian City. It has contributed to the development of the Xinghua Plain. It supplies water to industrial production, agricultural production, and domestic life; it also plays a part in shipping transportation, and aquaculture, especially in defending against flood. The project witnessed an increase in population and rapid development in South China during Tang and Song dynasties.

The structure bears the stamp of a past civilization. Architects and builders of the Mulanbei project are considered guardians of the area and are fondly remembered today. The government has supervised the construction of the Mulanbei project since the Song dynasty. Special personnel took charge of annual repair outlay, labour expenditure, construction supervision and so on. Currently, the Mulan River administrative office and the local administrative office of the south and north canals are responsible for floodwall management in the area.

2.17 NINGXIA ANCIENT YELLOW RIVER IRRIGATION SYSTEM

Name	**Ningxia Ancient Yellow River Irrigation System**
Location	**Ningxia Hui Autonomous Region, China**
Latitude	**37.445**
Longitude	**105.022**
Category of Structure	**Irrigation System**
Year of commissioning	**2nd Century BC**
River Basin	**Yellow River Basin**
Irrigated/Drained Area	**552000 ha**

History

The Ancient Yellow River Irrigation System of Ningxia is the oldest and largest one in the upper reaches of the Yellow River. With an arid and semi-arid climate, the irrigation district has an annual precipitation of 180–220mm and evaporation of 1000–1550mm. Home to different ethnic groups, it is where the nomadic and agricultural civilizations co-exist. The continuous Yellow River irrigation and wasteland reclamation have laid the foundation for the region's stability and social and economic development. Together with the Great Wall, the Yellow River irrigation system has witnessed the collision and integration of different civilizations in history.

The Yellow River Irrigation System of Ningxia has a history of over 2,200 years. As recorded in historical records, during the reign of Emperor Wu of Han in the 2nd century BC, projects were built to divert water from the Yellow River, and soldiers and farmers were garrisoned in this area to open up a wasteland and fight against the Huns. Since then, the irrigation area has become larger and larger. Till the golden age of the Tang Dynasty (the 7th–8th century), there were 13 canals in the area, and the gravity irrigation network in Yinchuan Plain and Weining Plain began to take shape, the irrigated area reaching nearly 67,000 ha. During the Western Xia period in the 11th century, irrigation projects and their management systematically improved. With the irrigation network consisting of 12 trunk canals and 68 branch canals formed, the irrigated area increased to 1,07,000 ha. During the Yuan, Ming and Qing dynasties (1271–1911), more canals were built, and the irrigation systems in Weining Plain and Yinchuan Plain were further improved. Till the 19th century, more than 20 trunk canals covered over 1,500 km, and the irrigated area reached 1,40,000 ha.

In the 20th century, some traditional engineering structures were updated using modern water conservancy science and technology. The Qingtongxia Water Control Project and the Shapotou Water Control Project completed respectively in 1968 and 2004 resulted from integrating and optimizing the irrigation system in Ningxia, which further expanded the irrigated area and improved irrigation reliability. At present, the irrigation system with 25 trunk canals covers 86,000 km2, and the total irrigated area is 5,52,000 ha.

Description

The Ancient Yellow River Irrigation System of Ningxia includes the irrigation canal network, the drainage ditch network, and various control works such as sluices, dams and culverts. The headworks mostly adopted the dam-less water diversion structure. After constructing the Qiongtongxia Water Control Project and the Shapotou Water Control Project in modern times, some canals were built to divert water from reservoirs. Now in the irrigation district of Ningxia, there are 25 trunk canals, including 14 ancient ones, 34 major drainage ditches and 9,265 control works. Besides, there are more than 500 historical documents, tablet inscriptions, water god worship facilities, and water conservancy relics.

Yellow River irrigation system in Ningxia witnessed a smooth, structured and sustainable management system which has carried forward even today. Joint participation of government and nongovernmental forces was adopted traditionally. Government-led and even militarization management was implemented for the irrigation system's construction, operation, and water distribution. In peacetime, the management model of government construction, nongovernmental operation and official supervision was practised. The annual repair was usually done in early winter to block the water intakes and dredge the canals. When summer began, the irrigation system was put into use. For a long time, the regions in the lower reaches of the Yellow River were irrigated before those in the upper reaches. The management for the irrigation system of Ningxia now is roughly the same as that practised in history. The Water Management Bureau and ten offices under Ningxia Water Conservancy are in charge of the trunk canals' water distribution and project maintenance. The water management bureaus at city and county levels organize and direct the water user associations in the on-farm irrigation water management and project maintenance under the level of the branch canal. Currently, there are 925 Water User Associations and a triplicity management system of water management authority and water user association was formed.

Systematic irrigation project management and complete rules and regulations, and effective joint management systems guaranteed the comprehensive maintenance of the works and the achievement of irrigation benefits. Ningxia Water Conservancy Museum is built to collect, preserve, and showcase water conservancy relics to preserve its rich history. It gathers remains and hosts exhibitions to explore the history, science and technology, and culture related to the Ancient Yellow River Irrigation System of Ningxia.

Water Heritage

The preliminary Yellow River irrigation system became a milestone in the history of the agricultural development of Ningxia Plain. Since the construction of irrigation canals, irrigated areas and grain yield gradually increased. According to statistics, the total grain output of the irrigation district, which was about 1,11,500 tons during the 16th century, increased to 1,76,000 tons in the 18th century, 266,500 and 2,961,000 tons in 2016, accounting for 4/5th of that of Ningxia Autonomous Region. The construction and development of the Yellow River irrigation system directly promoted the agricultural, social and economic development and prosperity of Ningxia Plain over 2000 years. It has played a significant role in improving the local people's living conditions and is of strategic significance to the stability of Northwest China.

The unique and scientific dam-less water diversion structure was used for water diversion. At the headwork, a riprap diversion dike which may be 1 km long, was constructed to divert water, some dikes being 5 km in length. On the dike, the spillway dam was built to ensure the water intake stayed firm in floods. The water intake was usually installed with a sluice to control the amount of diverted water and prevent silt. The gradient of the irrigation canals is 0.2-0.5‰. The water intake sluices controlled the amount of diverted water through water level measurement, and stones were buried in the canal's bottom as the standard for dredging work. Such techniques were relatively advanced at that time. The dam-less riprap water diversion headwork first used in the 2nd century BC was revolutionary. With its gradual increase in project scale and irrigated area, the irrigation system covered an irrigation area of 140,000 ha at the most in history. That was an engineering wonder before the achievements of the industrial revolution were introduced to China.

The irrigation system has worked well for more than 2,000 years without negatively influencing the environment.

The dam-less water diversion design helped reduce the negative influence, and the scientific canal layout guaranteed the balance between erosion and silting. The comprehensive utilization of water and silt of the river with high sediment concentration and the design and construction of sustainable waterworks of the Yellow River irrigated area in Ningxia has provided reference and experience for the comprehensive control of the rivers with high sediment concentration, the prevention, and control of soil salinization in large irrigation districts and the water conservancy development of big rivers. As Ningxia Plain is in an arid climate, the irrigation system has improved the water resource condition and the ecological environment, building a vast oasis and a series of harmonious and beautiful agricultural landscapes in the region surrounded by plateau and desert. It is a model for improving the ecological environment through water conservation works.

The design and management of the Ancient Yellow River Irrigation system of Ningxia reflect the idea of harmony between man and nature advocated in traditional Chinese philosophy and distinctive oriental cultural features. Ningxia Plain now is still a vital granary in northwest China. The construction and development of the Yellow River irrigation system have directly promoted the agricultural, social, and economic growth and prosperity of Ningxia Plain. In addition to the direct economic benefits of irrigation agriculture, the Yellow River irrigation system of Ningxia has also produced remarkable environmental and ecological benefits.

2.18 QIANJINBEI IRRIGATION SYSTEM

Name	**Qianjinbei Irrigation System**
Location	**Fuzhou, Jiangxi Province, China**
Latitude	**27.516 - 28.233**
Longitude	**116.067 – 116.650**
Category of Structure	**Irrigation System**
Year of commissioning	**868 AD**
River Basin	**Yangtze river basin**
Irrigated/Drained Area	**1467 ha**

History

Commissioned in the 9th year of the Xiantong Reign Period (868), the Qianjinbei irrigation system enjoys over 1,100 years of history, and the existing body is now 395 years old. Zhongzhouwei was completed in the 17th century and has been in existence for more than 300 years. Located in Fuzhou, Jiangxi province, Qianjinbei-Zhongzhouwei Irrigation Structure sits on Fuhe River, a branch of Poyang Lake of the Yangtze River Basin. It has become a typical example of a large-scale masonry irrigation structure and combines multiple functions, including irrigation, river transport, drainage and flood control.

Commissioned in 868 during the Tang Dynasty, the Qianjinbei irrigation structure formed with the Zhongzhouwei irrigation system as an integrated and unique irrigation system that built dykes around farmland, which realized functions of flood prevention, water supply, river transport and ecological improvement, and supported the development of local society, economy and culture.

The existent Qianjinbei structure is the heritage of several overhauls and renovations over the years. With the completion of the Zhongzhouwei structures, the Qianjinbei-Zhongzhouwei Irrigation Structure realized integrated functions such as irrigation and shipping and provided a stable water supply. In the mid-stage of the 19th century, the banks of Zhongzhouwei reached 31.1 km, providing water for 1,633 ha of farmlands and 43,500 people in the irrigation area. In January 1935, the water conservancy committee of Linchuan reconstructed the banks in Linchuan to further improve the system, which included the building of 30 km long banks and four floodgates. In 1958, the newly-built Jinlin canal diverted the Fuhe River upstream of Jinxi county, with one channel entering Zhongzhouwei to supply irrigating water. The ancient water and channel system in the Zhongzhouwei irrigation area is still operating for drainage and irrigation.

Description

Qianjinbei-Zhongzhouwei Irrigation System consists of the Qianjinbei system and Zhongzhouwei system. The Zhongzhouwei irrigation system comprises embankments, culverts, canals and channels, regulating structures, reservoirs, and lakes. The existent Qianjinbei structures were built during the last large-scale renovation project in the 1620s. The bank made of masonry is 6-7 m high and 9-12 m wide and is still functioning to diversify and control the Fuhe River. The length of Qianjinbei experienced impressive changes with the development of history and the width of branch river mouths, as the original length in the Tang dynasty was only over 400 m long, 3,000 m in the Song dynasty, 1500-2500 m in Ming dynasty, and 1,100 m now.

Zhongzhou is the main area surrounded by the Fuhe River and its branches, and also the field irrigated by Qianjinbei and Zhongzhouwei. The embankment is 304,000 m long in total, 6-8 m wide at the top, 5-6 m high, and the area irrigated is 1,467 ha. Xiaoyigang the ancient canal of the Zhongzhouwei irrigation system diverts the Fuhe River from Qianjinbei and stretches 13 km long. Though part of its diversion function has been replaced by another canal called Jinlinqu, most parts of Xiaoyigang are still kept as when it was constructed and are still operating for drainage and irrigation.

The Qianjinbei Irrigation System is one of the irrigation systems in the middle reaches of the Yangtze River. The flood control embankment is composed of river flood control dikes. The area surrounded by the structure is called Wei, meaning enclosure. In the enclosure, the channels and canals, regulating gates and water storage reservoirs constitute a multi-functional engineering system for irrigation, water transportation and drainage.

Qianjinbei Irrigation System was built in the last years of the Tang Dynasty and has been operated continuously during Song, Yuan and Ming dynasties. Since the Song dynasty, Fuzhou has become a region with a prosperous economy and culture in the middle reaches of the Yangtze River. Qianjinbei-Zhongzhouwei is a model for sustainable water conservancy projects in ancient China. The Zhongzhouwei Weir area has become an irrigation area that ensures steady harvest even during droughts and excessive rainfall, which has rapidly promoted agricultural development, regional grain output, and the population-carrying capacity of Fuzhou.

Qianjinbei controls and diverts the Fuhe River in a particular way. During the dry season, the water inlets on both sides of the Fuhe River can usually divert water to support urban and rural life, irrigation water supply and water transport. During the wet season, the Fuhe River would be divided into two branches by Qianjinbei, and the main canal and the branches pass water in parallel. Qianjinbei should play a critical role in flood diversion and ensure the safety of Fuzhou city.

Qianjinbei and other irrigation structures greatly improved water transportation in Fuzhou facilitated communication among various businesses and laid an indispensable foundation for developing the commodity economy. Food produced in Fuzhou had been sold overseas through the Fuhe River. According to the Examination of Fuzhou Agriculture, during Emperor Guangxu's reign in the Qing dynasty, Linchuan exported about 11.2 million kg of grain each year. From the Ming Dynasty to the Qing Dynasty, many piers and docks were built alongside Zhongzhouwei downstream of the Qianjinbei Canal, which promoted trade. The water transport function has promoted economic development, as well as material and cultural exchanges. Where there is good transportation, there is an open and inclusive society witnessed in the literature of that time.

Water Heritage

Qianjinbei irrigation system radically promoted the development of agriculture in the whole Fuzhou area, suggestively increasing the grain output and population-supporting capacity, making the Ganfu plain a rich granary.

The Qianjinbei Irrigation System showcased excellent engineering design and construction techniques. Built during the Tang dynasty, it is a large gravity-type dry stone masonry structure. Its scale, basement treatment, and hydraulic construction technologies were ahead of their times. The foundation works constituted special stones to reduce the uneven settlement of gravity bodies and ensure the safe operation of the structure. The masonry stones are uniform bricks of tuff, which are used between the concrete and the slab to increase the integrity and stability of the work. The foot of the reservoir is arranged in the shape of a triangle, which could resist the impact of river flows and protect the banks. In particular, Zhongzhouwei secured a water supply and flood control of 24.14 km2 within the irrigation area, which vastly increased food output, facilitated agricultural development, improved farmers' livelihood, and promoted rural prosperity.

The engineering structure and materials of the dry masonry have sound ecological and environmental effects, optimized the spatiotemporal allocation of water resources, and played an imperative role in maintaining the agro-ecosystem of the irrigation area. The Qianjinbei irrigation system had a profound impact on the natural environment of the Fuhe River system and the Fuzhou area. Qianjinbei structure diverts the river to return to the mainstream of the Fuhe River from its branches, forming a route that circulates the city and surrounds it from three directions. It fundamentally restores the water environment of Fuzhou City, which not only facilitates the domestic water consumption of the residents in the city but also contributes to the military security of Fuzhou City and improves the urban ecological landscape. Qianjinbei has effectively regulated and distributed the water resources in Fuzhou city, which has profoundly impacted the local environment. It is a typical excellent ecological water conservancy project.

The management of Qianjinbei-Zhongzhouwei combined the government authority and non-governmental forces. In ancient times, the main structures of Qianjinbei, the banks and canals, were under the administration of local governments. In contrast, branch canals, lakes and reservoirs were taken care of by non-governmental organizations. Such management of public structures reflected the coordination and responsibility sharing, rights and interests of various parties.

The Qianjinbei Irrigation System created cultural norms and traditions. Since the establishment of Qianjinbei in the Tang Dynasty, Qianjinbei has become the most iconic water conservancy project in Fuzhou, and its cultural influence has spread to the distant Lingnan area. The project has been deeply rooted in the Fuzhou and Zhongzhouwei area and is widely reflected in the genealogical records and folk culture, forming a unique irrigation culture. The operation management of Qianjinbei-Zhongzhouwei has spawned a unique culture of water god worship and sacrificial culture. Worshipping of water deities created a unique cultural bond connecting authorities and non-governmental forces for joint efforts in protecting and preserving the irrigation structures in ancient times. Qianjinbei has therefore left an impressive mark in the irrigation culture of the Fuzhou area and Ganfu plain. A worshipping temple called Lingchang Temple (then renamed Shuihu Temple, Shuifu Temple) and bull-like iron sculptures are erected beside the Qianjinbei reservoir.

2.19 QUEBEI POND

Name	**Quebei Pond**
Location	**Anhui Province (Anfeng Pond Town, Shou County), China**
Latitude	**32.533**
Longitude	**116.102**
Category of Structure	**Water Storage Structure**
Year of commissioning	**6^{th} century BC**
River Basin	**Middle reaches of the Huai River**
Irrigated/Drained Area	**44867 ha**

History

Quebei is located in the middle of Anhui Province and on the southern bank in the middle reaches of the Huai River. Also called Anfeng Pond, it dates back to when Monarch Zuang of the Chu Kingdom ruled (601 B.C. – 593 B.C.) and is a pond water storage and irrigation project with a history of over 2600 years. This project has facilitated the development of agriculture in the middle reaches of the Huai River and turned this region into a significant base of grain output in China. Historically, Quebei used to have an irrigation area as large as 10,000 ha. Shou County has an annual rainfall of 906.7 mm. As a reverse regulatory reservoir in the Pishihang Irrigation District, Quebei has a mean yearly water inflow of 260 MCM, a perimeter of 26 km, a water storage area of 34 km2, a designed reservoir capacity of 84 MCM and an irrigating area of 44,867 ha. It still plays a vital role in irrigation, water diversion, water storage, irrigation and flood prevention. It is a typical irrigation project that utilizes natural landforms for embankment, water storage, and irrigation.

Quebei was only a seasonable pond upon initial completion. With a landform high in the east, south and west but low in the north, a canal was dug to attract water inflow here, and an embankment with a sluice was then constructed for water storage and irrigation. Throughout 1,000 years of continuous improvement and repairs, sluices increased from 6 to 36 at Quebei in the 6th century. A well-established project thus came into being and has remained the same until today. Due to the rapid increase in population after the middle of the Ming Dynasty, nearly half of the lands to the south of Quebei were reclaimed and turned into farmlands at the end of the Qing Dynasty, with mean water storage of about 30 MCM. In the 1950s, Foziling and other reservoirs were constructed in the upper reaches of the Pi River, and Quebei was incorporated into the new Pishihang Irrigation District. Pidong Trunk Canal branched out from the Pi River's trunk canal and flew into Quebei.

Description

Quebei mainly comprises four major parts, i.e., the water storage work, the embankments and sluices, the irrigation and drainage canal system and the accessory facilities, and flood relief work. The facilities and operating mode of the 19th century have been preserved till today. The sluice work is the regulatory work of Quebei, which controls the water flow and canal water distribution. Five sluices were distributed around the pond, i.e. Jing, Dukou, Yangtouxi and Xiang sluices, and the water inlet sluice near Wumenting, connected to the trunk canal. There are still 21 sluices at Quebei today, and most of them continue to use the names from Ming and Qing Dynasties. Quebei Irrigation District has two trunk canals, 54 branch canals, 151 lateral canals and 298 irrigation canals with a total length of 678.3 km. The canals are equipped with several hundred water diversion sluices, regulatory sluices and water return sluices to satisfy the irrigation and flood relief needs within the irrigation district. In total, 114 villages of 13 townships have benefited from this project.

As a medium-size reverse regulatory reservoir of the Pishihang Irrigation District, Quebei has a perimeter of 26 km, a water storage area of 34 km2 and an irrigating area of 44867 ha that covers 13 townships. Besides irrigation, it also brings benefits in flood control, aquaculture, hydropower generation, and ecological landscaping. Besides, over the past 2000 years, Quebei has also served as the carrier of traditional production and living modes and cultural values.

Quebei is a remarkable pond water storage and irrigation project in China. A reasonable layout characterizes it, and ingenious design with the ancient engineering structure retained today. As a result, it irrigates a vast sprawl of farmlands in the Huainan Region and plays an irreplaceable role in promoting the social development and economic prosperity of Shou County and alleviating natural disasters.

Quebei Pond was honoured as one of the key cultural relics under government protection, a state-level scenic irrigation zone by the Ministry of Water Resources and nominated for the World Cultural Heritage of Agriculture in 1988, 2013, and 2015, respectively. In light of such recognition, higher protection measures for the sustainable operation of the Quebei Pond are imposed. In the past 2000+ years, the joint administration of Quebei by the government and civilian organizations has given full rein to the irrigation development of Quebei and turned Shou County into an outstanding representative of the farming culture. The traditional production and living modes and culture have been passed down in the irrigation district till today.

Water Heritage

The construction of Quebei Pond is a milestone in the irrigation and agricultural development of the Huainan Region. It promoted the development of agriculture in the middle reaches of the Huai River, and the Chu Kingdom here hence became rich and grew into one of the six greatest powers of the Warring-States Period. Due to the irrigation benefits of Quebei, the Huainan Region gradually became the main base of grain output in central China. Agriculture is an important constituent of the economy in the Huainan Region. It is the foundation of regional economic and cultural development.

Quebei Pond is a typical irrigation project that utilizes natural landforms for embankment, water storage and irrigation and emphasizes environmental protection. As a water storage and irrigation project, it fully utilizes the local landforms and water resource conditions and is characterized by its scientific and reasonable layout and ingenious design. It fully reflects the architectural concept of respect to, harmony with, and integration into nature. It has a landform that is high in the east, south and west but low in the north. Located at the transition belt between the southern and the northern climates, it has uneven rainfall distribution as floods easily arise during the rainstorms in summer and autumn and extensive droughts occur after the rainy season.

Quebei Pond was an innovation when it was constructed and played a unique and constructive role in the development of modern engineering theories and methodologies. The weir and dam work of Quebei, constructed in the 2nd century AD and excavated in 1959, includes a structure similar to the modern stilling basin. When the water level in the pond rises above the maximum storage capacity, it will flow into the stilling basin via the overflow weir and then pass the overlapping beam wooden dam for double-tiered energy dissipation before it is discharged safely. This helps to guarantee sufficient irrigation water supplies on normal days and the safety of the pond during floods. Such a double-tiered energy-dissipating hydro-engineering construction reflects ancient China's level of development in the hydro-engineering sector.

The administration system of Quebei Pond has features of traditional Chinese culture. It is a paradigm of sustainable management of irrigation projects. In the 2nd century BC, the government designated an official to manage Quebei to establish the local government's authority. Wang Jing, the famous irrigation expert, established an annual repair policy for Quebei and erected a stele to publicize this policy. In the 19th century, a well-established system of water use, annual repair and operating expense management existed. Water users signed the New Covenant, which became a civilian regulation on maintaining the grassroots irrigation order. Anfeng Pond Branch of the Water Affairs Bureau of Shou County is directly in charge of Quebei today. Public finance provides routine administration and maintenance costs.

It is a cultural relic. Sungong Temple (commemorating Sunshu Ao, the founder of Quebei Pond), located on the northern bank of Quebei, has a history of more than 1400 years. Inside the temple, 20 well-preserved historic steles are recording the evolution of the pond. Sacrificial ceremonies are held at the Temple in spring and autumn each year to pay tribute to the ancestors for their contributions and pray for good weather and harvests. The traditional production and living modes and cultural traditions are still well preserved in this region.

2.20 SAKYA WATER STORAGE IRRIGATION SYSTEM

Name	**Sakya Water Storage Irrigation System**
Location	**Sakya County, Tibet Autonomous Region, China**
Latitude	**N 28°54′**
Longitude	**E 88°03′**
Category of Structure	**Irrigation System**
Year of commissioning	**13th Century A.D.**
River Basin	**Yarlung Zangbo River**
Irrigated/Drained Area	**6,700 ha**

History

From the perspective of development, the history of Sakya water storage irrigation can be roughly divided into three stages:

Stage1: from the origin in Tibet period to the Yuan dynasty, the farmland of Sakya was mainly irrigated by natural canal, and the agricultural production in this period was low and rough.

Stage 2: During the Yuan Dynasty (1271-1368), the water storage irrigation gradually developed and expanded to the surrounding areas with the spread of Sakya culture, which greatly improved the agricultural productivity at that time and finally promoted Sakya with more developed agriculture to become the capital of Tibetan area and the political, religious and economic center at that time.

Stage 3: During the Ming and Qing Dynasties, the improvement of agricultural technology and the increase of agricultural water consumption triggered deep-rooted social contradictions around water storage irrigation and even caused fights for water. As a result, a complete water storage irrigation management system was developed under the supervision of the local government and religious figures, which was the embryonic form of the modern "Canal Chief System".

Description

Between the Himalayas and the Gangdise-Nyainqentanglha Mountains, there is a valley plain. The Chongqu River, which originates in the northern foothills of the Himalayas, flows through this valley before entering the Yarlung Zangbo River.

In the 11th century AD, on the hillside above the northern bank of the Chongqu River, a Buddhist monastery was built. It was named "Sakya", meaning "pale gray earth" in Tibetan. In the 13th century AD, the central government established a local seat of power in Sakya.

Sakya, currently a county under the Shigatse Municipality in Tibet Autonomous Region of China, is located on a plateau with a temperate, semi-arid monsoon climate. The plateau boasts an average altitude of more than 4,000m, an average annual temperature of 5 to 6, and an annual rainfall of about 150 to 300 mm. The frigid climate of the Qinghai-Tibet Plateau is mildened in the Sakya valley. In this dry region of deep soils, the running Chongqu River is the precious source of water.

In order to make full and effective use of the limited water resource, the people of Sakya started the construction of a water storage irrigation system along the Chongqu River in no later than the 13th century. Large difference in altitude, complex terrain and diverse landscapes in Sakya has made it especially difficult to transport building materials. Therefore, most of the water pools were built near the Chongqu River. These pools have adopted different structures depending on different topographical conditions. Some are natural pools embanked with stones; some are man-made water storage facilities using weirs; and some are excavated to store water diverted from the Chongqu river. The water storage capacity of a single pool is about 30,000 to 50,000 m3 during the wet season. In addition to water storage, the pools have another important function: to increase the temperature of the irrigation water. The water of the Chongqu River is mainly meltwater from the surrounding snowcapped mountains. The water temperature in the irrigation season is generally around 3°C, but thanks to the pools, the temperature could be raised to around 13°C, which could promote crop growth and increase yields. At present, there are more than 400 pools still irrigating farmland in Sakya County.

For example, the northward-flowing Chongqu River forks into three branches on the north of the Sakya Monanstery. At the forking point, the river is controlled by a three-gate sluice after which the water runs to three pools respectively. The pools, also equipped with sluices, provide water for downstream canals and then farmland.

American Tibetologist Robert B. Ekvall said that Sakya's water storage irrigation system is unique in the Tibet region. Apart from its unique location and structures, it also features a unique irrigation management system. The irrigation system is managed by two full-time officials called "tsho-dpon". They work together to maintain the irrigation system, control the main canal gates, and settle water use disputes. Every water user has to send a representative, also called "water girl", to open the stone or wood gates to their own land after the sluices on the main canals are opened. This management system is still in use today.

Water Heritage

The Sakya Water Storage Irrigation System has promoted regional social and economic development, and at the same time led to the rapid rise of Sakya's political status. According to the Sakya Mottos which was written in the early 13th century, the water storage irrigation system is closely related to the rise of the Sakyapa Sect of Tibetan Buddhism. The book contains a lot of insightful content related to the System, such as: "If you want to utilize the river water, it is a good idea to introduce the water into the pools", "If a poorly maintained pool is filled up with water, it will inevitably collapse", and so on. By the middle of the 13th century, Sakya had become the capital of the Tibet region.

The Sakya Water Storage Irrigation System, high atop the roof of the world, has been in operation for centuries and still irrigates thousands of hectares of highland barley. On the Qinghai-Tibet Plateau which sits more than 4,000 meters above the sea level, the natural conditions are extremely harsh. Despite that and the rudimentary engineering equipment and building materials, local people have managed to build a marvelous project, leaving the field of hydraulic engineering and human civilization with a formidable legacy.

2.21 SANGYUANWEI POLDER EMBANKMENT SYSTEM

Name	**Sangyuanwei Polder Embankment System**
Location	**Foshan City, Guangdong Province, China**
Latitude	**23**
Longitude	**113**
Category of Structure	**Canal System**
Year of commissioning	**12th Century**
River Basin	**Pearl River Basin**
Irrigated/Drained Area	**4126.8 ha**

History

Sangyuanwei Polder Embankment System is located in Foshan City, Guangdong Province, in the Pearl River Delta. The south subtropical marine monsoon climate zone has a warm climate and annual average precipitation of 1,620 mm. It has a circumference of 83.86 km and covers an area of 265.4 km². Surrounded by the Xijiang River, the mainstream of the Pearl River, and the Beijiang River, a tributary of the Pearl River, it is vulnerable to floods, tides from the two rivers, and typhoons.

Sangyuanwei Polder Embankment System was first built in the early 12th century of the Northern Song Dynasty (AD 960–1127) and completed at the end of the 14th century. Its construction ushered in the history of large-scale agricultural development in the Pearl River Delta and the southward shift of the Eastern China Economic Zone. It is a milestone in developing irrigation agriculture in the Pearl River Delta and still provides water conservancy for regional social development.

Sangyuanwei Polder Embankment System was first built between the Chongning and Daguan periods (1102–1110) during Emperor Huizong of Song's reign. After the Mid-Tang Dynasty (AD 618–907), the unceasing wars in the North led to the persistent southward migration of the population in the Central Plains, which promoted the agricultural development in the areas south of the Yangtze River, Zhejiang, Fujian and the Pearl River basin. At the beginning of the 12th century, polder embankments and Jizan Embankment were built along the Xijiang and Beijiang rivers of the Pearl River, with a height of about 1 to 2 m. In the Yuan Dynasty (1271–1368), the embankment was further raised and thickened, with a height of about 4 m. The Ganzhuxi area is the lowest in the whole System. Due to the influence of reclamation and natural deposition of sediment, the problems of poor drainage, flood and tidal backflow gradually appeared in the Ganzhuxi area in the 14th century; the place was known as a Flowing-Back Port.

In the 29th year of the Hongwu period in the Ming Dynasty (1396), Chen Bomin, a native of Jiujiangbao, led people, and Sangyuanwei Polder Embankment System was enclosed. With the increase in population, to prevent flood, the levees were further heightened, and the levee line was extended in the Ming Dynasty (1368–1644). In addition, many small embankments were built in each village, and sluices were built to control the water volume. In the 17th century, Sangyuanwei Polder Embankment System had become a complete water conservancy project system including embankments, a watercourse system, a gate system for flood and tide control, irrigation and drainage, and water transport.

In the 59th year of the Qianlong reign of the Qing Dynasty (1794), initiated by Wen Rushi, a native of Longshan County in Shunde, the General Administration of Sangyuanwei Polder Embankment System was established jointly by the gentry of 14 villages within the Embankment. This marked the beginning of the unified management and maintenance of the Sangyuanwei Polder Embankment System as an integrated regional water conservancy project. By the end of the Qing Dynasty, Sangyuanwei Polder Embankment System had become the first fertile farmland in the surrounding provinces and the largest production base of grains in eastern Guangdong with a circumference of over 50 km, hundreds of thousands of households and more than 1,000 ha of agricultural mulberry fields, and became one of the largest water conservancy projects in ancient times.

The Shihankou, Longjiang and Gejiao water gates built successively from 1925 to 1926 were made of reinforced concrete materials, improving control capacity. In the 1950s, Sangyuanwei Polder Embankment System and Qiaobei Polder were merged, known as Qiao-Sang Polder. At present, the overall flood control standard of the Sangyuanwei Polder Embankment System has been raised from less than a 10-year return period to more than a 50-year return period, and the current irrigation area is 4,133 ha. The historical pattern and cultural texture of the Sangyuanwei water conservancy project are still intact.

Description

Sangyuanwei Polder irrigation and drainage system mainly include embankments, watercourse irrigation and drainage system, and watergate control work. The perimeter of the whole polder is 83.86 km, surrounded by the northern hills and Jizan Embankment, Xijiang Embankment, Dongjiang Embankment and Ganzhuxi Embankment which together form the flood control barrier of the whole area. The total length of the project is 64.84 km. The watercourses within the Embankment crisscrossed, creating a perfect irrigation and drainage canal network. Within the Embankment, there are 57 watercourses (281.21 km), including 14 main watercourses (75.91 km). The control work of the Sangyuanwei Polder Embankment System is called a dou-, watergate that can control water diversion, drainage and water transport. Most of the gates are culvert gates. Some use herringbone wooden gates, which can automatically open for drainage when waterlogging sites are high and close to block the tide automatically when the external tide or flood water level is high. Some of the water gates are also engraved with water rules for quantitative control. The water system within the Embankment is connected with the outside water through the gates on the embankments. The water level difference between the two rivers is used to draw water into and drain water out of the polder due to the difference in the degree of tidal bore patency. At present, within the Embankment, there are 63 ancient gates of historical value. Rice and mulberry fish pond are the main agricultural products within the Embankment, and the current irrigation area is 4,133 ha.

In addition, there are 60 building facilities related to water conservancy management and water deity worship and 20 water conservancy inscriptions within the Embankment. The water conservancy documents and archives are well preserved and inherited. They witness the Sangyuanwei Polder Embankment System's history and value and form an integral part of the Sangyuanwei Polder Embankment System irrigation project heritage.

Currently, the system's protection and maintenance are jointly done by the water conservancy departments of Foshan City, Nanhai District and Shunde District, including the management of embankments, watercourse systems and water gates to ensure the safety of the project structure and the regional flood control and drainage.

Water Heritage

Sangyuanwei Polder Embankment System was first built more than 900 years ago, between the Chongning period and the Daguan period (1102–1110) during the reign of

Emperor Huizong of Song. It was enclosed in the 29th year of the Hongwu period in the Ming Dynasty (1396) over 600 years ago.

The construction of the Sangyuanwei Polder Embankment System not only ushered in the history of large-scale agricultural development in the Pearl River Delta but also witnessed the historical process of the expansion and southward shift of the Eastern China Economic Zone. It is a milestone in the development of irrigated agriculture in the Pearl River Delta. Sangyuanwei Polder Embankment System is 83.86 km in length, and the enclosed area is 265.4 km^2. The irrigation area reached more than 13,333 ha in history. It took the lead in its time in terms of scale. It was revolutionary in terms of construction techniques and dimensions.

Sangyuanwei Polder Embankment System irrigated more than 13,333 ha of farmland in history, and its current irrigated area is 4,133 ha. In addition to rice and other grains within the Embankment, mulberry fish pond and other agricultural operation modes are also developed, making Sangyuanwei Polder Embankment System the area with the most developed agricultural economy in the Pearl River Delta and providing water conservancy for rural prosperity.

The concept of the overall regional enclosing for flood control represented by the Sangyuanwei Polder Embankment System has been popularized and developed in modern urban or regional flood control practice. The recycling agriculture mode of the mulberry fish pond within the Embankment is relevant for contemporary agricultural development and ecological progress.

The planning and design of the Sangyuanwei Polder Embankment System reflect the overall coordination of water environment contradictions such as flood control, tide blocking, irrigation and waterlogged farmland draining, realising the change, optimization and maintenance of the living environment, ecological environment and production environment in the enclosed area, and has good ecological environment effect.

In the long-term, Sangyuanwei Polder Embankment System and its water conservancy features have profoundly impacted society, the people, folk activities, and folk worship in the enclosed area. For example, the characteristics typical of the waterside areas south of the Five Ridges, the Dragon Boat Race and the old and diverse activities of water deity worship endow Sangyuanwei Polder Embankment System—an irrigation project—with distinctive traditional cultural characteristics.

Since its completion, Sangyuanwei Polder Embankment System has played a critical role in regional flood control, irrigation and drainage, tide blocking and other respects. It also played a role in water transport in history. At present, Sangyuanwei Polder Embankment System is still contributing to the flood control and drainage safety of 265.4 km2 of land, ensuring the irrigation and water supply of 4,133 ha of farmland and providing for nearly 900,000 people in the area.

Sangyuanwei Polder Embankment System witnessed a sustainable and systematic form of management that continued over the years and passed on from generation. It evolved from section management by each village to a three-level management system of General Administration, village and household. Government supervision was gradually intensified. In addition, some individual management systems were also formulated, such as Regulations for Protection of Sangyuanwei Polder Embankment System and General Rules for Saving Sangyuanwei Polder Embankment System, which refined the rapid response mechanism for emergency rescue. The Board of Sangyuanwei Polder Embankment System was established in 1937 through a democratic election, and it was responsible for the management, maintenance, fundraising and flood control construction.

After 1949, Sangyuanwei Polder Embankment System continued and improved the management system of government and private participation. After the establishment of the Qiao-Sang Polder in the 1980s, Sangyuanwei Polder Embankment System was under the management of the Nanhai District Office for Qiao-Sang Polder Management. At present, the water conservancy institute of each town and the Qiao-Sang Polder Management Office is mainly responsible for the water conservancy construction and management of the Sangyuanwei Polder Embankment System.

2.22 SONGGU IRRIGATION SCHEME

Name	**Songgu Irrigation Scheme**
Location	**Zhejiang Province, China**
Latitude	**N 28°14'~28°36'**
Longitude	**E 119°10'~119°42'**
Category of Structure	**Irrigation Scheme**
Year of commissioning	**2nd Century BC**
River Basin	**Oujiang River Basin**
Irrigated/Drained Area	**more than 11,000 ha**

History

In 138 BC, a small kingdom called Dong'ou moved northward and relocated to Gushi of Songyang County, Zhejiang Province. Thanks to the excellent irrigation conditions there, some of the Dong'ou army and civilians started land reclamation, transforming Gushi into a place with well-developed agriculture and a thriving market and launching Songyang's history of agricultural irrigation. Before the period of 1041-1048 in the Northern Song Dynasty, Bairen Weir, also called Qinglong Weir, had been completed on the south bank of the Songyinxi Stream at the foot of Dushan Mountain; the village of Shisandu built two weirs on the Fangxi Stream, irrigating more than 500 ha of farmland; by 1340, Bailong Weir was built in the south of Songyang County, irrigating more than 130 ha of farmland.

During the Song and Yuan Dynasties, the irrigation scheme had gradually taken shape. By the late Ming and early Qing Dynasties, Songyang County was already home to 116 weirs, ranking first among all counties in the Oujiang River basin. The irrigation scheme was improving and increasingly complete, with Songyinxi Stream as its water source, a dense network of weirs and canals, and a sound management system. In ancient times, the people of Songyang considered the local terrain when building weirs and canals for water diversion. As a result, sustainability has been achieved, and many ancient weirs are still functioning. Fourteen of them could still be irrigating hundreds of hectares of farmland each. Within the Songgu Irrigation Scheme, there are more than 1000 ancient weirs, and 50 of them were built before the Qing Dynasty. Such great density is of extreme rarity. The canal systems of the irrigation scheme are largely geometric. For instance, the canals of Jinliang Weir are perpendicular to each other and of a graded structure; the Fangxi Weir is built at the source of the stream and has a fan-shaped canal system.

Description

Songyang County, located in the southwest Zhejiang province of China, is surrounded by mountains and has four distinct seasons, with an average annual precipitation of about 1700 mm. Songyinxi Stream, a first-class tributary of the Oujiang River basin, has a total length of 109.4 km. Running from northwest to southeast, it flows across the entire Songgu Irrigation Scheme. As the largest grain-producing base of the Oujiang River Basin, Songgu Irrigation Scheme has an irrigated area larger than 11,000 ha. As an old Chinese saying goes, "When Songyang county has a bumper harvest, the entire region of Chuzhou City will enjoy sufficient food supply", which reflects the abundance and prosperity of Songyang.

Currently, there are 14 ancient weirs, each irrigating more than 66 ha of land. Springs along the Songyinxi Stream gush out from the mountain valleys and never run dry; in addition, there are more than 1000 wells within the irrigation scheme. Generations of farming have gradually created the proper combination of weirs, canals, ponds and wells, and the orderly scheduling of water storage, diversion, irrigation and drainage. Under such an adaptive irrigation system, with the water storage capacity of ponds, wells and springs, the water use is optimized, and the impact of drought is minimized. The Songgu Irrigation Scheme enjoys a beautiful landscape and thriving agriculture.

With its excellent natural environment and sound irrigation system, it is a major grain-producing base in the southwest Zhejiang province. Meanwhile, it has a long history of tea cultivation and is also the largest green tea market in China. In addition, dried red tobacco leaves, a local speciality, had won the gold medal during the EXPOCOMER 1915 held in Panama City.

Water and irrigation have brought prosperity. Within the irrigation scheme, there are hundreds of well-preserved historic villages which open a window to the idyllic life of the ancient Chinese, giving people a taste of mystery and tranquillity. Weirs, ponds, wells and springs, connected with main and branch canals, form an irrigation system resembling a long vine with melons. Within this system, water diversion, storage, irrigation and drainage are orderly and organized, just as in a modernized water scheme.

The siting of a water scheme has a direct impact on its performance and local social stability. In the Ming Dynasty, Zhou Zongbin adopted the method of the seventy-thirty ratio to select sites for weirs, solving the water distribution conflicts between the south and north banks of the Songyinxi Stream. This is an early application of quantitative analysis in the siting of water projects. Downstream of Fangxi Weir, there is a pool with a giant rock in the shape of buffalo back. By observing how much of the buffalo back is submerged in water, people were able to forecast drought and flood and manage water affairs accordingly. This is the earliest evidence of hydrological monitoring in the Oujiang River basin.

By standardizing the specifications of canals and water intakes, the locals allocated water according to demand and solved water distribution conflicts which had lasted for more than a century. Also written in the historical records are the canal-farmland-combined system for long-standing and coherent management, the establishment of the board of directors for weirs and canals for collective leadership, and the water rights management mechanism covering aspects of water use permission and the change and transaction of water right.

To conclude, Songgu Irrigation Scheme was equipped with a finely tuned management system. In the Water Museum of Songyang, there is a collection of 16 notices and several inscriptions left by 16 county magistrates which record the historical facts of the rehabilitation, management, water distribution and water dispute settlement of Fangxi Weir over 555 years, as well as the spirit of water management persistently pursued by local officials and people in the past centuries. With its complete and rich heritage engineering system, vivid and detailed historical records, and brilliant water governance practices, the Songgu Irrigation Scheme is a distinctive living museum of heritage irrigation structures and a model of historic irrigation projects in small and medium basins.

Water Heritage

The construction of the Scheme has provided Songyang County with higher productivity in agricultural production. Songyang was a traditional agricultural county in the past. Through improvements made by generations by generations, the Songgu basin has become an area with fertile paddy fields and a dense network of canals and ditches. The subtropical monsoon climate is favourable for rice cultivation. In addition, the residents of Songyang County are hard-working and good at intensive farming. Therefore, agricultural produce is abundant in the county. It has been the granary of the Lishui region (called Chuzhou in ancient times). Songyang County was a main grain production region in the southwest of Zhejiang Province in ancient times and was well-developed in the economy, commerce and trade. The dock at the south gate of the county was buzzing with merchant ships and boats. The prosperous economy promoted regional population growth. Due to its good living conditions, the county is home to many historical celebrities. Many historic villages have been retained.

The Scheme resembles a long vine with melons: A large number of weirs, ponds, wells and springs are connected by the main and branch canals and ditches, forming an irrigation system resembling a long vine with melons, which is similar to the contemporary tiered irrigation system. With rotational irrigation and orderly water diversion, storage, irrigation and drainage, the Scheme has realized systematic management, which is a model of systematic engineering of ancient times. Many historic official public notices and announcements concerning water affairs are preserved in the archives of Songyang County. The following map of the river and canal system records the flow direction of No.2 Fangxi Weir and the locations of several dozens of small reservoirs and culverts.

Scientific weir design: Qinglong Weir is not parallel to the flow direction of the water. It is skewly positioned relative to the flow direction. Due to geological and economic restraints, this kind of weir design is a solution to many problems. With limited upstream water head, fixed canal width and the purpose of reducing energy loss, a skewly positioned weir could effectively increase the weir discharge. Due to the limited canal width, the weir top axis is oblique to the flow direction, so the length of the overflow front increases. Under a fixed flow rate, when the head decreases or stays stable, the flow capacity of the weir increases.

The adoption of the skew weir design could help flush away sediment in front of the weir when the water level is low, preventing or at least reducing siltation. The construction of a skew weir in the river could increase the discharge flow over the weir and the uniformity of the discharge flow running through the cross-section of the river, and thus stabilize the watercourse near the weir.

Scientific design of water allocation and diversion: The siting of a water scheme has a direct impact on its performance and local social stability. In the Ming Dynasty, Zhou Zongbin adopted the method of the seventy-thirty ratio to select sites for weirs, solving the water distribution conflicts between the south and north banks of the Songyinxi Stream. This is an early application of quantitative analysis in the siting of water projects.

Historically, the Scheme was constructed with locally available and eco-friendly materials such as bamboo and pebbles. The weirs and small reservoirs constructed have created an excellent water ecosystem and promoted biological diversity. The history of the Songgu Irrigation Scheme exceeds 100 years (dating back to the 2nd century BC). The Scheme is composed of water diversion structures such as weirs, canal systems, water storage structures, etc. Its engineering form remains unchanged today.

Songyang County is home to many historic figures well-known for their contribution to water governance. Many of the popular traditional songs of Songyang County are about irrigation. Within the Scheme, there are 75 historic villages built in the Ming and Qing Dynasties. Such a good status of preservation is rare in China. In the ancestral halls of the villages, there are many records of irrigation and water diversion in the genealogical books. Visitors here could enjoy the fun of local folk culture.

It is an outstanding example of Operation & Management over a long period. The weirs of the Scheme have been managed by democratically elected weir chiefs who then set up boards of directors. One board of directors has 7-8 representatives of the benefiting villagers. The management team is in charge of the weir and canal repair and maintenance, maintaining daily water use orders, recruiting villagers for maintenance and repair work, and collecting water fees.

All the important water conservancy projects in the history of Songyang had charters and regulations on water use and water distribution, which were carved in stones. The rules and regulations on water use and water distribution in Songyang County have a long history and excellent tradition. Its good management system has ensured the sound operation of the Scheme for more than two thousand years, making it a model of sustainability.

As early as before the period of 420-489, the locals of Songyang County had built weirs and dams on the mainstream of Songyinxi Stream for farmland irrigation. Initially, the building materials were wood, bamboo and stones. During the Song and Ming Dynasties (960-1644), the weirs were built with rocks. Such a building method is still used today in some places. At the same time, the local people made full use of the high-lying deep pools of the rivers to carry out weir-free water diverting for irrigation almost a thousand years ago. Some water inlets were equipped with gates for drought and flood control.

Qinglong Weir is also called Bairen Weir or Hejia Weir. Its initial construction time is unknown. According to the Annals of Songyang County, its records date back to the Qingli period of the Northern Song Dynasty (1041-1048). The original location was close to the foot of Mount Bairen. It was moved to the location 400 meters west of Mount Bairen in the winter of 1594, at the confluent point with the source of Zhuxi Stream. The weir was damaged by a flood in the Qingli period (1041-1521) of the Song Dynasty and restored in the Zhengde period (1506-1521) of the Ming Dynasty and damaged again later. It was reconstructed twice in the Wanli period during the Ming Dynasty (1573-1620).

Qinglong weir was constructed on the riverbed of the main stream of Songyinxi Stream near the entrance of Silingxia Village. The water was diverted from the main stream of Songyinxi Stream, flowing eastbound through Dushanjiao, Wayaotou, Shuinan, Qinglong, Chengxu and Hengshan villages to Huangkengyuan, and then into the main stream of Songyinxi Stream at Tabuxia Village. The canal is 7 km long, irrigating more than 180 ha of farmland.

Bailong Weir was first built in 1356 with a donation from Zhou Hanjie, a resident of Songyang County. The weir is located in the Hangchuantou section of Songyinxi Stream, 1.5 km away from Xiping Town. The weir was initially constructed with bamboo cages filled with gravel. Sitting on the northern bank of Songyixi Stream, the weir diverts water from the west to the east. The water flew through the road-leaved forest at Hanhchuantou and the densely populated south gate of the county, then passed by the east gate to Xiangnong and Baisha villages and then flowed back into Songyinxi Stream. Bailong Weir irrigated more than 60 ha of farmland along its canal and provided water for domestic use and firefighting.

Jinliang Weir is also known as Xuangong Dam or Jingliang Weir. The initial time of construction is unknown. The earliest record found is from 1340. The weir is located on Songyinxi Stream at the position north of Xiaoshi village of Zhaitan Township, 8.5 km away from the county town. The water was diverted through the weir by dam-free means from the main stream of Songyinxi Stream. The water inlet was built at the south margin of the Niududong pool. By making use of the natural condition of the deep pool on the main stream and the stream course of Songyinxi Stream, the water flew naturally and steadily. The main canal is 4.5 km long, irrigating 213 ha of farmland in 8 villages and providing water for domestic use. The following statements were recorded in the Annals of Songyang County published in the period of the Republic of China: "Jinliang Weir, located in 15th du (the local word for village), 10 km west of the county town, irrigates 400 ha. It was damaged in early 1340; the then county magistrate presided over the reconstruction, resuming its function and benefits for villagers. The name Xuangong Dam is to commemorate this local official."

Wuyang Weir is also known as Shimenzhen. The initial time of construction is unknown. The earliest record dates back to 1847. The weir is on Songyinxi Stream near Shimen village of Wangsong Street community. According to the record in the stone inscription "Notes on Shimenzhen", in the process of construction, the beneficiary village (Huanggongdu Village) downstream borrowed land for the construction of the project from the non-beneficiary village (Shimen Village). Borrowing land to build canals reflects not only the wisdom of the local people in the process of water governance but also their solidarity and determination on this matter.

Fangxi Weir was a project jointly constructed and shared by the 13th du and 14th du in the Songgu plain of Songyang County. It dates back to the Northern Song Dynasty (960-1127). Fangxi Weir, located at the source of a tributary of Songyinxi Stream in 13th du, has two weirs. Weir No. 1 is 58 m long, and its main canal is 2.5 km long. Weir No.2 is 90 m downstream from Weir No.1. It is 70 m long, and the main canal is 9.5 km long. The weirs were constructed with stones and rocks. Fangxi Weir irrigates the farmland of Xinxing Town and Zhangxi Town with a total area of 604 ha. They also provide water for domestic and ecological uses. The extant cultural heritages of Fangxi Weir include 18 original public notices and announcements on water affairs issued by the magistrates of Songyang County from 1530 to 1883, 1 ancient map of the canal system, and two stone inscriptions.

In May (the lunar calendar) of 1592, Songyinxi Stream experienced serious flooding. More than 900 meters of embankments were damaged, destroying several hectares of farmland and many houses near the Stream. Later the embankments were restored. This fact was recorded and carved on a stone. This is the beginning of the written record on the water governance of Songyinxi Stream.

2.23 TIANBAO WEIR

Name	**Tianbao Weir**
Location	**Fuzhou City, China**
Latitude	**25.71**
Longitude	**119.36**
Category of Structure	**Weir**
Year of commissioning	**749 AD**
River Basin	**Longjiang River Basin**
Irrigated/Drained Area	**1930 ha**

History

Located on the Longjiang River of Fuqing City, the Tianbao Weir is the oldest comprehensive water conservancy project in the Fujian Province, integrating the functions of irrigation, flood control, fending off sea tides and storing freshwater. Built in the Tianbao Era of the Tang Dynasty (742-756, hence its name Tianbao), the weir has maintained its original layout.

In the past 1200 years, the sustainability of the weir depended on efficient management. Since the Song Dynasty, a unique government organization was set up to manage the weir, with an annual repair system. According to the Annals of Fuqing County, in 1098-1100, Zhuang Rouzheng, the county magistrate then, established an outdoor law court near the weir, where the losing party of a lawsuit had to repair the weir if declared guilty. As a result, the reconstruction was completed. In the Ming Dynasty, Ye Xianggao, the Chancellor then, built a stele

to memorize the rebuilding of the weir. During the past millennium, the Tianbao Weir has inspired a series of principles and water management philosophies recorded on ancient steles. The extant steles are the witnesses and relaters of the vicissitudes of the ancient weir.

Description

Short and turbulent, the Longjiang River flows directly into the sea and is subject to the influence of sea tides. The biggest challenges faced by Tianbao Weir are floods and sea tides. Located downstream of a river bend, the Tianbao Weir is in an elevated position, enjoying sufficient catchment area and water head to store fresh water and resist the intrusion of salt tides. The circulating currents formed at the river bend help separate water from sand and stones. In this way, clean water is diverted from the river for gravity irrigation.

Running from east to west, the weir is 216 m long, 3.5 m tall, 1.5 m wide on the top, and 14-24 m wide at the base. The weir body is built with stone slabs and takes the shape of a terrace. 150 m of the weir body is the original structure built in the Tang Dynasty. The water intake, located at the right bank of the river, has a flow rate of 1.5 m3/s and is connected with the 19.4 km-long main canal, which irrigates 1267 ha of farmland of 14 villages and two large farms.

The Tianbao Weir is composed of three fundamental structures—the barrage, the sluice, and the water intake of the canal. The weir body, with a trapezoidal cross-section, runs 258 m from east to west (including the sluice and the central bar). On the left side of the barrage stand the sluice and the central bar; the barrage body is 216 m long. The sluice is of three gates, and each opening has a net width of 9 m.

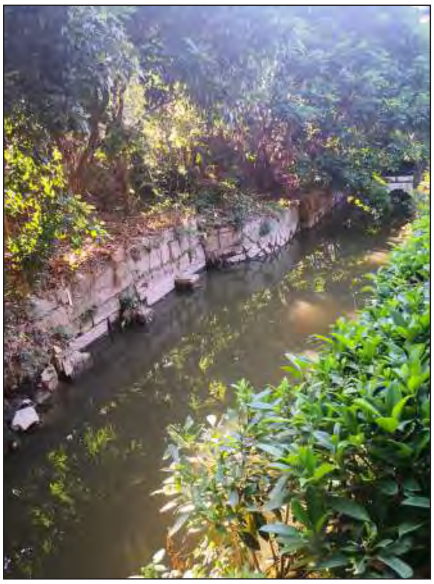
Built close to the Longjiang River, the canal of the Tianbao Weir is 19 km long. When it flows across the irrigation district, it branches to cover the inland. When it meets mountains, stone canals are opened for the water to pass. The stone canals, located at the headwork and the Haikou Township, are called Tang Canals by the locals. Stone canals are structurally stable, even though built in the Tang Dynasty when the weir was first constructed, hence their name Tang Canals.

Due to floods and limited technology initially, the Weir has gone through damages and restorations in the Song, Ming and Qing Dynasties and the Republic of China era. Currently, the well-preserved weir is still functioning.

Water Heritage

During a repair in the Song Dynasty, melted iron was used to reinforce the weir's foundation and prevent leaking in the base. This is the earliest record of such practice in China's history of irrigation project construction.

The construction of the weir, which guaranteed local crop yield despite extreme climate events, was the turning point of local agricultural development. For Fuqing County, the weir has boosted agricultural development, increased crop yield, and raised farmers' income. In the early Song Dynasty, due to the improved irrigation conditions, Champa rice was first planted in Fuqing and later extended to all over China, leading to the growth of the Chinese population.



Constructed before the Mulan Weir and the Tuoshan Weir, the Tianbao Weir is China's earliest extant water project to fend off sea tides and restore freshwater. The body of the weir, arching towards the downstream, forms a funnel with the right bank of the river, while the water intake of the main canal is located right on the mouth of the funnel. Such a structure could help adjust river flow and make water diversion easier in dry seasons. In addition, this could increase the length of the Weir, hence improving its discharge capacity during flood seasons and reducing the pressure of invading sea tides. Such a design is similar to that of long-axis weirs of modern times, such as duckbill and irregular weirs. The Tianbao Weir was first built in the Tang Dynasty. Later during its repair in the Song Dynasty, stone slabs and iron were used. It was still rare to use these materials in the building of barrages and weirs.

The Tianbao Weir is an environmentally sustainable irrigation model. Most of the building materials, such as pebbles, stone slabs, and iron, are cheap and easy to get during repairs since they are commonly seen in the region. In addition, the design of the long-axis weir raised the discharge capacity of the project, which is beneficial to the river's ecosystem.

Water management follows the ancient Chinese philosophies of the Tao to operate in line with nature. To commemorate Lang Jian, the county magistrate who presided over the weir's reconstruction in the Song Dynasty, the locals built a temple near the weir. In the Ming Dynasty, Ye Xianggao, the Chancellor, built a stele to memorize the reconstruction of the weir. Today, the memorial gate for Chancellor Ye is still standing in the old town of Fuqing.

The Fuqing County was established in the Tang Dynasty (699). After the An Lushan Rebellion (755-763), the economic centre of China gradually moved to the south. Located in a hilly area, Fuqing needed irrigation projects to boost its crop yields. With the encouragement of the government then, many irrigation and drainage projects were built, and vast wastelands and lowlands were turned into fertile farmland with high grain output. Against such background, in the Tianbao Era of the Tang Dynasty, Tianbao Weir was built. Despite considerable damages and reconstructions, the weir has stayed at its original location and maintained its original structure and form. Currently, the weir irrigates 1267 ha of farmland and supplies water to hundreds of thousands of residents.

2.24 TONGJIYAN IRRIGATION SCHEME

Name	**Tongjiyan Irrigation Scheme**
Location	**Sichuan Province, China**
Latitude	**N 29°51'~30°27'**
Longitude	**E 103°41'~103°55'**
Category of Structure	**Irrigation Scheme**
Year of commissioning	**141 BC**
River Basin	**Minjiang River Basin, a tributary of the Yangtze River**
Irrigated/Drained Area	**more than 34,600 ha**

History

Tongjiyan Weir was first built in 141 BC. Wen Weng, the then governor of Sichuan, ordered the construction of a giant weir on the Minjiang River in Wuyang County, or the east of Pengshan today. As the headwork of the Tongjiyan Irrigation Scheme, this weir featured six water gates to regulate water flow according to irrigation demand. Later, he ordered the construction of a new canal to facilitate the transport of bamboo and wood from the mountains to the west of the Weir. With these building materials, thousands of water storage facilities were built. As Li Jifu of the Tang Dynasty writes in his Yuanhe Chorography of Counties and Prefectures, Tongjiyan Weir, 12.5 km to the southwest of Pengshan County, was a giant structure on the Minjiang River with six water gates for irrigation.

In 740, Zhangchou Jianqiong, the then-governor of Sichuan, rebuilt the Tongjiyan Weir, expanding the irrigated area to more than 10,000 ha, which has laid a solid foundation for the sustainability of this water-diverting system. In 907, Zhang Lin, the mayor of Meizhou, launched another round of rehabilitation, further enlarging the irrigated area to 15,000 ha and benefiting the locals greatly; as a result, the water supply to the downstream farmland was improved, further boosting local agricultural development.

In 1145 of the Song Dynasty, Julong Tingshi, the then mayor of Meizhou, presided over the rehabilitation of the Weir, after which the Weir was 924 m long with 119 tube weirs. During the Xinglong Period (1163-1164) of the Southern Song Dynasty, Fan Chengda, the then governor of Sichuan and a water expert initiated another round of restoration. He built embankments with stones, installed 49 water gates, set up water gauges, and ensured orderly irrigation; the local people benefited greatly. The maximum irrigated area of the Tongjiyan Irrigation Scheme was 22,667 ha in the Song Dynasty (960-1279).

In 1432 of the Ming Dynasty, the Weir was again rehabilitated. Water was diverted to Pengshan through

16 canals, nourishing 1667 ha of farmland. This was the first rehabilitation in the Ming Dynasty, though the benefit it brought was much smaller than that of the Tang and Song Dynasties. In 1442, a relatively large-scale restoration was carried out; it is recorded that both civilians and soldiers were called up to work, and local officials were ordered by the Emperor to control the cost.

In 1733 during the Qing Dynasty, Huang Tinggui presided over another round of rehabilitation. Learning from the Dujiangyan Weir, he replaced giant rocks with bamboo cages filled with pebbles as building materials to reduce cost. The new materials, enjoying both flexibility and solidness, were cheaper and easier to use, more resistant to the impact of the turbulent water, and more adapted to the deformation of the weir foundation. However, they lacked durability, which means annual repairs were needed. In 1753, the local officials initiated a project of repair and expansion. By 1755, the canal system in Meishan had been restored. In addition, new embankments were built at the headwork, the old weir grew longer, and more than 40 km of old ditches were dredged. In Pengshan, 28 abandoned canals were restored, irrigating 2615 ha; in Meizhou, 14 abandoned canals were restored, watering 1952 ha, and if the irrigated area of Xinjin is included, the total irrigated area reached 4874 ha.

In 1802, the officials of Meizhou, Xinjin and Pengshan bought land from a resident called Lv Chao and opened a 500-meter-long canal upstream of the headwork of Tongjiyan Weir. The canal, called Baijihe, diverted water from the Yangmahe River to the Weir. In addition, they blocked the ditch connecting the Xihe River with the Minjiang River. In this way, the water supply was increased, and irrigation water was guaranteed.

In 1915, Xu Yuanlie, the director of the water conservancy bureau of Pengshan, reported to the provincial government and required the rehabilitation of Tongjiyan Weir. He planned to rebuild the weir body with stone slabs and cement them with tabia and only use bamboo cages filled with pebbles to block the temporary discharge gates. He also suggested using Macha, a temporary damming tool used at Dujiangyan Weir.

With agricultural and industrial development in the region, the old headwork was unable to meet the newly added water demand as a result of economic growth. Therefore, a permanent dam was built in 2005, ending the history of low-dam water diversion. The new dam is 417 m long: the overflow dam is 172 m long, and 245 m are the flood discharge gates (14) and flushing sluices (3).

The management agency of the Scheme has adopted effective protective measures to minimize the risks of encroachment and water pollution and to increase its resilience to flooding, earthquake and pressure brought by the development of tourism.

Description

Tongjiyan Weir, also known as Yuanjiyan Weir, is located on the Meizhou-Pengshan Plain in the Sichuan Basin of China. Sitting at the confluence of the Minjiang River, Nanhe River and Xihe River, it irrigates about 35,000 ha of farmland in Xinjin, Pengshan, Dongpo and Qingshen counties under Chengdu and Meishan cities.

During the period of 713-741 AD, Zhangchou Jianqiong, the then-governor of Sichuan, rebuilt the Tongjiyan Weir, expanding the irrigated area to more than 10,000 ha. In 1145 of the Song Dynasty, Julong Tingshi, the mayor of Meizhou, presided over another rehabilitation of the weir. At that time, the weir was 924 m long, a rare record for an ancient weir, and the irrigated area grew to exceed 22,000 ha.

Tongjiyan Weir was built with bamboo cages filled with stones. Different types of cages called Shunlou and Pinlou were used for the construction of levees and the weir, respectively. Pinlou has a trapezoidal cross section. Every year, before the spring irrigation, craftsmen would make cages with local bamboo, fill them with stones, and put them into the river to block the water for diversion. These building materials, enjoying both strength and flexibility, were readily available, affordable and easy to use. Lu You, a famous poet of the Song Dynasty, once wrote a poem to depict the rehabilitation of Tongjiyan Weir: “Lying on a rainbow, the barrage is three hundred meters long; …bamboos from the West Mountain are woven into ten thousand cages.” Wang Menggeng, a local magistrate in the Qing Dynasty, also recorded such a spectacular scene in his poem. Song Hao, another local magistrate in the Qing Dynasty, drafted the Statute of Tongjiyan Weir, setting out special regulations on the construction techniques and annual repair method of the headwork.

In ancient times, the dam-less water diversion technique was popular in the Sichuan basin. Tongjiyan Irrigation Scheme is one of the few projects of the Minjiang River basin which relies on barrages for water diversion. Tongjiyan Weir intersects diagonally with the Nanhe River at an angle of 137.5°. As the largest and longest-standing movable weir in Chinese history, Tongjiyan Weir represents major progress made in the field of hydraulic engineering. The bamboo cages filled with stones are easy to make and use locally available materials. A weir built with such materials could both withstand flooding and meet the irrigation demand downstream. As a result, the bamboo cages and pebbles had not been replaced by a concrete dam with sluices until recently.

Tongjiyan Irrigation Scheme has three main canals, 65 branch canals, and thousands of lateral canals and field ditches. The rivers to the west of the Minjiang River, including the Maohe River and Liquanhe River, intersect with the canals of the irrigation scheme. Meanwhile, different levels of canals are distributed in a braided pattern. The main stream of the Minjiang River is replenished with melted snow, and the seasonal changes in its runoff correspond to the shifts between the rainy and dry seasons. The impact of rainstorms covering large areas could spread through flood peaks. The braided distribution of the canal system, combined with its flood discharge gates, could widen the river bed when flood peaks arrive and help discharge flood at different sections to quickly reduce the water level.

The distribution of the irrigation canals displays a complex and interlocking nature. Despite being man-made, the canals share similar characteristics with natural watercourses.

Tongjiyan Irrigation Scheme has played an irreplaceable role in flood control and water ecosystem improvement in the small basins on the west bank of the Minjiang River, fundamentally bettering the urban and rural ecosystems of the region.

Water Heritage

The water intake of Tongjiyan Weir is located at the confluence of the Minjiang River, Xihe River and Nanhe River, which has guaranteed its water supply. On its right bank stands the Xiujue Mountain which is hard enough to resist the scour, solving the problem of convex bank erosion. By adapting to and even utilizing the natural conditions, the Weir, with its smart siting, has successfully transformed water from a damaging force into a source of prosperity for the Chengdu plain.

Sichuan used to be a major source of tax income in ancient China (the Tang and Song Dynasties), and the region surrounding Dujiangyan Weir and Tongjiyan Weir was the main contributor to Sichuan. In the Song Dynasty (960-1279), the irrigated area of Tongjiyan Weir exceeded 22,000 ha. Located 250 m upstream of the confluence of the Minjiang River and the Nanhe River, the Weir enjoys sufficient area for rainwater collection and thus abundant water for irrigation at its downstream. Standing at the starting point of the Meizhou-Pengshan alluvial plain, the Weir covers vast farmland, increases grain yield and bolsters regional agricultural development and rural prosperity.

Tongjiyan Weir was built with bamboo cages filled with stones. Different types of cages called Shunlou and Pinlou were used for the construction of levees and the weir, respectively. Pinlou has a trapezoidal cross section. In this way, the water resource could be fully tapped, and the impact on the natural watercourse minimized. By utilizing the local terrain and how the Minjiang River flows around the curve, Tongjiyan Weir could perfectly meet the demand for water diversion, flood discharge, and sediment flushing and serve the local people without causing damage to the natural resources.

Its headwork and different levels of canals, with the functions of irrigation, flood control, water transport, and urban water supply, has formed a canal network similar to that of natural watercourses. Its building materials such as stones, timbers and bamboo are locally available. Tailored to the local terrain and resource conditions, the Scheme fits well into the water ecosystem and is an embodiment of ancient people's perception of nature and the philosophy of man learning from and being an integral part of nature.

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The history of the Tongjiyan Irrigation Scheme exceeds 100 years (dating back to 141 BC). The Scheme is composed of water diversion structures such as weirs and barrages and canal systems. Its engineering form remains unchanged today. As the theme of a large number of ancient poems and essays, the Scheme is deeply rooted in Chinese history and culture and has itself cradled multiple local sub-cultures of poetry, longevity, bamboo, loyalty and piety.

Many unique water measuring facilities and standards have been introduced. To monitor and regulate the water level, stones with six grooves were used as water gauges, and the standards of water level regulation set by Zhangqiu Jianqiong remained in use till the Qing Dynasty; iron walls with embedded tubes, invented by the locals in practices are tools of water measurement and allocation rarely seen in China. At the water intakes of the branch canals of the Tongjiyan Irrigation Scheme, water was diverted by weirs or the above-mentioned tubes, the size of which is proportional to the size of the irrigated farmland. Made of stone or iron, these tubes are very durable. In 1764, one local official set up steles in the Erwang Temple of Xinjin with inscriptions of the standards and specifications of the tubes and the bans on changes without permission. From the water governance practice over the past 2000 years, the managers of Tongjiyan Irrigation Scheme have summed up the principles of weir operation, formulated annual repair guidelines, mastered the technique of draining out excess water and sediment at proper sites, and set up a management system tailored to the Scheme by establishing a professional management agency and the weir chief system.

2.25 TONGJIYAN IRRIGATION STRUCTURE

Name	**Tongjiyan Irrigation Structure**
Location	**Zhejiang, China**
Latitude	**28.316**
Longitude	**119.750**
Category of Structure	**Arch Dam Irrigation Structure**
Year of commissioning	**505 AD**
River Basin	**Songyinxi River, a tributary of the Oujiang River**
Irrigated/Drained Area	**2000 ha**

History

Tongjiyan irrigation structure, constructed in 505 AD, consists of a dam, canal systems, water gates, aqueducts, and ponds. It is located in Bihu Plain in the southwest of Zhejiang Province. It was dammed up Songyinxi River 1.2 km upstream from the confluence of the Songyinxi River into Oujiang River and allocated water by gates into the canal systems and fields in the Bihu plain. The Songyinxi River is a tributary of the Oujiang River. Its annual runoff is around 1.9 MCM. According to historical records, the irrigation area of the Tongjiyan irrigation structure reached 2,000 ha by the 13th century. It accounts for one-third of the Bihu Plain. The scope of irrigation has not changed much since then.

The earliest Tongjiyan dam was a weir built with a rock-filled timber crib. It was destroyed during floods and was rebuilt in the following winter and spring seasons. After 700 years, the weir was substituted by a stone dam in 1205. A sand-flushing sluice and a ship lock were built subsequently on the dam. Since then, the Tongjiyan dam has become a multi-functional project for water storage, water diversion, overflowing, sand flushing, shipping, etc. Although it was repaired over the years, the dam's location, structure, and construction materials have remained unchanged to this day.

Description

The Tongjiyan dam forms a low arch upstream of 120 degrees. The length of the dam is 275 m. Its crest width and base widths are 2,5m and 25m, respectively. According to historical records, the Tongjiyan irrigation structure systems had been preliminarily formed before the Tang Dynasty (618-907) and then improved gradually and become a bamboo-irrigation system with gates, main canal, branch canals, sublateral canals, and ponds in the Song Dynasties (960-1279)

The gate regulating the water of the Songyinxi River into the canal systems is called Tongji Gate. It was first located at the main canal 15 m downstream from the Tongjiyan dam and moved to the dam during repairs in 1954. Three gates with the same names as the Kaituogai gate are located 6.14 km downstream from the Tongji gate. The main canal is between the Tongji gate and the Kaituogai gate; divided into three parts of east, west, and middle by the Kaituogai gates. The middle canal also called the secondary main canal, is the longest (18.12 km) and irrigates more fields than those the two others. It runs through the irrigation area of Tongjiyan and finally flows into the Oujiang River. The water in the secondary main canal is divided by different gates into the branch canals, then into the sublateral canals, and finally into the fields. There are hundreds of branch canals and sublateral canals altogether, including the south and north branch canals, and more than 70 gates. There are lots of ponds in the Tongjiyan irrigation system. Some of them were low-lying areas, and others were dug manually. These ponds connect with the end of branch canals and sub-lateral canals and store the extra water for drought seasons.

Yexue Gate and Aqueduct: The Songyinxi River is a sand-carrying river carried into the canal systems in the flood seasons. To discharge flood and reduce canal sedimentation, a scouring sluice was built in the main canal about one km downstream from the Tongjiyan dam in 1092. It is called Yexue Gate because of located in Yecun village. The Yexue gate drained flood and sediment directly into the Oujiang River. It had been working for more than 800 years until the 20th century. Xiekengshui River, a tributary of the Songyinxi River, flows across the main canal 300 m downstream from the Tongjiyan dam. The main canal of the Tongjiyan irrigation system is often destroyed and silted by flood and sediment of the Xiekengshui River. A canal aqueduct was constructed in 1111. It conveys water from the Xiekengshui River over the main canal into the Songyinxi River. Thus, it protects the main canal from the Xiekengshui River.

Water Heritage

Bihu Plain is the chief agricultural area in the southwest of Zhejiang province. The Tongjiyan Irrigation Structure built in the early 6th century supplies irrigation water for 2,000 ha fields, accounting for one-third of the Bihu plain. The Bihu Plain has become a crucial granary in the south of Zhejiang province since the 13th century. Nowadays, cash crops, such as vegetables, are planted in the Bihu plain. Agriculture is still a critical part of economic development, and the structure plays an essential role in economic and social development.

The Tongjiyan Dam is the earliest arch dam in the world. The dam when built first in 505. It dammed up the Songyinxi River with peak discharges of 5400 m3/s by a rock-filled timber crib 270 m long. The dam construction technology was the most advanced in the world in the early 6th century. The design and construction technology of the Tongjiyan dam and the canal aqueduct was unique and exemplary, and innovative in their times. Tongjiyan dam and canal system made significant contributions to the theories and practices of hydraulic engineering. After sand-flushing sluice and ship lock were built on the Tongjiyan dam, the dam became a multi-functional project for water storage, water diversion, overflowing, sand flushing, and shipping even in the 13th century. The planning and designing of the above projects are scientific, even by modern standards. They have made historical contributions to the development of irrigation engineering.

The management of the Tongjiyan Irrigation Structure is stamped with the brand of China's traditional culture, and it is an excellent example of sustainable operation and management. The joint management by the authorities and the people represented Chinese traditional social structure and cultural background. Moreover, the water conservancy projects prompted local people to form a social community to manage the water conservancy projects regularly. The provincial government was responsible for the maintenance and repair of the irrigation structure. The non-government organization was responsible for water allocation for water users. These were recorded in the management regulation of the Tongjiyan irrigation structure and chiselled an inscription on a stone. Historical records convey that the earliest Tongjiyan management regulation was made in 1092.

With the development of society and irrigation technology, some new pieces have been added to the management regulation. However, the joint management forms by officials and people have lasted in the Tongjiyan irrigation area to this day.

2.26 TUOSHAN WEIR

Name	**Toushan Weir**
Location	**China**
Latitude	**29.933**
Longitude	**121.316**
Category of Structure	**Weir**
Year of commissioning	**833 A.D.**
River Basin	**Yin River (Sub Basin: Fenghua River basin)**
Irrigated/Drained Area	**13829 ha**

History

As a dam-based water-guiding and irrigation project with over 1180 years, Tuoshan Weir is located in Yinzhou District, Zhejiang Province and on the Yin River, a tributary of Fenghua River. Its construction turned the Yinxi Plain into a strong base of grain production in East Zhejiang Province and fuelled the development of Ningbo City. The headwork of its canal is located between Shamao Mountain and Tuoshan Mountain, guiding water to maximize the scope of irrigation. Tuoshan Weir irrigated several thousand ha of land upon initial construction and currently has an irrigation area of about 13,829 ha.

Tuoshan Weir was initially constructed as a river dam of brick and stone structure in 833AD. There were Wujin, Jidu and Xingchun flood sluices at the trunk canal, and it became an irrigation hub capable of water guiding, storage, and water regulation. Thereafter, the canal system kept improving, and the project became vital irrigation infrastructure in the region and a source of water supply for Ningbo City.

In the 13th century, the Water Level Gauge stele was erected at the headwork of the canal, and the end of the trunk canal and the flood sluice operations were controlled via the water level. In the 16th century, The Official Pond

(Guantang in Chinese) was constructed at the inlet of the trunk canal to increase water storage and improve the regulation of the irrigation zone. After the 1980s, the flood sluice and regulatory sluice constructions were renovated, and an opening/closing gear was added to the irrigation zone.

Description

Tuoshan Weir was located at the outlet of the Yin River, which flows off the mountain. Blocking the upflow of the salty tides from the lower reaches, the weir is a typical project of water desalination on the southeastern coast of China. Since its completion in the Tang Dynasty (833 AD), it has gradually developed and formed an irrigation system comprising well-established trunk and branch canals. It still works effectively today.

The river dam is also called Tuoshan Weir, a dry-laid masonry dam with slat energy dissipation underneath. It is 113.6 m long, including the 107 m-long overflow section, forming a 6-degree arch towards the upstream. Tuoshan Weir's irrigation system comprises the canal headwork, the canal system, the irrigation regulation work, and the water storage project. The headwork comprises the river dam, the Huisha Sluice, the Official Pond, and the Flood Pond. The dam base comprises wooden piles and jackstones. The canal system of Tuoshan Weir includes the trunk canals, the branch canals and the lateral canals. Nantang River, the trunk canal, flows through downtown Ningbo and its tailwater is discharged into the moat of Ningbo. The trunk canal is 24.5 km long, and there are also two sub-trunk canals, 19 branch canals and more than 100 lateral canals with a total length of 673.23 km.

Tuoshan Weir has well-established accessory works. According to 19th-century literature, the accessory works included nine flood sluices, five overflow weirs and 13 water ponds. After 1970, some regulation sluices, water diversion weirs, water return weirs and overflow weirs were converted into modern engineering facilities and became better regulated.

As a medium-sized irrigation project, Tuoshan Weir blocked salty tide upflow, diverted water and created freshwater storage, flood alleviation, urban water supply and environmental water supply in Yinzhou District of Ningbo. Ever since its completion, Tuoshan Weir has played an essential role in agricultural irrigation. Currently, it has an irrigated area of 13829 ha and covers a population of 280,000 in the irrigation zone. Other than agricultural benefits, it also promoted urban and rural production, shipping, ecology and landscaping. Yinjiang Town, located at the head of the canal and with scenic views and the ancient Tuoshan Weir, has developed into a vacation resort.

Tuoshan Weir is a key cultural relic site under the protection of the Chinese government. It is protected under the Law of the People's Republic of China on the Protection of Cultural Relics. The Master Plan for the Protection of Tuoshan Weir specifies the scope and requirements of protection. Accessory works are also planned, developed and constructed for the effective protection of the heritage.

As the administrator of Tuoshan Weir, the local authority of water resources manages the irrigation system, the water resources and the water environment of Tuoshan Weir systematically. It has formulated a series of local regulations and measures to ensure the project's safety and irrigational benefits. Meanwhile, the authority retains the weir's historic messages during project repairs and renovations.

Water Heritage

With a history as long as 1180 years, Tuoshan Weir was initially constructed in 833 A.D. Its irrigation system comprises the canal-head project, the canal system, and the regulation work. It is a milestone that has witnessed the rise of Ningbo City. It blocked the flow of salty water from the sea and guided water. It addressed the water salinization issue and guaranteed a sufficient water supply for agricultural production. It turned the local area into a main agricultural production base in East Zhejiang and promoted regional social and ecological development. In the Tang Dynasty, Mingzhou City (Ningbo today) was relocated from Yinjiang to Sanjiangkou. The irrigation and water-guiding canal of Tuoshan Weir laid the foundation for the development of Ningbo today.

The river dam project was an innovative design at the time of its construction. Tuoshan Weir is the most time-honoured masonry gravity dam in China. The bottom of the weir is tilted towards the upper reaches at an angle of 5 degrees. Proposed more than 1000 years earlier than the contemporary dam base theory, such a slanting bottom reinforces the anti-slipping stability of the dam body by 100%. The dam body takes an oval shape; the riverbed is about 5m thick at the maximum in the middle while the thickness gradually decreases to 2m on both wings, which reinforces the rigidity of the dam by seven-folds. The cambered profile of the dam body works as an arched dam. It reduces the erosions of floods on both banks to extensively in the same principles as the energy dissipation mechanism of contemporary mechanics.

The administration by both official and civilian organizations ensures the continuous operation of the project. Such an administrative mechanism represents China's traditional social structure and culture. The irrigation project turned the irrigation zone into a community, and the rural esquire class organizes annual repairs and performs other common obligations to ensure equitable water distribution. With the vicissitude of time, this administration mode remained effective. With a history of 1100 years of continuous operation, Tuoshan Weir has become a typical representative of China's traditional irrigation project and a paradigm of the sustainable development of an irrigation project.

Tuoshan Weir has unique cultural values. In memory of Wang Yuanwei, the founder of Tuoshan Weir, the villagers constructed Tuoshan Temple on Tuoshan Mountain. Meanwhile, large-scale temple fairs are also held at Tuoshan Temple annually to commemorate Wang Yuanwei and the construction of Tuoshan Weir. These activities have become important local cultural symbols. The Tuoshan Weir irrigation project has created the regional river and lake system and led to harmony between human beings and nature. The Moon Lake is an important water storage project of the irrigation zone that improves the natural environment of Ningbo and provides a beautiful place for Ningbo citizens to enjoy their leisure hours amidst garden views.

2.27 XINGHUA DUOTIAN IRRIGATION AND DRAINAGE SYSTEM

Name	**Xinghua Duotian Irrigation and Drainage System**
Location	**Jiangsu Province, China**
Latitude	**N 32°85'~33°17'**
Longitude	**E 119°70'~119°96'**
Category of Structure	**Irrigation and Drainage System**
Year of commissioning	**15th Century AD**
River Basin	**Huaihe River Basin**
Irrigated/Drained Area	**52.88 km^2**

History

More than 7000 years ago, during the Neolithic period, the Lixiahe plain was a gulf between the Yangtze River and the Huaihe River. As the coastline moved eastward, this area formed into an enclosed lagoon and then gradually into a plain. To prevent seawater intrusion, Changfeng Weir and Fangong Dike were built during the Tang and Song Dynasties between the 8th and 11th centuries AD. This created a coastal barrier of about 300 km in length, laying the spatial foundation for future agricultural development within the plain.

From 1194 to 1855, the Yellow River encroached on the lower reaches of the Huaihe River to enter the sea, bringing frequent flooding and large amounts of sediment to the Lixiahe area and silting up the local lakes and swamps. During this period, in response to the frequent flooding, local people dug canals in shallow water and mounded the earth into elevated platforms, or Duotian as called by the locals. After years of hard work, these raised fields were gradually transformed into arable land. These elevated platforms are often built in strips to facilitate construction and later cultivation using a boat and to ensure smooth water flow.

Description

Xinghua Duotian Irrigation and Drainage System is located in the hinterland of the Lixiahe Plain on the eastern coast of Jiangsu Province, China, a region with a dense network of rivers and abundant water resources. In its early days, Duotian was formed to withstand flooding by height. Traditionally, Duotian could generally reach a height of around 5 m, and even the low ones could be 2 to 3 m high. To further protect the raised fields from floods, small dikes were built around them from the 18th century onwards. Gradually, they linked together to form larger dikes.

After 1949, the government began to build even larger dikes with gates and pumping stations for drainage and flood discharge, which greatly enhanced Duotian's flood control capacity and stabilized its water level. Since the raised fields no longer need to rely on their height for flood control, their height is reduced to 1 m to expand arable land and for ease of cultivation.

Duotian is irrigated using bailing buckets. When the water level is high, people stand on boats and irrigate the fields with water directly bailed from the canals. When the water level is low, people water the fields by forming a water-bailing cascade. For the highest field, the cascade would have 4 to 5 stages.

Due to its geographic uniqueness, Duotian is not suitable for modernized farming tools and thus largely maintains the traditional way of farming, such as bailing water for irrigation and using silt as fertilizer. Only a small part of the fields are irrigated using motor pumps installed on boats. Surrounded by water on all sides and with steep slopes, the raised fields are subject to erosion by both rain and river water, but local farmers have drawn a collection of soil and water conservation measures from centuries of hard work.

Duotian's water level is high in summer and autumn and low in winter and spring. When the water level is low, people raise the height of the fields with the silt scooped out from the canals to prepare for possible flooding.

After the harvests in summer and autumn, people throw the rest of the crops into the canal to produce wet compost. In winter and spring, this natural and organic fertilizer is applied to crops.

The abundance of water combined with the high fertility of the soil has enabled the raised fields to produce high-quality fruits and vegetables since ancient times. Vegetable production has become one of the main sources of income for local farmers. The unique water landscape, sound ecological environment and varied folk customs and culture are all valuable resources for the local tourist industry. Famous scenic spots such as the rapeseed Duotian, the forest on water, the wetland park and the fishing eco-park serve as key drivers for the local economy.

Duotian is a unique creation in the Lixiahe area. Adapting to and transforming nature at the same time serves as the basis for the local development of agricultural irrigation and water transport and as the source of rich culture. Today, it continues to provide fundamental support to local social and economic development and ecological security. As the cultural heritage of this agrosystem, the Duotian temple fairs, the stilted dragon dance of Gaojiadang, the Duotian singing festivals, farmer painting, and Shipohua painting all enjoy great vitality and local characteristics.

Water Heritage

The establishment of the Duotian Irrigation and Drainage System has improved the regional natural environment and conditions of social and economic development, promoted the development of agriculture in the whole Xinghua region, and increased the grain output and population carrying capacity. According to the records of the Revised Xinghua County Annals, at the beginning of the Qing Dynasty, there were only more than thirty thousand residents, and the number increased ten times in two hundred years.

The Duotian system also has ecological functions, and the most prominent is the flexible allocation of water resources. The ditches and the inner rivers, as well as the surrounding lakes and rivers, constitute a perfect drainage network with a strong function of flood detention, drainage and irrigation. Secondly, Duotian, as a secondary wetland, has an obvious land-water edge effect and rich biodiversity. With agriculture, forestry and fishery as the central link, it builds a biological chain with very close internal connection and forms a complex and diverse ecosystem with land-water interaction.

The farmers in Xinghua Duotian have accumulated rich experiences in the development of shoal land and adopted the multi-level spatial and multi-sequence temporal structure in the utilization of the natural resources of shoal land. The multi-level spatial structure refers to the organic combination of forest, grain and fish so that the space above ground and underground can be fully utilized. The multi-sequence in time refers to the reasonable arrangement of planting crops in different seasons, which can help obtain relatively high economic returns on inter-crop under the premise of guaranteeing the good growth of trees. To make full use of the space resources, the farmers not only plant vegetables in a large area on the Duotian but also afforest some of the Duotian. In the area of Duotian forests, the radiation is generally 45%-52% lower than that on the farmland, the temperature is 0.8-1 lower than that outside the forest, and the humidity is 3%-5% higher than that of the farmland.

2.28 ZHENGGUO CANAL IRRIGATION SYSTEM

Name	**Zhengguo Canal Irrigation System**
Location	**Shaanxi Province (Sanyuan County), China**
Latitude	**32.533**
Longitude	**116.102**
Category of Structure	**Canal Irrigation System**
Year of commissioning	**246 BC**
River Basin	**Jing River, the secondary tributary of the Yellow River**
Irrigated/Drained Area	**97000 ha**

History

Zhengguo Canal is located in the middle of Central Shaanxi Plain, and it is one of the earliest large-scale dam-less water diversion and irrigation systems in China. Zhengguo Canal was first constructed in 246 BC, and its construction laid the economic foundation for the rise of the Qin Kingdom and the unification of ancient China with an irrigation area of about 186667 ha and a grain output of 1875 kg/ha. The Canal has worked effectively as an irrigation infrastructure for more than 2000 years.

During the rehabilitation of the Han Dynasty, measures were taken to integrate and improve the canal systematically. The conventional irrigation method of treating saline-alkali land with sandy water was preserved, and the irrigation area amounted to 21000 ha, which was substantially smaller than the original irrigation area. In the Western Han Dynasty, farming tools were improved, a zoned farming system was adopted, and winter wheat was introduced into Central Shaanxi. Meanwhile, the adoption of a series of policies, including tax reduction, helped to promote the development of agriculture. Although the irrigation area shrank, branch canals were built to guarantee the availability of irrigation water; therefore, the irrigation area became even richer.

In Tang Dynasty, through large-scale renovation and improvement of the canal system, the canal head was converted into a system of low-dam water diversion projects equipped with the main, branch, and sub-lateral canals and three sluice gates. The head of the Canal was located about 1 km northwest of Wangqiao Town, Jingyang County and the Canal bottom is about 15 m above the bed of the Jing River today. In 1074 in the Song dynasty, the intake of the Canal was relocated upstream, and a stone canal and an earthen canal with a total length of over 2 km were newly constructed. It took 36 years to complete the renovation, and the irrigation area reached 100,000 ha.

In the 11th century, the Canal was renovated again, and the bedrock was dug to widen the mouth and the course of the canal. In the 14th century, the intake was moved upstream again. In the 15th century, the canal head was further relocated upstream by 990 m, excavating a tunnel for water diversion. This renovation took 18 years to complete. In 1517 and 1822, another two water diversion tunnels were excavated to shorten the distance the water flows by making it run straight. After renovation, its irrigation area was recovered to 40,000 ha. In Qing Dynasty, the Canal began to use both Jing River water and spring water as water sources. Despite lower discharge and a smaller irrigation area of only 4700 ha, the water supply was stable and thus no longer required frequent dredging work at the headwork.

In 1932, the Canal was rehabilitated again. A water diversion hub with a dam was built upstream of the original canal intake. And the Canal was renamed Jinghui (the benefits of Jing River). In 1966, the dam was destroyed by floods, and thus a concrete overflow dam was reconstructed 16 m downstream. Other than water diversion and irrigation, this canal also generated power.

Zhengguo Canal diverted water from the Jing River to the east. The canal was 125 km long and irrigated a farmland area of 1,86,667 ha. In the dynasties that followed, the Canal and its irrigation system were adjusted a few times, and the irrigation area dwindled. Today, its irrigation area covers the eastern parts of the Jing River and the western parts of the Shichuan River, including 48 townships of six districts and counties in a total area of 1,180 km2 and an irrigation area of 97,000 ha. The project changed the local production conditions, resisted natural disasters, promoted agricultural production, increased grain outputs, and facilitated history development.

Description

Zhengguo Canal Irrigation System comprises the canal head, irrigation canal system, and auxiliary infrastructures. Currently, the Canal has a designed water diversion discharge of 50 m3/s. The irrigation and drainage canal system comprise one general main canal and five main canals with a total length of 92.324 km; 25 branch canals with a total length of 336.21 km; 593 sub-lateral canals with a total length of 1,477.5 km. There are 1,984 control works on the main and branch canals. These project infrastructures constitute integral work to ensure the safety of the irrigation area during drought and floods. Today, 14 steles are preserved as a record of the canal's historical events and irrigation regulations in all the dynasties, and a multitude of historical literature is also available. These written records are all important constituents of the heritage of the Zhengguo Canal Irrigation System.

Zhengguo Canal has a history of over 2,000 years since its initial construction. It turned the dried and arid land of Central Shaanxi Plain into fertile soil, contributing to the Qin Dynasty's founding, the first centralized government of Ancient China. Thus, it generated significant and far-reaching impacts on China's political, economic, social, and cultural sectors. Having undergone multiple rehabilitations, it has successfully guaranteed sufficient grain outputs in the Central Shaanxi Plain despite droughts and floods and thus made significant contributions to the social development of China.

Zhengguo Canal is a living cultural relic under the protection of China's State Council. Protection plans are in place, and the system has been well-preserved. The historic layout of the canal system within the irrigation area has been preserved. The irrigation management system featuring joint government and private management is also preserved. Today, Zhengguo Canal has an irrigation area of 97,000 ha and plays an important role in irrigation. Jinghui Canal Administration of Shaanxi Province is in charge of the irrigation area, and well-established systems for the irrigation system's protection, operation, and maintenance are in place today. The government allocates a special budget for the operation and protection of the canal, hence ensuring the sustainability of Zhengguo Canal's irrigation benefits.

Water Heritage

Zhengguo Canal was constructed in 246 B.C. and had a history of 2,200+ years. It represented a historic milestone that led to the unification of ancient China and the rise of the Qin Kingdom. The Zhengguo Canal diverts the water of high sediment concentration from the Jing River to irrigate the Central Shaanxi Plain and has turned it from a barren place into a fertile piece of land. As a result, the Qin Kingdom became more powerful and acquired the base for its unification of ancient China later (221 BC). Zhengguo Canal played a significant role in the history of China's agricultural development and even Chinese history. Even today, it covers only 2.4% of the farmlands of Shaanxi Province but accounts for 5.8% of the total grain output of the province, offering 190 million kg of commodity grains each year. The irrigation area has become an important grain, fruit and vegetable growing base of Shaanxi Province. It plays an increasingly important role in guaranteeing food security, developing modern agriculture, constructing new countryside and increasing farmers' income.

Zhengguo Canal adopted dam-less water diversion when it was first built. Its general main canal was built along the contour line and had a length of 150+ km. The main canals, branch canals, and sub-lateral canals were designed reasonably with a gravity irrigation area. The irrigation system led its peers in design, scale, irrigation area and agricultural performance in that era.

The technologies adopted for the construction of Zhengguo Canal innovatively addressed multiple technical problems at that time (the 3rd century BC), e.g. canal line planning and arrangement based on extensive topographical surveying, the layout of canal head, expansion of irrigation water sources via crossing where the trunk canal meet natural rivers and treating saline-alkali soils with water of high sediment concentration. These technologies were major innovations considering the low technical level at that time. Meanwhile, the dam-less water diversion minimized the adverse impacts on the natural environment and generated sound ecological effects.

The Canal's utilization of rivers with a high sediment concentration provides good historical references to the contemporary harnessing of rivers with similar conditions. Yao Hanyuan and other scholars once researched its historical experiences and proposed the comprehensive treatment of the Yellow River and other highly sandy rivers.

The engineering concepts of the Zhengguo Canal reflect the philosophies of ancient China. The shifts of the irrigation system and its administrative system witnessed the changes due to natural and geographic environments in the Jing River basin at different historical periods and the various political, economic and cultural features of diverse dynasties. Therefore, it is precious historically and culturally.

The administrative system of irrigation has been a joint function of the government and private resources, and different administrative regulations was introduced to address different problems in different historical periods, hence guaranteeing the continuation of the irrigation project. In 1934, Shaanxi Water Resources Bureau set up the Jinghui Canal Administration, preserved until today. In 1951, the Irrigation Committee of Jinghui Canal Irrigation Area was established. Today, section chiefs are selected from farmers and designated by the Administration to overview the patrol, maintenance, and water distribution of a specific system area. Such a constantly updated administration system has guaranteed the irrigation performance of the System.

When it was first built, Zhengguo Canal had an irrigation area of 1,86,667 ha. It turned the barren saline and alkaline lands into fertile farmlands with a yield of 1875 kg/ha, laying the economic foundation for the Qin Kingdom's unification of ancient China. Today, the irrigation area covers 48 townships of six districts and counties in a total area of 1,180 km2 and an irrigation area of 97,000 ha.

2.29 ZHUJI SHADOOF

Name	**Zhuji Shadoof**
Location	**Zhejiang (Zhaojia City), China**
Latitude	**29.733**
Longitude	**120.450**
Category of Structure	**Shadoof**
Year of commissioning	**Earlier than the 17th century AD**
River Basin	**Huangtan Brook (Sub Basin: Puyang)**
Irrigated/Drained Area	**27 ha**

History

The Zhuji Shadoof Irrigation System is located at Quanfan and Zhejiang Province on the alluvial Huangtan Brook basin at the foot of the prominent peak of Zhoumagang of Kuaiji Mountain with an average annual rainfall of 1462 mm. The soils are primarily sandy soil rich in groundwater resources at a depth of only 1-3 m in the drought period and within 1m in the rainy season. In the last hundred years, digging and carrying water with Jiegao, or shadoof, has become a primary irrigation mode for the people. The Irrigation System of Zhuji is a living fossil of the ancient water-carrying device of the shadoof.

Jiegao or shadoof is a historical water-carrying device extensively applied in ancient Babylon and Egypt before the 15th B.C. The inhabitants at Zhaojia Town of Zhuji are descendants of migrants from Central China in the 12th century, and they primarily belong to two families—the He's and the Zhao's. Their ancestors dug well and carried water for irrigation and agricultural development, hence the origin of Quanfan and Zhaojia villages. In the 16th century, predominantly shadoof was used for irrigation in these villages. In the 17th century (1662-1722), Yongkang Weir was constructed on Huangtan Brook to store water and increase groundwater supply via infiltration. Yongkang Weir has flushed away in the middle of the 20th century, and thereafter, a new river dam was constructed on the upper reaches to restore the historical functions of the project.

There were many shadoofs and wells in Zhuji historically, and their combinations were called Ao Well. There used to be more than 8,000 wells in this basin before the 1930s and 3,633 wells in 1985 with an irrigating area of 440 ha. However, many wells have been buried in the urbanization process in the past 30 years. Today, the number of Ao Wells in Quanfan Village is the largest. There are still 118 ancient wells that irrigate about 27 ha of farmland. The traditional Ao Well irrigation mode is well preserved today.

Description

Zhuji Shadoof Irrigation System comprises a river weir, ancient wells, shadoofs and field canals. The weir, located on Huantan Brook, increases the infiltration of surface water and the water-carrying capacity for irrigation. One well, one shadoof, one piece of farmland and field canals constitute an independent and well-established well irrigation unit. Such a field is called Jishui Field, with Jishui meaning water-lifting. The core zone of the system comprises 118 ancient wells and an irrigation area of 27 ha. A well is normally 2-5 m deep and takes the shape of an inverted bell. The well mouth and bottom diameters are usually 1-2 m and 1.5 m - 2.5 m, respectively. The well walls are dry-laid with pebble stones, and some of the wells in the silt field have pinewood supports at the bottom. The exterior circumference of the well walls has broken stones and sand as the reverse filter. A Jiegao, or shadoof, comprises a pile, a lever, a rod, and counterweight stones. The tailor-made water-carrying barrel comprises a wooden axle that is connected to the lower end of the pile. People call this combination of a well and a shadoof Ao Well. Ao Well also refers to the process of well irrigation and water carriage. To lift water, the operator stands on two bamboo beams or a wooden plate set up at the well opening and pushes the rod so that the barrel sinks into well water. The use of the lever reduces the effort needed to lift a barrel of water. A straw braid is located where the water flows out from the well to protect the barrel from damage. A simple hut is created among several wells for shelter from the rain and as a farming tool storage.

Zhuji well irrigation project still plays a vital role in irrigation and water supply. Quanfan Village, as the core area of the well irrigation project, has 118 ancient wells with an irrigated area of more than 26 ha. Quanfan, Zhaojia and Huamingquan Villages still primarily rely on groundwater as the main water supply source. The project benefits a total population of about 10,000 today.

The main challenges facing the protection and continuation of the Zhuji Shadoof Irrigation System today include rapid urbanization, which has led to shrinking farmlands, the burial of ancient wells, and the promotion of water pumps and other modern water-carrying devices. Many farmers have abandoned Jiegao (shadoof) in favour of the more efficient electric water pump. Nevertheless, with the joint effort of government, society and the farmer community, the Shadoof Irrigation System, with its rich history in Zhuji, will achieve sustainability.

Zhuji Shadoof Irrigation System is convenient and cheap, with no electricity requirement, and is enough to meet the demand for irrigation. Secondly, an independent irrigation unit, with its land, well, and shadoof, belongs to and is managed by one family, which means the ownership and right of use are specified with reduced exploitation of groundwater. Such regulations avoid conflict over water use at the lowest management cost and thus make the irrigation mode simple yet sustainable.

Last but not least, the local government has attached great importance to protecting the shadoof irrigation system. They took comprehensive measures, including developing ecological and leisure agriculture and cultural tourism industry to increase farmers' income and motivation for shadoof protection, setting up the water level and water quality monitor stations, protecting water quality and farmland ecology by reducing the use of pesticides and chemical fertilizers, and restricting the use of motor-pumped wells.

Water Heritage

Zhuji Shadoof Irrigation System has made significant contributions to the agricultural development of Zhaojia and Quanfan Villages for hundreds of years and the peace and prosperity of the He's and the Zhao's families, which migrated from Central China. According to the epitaph of an ancestor, any family owning "more than 0.66 ha of Jishui Field" can achieve self-sufficiency. It shows the difference the well irrigation made in the farmers' lives. Today, there are still 118 ancient wells that irrigate about 27 ha of farmland.

As the most time-honoured water-carrying device, Jiegao has a particular position in the history of irrigation civilization. It has been well preserved till today. It is a living fossil that provides irrigation benefits and witnesses with the ancient irrigation civilization and culture. The shadoof irrigation system in the past hundreds of years has made a cultural impact on local people's lives, which is reflected in local ballads and operas. And the villagers are aware of the inherited legacy. There is a Lantaigushe Stele engraved in 1809 inside the ancestral temple of Zhao's family. The stele states that the Zhaojia Village prospered with well-ploughed farmlands which had great harvests even in years of drought.

Zhuji Shadoof Irrigation System plays a vital role in irrigation and living water supply. Quanfan, Zhaojia and Huamingquan Villages still primarily rely on groundwater as the living water supply. The project benefits a total population of about 10,000 today.

2.30 ZIQUEJIE TERRACES

Name	Ziquejie Terrace
Location	Hunan, China
Latitude	27.667
Longitude	110.0167
Category of Structure	Irrigation system
Year of commissioning	900 AD
River Basin	Zijiang River
Irrigated/Drained Area	6416 ha

History

Located in Hunan Province of South-Central China, Ziquejie Terraces are built on hills with altitudes ranging from 460 m – 1540 m and surface slopes varying between 25o - 40o. The area is rich in water resources enjoying average annual precipitation of 1700 mm. The lack of plains at Ziquejie has forced the ancient people to reclaim terraces chiselled into shape by the 10th century AD.

Covering a total area of 6416 ha, Ziquejie Terraces are the product of local people's wisdom and hard work and are an excellent example of planning and sustainable utilization of water and land resources. As a full-fledged gravity irrigation project built with simple technology and natural materials, Ziquejie Terraces are perfectly adapted to local conditions and have provided the local farming system with adequate water for more than 1000 years and serve as a tool for water and soil conservation and artificial wetlands.

Description

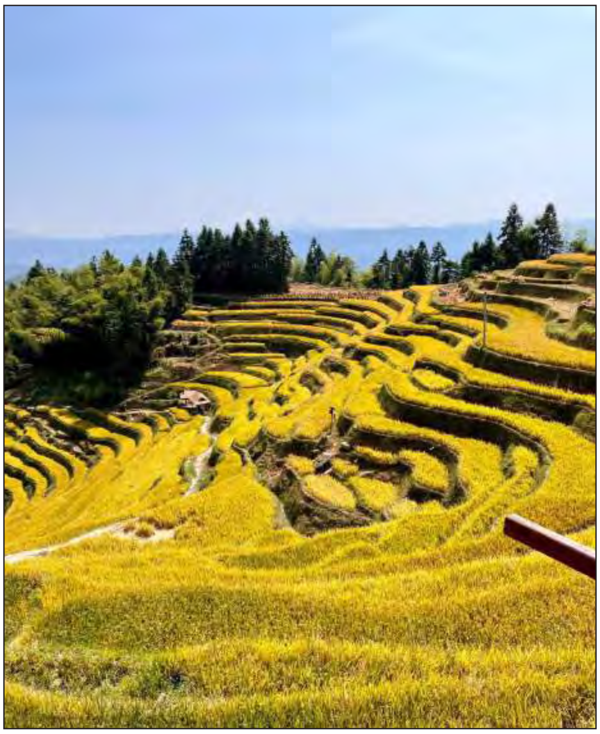
The irrigation and drainage system of Ziquejie Terraces comprises three parts: water storage, irrigation and drainage canal system, and control devices. In the valleys of Ziquejie, many streams do not dry up throughout the year. These streams are dammed up with small weirs. In normal times, these weirs ensure water diversion to the terraces; during torrential rains, the floodwater overflows from the top of the weirs. Water inlets are located a few meters upstream of the weirs. The angle between the mouth and the stream is larger than 60O to ensure safety. The weirs are equipped with grit chambers and flushing sluices to reduce silting of canals. Ridges with 0.2-0.3 m height convert the terrace fields into major water retaining structures with a capacity of 10 MCM. Coupled with the abundant water retained within the soil, the water-retaining terrace fields provide an adequate water supply for terrace agriculture. For delivering water to the platform fields on independent hills, people set up bamboo tubes as aqueducts. They are employed for trans-altitude water delivery to avoid ridge erosion.

Drainage outlets are built in the proper place of the terrace fields and canals to ensure waterlogging and tailwater discharge. Perpendicular to the contours, these valleys and streams can either be dammed up to be water sources or serve as main drainage canals. The expansion of farmland has facilitated the development and integration of different ethnic groups. Today, Ziquejie Terraces still support more than 17000 people from 16 villages, and the traditional way of life and cultural diversity have been retained.

As rice farming expands from plains to mountainous regions, Ziquejie Terraces have witnessed the spread of irrigation methods. The local village organizations in charge of water distribution and project maintenance are still subject to unwritten village rules and conventions that have been in effect for thousands of years. According to these rules and conventions, water from canals of higher altitude irrigates terrace fields of higher altitude, while water from canals of lower altitude irrigates terrace fields of lower altitude, thereby fully employing gravity. Community-based management led to the increased coverage area of 6,416 ha of Ziquejie Terraces which are still in good shape and functioning well.

Water Heritage

With a history as long as 1100 years, Ziquejie Terraces have an irrigation system that consists of infrastructures such as weirs, canals, and bamboo aqueducts. The unique but scientific water-land development method and the simple but developed irrigation and drainage system have helped Ziquejie break the rule that hills with a slope greater than 25 degrees are unsuitable for terraces. In its design and construction, Ziquejie Terraces paid great attention to environmental aspects. Ziquejie Terraces fully utilized natural valleys and streams as the main drainage canals.

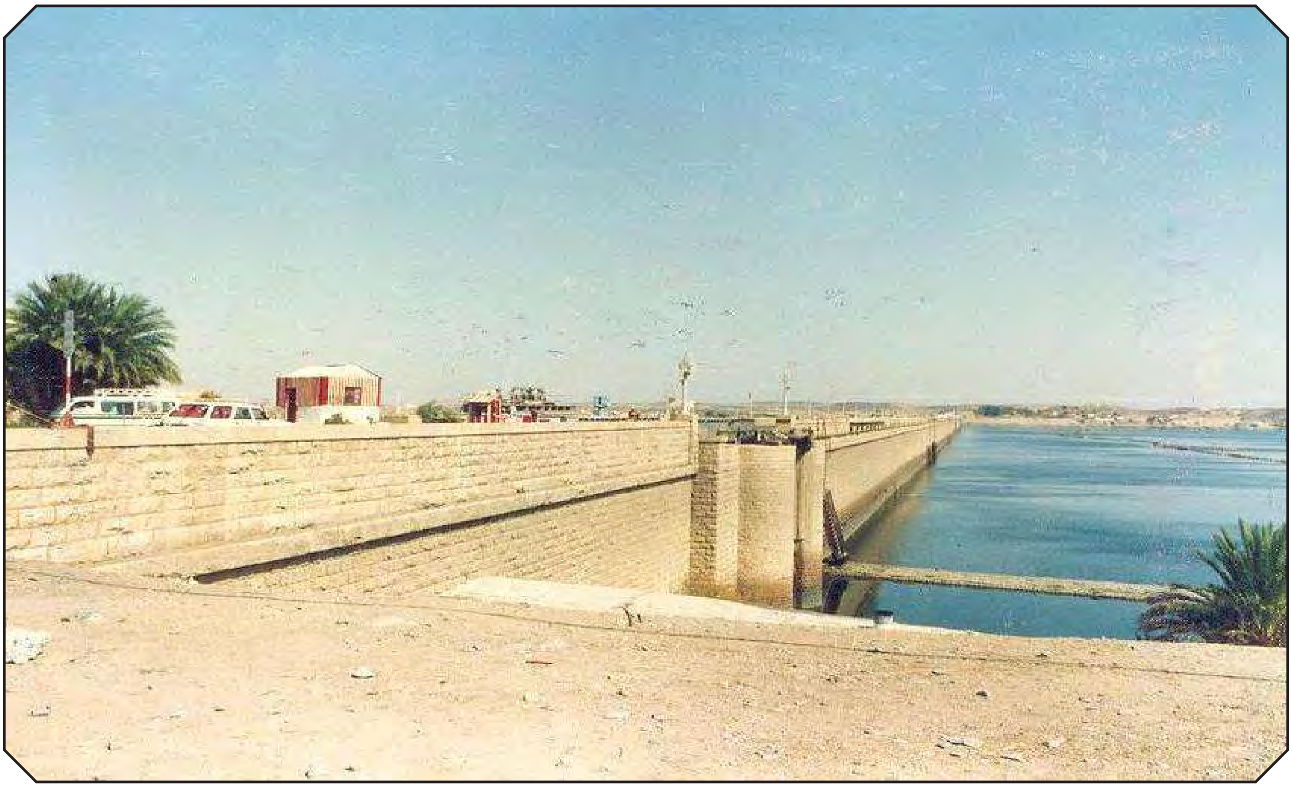


It increased the grain production area up to 6,416 ha of Ziquejie Terraces which are still in good shape and functioning well. Ziquejie Terraces unified the community leading to the integration and holistic growth of the ethnic groups. It bears a stamp of the local cultural tradition. The local village organizations in charge of water distribution and project maintenance are still subject to unwritten village rules and conventions that have been in effect for thousands of years.

3 EGYPT

3.1 ASWAN DAM

Name	Aswan Dam
Location	Giza (Aswan City), Egypt
Latitude	24.033333
Longitude	32.865833
Category of Structure	Dam
Year of commissioning	1902
River Basin	Nile River
Irrigated/Drained Area	320,000 ha



History

Built across the Nile, the Aswan Dam is an embankment dam in Egypt. Beginning in 1898 during the British rule in Egypt, the construction was completed in 1902. The project was designed by Sir William Willcocks and involved several eminent engineers, including Sir Benjamin Baker and Sir John Arid, whose firm, John Arid and Co., was the main contractor. The reservoir was filled for the first time (1902-1903) at a capacity of 1 BCM. It was heightened twice to store more water to meet the increasing demands and expand cultivated areas. The first heightening took place in 1908-1912 to store 2.5 BCM, and the second in (1929-1933) to store 5 BCM of water. The dam had a significant effect on the economy and culture of Egypt. As the population grew and conditions changed, the dam controlled the floods and protected the farmlands and the residential areas.

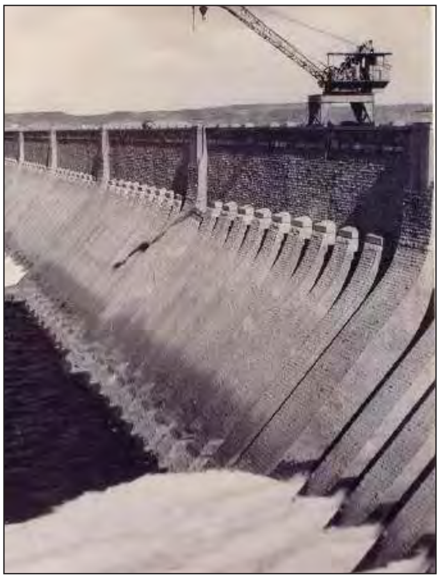
Description

The dam is a sluice-type gravity dam built in granite masonry. The batter on the upstream face is 1:18 and on the downstream face is 1:15. It was designed to hold up water at the upstream level of 106m, and the downstream level is 85 in, i.e., the maximum head is 20 m. The dam is naturally divided into two lengths. The first is about 1400 m long, which is pierced by sluices, and the other is about 550 m which is solid. In the pierced part, there are 180 slices. Owing to the uneven contour of the river bed at the cross-section of the cataract where the dam was built, the sluices were divided into series at different levels. One hundred forty of them were called lower sluices, 7 m high by 2 m wide, and were designed to manage the largest possible flood with a relatively small head of water. The remaining 40, called the upper sluices, are 3.5 m high by 2.0 m wide and were built to discharge under low heads of the normal flow when the reservoir is full. With only two exceptions, the sluices were divided into groups of ten each. Between individual sluices in each group, there was a length of in of masonry, and between each group of sluices, the length of masonry was increased to 10 inches where the buttress is 1.15 inches thick.

The Aswan High Dam is 3,830 m (12,570 ft) long, 980 m (3,220 ft) wide at the base, 40 m (130 ft) wide at the crest, and 111 m (364 ft) tall. It contains 43,000,000 m3 of water. At maximum, 11,000 m3/sec of water can pass through the dam. There are further emergency spillways for an extra 5,000 m3/sec, and the Toshka Canal links the reservoir to the Toshka Depression. The reservoir, named Lake Nasser, is 550 km long and 35 km wide, with a surface area of 5,250 km2. It holds 132 km3 of water. The High Aswan Dam became a key to the development following the Egyptian Revolution of 1952 due to its ability to control floods, provide water for irrigation, and hydropower electricity generation, which laid the foundation for Egypt's industrialization.

Water Heritage

The high Aswan Dam was an excellent piece of engineering work. Constructed by eminent leaders, it showcases durability, resilience, high-end engineering skills, and strategic planning, which transformed Egypt's pace in history for good. In his book The Nile-1936, Emile Ludwig described the dam, "With a volume of about 1.5 MCM of masonry, the dam surpasses the Great Pyramid in service." One of the highest dams of its time, its construction involved several excavations. The selection of the final location was a well-researched decision. After examining different sites between Halfa and Faiyum, south of Aswan was found to be the most favourable. The site chosen extends across the Nile Valley at a straight line, at Aswan Cataract, 6 km south of Aswan town, where the width of the valley is about 2000 m. The line chosen gave a probability of good rock for the whole length of the dam. The chosen site allowed for the construction of a dam to be of the smallest possible height. It was enough to allow the smooth construction of sufficient sluices to give a free waterway to the Nile in flood and to permit the water issuing from them to be well scattered and evenly distributed.



Even after the dam's construction, set protocols for monitoring and observation were followed. Devices were provided in the re-heightened dam to measure the movement of the buttresses relative to the dam body and the lock after heightening. Periodically the reservoir capacity was tested by making cross-sections along the reservoir. Even during the high floods of 1946, floodwater was retained up to an elevation of 107.5 m, and the capacity of the dam was not affected, i.e. no silt deposit was proved to settle in the river trough. With all its specifications and technical details, the dam was an engineering marvel of its time.

The dam contributed to enhanced food production, improved incomes, reduced floods in the region and led to regional development. The dam protected Egypt from the droughts in 1972–1973 and 1983–1987 that devastated East and West Africa. The High Dam allowed Egypt to reclaim about 840,000 ha in the Delta and along the Nile Valley, increasing the country's irrigated area by a third. The increase was brought about by irrigating the existing farmlands and the conversion of flood retention basins into cultivable areas of almost about 3,85,000 ha. About half a million families settled on these new lands. In particular, the area under rice and sugar cane cultivation increased. In addition, nearly 420,000 ha, mostly in Upper Egypt, were converted from flood irrigation with only one crop per year to perennial irrigation allowing two or more crops per year.

On other previously irrigated land, yields increased due to ensured water availability at critical low-flow periods. For example, wheat yields in Egypt tripled between 1952 to 1991. Most of the 32 km³ of freshwater, or almost 40 % of the average Nile flow previously lost to the sea every year, was put to beneficial use. While about ten km³ of the water saved is lost due to evaporation in Lake Nasser every year, the amount of water available for irrigation still increases by 22 km³.

The High Dam contributed in a positive way to the region's economy and well-being. The dam powers 12 generators, each rated at 175 MW, with a total of 2.1 GW. Power generation began in 1967. When the dam first reached peak output, it produced around half of Egypt's entire electricity production (about 15 % by 1998) and allowed most Egyptian villages to use electricity for the first time. The High Dam has also improved the efficiency and the extension of the Old Aswan Hydropower stations by regulating upstream flows.

The High Aswan is a critical historical irrigation infrastructure for Egypt and its people. The dam protected them from floods, droughts, and poor harvests and revitalized the economy directly and indirectly. Even after many decades, it is still contributing to the region's development today.

3.2 DELTA BARRAGES

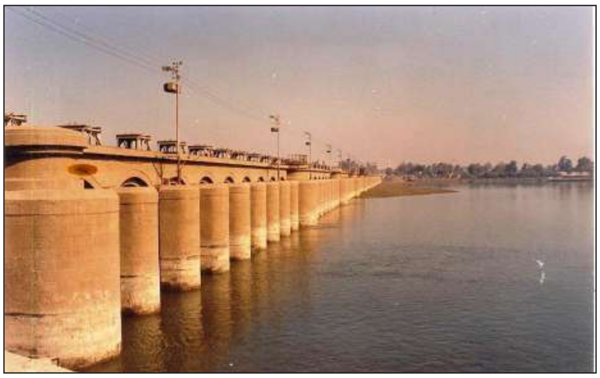
Name	Delta Barrages
Location	Embaba, Giza, Egypt
Latitude	30.193
Longitude	31.129
Category of Structure	Barrage
Year of commissioning	1861
River Basin	Nile River
Irrigated/Drained Area	1.8 Mha

History

Barrages and weirs were constructed on the Nile in Upper Egypt and on its two main branches (Rosetta and Damietta) to raise requisite water levels on their upstream side and command the canals without deep diggings or pumping water in the old basin irrigation system and for the perennial system. In total, three barrages were constructed on the Main Nile. From South to North, Isna, Nag—Hammadi, and Asyut barrages. These were constructed in 1906, 1930, and 1902 respectively. Isna is being replaced by a new barrage consisting of an earthen dam, spillway, hydropower station, and lock. Studies were carried out in 1980— 1985 for Nag-Hainmadi and Asyut and Damietta Barrages (Delta) and Zifta Barrage for the construction of a Hydropower plant, which was executed in the coming years.

Description

The Delta Barrage is a barrage-type dam constructed intermittently from 1833 to its initial completion in 1861. Its purpose was to improve irrigation and navigation along the main Rosetta and Damietta Nile branches downstream to the point of division between the north of Cairo, Egypt. Due to the structure's foundations' poor quality at its first operation, its main irrigation purpose was primarily abandoned for safety reasons. The barrages have been much maligned as only a romantic river crossing.



At the apex of the Nile Delta, four barrages on the main Nile branches (Rosetta and Damietta) and two weirs have existed. Branching from the Rosetta branch, two main canals with head regulators are found (Beheira and Menufi Raiyahs). From the upstream of the Damietta branch, Tawfiqi Raiyah diverts the water to the eastern part of the delta. From the Delta barrage's upstream and branching from the Nile, there are the intakes of Ismailiya, Sharqawiya, and Basusiya Canals. Midway between the Delta Barrage and the mouth of Damietta Barrage, there is Zifta Barrage (1903). The Old Delta barrages (Qanatir El-Khairiya) were completed and operated in 1861 and were strengthened by two submerged weirs at their downstream in 1898-1901. These pierced dams with gated vents were built on the apex of the Delta on both branches of the Nile at a distance of 22 km north of Cairo. They were replaced in 1938 by two new ones located midway between the barrages and the weirs. At the outlet of Rosetta, Idfina Barrage was constructed in 1948—1951 to replace the earthen dam, which used to be damaged yearly during the flood.

A similar dam was constructed on Damietta's mouth after each flood to prevent saltwater intrusion. A barrage and a lock replaced part of this dam, and the other part was strengthened in 1985-1989. All the operating barrages were subject to investigations and inspections periodically and even with the drilling of boreholes and soundings upstream and downstream to study their structural safety. Injection operations through boreholes in the piers and lock walls were performed in almost all the barrages for inspection and strengthening in 1979 and 1985.

Power generation studies from the barrages and head regulators were carried out in the same period with the assistance of specialized firms and consultants. The two old Delta Barrages were also restored in the same period to conserve them as monumental structures providing a historical view with towers on both ends.

Water Heritage

Delta barrages and associated structures were the first of their type globally and the biggest ever built in the 19th century. This great enterprise initiated the age of perennial irrigation and realized the development of the valuable cotton crop in the vast tracts of the Nile Delta. Before the construction of the barrages, the perennial irrigation was 2.0 million feddans (8400 m2) and was increased to 3.0 million feddans (12,600 m2).

Delta barrages improved the economic situation of the region, the industry as well as the local population. It was an engineering marvel of its time that became the light-bearer for irrigation technologies worldwide. At a regional level, the agricultural economy flourished, and disaster management greatly improved.

Over the centuries, the barrages have been repaired, remodelled and renovated many times to adjust to the developments and the ingraining of the latest technology and hydraulic inventions. Despite its ignoble beginnings, initial testing, and 1880 major repairs, the barrages provide water and positively impact Egypt's economy. Following the British Occupation of Egypt, repairs and maintenance continued largely, retaining the barrages' original intent and structure. Over the years, this maintenance work showed unexpected and startling results. In addition to a great reduction in the costs of lifting water to irrigate fields, the labour costs to unclog the canals from deposited silt were also reduced. More importantly, the cotton crop yield was doubled, and the costs needed to raise crops, in general, were cut in half. These combined factors stimulated demand for agricultural land, which witnessed skyrocketing prices and increased demand.

From a holistic perspective, the construction of the barrages completely transformed the region. The barrages lived up to their pre-decided objectives. With the Delta barrage, the downstream areas were irrigated smoothly, especially during the period of lowest levels (taharik), without the need to use lifting pumps. The use of lifting tools such as (Saqia and Shadoof) was discontinued soon after. Thus, it was possible to raise the income by cultivating the same land three times a year. Through the Mahinudiya Canal and the Khatatba Canal's water exchange mechanisms, the water availability became stable. Given the rugged terrain, it was challenging to irrigate before the upstream Cairo; however, the canals solved the problem as part of the complex. Another important aspect was the improvement of navigation. The barrages caused obstacles for the pirate ships on their way through the Nile to Cairo.

The Delta Barrage was unique and positive in its ideas during construction and benefitted the region and irrigation fraternity. The barrage was a trendsetter of its time in terms of irrigation technology. In the 1930s, the idea of a larger, higher, and stronger barrage led to the discontinuation of the old barrage, which was riddled with many obstacles like leakages and high maintenance expenses, among others. Construction of the new Mohammed Ali Barrage lasted from 1936 to 1939. Due to technological advances, its foundation was built in steel piling, and concrete cement was encrusted several meters below the sandy base. Granite from Aswan was also used for part of the body. The project work was a great success. The old Delta Barrage is now retained as a historical monument and is still used as a road bridge.

4 INDIA

4.1 BAITARANI IRRIGATION PROJECTS

Name	Baitarani Irrigation Projects
Location	Odisha, India
Latitude	200 -54’-55.5”N
Longitude	860-16’-42.6”E
Category of Structure	Irrigation Project
Year of commissioning	1871
River Basin	Baitarani River Basin
Irrigated/Drained Area	32752.63 Ha

History

The Baitarani Irrigation Project was taken up in the year 1871 and completed in the year 1878 during British rule. It has been serving for more than 144 years.

Description

The Baitarani is the only major river that originates from Keonjhar Plateau. Its source is the Guptaganga Hills of the Janghir-Dhenkikote region. The basin area lies mostly in Orissa, including 736 km^2 in Jharkhand State. Another peculiarity of Baitarani is that in lower reaches, it drains into the distributaries of the Brahmani south of Chandabali and has a common mouth with the Bay of Bengal at Dhamara. The river enters the plains at Anandapur & creates a delta below Akhuapada. The river Budha takes off from Baitarani near Rudhia; after flowing 16 Km, it falls into Kharasuan. The catchment area of river Baitarani is 10000 km^2; Baitarani and Budha Anicut were constructed by the Britishers during the year 1871 to 1878.

Budha Anicut

Baitarani Anicut

This Division deals with flood problems of river Baitarani from Raghupur in Korei Block of Jajpur District up to Tinter-ghat in Chandabali Block of Bhadrak District. River Baitarani is an uncontrolled river without any flood control structures at the upper reach. Irrigation is being provided to 13099 ha of ayacut in Kharif & 3238 ha of Rabi from Budha Anicut through Jajpur Canal and its system of Jajpur District & 19669 ha of ayacut in Kharif & 809 ha of Rabi from Baitarani Anicut through H.L.C. Range-III & its systems of Bhadrak District. It is a regular phenomenon that Kharif irrigation water is supplied through a canal system from 1 July to 15 November, and water is again supplied for light-duty Rabi crops from 1 January to 15 January, i.e., for 15 days only. The total length of the Jajpur Canal System is 197.87 km, and the H.L.C. Range-III System is 269.38 Km.

Water Heritage

The Baitarani Irrigation Project was taken up in the year 1871 and completed in the year 1878 during British rule. It has been serving for more than 144 years. The Baitarani Irrigation Project consists of one diversion structure (Akhuapada Anicut & Budha Anicut) having a total length of 463.93 m. River Baitarani is an uncontrolled river without any flood control structures at the upper reach. Thus most problematic flood hazard occurs in river Baitarani almost every year, and it becomes a difficult task to tackle the situation in Jajpur & Bhadrak District.

Jajpur Main Canal

HLC Range-III, Bhadrak

On this basis, Akhuapada Anicut, Budha Anicut and the canal system are the key milestones to controlling floods to some extent and utilising water in a sustainable way through the Jajpur main Canal & HLC Range-III canal by the farmers during Kharif and Rabi. It also bears exceptional testimony to the development of irrigation and the improvement of the economic status of farmers. This area of Jajpur District (Mainly Jajpur, Dasarathpur & Binjharpur Blocks) & Bhadrak District (Bhandaripokhari, Dhamnagar & Bhadrak Blocks) had two problems, mainly drought-prone conditions (lack of water) and after floods, water logging and stagnant water conditions (abundance of water).

After the construction of the Baitarani Irrigation Project, this drought-prone area was converted into a well-irrigated area. Water could be easily diverted to both canals for effective irrigation, and Ground Water recharge occurred. Through the distribution system, water could easily reach the farmers, and they got water for irrigation and also for different activities like drinking water etc. So the development of agriculture has improved in this area, and the farmer's area bled to grow different types of crops in different seasons.

Of this, Kharif & Rabi production increased along with the improvement in the economic conditions of farmers. At present also, the existing canal irrigates an area of 32752.63 ha in Kharif and 4047 ha in Rabi of 6 blocks in both Jajpur & Bhadrak Districts. This project has made an outstanding contribution to the improvement of irrigation facilities, vast development of irrigated agriculture, enhancing food production, rural prosperity and poverty alleviation in this region.

4.2 CUMBUM TANK

Name	**Cumbum Tank**
Location	**Andhra Pradesh, India**
Latitude	**15.566**
Longitude	**79.069**
Category of Structure	**Water Storage Structure**
Year of commissioning	**1522-1524 AD**
River Basin	**Manneru river basin**
Irrigated/Drained Area	**10300 acres (4168.26 ha)**

History

Cumbum Tank is the second-largest artificial tank in Asia. It is the third-largest pond in the world, the second-largest in Asia, and the first in India. It is a medium irrigation project, constructed during the Sri Krishna Devaraya era about 450 years back in 1509 AD, formed by damming a gorge through which the Gundlakamma and Jampaleru rivers flow. At the time of its construction, the population of Cumbum Village was 6000. Varadarajamma, the daughter of Prataparudra Gajapati, the wife of Sri Krishnadevaraya, lived here. The Cumbum tank was constructed during her time. Varadamma became known as Varadarajamma as a mother who gave alms to the people, supported the poor, and gave gifts to the people of the area. The royals built a pond there to mark her. That pond is today's Cumbum tank. Later, people built a temple on the pond embankment for Varadarajamma. It is believed that tank construction took place during 1522-1524 AD; it has been utilised since 1525 AD.

Description

The anicut was built by the Vijayanagar Princess Varadharajamma (also known as Ruchidevi), wife of Sri Krishna Devaraya. The lake is about 7 km long and about 3.5 km wide. Two brothers, namely Pedda Khambadu and Chinna Khambadu, sacrificed their lives for ensuring the strength of the bund portion of the tank. Hence, the tank got the name, Cumbum Tank. Consolidation of the earthen bund was done during ancient times by elephants. According to the Imperial Gazette of India, at the turn of the 20th century, the dam was 57 feet (17 m) tall, and the drainage area was 430 square miles (1,100 km^2). The project mainly provided irrigation facilities and drinking water to an ayacut of 6,944 acres through 5 channels in 19 Villages of Cumbum and Bestavaripet Mandals of Prakasam district with a capacity of 2.952 TMC.

The tank is a centre of socio-economic activities catering to the myriad needs of the village community. The tank is not simply an irrigation system appended to big reservoirs. It has multiple uses and serves the diverse needs of people, animals and plants. The tank contributes to the recharge of groundwater, microclimate and the environment to keep the surrounding area green and cool. It also attracts migratory birds from far and near.

Sustainability of livelihood through the supply of drinking water and irrigation in drought-prone areas: The tank is not simply an irrigation system that starts from the reservoir down. It is also a collection point for run-off from the catchment area, a pond for pisciculture, a source of silt for fertigation and construction material, a recharge structure for local groundwater, a location for cultivation on common lands, a source of drinking water for livestock, and finally, an irrigation system for crops. The advantage of tank irrigation is its proximity to the command area so that the crop's water requirement can be assessed and supplied from the tank, which is the core issue of water management. Cumbum Tank serves 19 villages and its hamlets, enabling de-centralized management to be effective. Indigenous systems of irrigated agriculture represent sustainable solutions to the demands of intensive crop production by successfully adapting to local environments. They have proven themselves over centuries to be environmentally sustainable and productively viable.

Achieving food security for underprivileged rural communities has been one of the highest priorities for the Government of Andhra Pradesh during the last several decades. Restoration of the old tanks constructed centuries ago has been identified as one key enabler towards addressing these issues. This will increase the rainwater storage capacity for both agriculture and household use. Realizing the importance of tanks, the Government of Andhra Pradesh, through its Irrigation Policy, has initiated several programmes to revive water conservation systems. Over the years, silt accumulation has reduced the tank's water-holding capacity. Restoring tanks through government programmes has been undertaken to increase their water-retention capacity by de-siltation, thus improving on-farm moisture-retention capacity.

The Government has undertaken modernization of the historical Cumbum tank to revive, restore and rehabilitate the traditional water body under the Japanese International Cooperation Agency (JICA) with a project cost of Rs 912 lakhs (12,30,586 USD). The rehabilitation works include replacing leaky old sluice gates and C/C lining to the main and branch canals, construction of regulators, Off-take sluices, and repairs to the dilapidated Cross Masonry & Cross Drainage works. These restoration works have multiple objectives like comprehensive improvement and restoration of water bodies, thereby increasing tank storage capacity, groundwater recharge, increased availability of drinking water, improvement in agriculture/horticulture productivity, improvement of catchment areas of tank commands, environmental benefits through improved water use efficiency by the promotion of conjunctive use of surface and groundwater, community participation and self-supporting system for sustainable management for each water body, Capacity Building of communities in better water management and development of tourism, cultural activities, etc.

Water Heritage

The Cumbum tank is the historical evidence of human interventions in managing village water bodies for agriculture and drinking water through efficient construction of irrigation structures, systems, and management. The tank is a simple earthen banked rainwater harvesting and storage structure formed by damming a gorge through which the Gundlakamma and Jampaleru rivers flow, designed using their indigenous wisdom and constructed with the generous support of native rulers and chieftains over the past several centuries. Surprisingly these earthen structures have withstood the test of time and survived over many centuries. These are simple technological innovations developed by people to accommodate their primary needs and adapted to the distinctive Indian climate – intense monsoons followed by protracted droughts. Sir Arthur Cotton, a well-known British Engineer who worked in India at the time of Colonial imperialism, exclaimed on seeing the constructed tanks: "The natives have constructed tens of thousands of tanks in almost every kind of soil with earthen bund without the puddled bank, which English Engineers fancied necessary".

Irrigation rights in tanks were primarily governed by custom and local practices. Though they were not recorded, they were meticulously observed by the riots and the community from times immemorial. The ancient donors did not stop their work after creating tanks. They also provided grants and tax remissions to those maintaining the tank to ensure their periodic good repair. Maintenance of these structures for sustained irrigation was a priority. They had a very elaborate system of management, including repairs, maintenance and improvements. The tanks, channels and sluices, especially those not wholly built of stones, bricks and mortar, required great care. Frequent removal of silt was considered to be an essential aspect of the maintenance of tank complexes. Due to excessive rainfall and floods, the breaches in tank bunds and supply channels had to be repaired promptly. Many South Indian inscriptions contain descriptions and references to the damages caused to irrigation works on account of heavy rains and floods, the action taken by Sabas (regional assemblies) for the upkeep of the tank complexes, and the endowment created for the maintenance and repair works by individuals. The village assemblies systematically managed the water from the tanks, ensuring equitable water distribution to all needy villagers. They also maintained the physical structures of the tank in good condition.

Tank irrigation systems are simple but fragile structures. They have to be continuously maintained, promptly repaired and constantly monitored. And yet, historically, people have devised a variety of property rights mechanisms to share water and maintain their tanks. The knowledge reflected in the physical features of indigenous irrigation systems and their management software is the product of a centuries-long learning process by which the community have come to terms with their environment.

4.3 DHAMAPUR LAKE

Name	**Dhamapur Lake**
Location	**Maharashtra, India**
Latitude	**16.033**
Longitude	**73.594**
Category of Structure	**Water Storage Structure**
Year of commissioning	**1530**
River Basin	**Karli River**
Irrigated/Drained Area	**237.6 ha**

History

Dhamapur lake dam, nestled snugly amidst the lush forests of the Sindhudurga district, is a glowing example of a traditional water harvesting system and how an intelligent and sustainable local system can support communities and wildlife. The dam was built entirely with local funds and had a very good foundation stratum. It is the main source of drinking water and irrigation for the Dhamapur and Kalse villages. The lake wetland also acts as a sponge in monsoon seasons, recharges the groundwater storage, arrests flood and allows the mixing of minerals in the water.

It is a freshwater reservoir formed by one of the oldest earthen dams in Maharashtra, India. Dhamapur village has strong historical links evident from ancient hero stones, sati stones and images of the deities tracing back to the Shilahara period (c. 10^{th} – 11^{th} century CE). Dhamapur lake dam was built in 1530 by villagers of Dhamapur and Kalse under the guidance of Nagesh Desai and Mandlik of the Vijaynagar dynasty. It is the biggest lake in the district and perhaps next only to Tadoba Lake. The dam site is situated on Kudal-Malvan road with very good foundation strata. The dam height above the lowest foundation is 11.43 m, while the length is 271 m. The total volume content is 2.867 MCM, out of which 2.441 MCM is live storage. Dhamapur Lake has a submergence area of 43.30 ha and a maximum depth of 11.43 m. A total of 9.97 km^2 catchment area is fed from the rainwater to the lake. The volume content is 2,687 km^3 (645 m^3), and the gross storage capacity is 2,867 km^3 (688 m^3).

The lake is almost 500 years old and withstood drought and other natural calamities like the Koyna Earthquake. Numerous failures of poorly designed earth embankments occurred, but the lake with its earthen dam remained functional. Generally, faults in the earth get activated due to the construction of a dam. But this Dhamapur Lake dam has not triggered such reservoir-induced seismicity. The lake led to economic and social prosperity.

Description

The dam gets filled with water at the early stage of the monsoon. The lake wetland acts as a sponge, recharges the groundwater storage, arrests flood and allows the mixing of minerals in the water. Some 61 minor streams meet the two major and one middle-order streams that feed the Dhamapur Lake. Two outlets emerging from the Kavadewadi dam and the Guramwadi dam also feed water to Dhamapur Lake. It is, therefore, imperative to preserve not only Dhamapur Lake but also protect the inlet streams that give this freshwater body a flourished biological existence. Among various unnamed streamlets, one streamlet, traditionally known as “Bhurkhyacha Whal”, is an old streamlet known since ancient times originating from a mountain in Kalse village. It holds an ideal site for water storage by forming valley shape catchment bounded by hills on both sides. The dam has a waste weir of length 26 m constructed in laterite stone. Dam’s top level is 99.60 m while the sill level is 91.60 m. Dhamapur Lake is a little irrigation freshwater body with a full reservoir level of 96.80 m while a maximum water level of 97.30 m has a flooded lift of 0.50 m. The forest area around the lake is a reserved dedicious forest—Dhamapur Lake harbours rich biodiversity with rare species of flora. Crotalaria filipes Benth, Gnetum ula Brong and Nothopegia colebrookiana (wight) Blume are some native rare endangered listed flora found at the banks of the lake. The dam site promotes biodiversity, wise tourism, nature trail, water supply, irrigation, and fishing.

Dhamapur Lake, constructed in 1530, is one of the finest dams listed in the country. As per the latest report of the National Wetland Atlas by the Space Applications Centre (SAC) of the Indian Space Research Organisation (ISRO), Dhamapur Lake covers an area of about 61.44 Ha. However, lately, the shrinking of the Lake Area has become a pertinent issue related to environmental degradation around the lake. There is a looming threat to this ancient traditional water harvesting system. The first issue is destroying ecology and water pollution. The dam is constructed out of highly porous laterite stone; a large amount of water gets wasted through the dam body and the foundation. Heavy leakages are observed throughout the year between porous joints of laterite masonry. The Water Resource Department is tackling it in the form of constructing a barrier structure like jacketing wall. The remedial work is in progress, and some percentage of leakages can be spotted; a high amount of water gets wasted, which could be used for several purposes.

Dhamapur Lake irrigates an area of 237 Ha every year with the left canal, right canal and backwaters of the lake; the famous Konkan crop paddy grows in tank command, which is a livelihood activity for farmers and stakeholders. Farmers are demanding fully closed pipelines instead of an open canal to prevent water losses. The Water Resource Department has laid HDPE pipes for the water supply.

The volume content of the lake is also shrinking in the last few years. As the dam is located in a high rainfall zone in a lush forest area, rainwater carries tremendous silt every year and gets deposited in dam submergence. Also, residents and their activities behind dam submergence threaten the dam. The digging and excavation processes have led to fissures in the laterite bedrock, which led to the percolation of the stored water and decreased the carrying capacity of Dhamapur Lake. Removal of accumulated silt from lake submergence will be the next activity. Very fertile silt can be useful for local farmers to use in their farms.

The third issue is water pollution. Water from Dhamapur Lake is being for drinking purposes which adds a serious threat to their health. If activities in Dhamapur Lake are limited to rowing and pedal boating, then it would not be harmful to ecology. Another issue is the religious activity of immersing Ganesh idols in Dhamapur Lake. Artificial water tanks could be formed to immerse idols keeping intact the purity of the Dhamapur lake water. Hence, such a beautiful dam and lake surrounding should be preserved, and conserved from various threats to retain such an ancient, historical structure.

Water Heritage

Dhamapur Lake is the main source of drinking water and irrigation for the Dhamapur and Kalse villages. Built in 1530 and is still fully functional today. The Lake is an exceptional testimony to agricultural development and increased food production. Water use associations (WUA) s manage the supply scheme smoothly and effectively with the cooperation of stakeholders. In 1997-2000 a drinking water supply scheme was set up at Dhamapur Tank Municipal Corporation, and water was supplied to four more villages. In 2005 farmers formed the WUA named "Shri Bhagavatidevi water user association" to supply water to other stakeholders. Dhamapur Lake's present irrigation outreach capacity through its 2.20 km canal is 238 acres (96.32 ha), but presently 125 acres (50.6 ha) of farmland are irrigated.

Traditionally, mud and rice fibre were used as binding material, and the "Trunks of Bhedla mad" were used as pipes. The villagers used to construct this water bund wall locally known as "Bandh", with these pipes placed at different heights to block water. Pipes from the top discharged water in channels that ran through villages supplying water. The channels ended at the "Karli" river. The earthen dam was constructed using natural soil with minimum processing and was built with primitive equipment available at that time. Unlike modern concrete dams, which require a sound foundation, this earthen dam was constructed to the adapted earth foundations. It is understood that the construction of the earth dam used simple operations and was done as a rule of thumb. The earth fill was further protected by laterite stone pitching. This protected the earthen dam from soil erosion. Steel gates recently replaced this system with concrete walls. Formed by damming a valley with an earthen bank, it holds water all year round.

The lake design reflects geographical thoughtfulness. It is constructed between two hills of Dhamapur and Kalse Village. The site indicates the vision to provide natural irrigation and drinking water to both villages. The irrigation is done through natural gravity as the villages are located at 4 m above surface level. This dam and lake contributed to the evolution of efficient and contemporary engineering theories and practices.

Dhamapur Lake was designed keeping in mind the environmental aspects. The lake's area of influence is 328.85 ha, out of which 21 % is forest, 72 % Agriculture, 5% Grassland and scrublands 2% rural settlements. It recharges water wells in nearby villages. Dhamapur Lake is a testimony to the intimate knowledge that ancient villagers had of the local climate, soil properties, geology, hydrology and ecology. It also testified to their technical knowledge, evident in the sluice gates built to control water flow. Water was channelized till 5 km to Hublichamal for irrigation by gravity through an earthen channel, known as Haran in the local language.

The dam site is surrounded by lush forests and high hills that offer biodiversity. A report shows 134 plant species containing 34 herbs, 33 shrubs, 14 climbers, 42 trees, and three orchids; species are reported as rare endangered species. As per the international union for Conservation of Nature, endemic species of birds have been sighted on the lake. Apart from this, smooth-coated otters, leopards, and wild boar-barking deer have also been known to inhabit the lake. The small population of otters inhabiting the lake is of critical importance since they are considered an indicator of a healthy ecosystem—thirty-nine butterfly species out of which Wax Dart Species reported first time in Maharashtra at Dhamapur Lake. Thus, a variety of species and wildlife winter visitors can easily see in surrounding forests distinguishes Dhamapur from other dam bodies.

The historical Gazetteer of the Bombay Presidency – vol X (Ratnagiri and Sawantwadi) published in 1880 stated, "Dhamapur lake has an area of 55 acres (22.26 ha), and a maximum depth of 37.5 feet. Formed by damming a valley with an earthen bank, though the dam leaks considerably, it holds water all the year-round and shows no tendency to slit. It waters about 500 acres, 40 of the garden and the rest rice land." Ancient Hemadpanthi style architecture temple "Bhagwati Mandir" was constructed on the top of the dam in 1531 on one side and the spillway to drain the overflow of water above the holding capacity of the dam on the other side.

4.4 DHUKWAN WEIR

Name	Dhukwan Weir
Location	Uttar Pradesh, India
Latitude	**25° 11' 30" N**
Longitude	78° 32' 30" E
Category of Structure	Weir
Year of commissioning	1909
River Basin	Ganga Basin / Betwa Sub Basin
Irrigated/Drained Area	Storage of 3845 MCFT

History

Dhukwan weir was constructed across river Betwa in district Jhansi of Uttar Pradesh during the years 1905-1909. Betwa River is a major tributary of river Yamuna in the Ganga basin and has a catchment area of 8140 sq. miles from its origin at Bhopal to the reservoir. The catchment is entirely monsoon fed containing wooded hilly country and cultivated land.

Description

To fulfil the objective of subsidiary storage for the Parichha weir, a masonry weir of 3845 feet in length was constructed to store 3759 mcft of water submerging 5000 acres of land. The maximum height of the weir above the deepest riverbed is 50 feet. The weir is constructed with granite stone masonry with a hearting of cement concrete. The weir has been provided with 383 no-falling shutter gates of size 10 feet X 8 feet above the crest level 890 feet, making the full reservoir level 898 feet. The water from the reservoir is released into the river for utilization at Parichha weir through two upper sluices at elevation 868.50 feet i.e., 21.5 feet below the crest and one lower sluice at 845.50 feet i.e., 44.5 feet below the crest. The sluice gates are operated from the sluice tower located in the middle of the weir.

The water is stored in the reservoir till the full reservoir level by manually erecting gates over the weir starting from 15 September and completed by 15 October every year. These gates remain erected till 15° June when gates are lowered to pass the monsoon flood. However, when gates are erected and any flood event takes place, for such exigency an arrangement has been made to lower the gate in minimal time. The first flignt of 99 gates from the left bank to the sluice tower can be lowered by a lever provided at the left bank and the remaining 284 gates can be lowered by pulling the chain provided in the weir at the corridor through the weir. Water during this period is passed to the Parichha weir through the sluice. Originally the water stored in the Dhukwan reservoir was released to the Parichha weir from 21st October till 12th July as per demand.

The weir was designed to pass a maximum flood of 6,52,000 cusecs with a water column height 12.75 feet above the crest, RL 902.75 feet. The afflux bund with a top-level kept at 907 feet was constructed with black cotton earth placed upstream of the core wall with a side slope of 1:3 and downstream slope with common earth. However, in the life history of 112 years of the weir, the ever maximum flood of 6,20,353 cusec was observed on 10 September 1983 with RL 904 feet highest flood level recorded. This flood caused damage to the weir and causeway downstream of the weir. The damage was repaired and the structure regained its original shape.

Later, with the construction of the Matatila Dam and the Rajghat Dam operation manual was modified. The water stored in the Dhukwan reservoir and release from the Matatila and Rajghat Dams is used for Rabi irrigation through upper and lower sluices. Water is also released to Madhya Pradesh through the Datia carrier canal, a new off-taking structure constructed at the left bank of the weir. Dhukwan Reservoir generally keeps empty by the end of January every year. From February onwards, the water released from Matatila dam as per crop water requirements. Over time, two new dams namely Matatila and Rajghat dam have been constructed upstream of the Dhukwan reservoir across the Betwa River. Due to the new storage and availability of water, the functionality of this structure is modified. In addition to the initial function of the pick-up weir for the Parichha dam, this reservoir is now utilized for the diversion of water to Madhya Pradesh through the Datia carrier canal. It also acts as the source of water for the 24 MW Dhukwan Small Hydro Power Plant constructed at the toe of the reservoir.

Dhukwan Weir is one of the key projects that has supported economic development and agriculture in the Bundelkhand region. The water stored in the Dhukwan reservoir is used for Rabi irrigation through upper and lower areas. Consistent conservation and improvement activities by the Government of Uttar Pradesh have helped in maintaining the higher potential of the reservoir.

With time Dhukwan Weir has gained importance through its present capacity is 2206 million cubic feet against 3759 million cubic feet of original capacity. This deficit is made up of the reservoirs constructed upstream supplementing water. Water discharged from the Rajghat dam and Matatila dam is diverted from Dhukwan weir thereby this weir is now providing water to three districts of Madhya Pradesh and three districts of Uttar Pradesh. With proper maintenance of this structure, it will serve its purpose for decades to come.

Details of the Structure are given below:

- Catchment Area - 8140 sq. mile
- Crest level - 890 feet
- Full Reservoir Level- 898 feet
- Top of dam – 907 feet
- Designed Highest Flood level (Above crest level) – 902.75 feet (12.75 feet)

Water Heritage

In the Jhansi, Jalaun and Hamirpur Districts of the Bundelkhand Region (Uttar Pradesh), the water has always been at immense depth, rainfall is scanty, irregular, and uncertain, and wells are brood at an expense that is prohibitive for irrigation purposes. People, therefore, had to migrate on any signs of upcoming draught. Apropos a necessity was accepted by the British Government towards the end of the 18th century to construct a catchment for fulfilling the water requirement of the region. After a detailed study by the experts, the area of Dhukwan was selected for the weir. Betwa River was a key tributary of the river Yamuna in the Ganga basin. Betwa River had a vast catchment area of 8140 sq. miles from its origin at Bhopal to the location of Dhukwan weir. The catchment was and is exclusively monsoon fed in the wooded, hilly country and cultivated land.

This weir was not constructed as a revenue project but as a welfare measure for drinking water and poverty alleviation by enhanced irrigation facilities for crops. Dhukwan weir provided much-needed water for irrigation in the region which had not such correctly placed weir earlier.

It was a revolutionary step to plan and construct this architectural marvel Dhukwan Weir approximately 112 years earlier through 1905-1909 to augment and regulate water across river Betwa in the Jhansi district of Bundelkhand Region of Uttar Pradesh.

This design was way ahead of its time as such a massive structure (1,194 m long, 50 ft high, 383 falling shutter type gates with cranes and three sluice gates). An astonishing corridor through the weir was provided for communication with the far bank and with the sluice tower during the floods. This massive structure was constructed without machinery in a record time of just five years with high efficacy. It is still functional and fulfilling its obligation for irrigation of the region through its large storage capacity.

The weir not only led to a paradigm shift in the cultivation methodology but also enhanced crop production of food grains in the region. Dhukwan is subsidiary storage for Parichha weir. It provides water for the lone Betwa canal system, the lifeline for the region off-taking from Parichha weir for Jhansi, Jalaun and Hamirpur.

It was constructed to provide water for Rabi and Kharif crops which had an original storage capacity of 3,759 Mcft and it enhanced the Irrigated land from 62,000 acres of Rabi in 1899 - 1900 to 6,01,927 acres (2,22,936 ha) presently, with average annual irrigation of 6,07,580 acres (2.45.984 ha).

It was because of this visionary perspective planning for the next 200 years that now after the construction of Rajghat and Matatila Dams, the Dhukwan weir feeds the water released to the Betwa canal system and water utilization has increased from 6003 Mcft to 41590 Mcft as per current record. Now the water is also directed to the state of Madhya Pradesh through the Datia carrier canal off-taking from the left bank to the tune of 20,775 Mcft in the current year. Now the water is being used for the Hydro Project of 24 MW generating annually 17.82 MU.

Dhukwan Weir has gained further significance with time now providing water to three districts of Madhya Pradesh and three districts of Uttar Pradesh. Through appropriate preservation, this weir can serve the purpose for decades to come.

The weir is still very robust and has no sign of any decline. It has stood the test of time and has truly accomplished its goal. The efficacy and the significance of the same have only amplified with time. As this is one of the oldest, functional and necessary projects for the region, it must be taken under the Heritage umbrella as the masonry technique used here, which is now getting obsolete, once preserved properly, will be a marvel to be witnessed by not only the next generations of Water commissions, irrigation fraternity but also general people to admire the ancient and service able engineer spectacle.

The original capacity of Dhukwan Reservoir at the time of its construction in 1909 was 3759 Mcft (106.38 MCM) but the present capacity of the reservoir at full reservoir El (273.40) 898 ft is 62.48 MCM. The rate of sedimentation in its first 30 years (1907-1937) was 0.9 MCM per year. It remained almost the same during the next 15 years till 1952. After the construction of the Matatila dam in 1956 (21 Km upstream of Dhukwan dam), the rate of siltation was reduced to 0.25 MCM per year.

From the years 1980-87, the reservoir has not shown any silting tendency, but rather showing scouring tendency. This is due to the operation schedule of the reservoir. For a period of 5 months a year (from Feb to Jun), the reservoir is used as a conveyance channel for passing the discharge released from the Matatila Reservoir. The sediment-starved water picks up the material deposited in the Dhukwan Reservoir. Since the flow is passed through the Dhukwan sluice without ponding, it is showing a scouring trend rather than siltation during the non-monsoon period too. So, even if the reservoir's storage capacity is reduced, it is still useful for the purpose it was constructed for.

With time, stone masonry work has become obsolete as not much work is done with stone masonry these days. However, the masonry structure is still sound and has no sign of deterioration. Masonry arches in the corridor require general repair and maintenance work. Since arch structures have been replaced by RCC these days, getting skilled workmanship for arches is a problem. But with some effort and guidance, these small problems are well managed and overcome.

Steel gates were manufactured and still maintained by the departmental workshops. Now workshops are finding it a bit difficult to maintain them due to obsolete technology, time and manpower consumed to lift the gate and check the seepage from the joints. Due to manual lifting arrangements and sometimes untimely rains during the non-monsoon period, lowering of the gate becomes inevitable, so water stored above the crest is lost. Nowadays with the availability of improved technology, sometimes the department feels modernization of the gates and replacing it with hydro-mechanical gates would be better for optimum utilization of water. However, such changes have not been proposed to keep the structure in its original state, since water seepage loss is being utilized at Parichha weir.

Dhukwan Weir has gained further significance with time now providing water to three districts of Madhya Pradesh and three districts of Uttar Pradesh. Through appropriate preservation, this weir can serve the purpose for decades to come. At present the structure is intact and the original status, as well as the purpose, is properly maintained. The utility of this weir has only increased with time.

Dhukwan Weir is just 40 Km from Jhansi and has therefore gained popularity as a picnic spot during monsoon. The panoramic views of water falling from the weir attract tourists to spare some time for recreation at this site. Many YouTube videos of the weir and its tourist importance are available. However, the potential for tourism activities can be further enhanced as the Bundelkhand region is known for its heritage sites, religious places and unique culture. Tourists from across India and abroad visit the region. This tourism activity can be leveraged to attract additional activities in the Dhukwan Weir which can also supplement the livelihood generation for local youth.

4.5 GRAND ANICUT CANAL (KALLANAI DAM)

Name	**Grand Anicut Canal (Kallanai Dam)**
Location	**Tamil Nadu, India**
Latitude	**10˚49'48"**
Longitude	**78˚49'08"**
Category of Structure	**Dam**
Year of commissioning	**2nd Century AD**
River Basin	**Cauvery Basin/Cauvery Sub Basin, Vennar Sub Basin, GAC Sub Basin, Thanjavur Coleroon Sub Basin, Anaikarai**
Irrigated/Drained Area	**13,20,116 Acres**

History

Kallanai Dam is the fourth oldest dam in the world, and first in India. It is a rock-solid project that has survived 2,000 years. It was built during the 2nd century AD by Karikalan, a king of southern India's old Chola Dynasty and is also one of the oldest irrigation systems in the world that is still in use.

Description

The purpose of the dam was to divert the waters of the Kaveri across the fertile Thanjavur delta region for irrigation via canals. The Kallanai is an anicut of unhewn stone (not given a finished form by or as if by hewing: rough, unpolished) that stands in the Kaveri parallel to the riverbank; it is more than 300 m long, 20 m wide, and 4.5 m high. It is believed that Kallanai initially irrigated about 69,000 acres, though it now irrigates close to 1 million acres.

The Kallanai dam across the Kaveri River is 329 m long, 20 m wide and 5.4 m high and is constructed from unhewn stones. The anicut was constructed on interlocking technology without cementing material. The unique structure of the Kallanai dam involves large stones sunk in the Kaveri River to divert the water flow to the fertile delta.

Water Heritage

The Kallanai was built to divert floods from the Kaveri branch of the river into the Kollidam branch via a short connecting stream when the water level in the river rose above its crest. The Kollidam was the wider (also the steeper, straighter, and hence faster) of the two river branches and the flood carrier. It was barely used for irrigation. Almost all of the 600,000 acres irrigated by the river in 1800 were delta lands south of the Kaveri branch. So the Kaveri branch was the lifeline for delta farmers, while the Kollidam was of little consequence for them. Once the floods were diverted to the Kollidam, they flowed directly to the sea, causing minimal damage to agriculture. The construction of the dam proved to be beneficial for the farmers of the Cauvery Delta region.

Modernisation works during the British Period

- In 1804, Captain Coldwell repaired the Grand Anicut and provided dam stones 0.69 m in height on its crest and at the same time, raised the river embankment above, ensuring additional water to the Cauvery.
- In 1829, Major Sim proposed under sluices in the Cauvery with outlets into the Coleroon to prevent the accumulation of silt in the upper reaches.
- Improvements were made to the dam in the 19th century by Arthur Cottons, a British general and irrigation engineer. The Lower Anicut built by Sir Arthur Cotton in the 19th century AD across Coleroon (Kollidam), the major tributary of Cauvery, is said to be a replicated structure of Kallanai.
- The word, `Kollidam', means a place that can contain or fit things. It can fit 300000 to 400000 Cusecs of water.

The dam is fast emerging as a tourist spot in the region. It is also home to a large variety of flora and fauna. Bird lovers can observe the bird life in the basin and can take photographs of these beautiful creatures. The dam flaunts a magnanimous panoramic view of the water all around. You will feel relaxed and refreshed in the cool and pleasant climate of the surroundings. People mostly visit the place and have an escape from busy urban life.

In her pioneering study, Dr. Chitra Krishnan combined historical studies of old descriptions of the anicut from a variety of archives with archaeological and anthropological field surveys and original hydraulic research. This enabled her to piece together a picture of the Kallanai. Krishnan's reconstruction suggests that the original Kallanai had some very peculiar design features: the curved shape of the masonry section, a sloping crest, and an irregular descent from front to rear.

4.6 KALINGARAYAN ANICUT AND KALINGARAYAN CHANNEL SYSTEM

Name	**Kalingarayan Anicut and Kalingarayan Channel System**
Location	**Tamil Nadu, India**
Latitude	**11˚26'32.43"**
Longitude	**77˚40'36.14"**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**1285 AD**
River Basin	**Cauvery Basin / Bhavani sub-Basin**
Irrigated/Drained Area	**15,743 Acres**

History

The Kalingarayan channel in Erode Taluk is one of the oldest channels of the Bhavani River and it takes off from the right side of the Kalingarayan Anicut. The Kalingarayan Anicut is also the oldest constructed across the river Bhavani just above its confluence with river Cauvery near Bhavani town about 740 years ago in the pre-British era by one Kalingarayan Gounder a native chief. This is the second and the last Anicut across the river Bhavani below the Bhavanisagar Reservoir.

Description

The Kalingarayan Anicut consists of three parts Main Anicut, Central Anicut and Murian Anicut. The main anicut consists of a length of 231 m, Central Anicut consists of a length of 260 m and the Murian Anicut consists of a length of 411 m. The maximum flood discharge of Kalingarayan Anicut is 126771 cusecs that occurred on 09.12.1972. The High Flood Level of Anicut is +167.035. In the sand vent, there are 3 vents the size of each vent is 6'x4' + 2' semi-circular arch and the sill level of the sand vent is +161.825 m.

The Kalingarayan channel head sluice has a maximum discharging capacity of 584 cusecs in 6 vents the size of each vent is 5'10" x 4'6". The sill level of the head sluice is +162.350 m. The Kalingarayan channel runs for 91 km and irrigates about 15743 Acres of land in Erode, Modakkuruchi and Kodumudi Taluks of Erode District. In the Kalingarayan channel, there are three branches namely the Malayampalayam branch, the Periyavattam branch and the Avudayarparai branch. The crops raised in the Kalingarayan Channel ayacut areas are mainly wet crops such as paddy, Turmeric, Banana and Sugarcane. This irrigation channel carries water for 10 ½ months every year with a closure period of 1 ½ months from 30th April to 16th June of the succeeding year.

Details of the Structure are given below:

- Length of the Main Anicut: 230.73 m (757 ft)
- Average Crest level: +164.93 m (541.13 ft)
- Length of Central Anicut: 260.3 m (854 ft)
- Average Crest level: +165.85 m (544.13 ft)
- Length of Murian Anicut: 411.48 m (1350 ft)
- Average Crest level: +165.475 m (542.9 ft)
- Highest Flood level: +166.420 m (546.0 ft)
- Maximum Flood Discharge: 126771 cusecs

Water Heritage

The Anicut and channel had served for more than 735 years. Till it would serve for many long years. The farmers of the channel are solely dependent on the channel source to cultivate their lands.

The Kalingarayan Anicut is one of the old Anicut of its kind. Only two anicut systems were in existence around 735 years back in the Bhavani River. In earlier days a provoking thought which created by the then-local chieftain Mamannar. Kalingarayan Gounder, who constructed the anicut across river Bhavani. The width of anicut is 902m. A channel named the Kalingarayan channel takes off from the right bank of anicut to a length of 91 Km, which is an earthen channel. This channel serves an ayacut of 15743 Acres. The irrigation channel carries water for 10.5 months a year. This channel caters for the needs of nearly 4000 farmers. The Kalingarayan channel finally confluences in river Noyyal. It is one of the ancient rivers linking projects.

In the fond memory of the Mamannar, Kalingarayan Gounder, the Government of Tamil Nadu constructed a memorial hall at an estimated cost of Rs. 1,65,00,000 in nearby Kalingarayan Anicut.

The Kalingarayan anicut is constructed by the Mamannar. Kalingarayan Gounder was a native chief around 735 years back. The anicut is located at LS 92 km from the Bhavanisagar Dam. Since the local farmers and public of the vicinity are treating this anicut as part and parcel of their livelihood, they all are of spiritual importance to the anicut.

Encroachment around the anicut is less. The anicut and channel serve well and fulfil the needs of the farming community efficiently.

In the head reach of this channel from mile 0 km to 25 km, there are a lot of tanneries, dyeing industries and textile factories functioning near the right side of the Kalingarayan channel. These factories are either directly or indirectly discharging their effluents into this channel. The Erode Corporation domestic sewage water is also directly let out into the channel by residents dwelling nearby the channel. Due to this polluted water, the agriculture fields of this command are very much affected with the resulting yield of crops from these agriculture fields are going on decreasing year by year.

The farmers of the Kalingarayan channel represent their grievance to the government to stop the industrial and domestic effluents that are directly let out into the channel. After accepting the demands raised by the ryots of the Kalingarayan irrigation channel and mitigating the above problem, the Government of Tamil Nadu has accorded administrative sanctions to rehabilitate the Kalingarayan channel in a phased manner.

After completion of this rehabilitation project, the impacts of pollution on water & Agriculture will be mitigated in the Kalingarayan Channel system, besides improving the strength & stability of the channels and also enhancing the functional efficiency of the above channel in the rehabilitation segments. The yield of crops also increased.

4.7 KC CANAL (KURNOOL-CUDDAPAH CANAL)

Name	**KC Canal (Kurnool-Cuddapah Canal)**
Location	**Andhra Pradesh, India**
Latitude	**15.882**
Longitude	**77.829**
Category of Structure	**Canal**
Year of commissioning	**1863-1871**
River Basin	**Tungabhadra river sub-basin in Krishna basin**
Irrigated/Drained Area	**265628 acres**

History

KC canal system is the first-ever artificial conveyance scheme that moves water from the Krishna River basin to the Pennar River basin. The purpose was to alleviate water shortages in the receiving basin for irrigation and drinking water purpose. Due to KC Canal, the water resources were utilised uniformly and economically towards a significant yield output in drought-prone Kurnool and Kadapa districts. Further, it has aided in enhancing irrigation potential, food grain production and achieving socio-economic development in the region.

The Canal is the major source of irrigation in the drought-prone Rayalaseema region of Andhra Pradesh, India. It was constructed between 1863 and 1870 as an irrigation and navigation canal. Initially, the KC Canal was designed for Navigation until 1933. This canal interconnects Pennar and Tungabhadra rivers and is the first-ever interlinking of rivers of two basins in India. It starts from the Sunkesula Barrage located on the Tungabhadra River near Kurnool.

In the middle of the 19th century, the British capital and enterprise entered India's construction of irrigation works. Sir Arthur Cotton, British Engineer, recommended the project comprising irrigation and navigation canals from the Tungabhadra River through Bellary, Kurnool, Cuddapah and Nellore districts, out of which only the Sunkesula – Cuddapah canal section was materialized.

The Sunkesula – Cuddapah canal takes off from an anicut, 30 km above the town of Kurnool, on the river Tungabhadra, which skirts the district of Bellary and joins the Krishna in that of Kurnool. The anicut supplying the canal is built across the Tungabhadra at Sunkesula. It is 1.37 km in length, is founded on a rock, has a clear overfall, and is furnished with a set of under-sluices. The canal enters the Cuddapah district at Suddapalle in Jammalamadugu taluk and, passing through the Proddatur taluk crosses the Pennar at 292 km, and finally discharges into a stream a few miles west of Cuddapah town.

Owing to famine, work in the Kurnool section commenced in 1860. After overcoming administrative hurdles by 1871, the canal was finished throughout its length, though its capacity and efficiency were by no means satisfactory. Over time due to sparsely populated areas and the command area being tracts of heavy black cotton requiring no irrigation, the canal incurred financial loss and created friction between the administration and the community. Ultimately the government purchased the canal and took over its operations. Despite the change in administration and concession irrigation rates, little improvement was shown either in the area irrigated or in the revenue realized. In reviewing the Administration Report of Irrigation Works in the Madras Presidency for 1887-88, the Government of India stated that the revenue expenditure on works and repairs alone was nearly double the income earned by the canal.

In August 1890, a Special Deputy Collector was assigned to enquire about the future possibilities of irrigation under the canal. It proved to be a successful measure with financial gains and expansion of the canal infrastructure. The canal has been a greater success in Cuddapah than in Kurnool, chiefly because the commanded area adapted to irrigation was higher in the Cuddapah district.

Description

Kurnool-Cuddapah Canal (KC Canal) off-takes from Sunkesula anicut on Tungabhadra River, traverses through Kurnool and Kadapa (Cuddapah) districts, and finally terminates at Cuddapah. This canal is connected to the natural streams Nippulavagu, Galeru, Kunderu and Pennar by controlling structures on these streams. Lock-In-Sula, Santajutur anicut, Rajoli anicut and Adinimmayapalli anicut, respectively. Statistics of cultivation under the canal for the five years until 1913 showed that the average annually irrigated area in this district was 28,702 acres, of which nearly 5,000 acres were cropped twice in the year. Connected with the Kurnool-Cuddapah Canal system, two crucial irrigation works known as the Chapad and Maidukuru (Mydukur) projects came into operation in the last decade.

The Chapad channel and its distributaries were extended about 12 miles south-eastwards from Gopavaram, a village three miles north of Proddatur, to the junction of the Kunder with the Penner, with a maximum breadth of about 6 miles between these rivers. The channel was opened for irrigation in 1904 and has at present five distributaries. The Maidukuru (Mydukur) project is named after the village Maidukuru, the northernmost of nine villages situated along the Cuddapah-Kurnool road, which benefited from the project. The Maidukuru (Mydukur) channel takes off from the left bank of the Kurnool-Cuddapah Canal at 171 miles, 40 chaius, and the project was designed to improve this channel to provide the necessary branch channels, and masonry works to irrigate 8,000 acres and to supply water during drought periods.

The traditional navigation system was completely abandoned in 1933, and the canal continues to be a major irrigation source today. To improve the system's efficiency, modernization and reconstruction are under progress to stabilize the entire ayacut of the KC Canal, providing for the gap of 60,000 acres.

K.C. Canal modernisation project was taken up with loan assistance from the Japanese Bank of International Co-operation (JBIC) to rehabilitate the 130-year-old irrigation system. In the recent KC Canal renovation scheme (1994-2012), repairs of structures and canal lining have been implemented, considerably reducing losses and enhancing the actual discharge capacity of the canals. Furthermore, the parallel Srisailam RBC construction to the west of the KC Canal and the Telugu Ganga Canal project on the east side in the same valley produces 'regenerated water' (drainage losses) that flows into the river and can be picked up for KC Canal irrigation. The 'pick up' system has been maintained with periodic repairs of weirs and upgrades of canals through the lining. The engineering discourse on modernisation is about water losses, savings and technical quality and efficiency.

In management terms, the system is treated as any other large-scale irrigation system where integrated water resources management is inherently embedded within the system's design. The canal presently irrigates nearly 1,65,000 acres with 40 TMC (thousand million cubic feet) water utilization from the Krishna River.

Water Heritage

Transbasin transfer by KC canal is socially, economically, ecologically, and technologically sustainable. It holds immense potential to unite the people by emphasising integration, interdependence, and avoidance of fissiparous tendencies. A great boost in growth and development has been witnessed. Its indirect, incidental, multiplier and triggering effects on the benefits stream at the macro level envisaged will be substantial.

Experimenting with Commercial Irrigation Development in Colonial India: The Kurnool-Cuddapah Canal. The first peculiarity of the KC Canal is its location. This canal diverts water from the Tungabhadra River to the Pennar Basin (the KC Canal enters a sub-basin and flows alongside the Galeru and Kundu rivers, tributaries of the Pennar). The navigation objective and suggestions informed this choice on the main canal alignment of the system. However, the founder's vision of connecting India from north to south by waterways remains unfulfilled.

Taking the water over the watershed to a new basin meant that the canal was effectively a source of additional water at the top of a basin. This is unusual as a diversion from rivers for large-scale irrigation schemes is usually made at downstream parts of the river, leaving the hydrology of the upper catchment untouched. The valley of the Galeru and Kundu rivers is also narrow, making the KC Canal Irrigation Scheme a long and narrow scheme. It can be seen that the curvy canal touches and crosses the local rivers several times. A peculiarity of the design is that the river system is used as part of the conveyance system, not only at the main canal level drawn on the map but also at lower canal levels not drawn on the map, where local natural drainage streams are integrated into a water conveyance. The exact considerations for this integration of canal and river and irrigation and drainage functions can only be speculated, as there is no detailed record. Cost reduction is a likely reason. The design discharge for a canal that reaches between two 'pick up' points where the canal touched or crossed the river was calculated based on only the area to be irrigated in that reach. Water for lower reaches moved through the river, to be diverted into the canal at the next 'pick up' point. This saved on canal size and thus constriction costs. Another possible reason is that it translates how canals were constructed in the delta areas shortly before – as extensions of natural streams to a large extent. An effect is that the water use efficiency at the scheme level is likely to be high – water 'lost' in drainage canals remains within the system.

A crucial managerial implication is that the KC Canal is effectively compartmentalized. The irrigation water entering the sub-basin at the top does not have to pass through the whole irrigated area to reach the lower, downstream part of the irrigation scheme. Irrigation water is conveyed through the river bypassing irrigated areas from the Lockin Sula diversion. This allows a level of managerial flexibility. KC Canal is the only system in India constructed in this manner. The concept has not been repeated. Rather than a conscious concept, the peculiar design may have been the unintended consequence of a series of other considerations and conditions: the navigation, cost reduction, and the narrowness of the valley.

4.8 LARGE TANK (PEDDA CHERU)

Name	**Large Tank (Pedda Cheru)**
Location	**Telangana, India**
Latitude	**18.311**
Longitude	**78.334**
Category of Structure	**Water Storage Structure**
Year of commissioning	**1897 (Restored)**
River Basin	**Godavari**
Irrigated/Drained Area	**858 acres**

History

The Large Tank is a minor irrigation source with a command area of about 350 ha covering 44 villages, i.e. Kamareddy, Sarampally, Kyasampally and Ugrawai of Kamareddy Mandal. The tank also provides drinking water to Kamareddy town and irrigation water to the agricultural fields and provides livelihood to the fishermen communities. This largest lake, popularly known as Pedda Cheruvu located on the outskirts of this district headquarters town, is spread over 618 acres. The lake has been in existence since the Nizam's Era, which was built in 1897 during the rule of Mir Mahaboob Ali Khan, the sixth Nizam of Hyderabad State.

Description

The tank has a 1.8-km-long tank bund and 145-m weir with three sluices, with one located at the weir. The weir is located on the left flank. The height of the maximum body wall is 3.75 m, and the length of the weir is 145 m in masonry. The maximum flood discharge is 8,860 cusecs. The length of the bund is 1,800 m, and the maximum height of the bund is 14 m. The capacity of the tank is 4.86 MCM, and the water spread area of the tank is 3.05 km^2. The catchment area spans over 68.97 km^2. There is a pickup weir located downstream from where water is supplied to the agricultural fields.

Water Heritage

With a capacity of 0.175 TMC, it provides water for irrigation to over 900 acres in Kamareddy, Sarampally, Narsampally, and old Rajampet. It also provides drinking water for residents of the area and promoted livelihood avenues like fishing. The project has served its intended design purpose.

The large tank has become an integral part of people's lives. From drinking water, irrigation water increased incomes its presence can also be seen in cultural traditions. Womenfolk plays *Bathukamma* (traditional songs) during the *Navaratrotsavalu* (festival) on its bund and immerse them in its waters. More recently, it has been developed as a recreation spot for residents and has a panoramic view of nature. The lake also enjoys a wide variety of flora and fauna, including migratory birds in the winter, thus positively contributing to the environment.

Sustainable maintenance and operations mechanisms are the main reason behind its sustainability over the years like the restoration works to improve the storage capacity and eliminate silt accumulation in the tank bund (>3m). Presently, the tank is providing water for irrigation and drinking purposes, and some preservation work of the mini tank bund is in progress.

4.9 LOWER COLEROON ANICUT SYSTEM

Name	**Lower Coleroon Anicut System**
Location	**Tamil Nadu, India**
Latitude	**110 06' 00'' N**
Longitude	**790 39' 00'' E**
Category of Structure	**Anicut**
Year of commissioning	**1836**
River Basin	**Cauvery Basin & Lower Coleroon Sub-basin**
Irrigated/Drained Area	**1,31,903 Acres / 29613 Sq Miles**

History

The Lower Coleroon Anicut has got a hoary past. It was constructed by Sir Arthur Cotton, the most illustrious Engineer of the period 1827 – 1836. The Lower Anicut was constructed in the year 1836 across the Coleroon River downstream of Upper Anicut at the 67th mile, where the Coleroon river Branches off from River Cauvery.

This Anicut is intended for the benefit of 1,31,903 Acres of land in the Thanjavur, Nagapattinam and Cuddalore districts. The irrigation needs will be met mainly from the regenerated Cauvery water and by supplementing supplies direct from Grand Anicut. Irrigation Supplies for three crops Viz. Kuruvai, samba and Kullakar will have to be given for the Ayacut under this system. This anicut system, therefore, functions effectively throughout the year except for a month of closure period for carrying out the maintenance repairs to the anicut and shuttering arrangements. Although the lower anicut is 187 Years old, it is still magnificently maintained by the maintenance work done on it in different eras.

Description

In this Lower Anicut, the surplus arrangements are made in two arms: North Branch Regulator (Length 372 m) and South Branch Regulator (Length 493 m). The North Branch Regulator consisted of 30 Nos of Vents with a span of 10.16 m and height of 2.75 m and was fully equipped with an electrified motor for operating arrangements. The South Branch Regulator consists of 40 Nos of Vents with a span of 10.16 meters and a height of 2.75 m with an electrified motor for operating arrangements.

The Regulator has been designed to discharge 450000 Cusecs of flood water. The maximum flood observed was 3,85,751 c/s in the year 8.7.1924 and in the year 1961 -1,77,415 C/s in 1972 -1,06,334 C/s, in 1977 -1,51,315 C/s in 1979 -1,74,594 c/s, 2005 -3,35,016 C/s in 2007 -1,17,023 C/s, in 2008 -1,09,428 C/s and 18.08.2018 – 2,19,707 C/s respectively. Therefore, to discharge the unprecedented flood in the forthcoming monsoon, it is essential to electrify the operating system for effective control and monitoring of floods. Anaikarai Bridge is located at Km 100/6 of NH – 45c - Vikkravandi –Kumbakonam - Thanjavur Road and is under the maintenance of NHAI Near Anaikarai village of Thanjavur District.

Water Heritage

The river Cauvery originated in Kudagu hills in Karnataka state, travelling 589 km and finally confluence in the Bay of Bengal in two places, Coleroon River confluence in Kodiyambalayam village, and Cauvery River confluence in Cauvery Poompattinam.

On the left side of the Coleroon River, 23 km away, the huge historically famous Veeranam Lake was formed by the Aditya Chola tenure 1011 to 1037. The Chola king managed to excavate the link canal from the Coleroon River to the Veeranam tank using soldiers. Ancient Veeranam Lake is fed by Vadavar and filled with water. With the help of bamboo and available local vegetation, clay balls used to make the Temporary Coffer Dam was built slightly across the river year by year to fill the Veeranam Lake and cultivate the field that flows into the Coleroon River. Sometimes heavy floods in the Coleroon River drowned and overwashed the Temporary Coffer Dam at the time Drought occurred in the area of the premises.

In the situation English Engineer Sir Arthur Cotton, while inspecting the river at Coleroon, was amazed to see the structure of the Corombu (Temporary coffer Dam) built across the river as well as the structure of the corombu and decided to build the gorge across the narrow passage where the fort was built across the river. He decided to use the raw material (Stones) on the distressed compound wall of the Gangai Konda Cholapuram temple created by King Rajendra Chola and the over-reserved stones and dedicated the construction of the northern passage from 1827 to 1831 and the southern passage from 1831 to 1836. An example of this is the construction of a similar structure called the Upper Anicut. Therefore, it is proposed that the tomb can be considered an ancient symbol as it has been majestically displayed and fruitful for over 184 years.

Furthermore, it is proposed that the canopy built by the English Engineer Sir Arthur Cotton may be considered a monument, although it has fallen into disrepair and is still flourishing today. It is proposed to consider the Inspection Bungalow, Assistant Executive Engineer office and Resident, which was built about 30 feet above the river bank at the time of the construction of the canal, as an ancient symbol as it is well maintained and in use till date.

The first bridge to be built along the 108 km stretch of the Coleroon River is the Lower Anicut Bridge, the only bridge in use for 184 years to reach the southern districts of Chennai using via Lower Anicut Bridge. In the south branch, the bottom ten sluice arch gates were erected in 1924; the horizontal girders fixed (beam) of the bridge were made of steel imported from England and still stand majestically to this day.

The Lower Anicut surplus water was drained by a river with the river confluence with the Bay of Bengal, and the sea fish spread up to Lower Anicut. As a result, plenty of fish was available in the lower Anicut, and a fish-catching culture was developed in the nearby villages. A very old, famous fish market functioned in Lower Anicut.

The 6 km long ellipse shape islands between the Northern and Southern parts of the island are used as tourist destinations without being submerged by all the floods. The Lower Anicut road bridge is 184 years old monument arch bridge. Furthermore, the bridge at the bottom became a very large shape of an arch. Its length is 10.16 m (33.4 ft). And its height arch is 18 ft (Grown Height). Still the old arch bridge but used by transport.

The Lower Anicut was built with in-depth engineering and experiential knowledge. Only if the management manages the floodplain in Cauvery will it be the best vulnerable to the general public, and in case of failure, the height of the +16.875 m of the embankment at the bottom will affect the people. If the dam is closed during the +21.50 m flood season. The banks will break, and the water shortage will be alleviated due to the low rainfall during the rainy season.

Also currently maintained capacity height 2.75 m or 9 feet not immediately built, very first 2 feet next 4 feet again raised 6 feet in 1950 raised 8 feet. Raise the blow and study the consequences and present: Flood water is discharged without any harm to the public during floods. Currently, the water reservoir, a 2.75 m shutter, lifts above the height of the arch bridge over the river to safely discharge 4.50,000 cubic feet of flood water, the affects the bridge (Deck Bridge) designed.

The bed level height is designed to carry the stagnant water to the seven main irrigation canals and the seven main lakes with a horizontal elevation of +46,34"+ 9'ft = 55.34" ft. Veeranam Lake was chosen 184 years ago by a forensic expert to provide enough water for irrigation and to supply drinking water to Chennai, 240 km away.

Nature of the earth, which is usually sloping from north to south, unnatural lower Anicut located south side, they discharge the water flow Northeast feed into Veeranam tank, Veeranam tank feed North end Sethiyathope Anicut and Chennai metro water, Sethiyathope Anicut feed north of Wallajah tank, Wallajah tank feed Perumal tank through the Paravanaru river, Perumal tank water confluence in Bay of Bengal near Cuddalore OT above chain of activities depend on chosen bed level of Lower Anicut. Currently, efforts are being made to connect the rivers. But for the past 184 years back, the river has been an example of downstream connections connecting the Cauvery and Vellar Rivers.

The Flood water indirectly facilitates multiple thousands of acres. It is also set up to facilitate groundwater supply and flood drainage main purpose of Irrigation. In case of heavy flood discharged in Coleroon River at the bottom of foundations, and aprons of Lower Anicut, Public Works Department workers find any crumble that is protected from damage by repairing it immediately.

An earth cushion was placed on the upper part of the arch on the Lower Anicut bridge, and a road was built on it to facilitate vehicular traffic. In some places, the earth's cushion caused damage to the surface. After examining this, the first cement road was laid from the left bank to the right bank in the year 1941. Up to 1950, 6 feet of water was stored and supplied for irrigation. From time to time, there was a shortage of water, and to rectify it, the 8 feet storage height raised water and provided for agriculture and irrigation.

The shutter height, which was 8 feet from 1950 to 1973, was again raised to 9 feet in 1973 and 1980 due to a shortage. To this end, the old Deck Bridge was raised in the new development plan as it could only be protected from flooding, and the water could be stored up to 8 feet 9 feet in height. Somewhere, floods passed lower Anicut due to some cracks developed in the bottom parapet and piers. The instant was conveyed to Cauvery technical cell chairman Thiru A. Mohana Krishnan, leader, then carefully inspected various parts of the lower Anicut bridge on 09.05.2009. Advised that Guniting work can be carried out to repair cracks in the pillar area, and traffic was restricted from two-way traffic to one-way traffic. With the aid of NABARD bank, the works carried out satisfactorily better lower anicut bridge came out of use.

After that, somewhere flood passed the lower anicut North and South Branch apron disturbed by flood and crocodiles. The DRIP Dam Safety Review Panel Engineers inspected affected the southern and northern branch Apron crocodiles by digging small ditches during the 2012 floods they did. It was implemented and maintained by the DRIP work in 2016 - 2017. Extreme levels of flood danger were announced in at least 2,22,000 cubic feet on 17.08.2018. Heavy vehicular traffic was temporarily banned due to the age of the bridge and the extent of flooding. In such an environment, the Chief Engineer's Committee of the Public Works Department advised that reputed educational institutions such as should be allowed to inspect the durability of the bridge and allow vehicular traffic, considering the usage of water supply for agriculture on the lower anicut bridge due to the collapse of the Upper Anicut Bridge built by Sir Arthur Cotton, who built both, at time contemporaries on 24.08.2018. Much of the maintenance work was carried out on a war footing basis at various stages, but despite all the contemporary bridges built with it collapsing, the lower bridge still looks majestic and is still in use today.

4.10 PORUMAMILLA TANK (ANANTHARAJA SAGARAM)

Name	**Porumamilla Tank (Anantharaja Sagaram)**
Location	**Andhra Pradesh, India**
Latitude	**15.014**
Longitude	**79.021**
Category of Structure	**Water Storage Structure**
Year of commissioning	**1367-1369**
River Basin	**Maldevi River sub-basin of Pennar basin**
Irrigated/Drained Area	**4031.29 acres (1631.41 ha)**

History

During ancient times, the Porumamilla tank (also called Anantharaja Sagar) was built by Prince Bhaskara Bhavadura of the first Vijayanagara dynasty. The inscription on two slabs set up in front of the ruined Bhairava temple at Porumamilla throws light on the history of the tank. The inscription gives complete details of this tank, the place, and the time of its construction. It states that 1,000 labourers worked for two years to complete the construction, and 100 carts were engaged in getting stones for walls which formed a part of the masonry work. Inscriptions also mention twelve essential elements to consider while constructing a dam for water storage (Verse 37), like clay soil, river water, deep river beds, and skilful masons. Further, six defects (doshas) may arise due to faulty construction of tanks (Verse 38). Some of them were leakages, saline soil, transboundary issues, and scanty water supply.

A linear measurement system called "Rekhadanda" was developed for measurements of bund length, height and width. A Rekhadanda was equated with being 1.25 yards, the distance between the top of the shoulder of one arm to the tip of the middle finger of the other arm measured along the chest for an average man. In the inscriptions, the tank's length, width, and height were 5,000, 8 and 7 Rekhadandas, respectively.

Description

Porumamilla tank, with a command area of 3,864.67 acres, is situated about 3.2 km to the east of the village called Porumamilla in the Rajampeta Revenue Division of YSR Kadapa district in Andhra Pradesh. The tank is elongated in shape, being 11.26 km long and 4 km wide. The bund consists of four natural hills, connected by three short earthen dams, riveted with Cuddapa Slabs. The western flank thus consists of the range of hills that runs north and south between Porumamilla and Badvel. The total length of the artificial bund is about 1.37 km, and the total length, including bills about 4.26 km. At the deepest portion, the bund is 3.65 m wide at the top and 45 m at the bottom, and about 10 m deep. The tank has two sources of supply, one natural and the other artificial. The latter was constructed only recently. The natural feeder is a stream called the Maldevi River. The reservoir is provided with four sluices, two of which have been repaired in recent times and provided with screw gear, and there are five weirs to discharge runoff. The tank provides drinking water facilities to 21 villages and irrigation facilities to 4,031 acres of farmland. Crops grown in the command area are paddy and groundnut.

Traditionally, these water bodies have played an important role in supplying drinking water for domestic needs and agricultural purposes. Realizing their importance, the government initiated several programmes to revive water conservation systems like the Porumamilla tank. Over the years, silt accumulation reduced the tank's water-holding capacity. Restoring tanks through such programmes increased their water-retention capacity by de-siltation, thus improving on-farm moisture-retention capacity.

The Government of Andhra Pradesh has undertaken Repair, Renovation and Restoration (RRR) of the historical Porumamilla tank to revive, restore and rehabilitate the traditional water body. Recent rehabilitation works include the reconstruction of breached bund due to floods, the replacement of leaky old sluice gates and repairs to the main channels and watercourses. These restoration works have multiple objectives like comprehensive improvement and restoration of water bodies, thereby increasing tank storage capacity, groundwater recharge, increased availability of drinking water, improvement in agriculture/horticulture productivity, improvement of catchment areas of tank commands, environmental benefits through improved water use efficiency by the promotion of conjunctive use of surface and groundwater, community participation and sustainable management. Efforts are made to build the capacity of communities for better water management and the development of tourism, and cultural activities. Another important issue is an encroachment on the foreshore of the tank in the form of temporary and permanent structures. The Government took several initiatives to prevent encroachment with the active involvement of local bodies to reduce the encroachments and safeguard the water bodies.

At present, the Porumamilla tank is being used as a balancing reservoir for Telangana Project apart from providing drinking water facilities to villages and irrigation facilities to the contemplated tank command area. Holistic efforts are required to preserve and conserve the historical Porumamilla Tank.

Water Heritage

A historic structure like the Porumamilla tank has a universal value from the historical and irrigation point of view. Passed over many generations, it guides the younger generations who can learn from their ancient irrigation practices and build upon their legacy. These heritage structures attract tourists from different parts of the country and add to the revenue for the government. The Porumamilla tank built in the medieval period (13th Century) is an indigenous tradition of irrigated agriculture that exemplifies the technical and managerial expertise that kept the infrastructure functioning. Such indigenous systems represent sustainable solutions in the face of intensive crops, increasing population and adaptability. They understood and promoted crop-water-soil relationships that helped in achieving self-sufficiency in food production in drought-prone areas.

Engineering features of the indigenous systems such as river diversion weirs, intake canals, structures to control the flow within the canal, construction of sluices and division structures to divide the flow in fixed proportions are evidence of sophisticated technical knowledge carried on from many generations. Other challenging engineering features include the degree of slope, the alignment and layout of canals, and the detailed designs of structures that may appear ad hoc but contain particular design principles (e.g., the angle, depth, and construction materials used in a river diversion weir).

The concept of Rekhadanda was introduced for linear measurement during this period. The knowledge reflected in the physical features of indigenous irrigation systems and their management strategies is a centuries-long learning process through which a harmonious relationship could be maintained between the community and the environment.

4.11 RUSHIKULYA IRRIGATION SYSTEM

Name	**Rushikulya Irrigation System - 1. Russelkonda Reservoir (Bhanjanagar Reservoir), 2. Sorada Reservoir, 3. Janivilli Anicut, 4. Madhabarida Anicut (Ghumusar Anicut)**
Location	**Telangana (Pochampad City), India**
Latitude	**19°58'16» N - Russelkonda Reservoir (Bhanjanagar Reservoir) 19°45'58" N - Sorada Reservoir 19°40'12" N - Janivilli Anicut 19°51'10" N - Madhabarida Anicut (Ghumusar Anicut)**
Longitude	**84°34'17» E - Russelkonda Reservoir (Bhanjanagar Reservoir) 84°25'17" E - Sorada Reservoir 84°33'46" E - Janivilli Anicut 84°40'43" E - Madhabarida Anicut (Ghumusar Anicut)**
Category of Structure	**Irrigation System**
Year of commissioning	**1894 - Russelkonda Reservoir (Bhanjanagar Reservoir) 1896 - Sorada Reservoir 1891 - Janivilli Anicut 1891 - Madhabarida Anicut (Ghumusar Anicut)**
River Basin	**Rushikulya Basin / Badanadi Sub-Basin - Russelkonda Reservoir (Bhanjanagar Reservoir) Rushikulya Basin / Padma Sub-Basin - Sorada Reservoir Rushikulya Basin- Janivilli Anicut Rushikulya Basin / Badanadi Sub-Basin - Madhabarida Anicut (Ghumusar Anicut)**
Irrigated/Drained Area	**983 Ha (64 km^2) - Russelkonda Reservoir (Bhanjanagar Reservoir) 43 km^2 - Sorada Reservoir 52675 Ha (1813 km^2) - Janivilli Anicut 8146 Ha (2255 km^2) - Madhabarida Anicut (Ghumusar Anicut)**

History

Rushikulya Irrigation System: It is an integrated project constructed in 1891 by the British Empire to mitigate the drought problem in Ganjam District. It consists of (1) Bhanjanagar reservoir across Baranga Nalla, a tributary of Badanadi near Bhanjanagar, (2) Sorada reservoir on a small Nalla near Sorada, (3) Sorisamuli Anicut across river Badanadi, a tributary of Rushikulya at Sorisamuli to divert the water of Badanadi to Bhanjanagar Reservoir (4) Padma Anicut across river Padma, a tributary of Rushikulya at Sorada to divert the water of Padma to Sorada reservoir (5) Madhabarida Anicut across river Badanadi near Madhabarida to divert Badanadi water to Janivilli Anicut. (6) Janivilli Anicut at Janivilli across river Rushikulya diverting water for providing irrigation through Rushikulya Main Canal. Out of the above, the renovation of Sorada Reservoir and Bhanjanagar Reservoir was taken up under DSARP in the year 1999 by raising of FRL of both the reservoir and replacement of fall board shutters of Spillway of both the reservoir by un-gated ogee spillway for Sorada Reservoir and vertical gated spillway for Bhanjanagar Reservoir. The Padma Anicut & Sorisamuli Anicut were replaced by the construction of a new Barrage under DSARP.

Description

Salient Features of Bhanjanagar Dam

Completed in 1894, the Bhanjanagar Dam is located on the Rushikulya Basin / Badanadi Sub-Basin with a catchment area of 74 km^2 in the Bhanjanagar Tehsil of Ganjam district in Odisha state. The dam was rehabilitated in 1999-2000.

The salient details of the Sorada Dam Reservoir pre- and post-rehabilitation are given below:

	Pre-Rehabilitation of the Dam	Post-Rehabilitation of the Dam
Bhanjanagar Dam Reservoir		
Top Bank Level of Dam (M)	98.30	100.00
Maximum Water Level (M)	95.70	96.60
Full Reservoir Level (M)	95.10	96.00
Minimum Draw Down Level (M)	80.77	80.77
Live Storage Capacity (Ham)	4700	5766
Water Spread Area at MWL (Ha)	891.13	1000
Water Spread Area at FRL (Ha)	822.58	931
Freeboard over FRL (M)	4.5	3.2
over MWL (M)	3.9	2.59
Bhanjanagar Dam (Homogeneous Rolled Earth Filled Dam with Puddle Core)		
Total length of dam (M)	1310.60	1310.60
Deepest foundation Level	78.95	78.95
Maximum Height of dam from deepest foundation level (M)	19.35	21.55
Top width of the dam (M)	3.05	4.75
Slope U/S	0.75:1 & 2:1	0.75:1 & 2:1
Slope D/S	1.5:1 & 2.5:1	2:1 & 2.5:1

Salient Features of Madhaborida Anicut

Completed in 1891, the Madhaborida Anicut is situated on the Badanadi and Loharakhandi Rivers with a catchment area of 2255 km^2 in the Bellaguntha Tehsil of Ganjam district in Odisha state.

The salient details of the Madhaborida Anicut are given below:

- Length of Anicut: 535.25 ft.; Crest Level of Anicut: 190.20 ft.; Top Level of falling Shutter: 193.20 ft.
- Details of the Canal:
- Off-taking right (Mahanadi canal): Length of the canal: 30.50 Km; Cultivable Command Area: 5455 Ha; Discharge: 828.17 cusecs
- Off taking left (Girisola canal): Length of the canal: 31 Km; Cultivable Command Area: 2691 Ha; Discharge: 78.5 cusecs

Salient Features of Sorada Dam

Completed in 1896, the Sorada Dam is located on the Padma River with a catchment area of 43 km^2 in the Sorada Tehsil of Ganjam district in Odisha state. The dam was rehabilitated in 1999-2000.

The salient details of the Sorada Dam Reservoir pre- and post-rehabilitation are given below:

	Pre-Rehabilitation of the Dam	Post-Rehabilitation of the Dam
Sorada Dam Reservoir		
Top Bank Level of Dam (M)	94.500	95.900
Maximum Water Level (M)	90.670	93.200
Full Reservoir Level (M)	90.220	92.300
Minimum Draw Down Level (M)	81.100	81.100
Live Storage Capacity (Ham)	3100	4975
Water Spread Area at MWL (Ha)	753	987
Water Spread Area at FRL (Ha)	732	910
Freeboard over FRL (M)	4.280	3.600
over MWL (M)	3.830	2.700
Sorada Dam (Homogeneous Rolled Filled Earth Dam)		
Total length of dam (M)	5500	5815
Deepest foundation Level	78.000	78.000
Maximum Height of dam from deepest foundation level (M)	16.500	17.900
Top width of the dam (M)	3.00	4.00
Slope U/S	3.1	3.1 and 2.1
Slope D/S	2.1	2.1
Dyke		
Length (M)	-	105
Deepest Foundation Level (M)	-	89.080
Top Level (M)	-	94.000
Top Width (M)	-	4.00
Slope U/S & D/S	-	2.1

Salient Features of Janivilli Anicut

Completed in 1891, the Janivilli Anicut is situated on the Rushikulya River Basin with a catchment area of 1813 km^2 in the Dharakote Tehsil of Ganjam district in Odisha state.

The salient details of the Janivilli Anicut are given below:

- Length of Anicut: 810.00 ft.; Crest Level of Anicut: 168.50 ft.; Top Level of falling Shutter: 171.50 ft.
- Details of the Rushikulya Main Canal (Off-taking from Right Side): Cultivable Command Area: 52675 Ha; Length: 87.417 Km; Discharge 46.439 Cumecs

Water Heritage

Rushikulya Irrigation System is a well-planned integrated System comprising two medium size reservoirs and four numbers of Anicut. The District of Ganjam, previously under Madras' presidency during British Rule, was a chronic drought-affected district. It was severely affected by famine during 1865-66, and 60,000 people perished either of starvation or of diseases induced due to starvation. Again, a similar famine occurred during 1871-72. Given this, the then British Ruler of India deployed Major Buckley, a Civil Engineer, to study the feasibility of an irrigation project by harnessing the water of river Rushikulya and its tributaries. Major Buckley made a detailed survey of the upper reaches of river Rushikulya and its tributaries and submitted a report to Govt. of India. While the Project was still under investigation, again, one more famine was apprehended in 1879 and Govt. of India sanctioned the project in their letter No. 266-1 dating. 06.06.1883 as famine protection work. The work of the project started in 1884. The cost of the project was revised thrice, and the project was completed in the year 1896, providing irrigation to 43,423.715 Ha in Kharif. The capital account of the Project was closed on 31.03.1901.

This is a century-old integrated project. This project has made an outstanding contribution to the socioeconomic development of the Ganjam district. Gradually food production increased, and famine eroded in this area. People got opportunities, got livelihoods, got prosperity above all, got life. Now the district is well known for its food grain production and its export. Agriculture forms the backbone of the district's economy, with more than 70 % of the population being dependent on it. The agricultural sector supplies about 75 % of the total workforce of the Ganjam District, and this historic Rushikulya irrigation system plays a major role in it.

During a severe cyclonic storm, TITILI and subsequently flood on 11.10.2018, the different components of Janivilli anicut such as the d/s apron, left-wing & retaining wall, the stone masonry cut-off walls and left embankment were damaged severely. As per the request of the Chief Engineer & Basin Manager, RVN Basin, the technical committee inspected the site on 17.12.2018 and suggested the following remedial measures.

(1) 1st d/s apron of length 14.5 m along the river, which was constructed with the random stone, has been washed away for the length of 64 m in the middle portion. The ditch created shall be filled up with compacted coarse sand duly watered and rammed and over which an inverted filter with 0.3 m sand and 0.15 m 20 mm CA & 0.15 m 40 mm CA shall be provided. Over the inverted filter, PCC (M-20) of 0.09 m thickness shall be provided with the provision of drainage holes. On the left side, for a length of 31.7 m, the 1st portion of the concrete apron has been undermined due to scouring of the d/s portion. The undermined portion is to be dismantled and made good following the same process.

(2) The 2nd d/s apron portion for a length of 24.5 m along the river has been washed away for a length of 118 m. The ditch created is to be filled up with compacted sand duly watered and rammed and over which an inverted filter with 0.3 m sand and 0.15 m 20 mm CA & 0.15 m 40 mm CA shall be provided. Over the inverted filter, the entire area shall be covered with a stone of thickness 0.9 m collected from the deposited stones on the d/s area.

(3) The 3rd d/s apron portion for a length of 20.7 m along the river, which has also been washed away for a length of 122 m, may be filled up with sand upon which stone packing of 0.6 m shall be done.

(4) The aprons are to be made as per the prevailing slope. The complete apron shall be made with alternate blocks of size 3m x 3m.

(5) A cutoff wall is to be provided at the end of the 3rd d/s apron.

(6) PCC cubes of M20 A40 with a size of 1.5 x 1.5 x 0.9 m above 0.6 m Stone layer of five rows leaving 75 mm gaps in between in staggered manned are to be provided. The gaps are to be filled up with Bajri /6 mm CA. A curtain wall of 1.8 m depth is to be provided in the d/s of CC cubes.

(7) The damaged left-wing wall and retaining wall may be reconstructed as RCC retaining walls over the pile foundation, providing a pile cap below the design scour level.

4.12 SADARMATT ANICUT

Name	**Sadarmatt Anicut**
Location	**Telangana (Pochampad City), India**
Latitude	**18.835**
Longitude	**78.642**
Category of Structure	**Anicut**
Year of commissioning	**1891-1892**
River Basin	**Godavari (G5)**
Irrigated/Drained Area	**6848 acres (2771.29 ha)**

History

The Sadarmattt anicut was constructed from 1891-92 across river Godavari on the left arm in Khanapur Mandal of Nirmal District by French Engineer J.J. Otlay. The anicut was built in two arms separated by a high mound and consists of a masonry structure 2 m high with a length of 437.4 m on the left flank and 23.8 m on the right flank. The left-arm supplies water to the left flank Khanapur channel to irrigate 6,048 acres of land in the Khanapur and Kaddam Mandals of the Nirmal district and feed 350 cusecs to Kaddan Reservoir. The right arm supplies water to the right flank Badankurthy channel for irrigating 800 acres in Badankurthy village of Khanapur Mandal of Nirmal district.

Description

The main canal traverses through a length of 21.53 km with an irrigation potential of 5,048 acres in two villages. A cross regµlator and a feeder channel of 3.5 km were constructed for the Kadam reservoir. The left canal becomes a distributory and traverses through a length of 12 km with an irrigation potential of 1000 acres benefiting seven villages under Kaddem Mandal. The right canal traverses through a length of 10 km with an irrigation potential of 800 acres benefiting Batlankurthy village under Khanapurmandai. There are 166 direct pipes to irrigate an *ayacut* (area) of 6,848 acres.

Water Heritage

The oldest known anicut constructed over the Godavari River for irrigation played a vital role in the agricultural development of the region, enhancing yields, increasing water availability, and regional development. The Sadarmutt anicut irrigated crops of the Kaddam and Khanapur Mandals that lie in the Adilabad district. Anicut and canal system provided irrigation to about 2,775 ha of farmlands. Though about 2775 ha was under its command, in actuality, the anicut irrigates more than contemplated ayacut. The Anicut receives the regenerated water downstream of the Sri Ram Sagar Project Dam, Kakatiya Canal and Saraswathi Canal command areas, thereby serving the ayacut under the Sadarmatt throughout the year.

Even today, the anicut is functioning and providing water for irrigation in the designated fields. It has withstood the challenges of urbanization, industrialization, increased demands and natural wear and tear. The project and structure are well preserved and fulfilling its contemplated design.

The irrigation system is a unique cultural representation of the region's history. The name Sadarmattt anicut itself is formed from two different languages. Anicut is an English word for Telugu's ana-katta, meaning a rainfall bund, while Sadarmatt is the region it is placed in. The system presents the beautiful milieu of two cultures from the region's rich history.

Currently, the anicut is a popular tourist destination due to its natural surroundings. The dam has been built at an idyllic location amidst green grasslands and sparkling clear waters. It has also served as a picnic spot spread over old undivided Adilabad, Karimnagar and Nizamabad districts. Due to its sustainable operations and maintenance mechanisms, the anicut is functional and adds to the historical and scenic beauty.

4.13 SIR ARTHUR COTTON BARRAGE (DOWLESWARAM ANICUT)

Name	**Sir Arthur Cotton Barrage (Dowleswaram Anicut)**
Location	**Andhra Pradesh, India**
Latitude	**15°0'52"N**
Longitude	**79°1'15"E**
Category of Structure	**Barrage**
Year of commissioning	**1852**
River Basin	**Godavari River at Dowleswaram**
Irrigated/Drained Area	**10,09,009 Ac (408331 ha)**

History

The Sadarmattt anicut was constructed from 1891-92 across river Godavari on the left arm in Khanapur Mandal of Nirmal District by French Engineer J.J. Otlay. The anicut was built in two arms separated by a high mound and consists of a masonry structure 2 m high with a length of 437.4 m on the left flank and 23.8 m on the right flank. The left-arm supplies water to the left flank Khanapur channel to irrigate 6,048 acres of land in the Khanapur and Kaddam Mandals of the Nirmal district and feed 350 cusecs to Kaddan Reservoir. The right arm supplies water to the right flank Badankurthy channel for irrigating 800 acres in Badankurthy village of Khanapur Mandal of Nirmal district.

Description

Godavari Delta System (GDS) is an established old Irrigation System in operation since 1852. The old anicut was constructed on River Godavari by Sir Arthur Cotton during 1847-52, which has served the delta system for more than a century. As it was showing signs

of distress, the anicut was replaced by Sir Arthur Cotton Barrage (S.A.C.B.) during the years 1970-82.

Genesis of the Project

Towards the end of the first half of the 19th century, life in the Godavari Delta regions had fallen into a sad case. The abolition of the East India Company's factories (related to cloth trade) due to competition from Manchester & European looms has drastically diminished the socio-economic conditions of the region. In 1832-33 a terrible famine ravaged the area, followed by three unfavourable years, 1835-36, 1836-37, 1837-38, followed by the calamities of 1838-39,1839-40 and almost equally calamitous season of 1840-41. It is known as 'Dokkala Karuvu' (only ribs are seen without any flesh). It is said that a third of the population perished during the same period. Later, while describing the above acute condition Lady Hope (daughter of General Sir Arthur Cotton) writes that children were sold for 'Two Annas' like other commodities in the farmers' markets to survive. The then Govt has responded to the above calamitous situation and deployed its ablest Administrators (Mr. Montgomerry) and Engineers (Sir Arthur Cotton) and provided the necessary Administrative sanctions for the construction of GDS & KDS. The sanctions included major items like Anicuts across the rivers, Irrigation canals, Aqueducts, channels & sluices, flood banks, river training works, Roads and bridges etc.

Construction of Sir Arthur Cotton (SAC) Barrage

The old anicuts consisted of anicuts in four arms of river Godavari near Dowlaiswaram with a crest level of +36.00 ft, and the irrigation potential originally envisaged in the year 1852 was 6.12 lakh acres. From 1862 to 1867, the crest of the anicut was raised to +38.00 ft, but the ayacut brought under cultivation by then was 4.36 lakh acres; only 2 ft falling shutters were installed, raising the crest level to +38.75 ft in 1898, increasing the Ayacut to 6.40 lakh acres. Even this level was found inadequate to meet the rapid expansion of irrigation, and during 1936, the Ayacut increased to 9.81 lakh acres with the introduction of 3.00 ft falling shutters. Due to the increased water level on the anicut and ageing, the soundness of the structures deteriorated. Extensive damages took place to the left end of Ralli anicut during the floods of 1963. The Geophysical investigations revealed that the anicuts are in a precarious condition due to the undermining of foundations. Due to the dilapidated condition of the old anicut, SAC Barrage was constructed during 1970 –1984. The pond level of the Barrage is +13.64 M. The Godavari Barrage Project includes the construction of new head sluices for all three main canals with silt elimination measures in canals.

Water Heritage

(1) Irrigation development and agricultural perspective in Andhra Pradesh to make it Annapurna (Goddess of Food) and Rice bowl of India

Agriculture and irrigation are the backbone of the economic development of the country. The state of Andhra Pradesh has a heritage of irrigated agriculture dating back several centuries. In the past, during the periods of Kakatiya and Vijayanagara kingdoms, several tanks, canals and diversion systems were constructed and dug wells which are still operating, and productive increase in agricultural production and productivity depends to a large extent on the availability of water. In 1832-33 a terrible famine ravaged the Godavari districts, followed by three unfavourable years, 1835-36, 1836-37, 1837-38, followed by the calamities of 1838-39,1839-40 and almost equally calamitous seasons of 1840-41. With frequent famine-affected and devasted by the cyclone, 1/3rd of the population perished during the times without food and shelter. The command area of the old anicut has been under irrigation for over 120 years and has a well-organized water distribution system. The host of the irrigable land has been levelled and cropped for a very long time. Rice is by far the most important crop in the delta region. There are two crops of irrigated rice, namely, (a) wet season or "Kharif", which is usually sown in June-July and harvested in November-December and (b) dry season or "rabi", which is usually sown in December-January and harvested in April-May. The Kharif rice crop covers some 375,000 ha of the command area; the remaining 28,000 ha is mostly under sugarcane. The Kharif rice crop is followed by a "rabi" rice crop of about 150,000 ha. Water availability is the limiting factor for rabi rice. To give equal opportunity to all farmers in the area, a rotational system for growing rabi rice has been introduced and is strictly followed. Other rabi crops are grown on some 90,000 ha with residual soil moisture following the Kharif rice; these include pulses, edible oilseed and chillies. On the whole, the cropped area totals 615,000 ha, giving a cropping intensity of 154%.

Several high-yielding varieties (HYV) of rice responsive to Fertilizer applications and non-photosensitive have been introduced in both Kharif and rabi crops since 1964-65. At present, HYV covers about 46% of the Kharif crop and 80% of the rabi crop. All the rabi HYV are dwarf varieties with an average yield of 3,500 kg/ha. Because of the recurrent water shortages in May and June, which delay sowing and transplanting, a large part of the Kharif crop is under tall varieties, reducing the average yield for the Kharif paddy to 2,600 kg/ha. In the low-lying areas, the risk of flooding in September.

(2) Self-righteousness and sincerity of Sir Cotton-having taken up the Indian cause to mitigate famine and drought

Sir Cotton was hated by his administrative superiors because of his loving attitude towards the people of India. At one point, impeachment proceedings were initiated by his superiors for his dismissal. Going through the famine and cyclone-ravaged districts of Godavari, Cotton was distressed by the sight of the famished people of the Godavari districts. It was then that he put in the process his ambitious plans to harness the waters of the mighty Godavari for the betterment of humanity. John Henry Morris, in the Godavari, writes about the work of Sir Cotton thus: The Godavari anicut is, perhaps, the noblest feat of engineering skill which has yet been accomplished in British India. It is a gigantic barrier thrown across the river from island to island to arrest the unprofitable progress of its waters to the sea, and to spread them over the surface of the country on either side, thus irrigating copiously land which has hitherto been dependent on tanks or the fitful supply of water from the river. Large tracts of land, which had hitherto been left arid and desolate and waste, were thus reached and fertilized by innumerable streams and channels.

In 1878, Cotton had to appear before a House of Commons Committee to justify his proposal to build an anicut across the Godavari. A further hearing in the House of Commons followed by his letter to the then Secretary of State for India shows his ambitiousness to build the anicut across the Godavari. His final sentence in that letter reads like this: My Lord, one day's flow in the Godavari river during high floods is equal to one whole year's flow in the Thames River of London. Cotton was almost despaired by the British Government's procrastination in taking along this project. That the Government of India's plans to interlink rivers was long envisioned by Cotton is a fact. Given the accomplishment made by Cotton in Irrigation Engineering, Govt of AP has established Cotton Museum near Barrage.

Sir Arthur Cotton Museum

Sir Arthur Cotton Museum was inaugurated by the Hon'ble Chief Minister of Andhra Pradesh Sri Nadamuri Tarakarama Rao on 25.2.1988, and the Museum is located in the building which was previously under the occupation of Executive Engineer, Godavari Head Works Division Dowleswaram. This museum was started to educate the people about how the great Engineer Sir Arthur Cotton during those olden days, constructed the mighty anicut across the Godavari river and converted the lands of East and West Godavari Districts into very fertile. The Museum also narrates the construction of the present Sir Arthur Cotton Barrage, constructed with advanced engineering skills.

A lot of Models collected from various places and projects were exhibited in the Museum to attract visitors and to make them understand various items connected to Irrigation works. An old anicut model true to its size together with 3 ft falling shutters, rail track, and plough machine which was originally used for lifting shutters on the anicut.

The machinery of various types which were used at the time of construction of the anicut (OLD) is also preserved and kept open for viewers. A model drawing depicting four arms of the New Barrage, with 3 Head sluices and three scour sluices, is also an exhibit in the Museum. Sir Arthur Cotton at the entrance and statue of Cotton riding a horse, and the beautiful fountain jalatarali are also a feast to the eyes of visitors to the museum. Besides the above, several lawns, flower plants, croton plants, and decorative plants in the garden around the Museum contribute to the pleasant Greenery.

Probably this is the only Civil Engineering Museum established and maintained in the State of Andhra Pradesh. Besides distinguished visitors from Andhra Pradesh. Visitors from other states and other countries are visiting the museum. This museum is being visited by the students of Engineering Institutions as a part of their educational tours to understand the Engineering skills available in the olden days and the commitment of Engineers of yesteryears and present days also.

(3) Engineering novice and marvel to save the cost of construction

To save on masonry work, Sir Cotton followed the method of construction used by the Cholas. "Cotton created a loose pile of mud and stone on the riverbed, which he then covered in lime and plastered with concrete, instead of building up entirely with stone." The whole project was finished at a third of the cost initially estimated, till 370 miles of canals (339 of which were navigable) irrigated some 364,000 acres of land, transforming a dry expanse into the "rice bowl" of Andhra Pradesh. And waterways, the Englishman demonstrated, were a doubly rewarding alternative to rail transport, simultaneously nourishing the farmlands of rural Indians.

(4) River and Canal Navigation as a means of cheap transport

The Godavari is the largest river in the Madras Presidency. This river attracted the attention of many Madras engineers who favoured large-scale investments for the improvement of irrigation and navigation facilities. In 1844, Arthur Cotton submitted a report concerning the requirement for roads and canals in the Rajahmundry district. Frederic Cotton, brother of Arthur Cotton, also submitted a report to the government regarding the practicality of steam navigation on the Godavari River. But three barriers of rocks were the main obstacles to navigation, and if these were removed, steamboats could easily operate on the river. Because there was no cheap transport, people had to pay very high prices for commodities like salt and dried fish. The Madras Chamber of Commerce's Chairman wrote a letter to the Board of Revenue and stated that if steamboats were introduced on the Godavari, Berar cotton could be sent to Cocanada instead of Bombay, thereby saving time and money.

After seeing the immense advantages derived from the Ganga Steamers, Lord Dalhousie, Governor-General (1846-56), was keen to extend the same facilities to Godavari, Indus and other rivers also. Haig was appointed to survey the Godavari. He submitted his report in 1859, in which he favoured improvement in the Godavari. After the improvement, the Godavari became a highway of commerce and travel. In 1864, 980 boats were registered in the Godavari Delta, while in 1865, this figure rose to 1,023 boats.

Cotton persisted for far more investment in canals meant for irrigation and navigation. In his book, Public Works in India, Their Importance: Suggestions for their Extension and Improvement, he goes on to prove that it is far cheaper per ton per mile to transport cargo and passengers through canals.

Cotton thought that if India were to have an equitable distribution of wealth in such a way that interior continental towns could be part of the development process, navigation set through canals would provide a better path than depending heavily on railways.

Renovation of Dowleswaram anicut and renaming as Sir Arthur Cotton Barrage

The old Dowleswaram anicut was built entirely of bricks and masonry and was constructed during the years 1847-1852. As irrigation demand in the command area increased, the weir crest was raised, and steel shutters were added, raising the pond level by 1.19 m over the original design level. As the weir is founded on the sand and as flood flows are large, erosion immediately downstream from the structure has been a continuing problem, and constant maintenance has been necessary. Despite such maintenance, however, the condition of the structure has steadily deteriorated. By 1965 deterioration of the Dowleswaram anicut had progressed to such a degree that a high-level committee was set up by the Ministry of Irrigation and Power, GOI, to advise on immediate remedial measures and the desirability of reconstruction. The committee recommended immediate construction of a new barrage and provided outline designs and cost estimates for the work. However, due to a shortage of funds, work was started only in 1971, and less than 5% of the construction had been completed by that time.

The primary cause of deterioration has been erosion on the downstream side of the weir, due in part to flows across the weir but also in some areas to strong lateral flows along the toe of the weir. The secondary cause of deterioration has been piping, aggravated by erosion of the downstream apron. Severe piping of fill from beneath the weir has caused the concentration of load onto the cylindrical brick caissons, which partially support it. This, in turn, caused the structural failure of the foundations.

Cost of renovation of Dowleswaram anicut (1970-82): Rs.36 crores

Modernization of Godavari Delta Canal system including Head works: Rs. 1660 crores (212.82 million USD)

4.14 VEERANAM TANK

Name	**Veeranam Tank**
Location	**Tamil Nadu, India**
Latitude	**79 O 32'40" N**
Longitude	**11O 20' 10" E**
Category of Structure	**Water Storage Structure**
Year of commissioning	**9th Century A.D.**
River Basin	**Coleroon Basin & Sub-basin**
Irrigated/Drained Area	**44, 856, Acres/165 Sq. Miles**

History

The Veeranam tank was excavated during the period of Paranthaga Chola-1 in the 9th century. This tank was excavated by his soldiers during the rest time available after the war. He named it in the name of Veera Naraya Perumal temple Veeranarayanan Eri and now it is called Veeranam Tank. It is the largest tank in Cuddalore District.

Description

It was constructed to store the rainwater from its catchment area to irrigate the ayacut downstream of the tank bund. Later, a supply channel was excavated from the Coleroon River at Anaikkarai and this channel is called as Vadavar Channel.

Then this tank was connected to the Vellar River through a channel on the northern end of the tank. The excess water is allowed to drain through the Vellar River. And sometimes the water from Coleroon river is taken to Veeranam tank and then from Veeranam tank to Vellar river. The water from the Vellar River is taken to ayacuts along Vellar Rajan Channel during scarcity of water.

The Veeranam tank receives rainwater from its catchment area of 165 Sq miles and Cauvery water from Coleroon River through Lower anicut (regulator) via the Vadavar canal. The water spread area of this tank is 15 sq. miles. Now the capacity of this tank is 1465 mcft and it is irrigating to an ayacut of 44856 acres through 28 nos of sluices along the main bund & 6 nos. in foreshore bund.

The Length of the main bund is 16 km. It irrigates the ayacut in 102 Villages in Chidambaram, Bhuvanagiri and Kattumannarkoil taluks of Cuddalore District. The maximum length of the field channel is the Boothangudi channel which is 24.30 km in length. The water is flowing in these channels only by gravitational force. The rainwater from the catchment on the Upstream side of the Veeranam tank is from Ariyalun & Cuddalore Districts. There are 2 surplus Channels to drain excess water during a flood and these surpluses confluence with the Bay of Bengal.

From 1997 to 2006, the Rehabilitation work on the Veeranam tank was done vide New Veeranam Project. The main Bund of Veeranam tank was protected with C.C. block revetment on its Upstream side to its entire length. The top of Bund was raised in the New Veeranam Project to a height of 2 feet. Due to this, the capacity of the tank was increased from 985 mcft to 1440 mcft. Hence a wave deflection wall was constructed upstream of the bund, to avoid overflow of water due to the wave effect. The supply Channel of Vadavar was protected with a concrete slab on the sides of the Channel and bed concrete is laid with weep holes at the bottom to the entire length of Vadavar. The foreshore of the Veernam tank is constructed with an earthen bund to avoid submergence of land.

The Tamil Nadu Water Supply and Drainage Board constructed a water pump at the left flank of the Veernam tank. The water pumped from the Veeranam tank by TWAD is around 70 cusecs. This water is taken through a pipeline to a length of around 225 km. Then it is supplied to Chennai City, after proper purification.

Structure's engineering utility as per its designed utility: Excess flood water is stored by increasing the top of the bund level from +45.50' to +47.50'. It receives water from Vadavar and supplies the water to the Vellar River and in turn to the Vellar Rajan channel for irrigation

Structure's engineering utility as per its functional utility: Due to an increase in the height of storage, the land in the foreshore bund was submerged. Hence the foreshore bund was formed. The infall points of all foreshore channels will be constructed with the regulator to keep +47.50'.

Water Heritage

The Veeranam tank is irrigating 44856 acres of ayacut in 102 villages of Kattumannarkoil and Chidambaram taluks of Cuddalore district and supplies drinking water to Chennai city. It was designed to store the excess water from the Coleroon River during flood time. It safely discharges the excess flood water through drainage canals. The lake is 235 km away from Chennai, and it is Chennai's lifeline, supplying roughly 50 to 180 million litres of water to the city every day. It is 11.2 km in length and 4 km in width, and when full of water, it is an awesome sight.

In the 10th century, he assigned his men the task of excavating this tank, to collect the surplus waters of the Kollidam River. When completed, Rajaditya christened it Veeranarayana, the name of Lord Vishnu and also one of the many names of his father Parantaka Chola I. This is now Veeranam. Kalki R. Krishnamurthy's magnum opus, Ponniyin Selvan, opens with the hero riding along and admiring this lake.

In the 1830s, (later Sir) Arthur Cotton, the engineer who later harnessed the waters of the Krishna and Godavari, studied the tank in detail. He noted that there was no serious defect in the tank (this, 900 years after it was constructed) apart from the narrowing of the mouth of the Vadavar River that connected the lake to the Kollidam and the tendency of the bund to breach when filled to the brim. Interestingly, Cotton's report is full of anglicised Tamil terms — Totie (Thotti or Tank) and Calingula (from Kalingu or sluice) being two commonly used words.

In 1967, C.N. Annadurai, then freshly elected Chief Minister of the State, mooted the idea of supplying water to the capital city from Veeranam. The project, estimated at Rs. 21,00,00,000, was then the biggest to be sanctioned in independent India. The contractor put up a plant at Tirukazhugukundram in collaboration with a Greek firm for making the pre-stressed concrete pipes.

The contractor suddenly died. The pipes were abandoned all along the Cuddalore-Madras route and were put to good use — entire families were raised in them and some others became latrines.

The project languished thereafter for over three decades only to be revived in 2000, and by then, the cost had ballooned to Rs. 720,00,00,000. The local ryots were none too happy at the metropolis guzzling their precious resource, but water began flowing into Chennai in 2004.

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5 IRAN

5.1 ABBAS ABAD COMPLEX

Name	Abbas Abad Complex
Location	AliTappeh (Al- Tappeh) Village, South-East of Behshar, Iran
Latitude	36.50
Longitude	3.50
Category of Structure	Dam
Year of commissioning	1021 lunar AH (approx. 1612)
River Basin	Neka-Rood/ Abbas Abad River
Irrigated/Drained Area	75 ha

History

The historical complex of Abbas Abad is located 9 km South-East of Behshar next to AliTappeh (Al- Tappeh) village within a dense forest of Alborz highlands. There are numerous springs in the southern, southwestern and south-eastern highlands of the forest region of Abbas Abad. Two of these springs are of more importance, namely: Sarcheshmeh and Qari-cheshmeh. Sarcheshmeh Spring is located about 3500 m southwest of the historical garden of Behshahr and has a high discharge of water. It is significant as it supplies the reservoir of Abbas Abad dam with water in winter. Qari or Quri Cheshmeh is located at a distance of about two km southeast of Abbas Abad complex and has less discharge than Sarcheshmeh spring but more than similar springs inside Abbas Abad. It serves as the only source of supplying water to Saro village north of the Abbas Abad complex. Studies on Bagh-e Abbas Abad waterworks showed that the architectural structure created a musical melody during the ruler Safavids' time when water was directed through different pipes besides providing a beautiful forest view.

Description

Abbas Abad dam of Behshahr was constructed in a deep valley. After the construction of its foundation, two arms were added to either side of its foundation, which increased the foundation's strength and enhanced the water intake of its reservoir. On the whole, the arm length of the dam was 70 m, and its width at its crown was 7m. Behind the dam wall, a backstay was built, which strengthened the dam against the potential energy of water and served as the control centre of dam water discharge. Characteristics of Abbas Abad dam are as follows:

- Foundation Dimensions: width - 20 m; length - 10 m; height - 10 m
- Total water intake capacity: 600,000 m^3
- Lake area: 98,000 m^2
- Maximum depth: 10 m
- Building materials: brick-stone and plaster of lime and ashes or sand (Saroodj)
- Dimensions of bricks used in the dam: 26 by 26 by 5 cm.
- Reservoir water is discharged via dam valves for agricultural villages located to its north, such as Shah-kileh, Al-Tappeh and Saro.

The combinational Chahar Taqi inside the pool: In the middle of the Abbas Abad dam reservoir, there is a brick structure in the form of a Chahar Taqi. It goes underwater during the water intake of the dam, and only the upper surface remains out like an island. Two brick towers were also constructed at a distance of 186m from the garden and 156m apart. Chahar Bagh compound plays a vital role in water distribution.

Chahar Bagh compound has an area of about 3200 m^2 and is located at a distance of 600 m southeast of the historical garden on the mountain's southeastern slope overlooking the dam. During the Safavids rule, the slope was scrapped and turned into a flat surface with an area of 46 m by 72 m. Due to the gradient, there is a level difference of 15 m between the compound and the garden, which is why the compound has been chosen as the water distribution point.

In 1380 solar AH, three test boreholes were dug together at the second phase of Abbas Abad excavations to better understand the water entrance route into the historical garden. In each borehole, an architectural monument of 120 by 120 cm was encountered. Next, part of a wall was removed, and inside the wall, a ceramic pipe was inserted with segments connecting each other in a rabbet fashion. The wall served as a protective shield for these ceramic pipes (Tanbusheh), considered vital veins for the garden. The second phase of excavations revealed that the entry and exit paths of water were on one side of the wall protecting the ceramic pipe that was connected to the Chahar Bagh compound. The other side went into the main basin inside the central platform of the historic garden. This connection indicated that the water supply was directed from the Chahar Bagh compound to the main garden. Interconnected ceramic pipes delivered water to the central basin of the garden in the form of a fountain. Then the excess water was supplied in the jet form to side basins located at the eastern, western, northern and southern parts by other ceramic pipes connected to the main one (the entry pipe). These pipes went into all four sides of the central platform basin. The eastern basin water was used for irrigating the eastside flower bed opposite the central platform. As the architecture of Abbas Abad is symmetrical, the function of the western basin was like the eastern one with this difference that the western basin, in addition to irrigating the western flower bed of the central platform, also supplied the water of the Hammam located about sixty meters west of it.

Role of Chahar Taghi: One of the key buildings of Bagh-e Abbas Abad is building pedestals (Chahar Taqi) inside its pool. The upper section has become a tourist attraction because it shows traces of a basin, watercourse and fountain. Apart from the recreational function, it also had technical and scientific functions from a construction point of view. It was made of eight piers with an approximate perimeter of 4 by 4 m and a central pier. The central pier had inter-connected network pores. This pier likely served as a valve in emergencies.

Consequently, if after closing the dam wickets and its full water intake, the dam remained underwater pressure or if it moved a little, there was no need to empty the water via wickets because it was directly controlled from the reservoir. For example, during emergency water discharge from wickets, water pressure and surge served as a destroying factor upon the dam. Chahar Taqi, with an inter-connected meshed pier, also prevented the dam's destruction during an emergency.

Role of Towers in Water Supply: According to studies conducted on the route between the Gol-Bagh compound (water distribution station) and the central garden, exactly two brick towers have been built upon the water supply axis. When water was cut off suddenly from above (Gol-Bagh compound), the central basin water flowed towards the second tower (due to the level difference between the garden and the second tower), and when the Gol-Bagh compound water began to flow again, the stimulant confluence of currents caused a severe clash which is termed as ram-like stroke in fluid engineering. Even today, such a strong blow causes the rupture of iron pipes used in urban waterworks. Historically, engineers, artists, and architects took measures to prevent it by building these dual brick towers on the water supply axis. In this way, they succeeded in protecting 600m of ceramic pipes against ram-like strokes. Also, by building two brick towers, they were able to prevent the rupture and breakage of pipes and adjust and control the jet water pressure upon the central basin. According to fluid engineering, the twin brick towers of the historical Bagh-e Abbas Abad in Behshahr served as safety valves and siphons (due to the level difference between the Gol-Bagh compound and the garden) for water supplying as well as preventing the sudden cracking or breaking of ceramic pipes.

Water Heritage

The first archaeological research in Behshahr- Abbas Abad was done on the flung open building in the centre of the Abbas Abad basin in 1977 before the Islamic revolution, the first of its kind. It was carried out for three reasons, namely:

1. To identify the water pipes and watercourses to know how the water enters the garden
2. To recognize the water allocation mechanism of the historical complex
3. Determining the core and buffer zones of the garden increased to 530 ha and excavating archaeological sites such as a mill, palace, ancient industrial centres of brick and crockery, and stone pavements of the Safavids period and the cemetery. (the first millennium B.C)

Based on the archaeological findings in Bagh-e Abbas Abad, it is observed that the complex was built and rebuilt thrice over the centuries due to the conditions then. Three historical layers were found in this historical complex. The first is the Safavids period which marked the beginning of the construction followed by two more upgrades in different eras like the pavement and platform corridors as far as the lower platforms.

The Abbas Abad complex is a historical structure showcasing the regional architecture, irrigation design, and heritage of the ancient civilizations. Constant efforts are made to understand its intricate designs and preserve them for future generations. Conservation actions were taken based on the archaeological findings in the historical garden of Abbas Abad in Gol-Bagh and its palace. Repair work and architectural discoveries are ongoing- the eastern road (the main entrance of the garden), the northern road, and some parts of the southern roads have been unearthed completely.

5.2 BALADEH QANAT AND WATER SYSTEM

Name	**Baladeh Qanat and Water System**
Location	**Northern Mountains of Ferdows, Iran**
Latitude	**34.0833 - 34.250**
Longitude	**58.3167 - 58.5167**
Category of Structure	**Water Supply System**
Year of commissioning	**Pre-Islamic era (around 2000 years ago)**
River Basin	**Ferdos plain**
Irrigated/Drained Area	**2081 ha**

History

Originating from the northern mountains of Ferdows Baladeh Qanat and the Water System can be regarded as the most important qanat of the region. It has been the main supplier of agricultural and potable water since ancient times for the Bāghestān-e Bālā, Bāghestān-e Pāeen and Eslāmiye villages and parts of Ferdows city.

Over the year, the qanat has experienced many renovations and restoration works as follows:

1. Restoration of Sheshtu qanats: These qanats were restored and dredged 50 years ago, and some new wells were dug, which increased water yield to 8 inches in summer and 20 inches in winter
2. Maintenance works: To prevent water drainage, the ditches were cased with earthenware tiles from Ghale Zard hill up to Haji Ābād village
3. Lāyroobi (removal of calcareous sections) of the qanats
4. Restoration of a 12 km qanat: The Baladeh Council and Ministry of Agriculture 1990 connected the Sheshtu qanat to the main canal. This canal passes from behind Haji Ābād village and at a place called Sar do Sar where several qanats meet Sheshtu and enter the main canal
5. Construction of 3 barrages: Barrages were constructed by the Ministry of Agriculture near Lotf Ābād village.

Description

Baladeh Qanat and Water System play an important role in the Fedrows region. It supplied water for irrigation as well as domestic uses. This qanat has a discharge of 250-300 l/s in dry years, whereas its discharge increases up to 1,300 l/s during wet years. The average is, however, 800 l/s. This qanat irrigates more than 2,081 ha of farms and gardens, out of which 554 ha is supplied to farms and 1,527 ha to gardens.

According to 2009 statistics, there are 204 wells, 31 springs and 351 qanats within the Ferdows study zone, which have an annual discharge of a total of 82.2 MCM, 59.6, 8.6 and 14.6 MCM, respectively. Twenty branches of qanats in this area have a water discharge ranging from 0.1 to a maximum of 12 l/s and a total annual sum of 1.17 MCM. The Baladeh stream is formed with over 15 central branches from the aquifer with a total discharge of 147 l/s.

Some of the features of the structure are as follows:

1. Main Branches and Shafts: Qanat of Baladeh consists of 15 branches and a total length of 19 km. This qanat is made of 440 well shafts. The water discharge of these qanats varies from 0.5 to 45 l/s.
2. Mother well: The mother wells are located on the western foothills of Siyah Kuh mountain, 32-33 km to the northeast of Bāghestān-e Bālā. The distance between the farthest Mazhar (Shesh Tu) and āb bakhsh, which is located on the northern side of Bāghestān-e Bālā, is almost 30 km. In addition to the mother wells, well shafts and gallery in the 15 branches, there are supplementary structures constructed during this qanat's digging and maintenance works, such as mard khāneh and zine.
3. Water Distribution System (Āb bakhshān): On the way to Qanat of Baladeh, some sections are built on the course of the stream to divide the water (maghsam) accurately.
4. Water Reservoirs (Āb anbār): The historic āb anbār of Ferdows City is of the structures related to the Baladeh water system, these water structures were constructed to store water rights (haghābe) of the Baladeh stream, some of which have been restored in recent years.
5. Mills (Āsiyāb): Up to 80 years ago, there used to be 12 watermills on the course of this qanat, but presently the only operational watermill in this area is Haji Khan Mill.

A detailed overview of the Water transmission management system is presented below:

- Water Muddying: The mechanism of water transfer from several kilometres through muddying (tire gari) increases water impermeability and increases the speed of water flow; this innovative mechanism led to better water management in the past.
- Planting shade trees: Shade trees were planted on the two sides of the main water stream. Given the arid and semi-arid area around the qanat and its windy climate, these trees slowed down the wind. They decreased the direct sunlight over the main water stream, reducing evapotranspiration.

Water distribution management system

To determine the water share between Bāghestān-e Bālā, Bāghestān-e Pāeen, Eslāmiye and Ferdows cities, a casting lot system has been applied. Similar to Qasabeh Qanat, the division system is based on a mechanism known as *fenjān*. In this system, the time required for filling of *fenjān* is measured and then used as a base for water distribution. Presently, it takes about 3 minutes; every 24 hours consists of 450 *fenjān,* and each *tāqe* consists of 225 *fenjān*. Qanat of Baladeh supplies 7200 cups distributed by two streams for an eight-day cycle; every 24 hours, the water share is equal to 480 cups.

The irrigation configuration Qanat of Baladeh is based on a two-season division, the winter season (*shatā*) and the spring season (*seyfi*). The season begins in September and continues up to June, while the water circle lasts for eight days. Water distribution is based on each shareholder's share determined during a special ceremony by moalef each year. Volgār starts in early June and lasts for 96 days. During the volgār period, the water is just allocated to the gardens. Elders determined the water share for each Garden in 1968, therefore water shares belong to the garden and not to its owner. In other words, if the shareholders of Qanat of Baladeh have no garden, they don't receive any shares during the volgār period. If a garden undergoes functional change, its water share is transferred to the Baladeh Water Company, which distributes it based on rules and shareholders' fees. There are 1800 gardens in Bāghestān-e Bālā, Bāghestān-e Pāeen, and Eslāmiye benefitting from Baladeh water based on the 14-day water cycle (an average of 8 irrigations for each garden).

Mirāb water distribution system of Qanat of Baladeh: To manage the issue, the water distribution system was slightly modified; however, the traditional distribution system is as follows:

1. Moalef: A person selected from prominent individuals and is regarded as the manager Qanat of the Baladeh Mirābi Organization.
2. Accountant: Baladeh Water Organization holds an accountant nominated by the moalef and approved by the shareholders. The accountant monitors and keeps a record of 7,200 water shares and their exact allocation to each shareholder.
3. Kayyāl: This person is in charge of water distribution during the volgār period. There are four kayyāls at Qanat of Baladeh, and each stream is controlled by 2.
4. Juybān: 3 people are in charge of maintaining and repairing water canals, known as juybān. Moalef of Baladeh hires kayyāls and juybāns for the entire volgār period.
5. Tire gar: Due to the long distance between water resources and its Mazhar-e qanat (about 30 km), water flow is muddied to decrease water permeability

and evaporation. Tire gar refers to a person whose job is to muddy the water and is locally known as gelok gar.

Sālār: Sālār is a person whose job is water distribution during seasons. Three sālārs are hired; 1 of them is superior and controls the other two called the barsālār. They are in charge of transporting water to farms. Considering the Qanat of Baladeh's role in the region's water supply, its maintenance and conservation have been the topmost priority for the locals since its long history. Due to the vulnerability of qanats to earthquakes and floods, it has received due attention. Some of the vital maintenance works carried out are- repairing Shastu by constructing a new bypass gallery which increased its water discharge, repairing 12 km qanat galleries, building several dykes in the upper qanat areas, restoring wells and qanats, and covering the open parts and recently the water passages were repaired to prevent water drainage.

Water Heritage

The Qanat of the Ferdows is considered one of the most critical water resources in Khorāsān-e Jonubi province. Numerous references have been made to this city and its qanats in historical documents, indicating their antiquity. Qanats drastically improved the region's economic conditions by boosting agricultural production, attracting human settlements, controlling migration, and opening new occupational avenues. Not only did the irrigation improve with the qanat, but the economic value of water also increased through rich water canals. In addition to an economic boom, the Qanat of Baladeh is a cultural, technological, and historical phenomenon. Native creativity, along with local and traditional knowledge, resulted in an environmentally efficient mechanism, i.e. supplying maximum water without causing any damage to the soil and water resources of the region.

This qanat with a structured water management framework created sustainable socio-cultural operations and maintenance model. The management and ownership of water follow clearly defined shares for waqf, private ownership, and the city and town shares specified in two distinct periods. Previously Moalef was the management in charge, and even today, after almost 1000 years, the qanat is managed with the same traditional method but on an arranged integrated basis.

5.3 KURIT DAM

Name	Kurit Dam
Location	Kurit Village, Tabas, South Khorasan, Iran
Latitude	33.433
Longitude	57.233
Category of Structure	Dam
Year of commissioning	Approx. 1397 (800 Lunar Hegria)
River Basin	Kurit River
Irrigated/Drained Area	245 ha

History

Located in the northeast of Kurit Village, 42 km away from the southeast of Tabas, the Kurit dam was constructed in 4 stages, completed in 1941 when the dam's height was increased by 4 m. Construction considering the sediment formation played a significant role in the operational age of the dam. In 550 years, the exceptional 54 m dams hold a record, which is one of the wonders of that era. From the mid-14th century until the beginning of the 20th century, Kurit Dam was considered the highest dam in the world.

Description

Kurit Dam is a sample of arch-gravity dams in ancient Iran, built in the middle of a very narrow valley in a mountainous region. The dam is 50 m long and 2.1 m wide. Intake outlets are used to discharge sediments from different reservoir levels, showing the ingenuity of the people who constructed them. Unlike gravity dams, the downstream of the structure is upright and the upstream is oblique due to the difficulty of accessing the dam downstream. Like other ancient dams of Iran, Kurit Dam was built with stone and mortar. The bricks are square with 37 cm in a dimension used in the last stage of construction. The dam regulated the Kurit River's water to irrigate farms. After passing the dam, the river flows down in a narrow valley of 5 km and then enters the plain. Due to the accumulation of sediments in the reservoir and operational hurdles, in 1998, a concrete dam was built upstream of Kurit Dam to harness the floods and protect the old structure, which is currently under operation.

Kurit Dam supplied water for Kurit Village for more than 600 years. The distance between the village and the dam site is approximately 26 km, out of which 5 km is in a very narrow valley, with hard accessibility. Therefore, it requires more than 10 hours of hiking to approach the dam site. The construction of the dam in such an inaccessible area shows the scientific selection of the dam's location. In 1978, a devastating earthquake ruined the village; however, the dam's body was not considered damaged. This event shows that high-quality material was used for the construction of the dam body.

Currently, after constructing the new dam upstream of Kurit Dam, the old dam is inoperational; however, measures are being taken to ensure its stability. Over time, some minor repairs and modifications are also conducted. The regional water authority of Khorasan takes initial actions.

Water Heritage

Kurit Dam's stability for 700 years demonstrates the knowledge and expertise of that era, which can be an inspiration for structural engineering in the present. With 64 m in height and 2.1 m in width, the Kurit double-arch dam had been the highest in the world for 550 years, till the early 20th century. The dam construction technique was a brilliant engineering achievement 700 years ago, and it still is. Moreover, using the intake tower to decrease the flow velocity is an exceptionally innovative sample, and the intake of water utilizing the intake tower shows the ingenuity of engineers in that era.

Building the dam in stages based on temporal demand is the best example of applied value engineering in water resource projects. Using appropriate materials has prevented any destructions during operation years, despite considerable numbers of floods. Furthermore, after the disastrous Tabas earthquake in 1978, there were no cracks in the dam body. The scientific selection of the dam's location in a section of the valley that resulted in a 50 m length and 64 m height is a point that contemporary dam architecture studies in the 90s admired.

The dam was an exemplary work of financial management and cost distribution. The costs for the diversion system, flood discharge and diaphragm decreased to zero. Additionally, the dimensions of the structure were built at the minimum possible cost and constructing the dam in stages distributed the costs over the years. Therefore, peripheral costs were minimized in the project, which indicates the architects' vision regarding the costs of depreciation.

Kurit Dam is a result of teamwork and a high level of accordance. Fact that residents of Kurit Village played the role of employer, consultant, contractor, operator, and user simultaneously, the dam had an advantage of a multidisciplinary team including specialists in value engineering. After the construction of the dam floods, the current from upstream wells could be stored, and accordingly, the mountains surrounded the reservoir, and evaporation was minimum. Following a cooperative approach in its construction and operations, the dam showcases the success of a multi-disciplinary approach.

5.4 MOON QANAT

Name	**Moon Qanat**
Location	**Isfahan Province, Iran**
Latitude	**33.381 - 33.3697**
Longitude	**52.380 - 52.367**
Category of Structure	**Water Conveyance System**
Year of commissioning	**1200**
River Basin	**The catchment of Ardestan is Rig Zarrin and SyiahKuh, which is one of the sub-basins of the central plateau basin area.**
Irrigated/Drained Area	**Farms in the south of Ardestan, agricultural demand area is 811 ha, and it stretches for 2-3 km and has two separate outlets (at 200 m distance from each other) irrigating about 100 ha of farmlands**

History

A qanat or kariz is a gently sloping underground water transporting channel from an aquifer or water well to the surface for irrigation and drinking, acting as an underground aqueduct. This is an old system of water supply from a deep well with a series of vertical access shafts. The qanats create a reliable supply of water for human settlements and irrigation in hot, arid, and semi-arid climates. Still, the value of this system is directly related to the quality, volume, and regularity of the water flow.

Located in Ardestan, Esfahan province Qanat of the Moon is a valuable two-level qanat unique from other qanats. The catchment of Ardestan is Rig Zarrin and SyiahKuh, which is one of the sub-basins of the central plateau basin area. The area of the catchment is 48,76,549 ha. Moon is one of the eight neighbourhoods of Ardestan, named after the area it provides water. Located between Natanz and Naein bordering desert, Ardestan has a population of 15,701 (2012) and is divided into two parts: semi-tropical and cold. The semi-tropical part covers the low northern areas called Rigestan and enjoys a sand and desert landscape. The cold area covers the southern hills and mountains called Kuhestan. On high foothills, on the edge of the Rigestan area, it has a slight slope stretched from south to north and enjoys underground water, especially water passed from higher areas. The town is 1250 m above sea level and has 11 qanats.

Description

There are two galleries in Qanat of the Moon instead of one; a gallery above, the other with a distance below; separated from Mother well up to Mazhar. Creatively, water flows in each gallery separately. Two levels of this qanat are called Zir (Below) and Roo (Above). The two levels do not enjoy common aqueous branches before the mother well, but from this well to Mazhar-e qanat, both levels share the same wells. This Qanat has two main tunnels located above each other with a 3 m difference in elevation with two separate mother wells. There is no leakage between the two tunnels due to the impermeable layer between the two tunnels. The top tunnel goes through a half-circle path when it reaches the vertical shafts. This Qanat is 2 km long and has 30 shafts that are spaced 42.4m apart. Its average outward flow rate is 50 l/sec.

While dredging the upper qanat hydrologist discovered a forger aquifer below it, leading to the digging of a second qanat. This is the oldest groundwater operation system highlighting the ancient Iranian expertise. This two-level qanat and its discharge system reflect the ancient hydrologists' work and deep understanding of nature. This traditional structure based on local technology is based in the central desert plateau of Iran.

Restoration and conservation of this historical hydraulic structure are permeated under the Jihad-e Agriculture and the Cultural Heritage organizations' budget. The budget is spent on opening the water routes and rehabilitation of qanats channels and repairing its vertical access shafts every year. The qanat is in good working condition and is regularly monitored by experienced well-sinkers. Maintenance works are mostly concentrated on the prevention of cave-ins. So, by periodic inspection, vulnerable sections of qanat with risks of falling are reinforced by Kaval, ring, or stone support walls.

Qanat of the Moon is cleaned out every year. With a windlass on the well shaft, the Roo gallery is cleaned, and the Zir gallery is dredged, in the same order moving on to another well shaft. There is a meter entryway about a meter higher than the water level used to go to the gallery and dredge Qanat's tunnels in every shaft. Dredging is the most important protective measure for the revival of the qanat for both layers. Dredging is carried out naturally and synthetically. Vertical access shafts are still all right; however, they are repaired and renewed as required.

Water Heritage

An engineering masterpiece and the strangest qanat is the two-level Moon-e Ardestan built approximately 800 years ago. It has ordinary wells together with different mother wells and side wells. The only two-level qanat ever known is the Qanat of the Moon, constructed by the knowledge and creativity of Moqannis (Qanat digger). As unique as it is, it is located in an area with rich underground water, enough for two qanats, with an accurate slope and aqueous layers higher than the Mazhar, allowing an incessant water flow.

The qanat is an excellent piece of work not just in its architecture but also in its contribution to the environment. Made out of native wisdom and locally available resources, qanats contribute towards a sustainable environment. The distance between two qanats is scientifically calculated so that the soil of both qanats is neither hard nor soft. The soil is a special kind of sticky clay that has a sweet taste and a good smell. With some pebbles in its mixture, the soil is high quality and durable. Ancient well sinkers realized early on that this soil would not dissolve in water, and the water from the upper qanat would not penetrate to the lower one. Traditional knowledge used at the time of its construction shows the advanced levels of expertise applied in digging qanats.

Maintaining environmental sustainability and an ancient water provider, the qanat led to agricultural production, and higher water levels in northern Ardestan, and considerably enhanced the region's economy. Water from these two qanats is used to irrigate 250 Jeribs of farms. Qanat-e Roo has three Farazeh of water for 100 Jaribs of farms, one Farazeh for Telk Abad town and two Farazeh for Moon neighbourhood. Qanat-e Zir has three Farazeh water for 150 Jaribs of farms, one Farazeh for Telk Abad and two Farazeh for Moon. Out of 250 Jaribs irrigated by this qanat, about 165- 170 Jaribs of both qanats are the share of Moon neighbourhood distributed in 10 days cycle for 1,320 shares.

The qanat has a rich history of complex water ownership and distribution models, which evolved and modified to take its shape today. These models are also a cultural reflection of the region and showcase the qanat's role in preserving such traditions and passing them through many generations. Historical documents show a water-sharing transcript for the region written by Sheikh Baha'i.

The ownership of farms and water in this area are separated. When the qanat was built, Telk Abad qanat's water was cut. Seven hundred years ago, due to some conflicts, the water from both the qanats was distributed as 1/3rd for Telk Abad town and 2/3rd for Moon neighbourhood, locals. This distribution of shares has been valid until now.

Traditional Distribution Unit and the water cycle: Until

1961, water distribution was calculated based on a bowl called Hendu or measurement (paymaneh) and water clock (sa'at-e abi). In Ardestan, it takes 11 minutes for Hendu to sink, and it is called one Saraqah/Sarajah/ Sahm (water share). Sarajah was divided into six parts, each one called a dang of time, usually about 2 minutes of water. Every 5.5 Hendu sinking was one hour of water. In the Moon neighbourhood, 24 hours are equal to two Taqs4, each equal to 12 hours of water flow or 66 Sarajah/ Sahm, and the total amount of which is 1320: (Each hour based on minutes 24×60)/(Two Taqs equal to 132 shares)= 10/9 a 24 hour). Sarajah or the total share of Moon neighbourhood is 1320, i.e. the duration of the water cycle period is 10× 24 hours in 2 Taq× 66 each Taq of Moon neighbourhood water share. The water cycle of the Moon region is ten days with a name of its own, of which the first day is Sari. The irrigation intervals based on water share in the districts are called cycle period (mar), out of which, after a night's irrigation cycle of a farm, on the next cycle, the farmer benefits from a day irrigation shard because of the time required to irrigate all the farms and gardens of the district.

There are different aspects of irrigation water cycles (Mar) such as water discharge of two qanats, farm areas, water quality (sweet or salt water), soil type (clays or sandy), and crop types, among which the last three are among the most important. After 1961 Hendues were converted to hours, and the same shares are reserved up to the present time. People who share a Taq of water are called a Ham-Ab group. They decide the expenses, and maintenance and make decisions regarding their own Taq of water. If the shareholders need more water in a cycle, the 10-day cycle extends to an 11-day cycle; this extension is called Saboo. This extra day distributes among all shareholders; however, the next cycle returns to its ten-day procedure. This two-level Moon Qanat is considered one of the transcendental ancient engineering works whose age and digging techniques are still popular today.

5.5 QANAT OF QASEM ABAD

Name	**Qanat of Qasem Abad**
Location	**Qasem Abad, Iran**
Latitude	**35.45**
Longitude	**51.4**
Category of Structure	**Water Supply System**
Year of commissioning	**Early 18th century**
River Basin	**Yazd Ardakan Plain**
Irrigated/Drained Area	**31 ha**

History

Qanat of Qasem Abad runs south of Yazd, irrigating the lands of Qasem Abad. Dating back 200 years ago, called after a famous charitable merchant Abol-Qasem Rashti it is 23.35 km long altogether, including its main tunnel with 17.43 km length and its side branches with a length of 5.92 km. This qanat enjoys 750 shaft wells along its main tunnel and side branches. According to Yazd Regional Authority, the qanat discharge was 40 l/s in 1998 but declined with groundwater drawdown and successive droughts. A watermill now located on the campus of Yazd University functioned with this qanat. This watermill has been put on the national heritage list by the Cultural Heritage Organization. Nowadays, some 31 ha of farmlands are being irrigated by this qanat, but it has been much more in the past. The urban sprawl is devouring the farmlands, and in this region, agriculture is buckling under the pressure of the buildings across Qasem Abad farmlands.

Description

A qanat combines shaft wells and a horizontal tunnel with a gentle slope (less than the surface gradient) to collect the groundwater seepage and drain it out to the downslope lands. Therefore, it can be considered a groundwater drainage system used for drinking and irrigation.

Qasem Abad qanat has been singled out from the active qanats of Yazd City after research and deliberations. One of its peculiarities is its water management system. Traditionally the qanat's water was divided into 1,560 shares for both Muslims and Zoroastrians. Each unit is locally called Jorreh-11 minutes of irrigation. Out of the 1,560 shares, 340 shares belong to Zoroastrians, distributed over 12 days (irrigation cycle). Each day has been named after owners of the most shares, respectively, as Maryam Abadi, Mohammadi, Sorkhabi, Foroodi, Gholami, Ali Akbari, Rezayi, Shahr Bamesi, Askari, Haji Ali, Khorramshahi, and Ramezani. According to the traditional water division system, each day is divided into eight sections, each containing 16 shares (Jorreh). Therefore, each day equals 128 shares of irrigation and two additional shares envisioned as the wage of Mirab- in charge of the water division. And each day equals 130 shares making up 1,560 shares over a 12-day irrigation cycle. Nowadays, the qanat irrigation cycle has shrunk to 6 days because of a dramatically decreased cultivated area in the wake of urban sprawl.

One of the interesting structures is an underground divider that bisects the water flow at the qanat. A part of the water goes to Qasem Abad farmlands. The other part joins another qanat named Rahmat Abad used by its owners. In this qanat, there are two types of derivation, one is the side branch bringing water to the qanat, and the other is the departing tunnel taking a portion of water to somewhere else.

In terms of preservation, the national rehabilitation program was prepared and ratified in 1998, with an allocated budget. Ministry of Jihad e-agriculture implements this program with 70 % of the rehabilitation cost of qanat covered by the government budget and the rest 30 % covered by the shareholders' arrangement. This program facilitated the release of 53 million USD for the rehabilitation of qanats since its beginning, and some 3,300,000 USD are invested annually in the qanats. In the face of depleting groundwater reserves, a permanent annual budget and supportive legislation is the main reason behind the high number of active qanats in Iran than in other countries. The Iranian Civil Law stipulates the bound or vicinity of qanats protect them. Several articles under the law protect and preserve the qanats and qanat' bound. Some of them are Article 136, 137, 138, and 139, which specifies the ownership, dimensions of the bounds, and the techniques to be used to maintain them.

Apart from the above, the International Centre on Qanats and Historic Hydraulic Structures (ICQHS) organized a Joint Qanat Committee to mobilize all the entities involved in Qanat affairs. The committee has held 12 meetings so far, attended by the representatives and experts of the ministries of energy and agriculture. The committee aims to create synergy between the missions and activities of both ministries, preventing any duplication or neutralization of policies and preserving qanats as the country's technical and cultural heritage.

Water Heritage

Qanat is a vital water irrigation technology that flourished in human civilizations by increasing agricultural production and creating new occupation opportunities even in a dry environment. The economic position of the qanat and its role in the social fabric of Yazd is vivid. Some unique properties of this qanat in terms of the cultural landscape, and sustainable local tourism, are as follows:

Qanat civilization: Yazd is the spirit of qanat civilization, referred to as the qanat lifestyle. Qanat civilization consists of a set of cultural, social and economic structures which have thrived around the technical possibilities of the qanat and facilitated sustainable interaction between humans and their environment. This covers a vast area of arid and semi-arid lands where surface streams are extremely rare, and people depend on groundwater through qanats. Therefore, qanat as technology established a new relationship between humans and their environment, underlies an intricate network of political, social, cultural, and economic structures.

Historical and cultural relevance: Qanat directly or indirectly relates to other historical and cultural attractions in Yazd. Qanats are not just some technical objects aloof and independent from urban life. Qanats are like a network of historical and irrigation bodies creating prosperity everywhere.

Tourism industry: Qanats are easily accessible, another potential for tourism and amusement. Qanats in Yazd originate from the Shirkooh mountains in the south and southeast towards the city, passing through various geological formations and providing a unique opportunity for geo-tourism. Each qanat denotes a particular historical event or crucial story making tourism more lucrative.

Intangible cultural values: The tradition of qanat construction and maintenance is deeply rooted in Iran's history. It inspired many customs and jargon still used today. These intangible cultural values are an essential part of qanat tourism.

Environmental sustainability: Qanat is an environmentally friendly technology extracting water without damaging groundwater resources. However, modern techniques like tube wells have taken over in recent times due to reduced time and costs of construction. It is important to note that traditional practices like qanats are more sustainable even though they are time-consuming and costly to build. Essentially, the hidden cost of modern methods is overlooked whose environmental consequences may surpass their profits over time.

Qanats and aqueducts: Touristic potentials of qanat are not less than that of aqueducts, but aqueducts have gained a much better position in the tourism sector. The resemblance between the qanat and aqueduct is perceptible in their profiles.

Unlike an aqueduct, a qanat is a dynamic system that cuts through the soil, advances into the saturated area underground, and develops some side branches over time to extract more water or keep its discharge steady. An aqueduct is built as an integrated structure to convey water from one place to another, but a qanat is built over a long period to maintain the aquifers. Qanat is dug a few hundred meters down, but it is extended to keep the groundwater balance. On the other hand, aqueducts– unlike qanats – are visible on the surface and are spared from the encroaching modern developments.

5.6 QAZVIN QANAT- FAZLALI KHAN

Name	**Qazvin Qanat - FazlAli Khan**
Location	**Qazvin Plain, Iran**
Latitude	**36.268**
Longitude	**50.004**
Category of Structure	**Water Supply System**
Year of commissioning	**More than 2000 years ago (247 BC – 224 AD)**
River Basin	**Abhar river basin**
Irrigated/Drained Area	**Variable (500-1500 ha)**

History

"Necessity is the mother of invention" is rightly showcased by Qazvin Qanat FazlAli Khan's story. The increasing population and conflicting demands led to the invention of the ancient Iranian irrigation structure called Qanat, which is still in use. It drives groundwater to the surface using gravitational force. The Persian qanat has a unique niche in the country's cultural, social, economic, political, and physical landscapes.

Qanat is a unique technological creation where architecture, technology, and science are manifested in nature. It is a prominent structure considering that, for ages, it influenced significant cultural indicators and social aspects such as settlement patterns and landscape, symbolism, public participation, sustainability, and literature (tangible and intangible heritage). Compared to deep wells, Qanats are cost-efficient, long-lasting, prevent evaporation in a dry climate, and transfer long-distance water without energy. At present, there are over 37,000 live qanats in Iran, with a total discharge of nearly 7 MCM of water per year. This considerable amount of water is supplied by qanats without any fuel or electric energy- an environmentally safe option.

Description

Located in Qazvin Plain, FazlAli Khan Qanat's main gallery was constructed more than 2000 years ago (during the Parthian Empire and the end of the Achaemenid Empire). This type of traditional qanat is built by a group of skilled labourers (Moqannis) with their hands. It requires a detailed understanding of subterranean geology and a degree of engineering sophistication. The gradient of the qanat is carefully controlled- a gradient too shallow yields no flow, and a gradient too steep will result in excessive erosion and collapsing the qanat. Misreading the soil conditions leads to collapses, which at best require extensive rework and, at worst, are fatal for the crew.

At FazlAli khan qanat, the main gallery wall was constructed with appropriate design features (for linings) to absorb the energy with minimal erosion and is unique among all Persian qanats. It was the most prominent structure at that time to provide groundwater without the need for pumping. The water drains by gravity, typically from an upland aquifer to a surface lower than the source. This old water supply structure included deep wells with a series of vertical access shafts leading to human settlements around the system. Extracted water provides drinking and agricultural water for more than 5,000 people. The climate of the FazlAli khan qanat region is arid and semi-arid with hot weather, especially in spring and summer, but the qanat supplies water over 30 km without contamination and evaporation losses. Many people of Qazvin depend on FazlAli khan qanat's water.

FazlAli Khan Qanat's water supply created human settlements, agricultural lands and prosperity. It includes three individual tunnels. The first tunnel is designed for drinking, irrigation and water-saving in the main reservoir. The second tunnel is designed for pottery at Dade Yaghot's ancient hill. For pottery, clay soil and water were mixed to make water containers. Some of these antiquities are available in the Qazvin's Museum of Anthropology. The third tunnel is designed for running six watermills at NezamAbad ancient hill. Watermills were used as water wheels or water turbines to drive mechanical processes such as milling (grinding), rolling, or hammering. Due to water table drawdown and land subsidence in recent years, a part of the main tunnel was diverted. Today, just the first tunnel is operational, and the other two have dried up.

Apart from its peculiar engineering design, the qanat is also known for its participatory operations and management mechanisms. Conservation and management of qanats have always been handled by local people with the least interference from governments. With pre-decided rules and outcomes, timely attention is paid to cleaning, maintenance, and conservation activities such as layroobi, abharzi and other conservation measures.

With minor modifications, the management mechanisms continue to the present day. A well-developed and coherent system of labourers is also formed for maintenance. Supervisors (Mobashers) are at the top of the management pyramid, and everything is done under their supervision. Users' cooperation is formed from qanat council members for 3-4 years who coordinate between users and governmental offices in their counties. They regularly monitor the qanats and water quality and report issues such as illegal diggings and polluting industries. Regional and geographical monitoring and evaluation are also performed. For example, in areas with declining groundwater levels, deep and semi-deep wells are prohibited.

Besides various national organizations, Iran's Cultural Heritage, Handicrafts and Tourism Organization (ICHHTO) is the leading organization responsible for conserving and safeguarding valuable historical properties and tangible and intangible cultural heritage.

Water Heritage

FazlAli khan qanat was an important innovation of its time; it enhanced food production, boosted the economy, and led to intercultural exchanges. It enhanced people's incomes and created deeper social ties that continue today. Constructing FazlAli Khan qanat led to agricultural development and new settlements (5 villages) in the

Qazvin region. With a stable irrigation water supply and available drinking water networks, migration dropped drastically, especially in rural areas.

The qanat was an engineering marvel, excellent in terms of its construction design, native techniques, and sustainability. Excavating the main horizontal tunnel of FazlAli Khan Qanat and extracting water without using energy were the most innovative technology in the field of geography and hydrogeology at those times.

At a glance, the qanat is a horizontal tunnel that drains out groundwater, but digging this tunnel requires a precise set of techniques. A qanat is a gently sloping subterranean canal, which taps a water-bearing zone at a higher elevation than the cultivated lands. It enhanced the human ability to better adapt to environmental conditions and led to technological advancements changing the course of history. The length of the structure is over 30 km. Vertical shafts (access wells) were excavated every 20 -30 m. These vertical shafts supported the construction and maintenance of the underground channel as well as the air interchange. The excavating technology of the main tunnel was very strategic and accurate, depicted by the structure's stability even today after around 20 centuries.

It was a great achievement that created its exclusive civilization and generated a distinct cultural tradition. A qanat system has a profound influence on the lives of water users. It allows those living in a desert adjacent to a mountain watershed to create a large oasis in an otherwise stark environment. The vital role of qanat has also been reflected in different aspects of Iranian approaches to life, including the creative design of household objects, and residential, public and administrative buildings and facilities in cities and villages. Diverse cultural and natural aspects have been combined to demonstrate significant reflections of Iranian traditions. The overall layout of the qanat, the specific techniques, and the design of water supplies resulted in the development of sustainable technology and balanced use of natural resources.

Institutionalized within the public management system of qanat are social relationships based on interaction, conciliation, equality, philanthropy, cooperation, contentment and optimal utilization of natural resources. Among the most important qualities of qanats, is its constable utilization system. The qanat is regarded as the first water resource to be constructed by consumers themselves, who are personally responsible for the usage and maintenance of the structure using a managerial framework for utilization and maintenance. Traditional maintenance methods such as harim (Qanat buffer zone) determining, pishkar kani, layroobi, kaf shekani, shakheh Zani, kaval gozari, sang bandi, kamargir, baghal-bori, ab harzi, and towqeh chini are still practised today. Enjoying validity and acceptability from the users, this managerial framework is still in practice.

5.7 SHUSHTAR HISTORICAL HYDRAULIC SYSTEM

Name	**Shushtar Historical Hydraulic System**
Location	**Khuzestan Province, Iran**
Latitude	**32.033**
Longitude	**48.850**
Category of Structure	**Water Mills**
Year of commissioning	**500 BC**
River Basin	**Karun and Gargar River**
Irrigated/Drained Area	**40000 ha**

History

Shushtar Historical Hydraulic System is an island city from the Sassanid era with a complex irrigation system in Iran's Khuzestan Province. It was registered on UNESCO's list of World Heritage Sites in 2009 as Iran's 10th UN-registered cultural heritage site. The famous French archaeologist Jane Dieulafoy considers this area as the largest industrial complex before the industrial revolution. The Shushtar Historical Hydraulic System demonstrates outstanding universal value in its present form.

The Shushtar system is a homogeneous hydraulic system, designed globally and completed in the 3rd century AD, probably on older bases from the 5th century BC. It is as rich in its diversity of civil engineering structures as it is utilised in myriad activities like urban water supply, mills, irrigation, river transport, and defensive system. Band-e Kaisar (Caesar's dam), an important part of Shustar was built by a Roman workforce in the 3rd century AD on Sassanid order. It was the most eastern Roman bridge and dam- the first structure in Iran to combine a bridge with a dam. Some parts of the irrigation system originally date back to Darius the Great's reign, an Achaemenian king of Iran.

Description

The Shushtar water mills are one of the best irrigation systems from ancient periods. These include a collection

of dams, tunnels, ancillary canals watermills utilized as an Industry–economic collection. Gargar weir is built on the watermills and waterfalls, abstracts don storms from the Gargar branches and leads water in the tunnels. Bolayti Canal is situated on the eastern side of the watermills and waterfalls supplying water from behind the Gargar bridge and preventing damage to the watermills. Dahaneye Shahr tunnel (city orifice) is one of the three main tunnels which channel water from behind the Gargar weir into several watermills. Seh koreh canal channels the water from behind the Gargar Bridge into the western side. In watermills and waterfalls, there are noticeable mills with a perfect model of haltering to run mills. The Gargar Canal is a veritable artificial watercourse that led to the construction and irrigation of a new town in a semi-desert area.

The Band-e Kaisar (Caesar's dam), an approximately 500-m (1,600 ft) long Roman weir across the Karun, is the critical structure of the complex, along with the Band-i-Mizan retains and diverts river water into the irrigation canals in the area. It partly consists of a pair of primary diversion canals in the Karun River, which is still in use today. It delivers water to Shushtar city via a route of supplying tunnels. The area includes Selastel Castel, which is the axis for the operation of the hydraulic system. It also consists of a tower for water level measurement, along with bridges, dams, mills, and basins. Then it enters the city's south plains enabling farming and orchards (over an area of 40,000 ha) in Mianâb. The whole area between the two diversion canals (Shutayt and Gargar) on the Karun River is called Mianâb, an island of the Shushtar city at its northern end. The site has been referred to as a masterpiece of creative genius by UNESCO.

Water Heritage

An engineering marvel of its time, the Shushtar Historical Hydraulic System testifies to the heritage and the synthesis of earlier Elamite and Mesopotamian wisdom. It carries the stamp of a past civilization that devised intelligent irrigation systems which are running even today. The construction of this system was influenced by the Petra dam and tunnel and by Roman civil engineering. This development increased water supply and led to intercultural technological exchange, creating a global irrigation fraternity way back in the 18th century. The Shushtar hydraulic system, in its ensemble and particularly the Shâdorvân Grand Weir (bridge dam), has been considered a Wonder of the World not only by the Persians but also by the Arab Muslims at the peak of their civilization.

Shushtar is a unique example of hydraulic techniques developed during ancient times, which had multiple structures and several use cases. By diverting a river flowing down the mountains, using large-scale civil engineering structures and creating canals, numerous water uses were generated like urban water supply, agricultural irrigation, fish farming, mills, transport, defence system, etc. It showcases traditional technological skills serving the sustainable development of human society in harmony with the natural and urban environment.

The Shushtar Historical Hydraulic System retains a high authenticity and integrity as a comprehensive and continuing functional system. The natural environment and characteristics of the System are completely intact even today. Despite the passage of time, natural weathering, and modernization, the Shushtar Historical Hydraulic System has always continued to serve its functions. This was guaranteed through regular maintenance, conservation, and valorization. During the last 2,000 years, the System has evolved technologically. For example, the first industrial electricity distribution centre in Iran was established within the Shushtar Historical Hydraulic System, which integrated some alterations to the facilities within the system. These interventions were integrated in a compatible and harmonious manner with nature and the system's modalities.

Shushtar became a starting point for technological innovations in Iran. The system contributed to higher agricultural produce and diversified the society with many occupational avenues leading to prosperity. Although the main objective was hydraulic energy water resources management, the system also became an exemplary environmental sustainability work. The continuous agricultural, economic, industrial, trading and cultural expansion of the Shushtar region also highlights its historical relevance.

The continuity of the system over the years is an excellent representation of its well-designed and implemented operations and management protocols. The first preservation master plan dates back to 1985, approved by Zista consulting engineers. Another master plan was prepared in 1988, followed by a Rehabilitation and Maintenance Plan for the Historical Fabric of Shushtar in 1992, ratified by the high council of the Iranian Ministry for Housing and Urban Development. In all these plans, special attention was given to historical conservation, which effectively prevented damage and preserved its original aesthetic characteristics.

Since 2005, the focus has been on legal regulations regarding cultural heritage buffer zones declared by Iran's Cultural Heritage, Handicrafts and Tourism Organization (ICHHTO). The ICHHTO Shushtar Historical Hydraulic System Base was established in 1999. Since then, all protection, preservation, restoration, research and tourism management actions have been planned and implemented and closely monitored by the supervisory bodies at ICHHTO. Shushtar Historical Hydraulic System involves 13 main properties. All 13 properties have been registered on the National Heritage Monument of Iran list and enjoy special protection and conservation legislation.

5.8 ZARCH QANAT

Name	**Zarch Qanat**
Location	**Yazd province, Iran**
Latitude	**31.983 - 31.733**
Longitude	**54.217 - 54.6**
Category of Structure	**Water Conveyance System**
Year of commissioning	**1200-1300**
River Basin	**Northern rivers of Shir Kuh such as Fakhr Abad (Banadak and Terezjan rivers), Manshad, Konj Kuh, Mehriz and Tang-e Chenar basins**
Irrigated/Drained Area	**300 ha**

History

In recent years, Zārch Qanat has been used for the irrigation of crop fields. The area irrigated by this qanat is estimated to be about 300 ha, which shows the influential role of this qanat in the agricultural domains of the region. Over the years, the qanat has been repaired and remodelled many times. In 2005, the broken calcareous parts of the qanat's galleries were removed, and a span of 15 km needed kaval gozāri, which has been done during the past years. Lāyroobi, removal of calcareous sections, and kaval gozāri operations are some of the maintenance works that control water flow decrease and expand the wet zone section to increase water discharge. The wet

zone expansion works date back to 1973, as written in Yazd Water Company archives. The overall structure of the qanat has been preserved and is in good working condition today.

Description

Qanat or kariz is an ancient underground tunnel system that supplies mountain water to dry lower places by gravity for irrigation. It consists of a tunnel dug at a very slight upward gradient into the rising ground so that water from deep within the earth runs out to the surface for irrigation and drinking. Qanats were developed in Persia and later adopted throughout the Middle East and North Africa.

Zārch is a 22 km^2 town and a part of Yazd-Ardakān great plain located in an arid area with low precipitation, high temperature and high evaporation. There are no permanent rivers or surface runoffs, so groundwater is the only water source used by qanats. There are several important qanats in the Zārch region. The catchment holds the biggest water storage in Yazd province. Receiving its water supply from the upper areas of the Siyah Kuh desert, the plain has no permanent rivers. Still, several seasonal runoffs originate from the northern foothills of Siyah Kuh.

A detailed review of the structure is as follows:

Main Branches and Shafts: It has three branches named: Shur, Shirin and Ebrāhim Khavidaki, the first of which is operational now. The total length of this qanat is about 80 km. The qanat has some new wet zones about 250 m long added in the past 25 years. The well shafts in the new wet zone are spaced at a 170 m distance, while in the old wet zone, they are spaced at an 80 m distance; this distance decreases to 50 m during the dry zone. The long wet zone in the upland fluvial in the southeast water routes provides a major part of this qanat's water.

Mother well: This qanat has four mother wells. The main mother well is the Shur Mother Well branch located at a 3 km distance from Fahraj village in southeast Yazd with a depth of 90 m and a discharge of about 25 l/sec.

- **Chāh Khāneh:** In the past, a specific well was dug in affluent residents' houses or the proximity of public hammams situated near the course of a qanat.
- **Pāyāb:** Pāyāb in the local dialect refers to a sloped corridor-like passageway which is dug underground to connect the qanat tunnel to the earth's surface. These corridors provide access to qanat water.
- **Golkarpayab:** Golkarpayab is the first payab located on the course of qanat from its mother well. Due to its extended depth and lack of construction materials, this payab has become a tourist attraction.
- **Watermill:** There are several āsiyāb (water mills) along the course Qanat of Zārch, one of which is Vazir āsiyāb. It is located in a large square called Lord āsiyāb.

- **Āb Anbār:** Āb anbār is an underground structure, constructed in the past to store freshwater for domestic uses. The water reservoir was fed from a near shallow qanat. In the absence of a water network until 1961, Āb anbār provided potable water to the city of Yazd, which was primarily filled by qanat waters.

Nowadays, kavalsare is used in galleries and well shafts to prevent damage. There is no gaseous zone on the routes of Zārch Qanat; therefore, no digging of Jofte Bādoo wells was conducted. On some parts of Qanat's course at Nosrat Ābād district, parts of the galleries' roofs have been reinforced by stone works to prevent a cave-in.

Water Heritage

Qanat of Zarch is the longest recorded qanat in the world which is located in Yazd province of Iran with a gallery length of 80 km, mother well depth of 90 m, and more than a thousand shafts. The Qanat contributed to the region's economic development by enhancing food production and providing water for domestic use.

Zarch Qanat, though simple in its design, was a complex irrigation structure that diverted water systematically from the upper lands to the barren plains. It was built on native wisdom and is still functional today. A revolution of its time, the qanat was an important irrigation structure. The engineering design and construction aspects were excellent and ahead of their time.

As the sub-branches join the main branch qanat of Zarch, it passes through Yazd and finally end up in Zarch. The supplying resources of aquifers are located in the upper parts of Fahraj and Khavidak in the vicinity of Mehriz. It has a gradient of about 0.5 %. The distance between well shafts in the newer pishkar (wet zone) is 170 m, whereas the distance between them in the old pishkar is 80 m and decreases to 50 m in khoshkan (dry season). The well shafts have a diameter of about 75-80 cm, the height of the gallery is 1.8 m, and its width is 60 cm. In addition to circular well shafts, there are some square-shaped shafts of 60×100 cm in size. It is claimed that digging these wells dates back to the pre-Islamic era.

In such an arid area with scorching weather during summer times, the qanat provides water for drinking, sanitation and irrigation purposes. Still, nowadays, it is only used for irrigating a few farms in Zārch. This qanat used to irrigate about 300 ha of farms and gardens of Zārch in the past, which was a miracle in ancient times.

The Qanat of Zārch has a sustainable operations and maintenance system, especially in distribution and ownership. The irrigation cycle is once every 15 days, i.e., each farmer can use the water every 15 days or 24 rounds per year. Each round is 140 Joré, and each Joré is broken down into 6 Dongs or shares. Therefore, the 15-day cycle of water consists of 12,600 shares or 2,100 Joré. The old method of tub and bowl (water clock) has been used to measure irrigation time. The bowl takes about 10 mins 17 secs to sink in the tub; this interval is called a joré. Some lines inside the tub show smaller units dividing the entire space into six sections, each equal to one share. Each joré was equivalent to six shares.

The Qanat of Zārch is currently managed by the Qanat council, behaving as a custodian to deal with its affairs. In addition, some other people, including the supervisor, manager and water distributor with defined duties, are involved in the matter. Furthermore, a representative is traditionally appointed to investigate issues. The farmers own the qanat. Records in the registered office identified 1,037 stakeholders, holding 11,656 shares out of 12,600. The ownership of the other 944 shares remains uncertain, probably because of unregistered shareholders. The main stakeholders and farmers include some wealthy citizens of Yazd and some residents of Sarcheshme and Tudeh in Zārch, who rent out their water shares to farmers. There is a systematic management of the shareholders, farmers and water rights which is still applicable today.

6 IRAQ

6.1 AL-ADHEM DAM

Name	Al-Adhem Dam
Location	Diyala Governorate, Iraq
Latitude	34°33′12” N
Longitude	44°30′10” E
Category of Structure	Dam
Year of commissioning	637-226 BC
River Basin	Al-Adhem River
Irrigated/Drained Area	250000 ha

History

Diyala Governorate is located in eastern Iraq, 57 km from the capital, Baghdad, to the north. It consists of six districts, the centre of which is the Baquba district, in addition to the districts of Muqdadiyah, Baladruz, Khalis, Khanaqin, and Kifri. The Diyala River passes through it, which flows from two branches, one from inside Iranian territory and the other from inside Iraq. The governorate's climate is characterized by being hot in summer and cold in winter. Agriculture is one of the most important sectors of the governorate and contains many different orchards and forests and is famous for citrus cultivation. The dams that built on the Tigris River in the governorate and still working to regulate water release for drinking and household uses, irrigating agricultural lands and generating electric power are (Hamrin, Alwand, Diyala and Al-Adeem). The archaeological Al-Adhem Dam was built on the Al-Adhem River, and its construction dates back to the Sassanid era (637-226) Before Christ.

Description

The length of the dam is 225 m and consists of a wall staged from the back in the manner of the supporting walls to resist the pressure of the water that gathers in front of the dam. The width of the wall is 11 meters at the bottom and narrows gradually to become 6 m at the top; its height is 12 m. As for its length between the two banks, about 140 m, the water drained about 60 m of it from the middle section, i.e. in the middle of the river. As for the material from which it was created, it is the sandstone found in Mount Hamrin at the site of the dam. The stones were cut in lengths ranging between (1.4) m, width (0.45-0.60) m, and thickness (0.35) m. It is inferred from the remains of the mortar that was used. Among the stones, they consist of a mixture of plaster, lime, and fine gravel. The river water was diverted after the construction of the dam into two branches, one of which branches from the right bank of the river at the front of the dam towards Salah al-Din Governorate and is known as the River of al-Bit and extends parallel to al Adhem river until its end near Samarra.

Several branches branch off from its right bank to irrigate the agricultural lands around it. From the left side of the dam, the second branch is called the Rothan River and extends to the east until it ends near Al-Khalis. One of the most important cities that were irrigated by this river is the ruins known today as (Tulul Al-Atwaniyat), which are the remains of huge brick buildings east of the Baghdad-Kirkuk governorate road, which is adjacent to a wide valley called abiter. These cities were the largest parts of Iraq in production, thanks to the dam on the Al-Adhem River. The left side of the dam had a huge regulator consisting of (4) huge supports, with a height of (4.2 m), a thickness of (4.5 m) and a length of (10.5) m; still, its remains constitute part of the construction of the dam itself. This regulator was built from proud stone and Al-Noura mortar and one of its openings was blocked from the left side by a sandstone building with which it was built. There is an arrow of stones above the regulator in the same way that the dam was built. This indicates that the regulator is a part of the dam, and they were built at the same time.

Water Heritage

The dam was used to store water and irrigate agricultural lands. Al-Adhem Dam is considered the oldest archaeological dam in Diyala Governorate, located 150 km northeast of Baghdad and 2 km south of the modern Al-Adhem Dam. The purpose of its establishment was to

irrigate the vast areas of agricultural land on both sides of the governorates of Diyala and Salah al-Din, whose area is estimated at 250000 ha, through two wide streams (Al-Bit and Al-Rothan), in addition to securing water in front of the dam with a depth of two meters from the level of the top of the dams and the storage of (7) million cubic meters of them. The streams branching from the Al-Adhem Dam in the Sassanid and Islamic eras were called AlRathanin, as the upper Rathan is the Al-Bit River, and the lower Rathan is the section that irrigated the Al-Rothan River.

Al-Adhem Dam is one of the prominent archaeological sites in the Diyala Governorate. It represents the second oldest archaeological dam in Iraq after the Sennacherib Dam in Wadi Khans near Mosul Governorate and the oldest irrigation project in Diyala Governorate. The dam was built on the Al-Adhem River, known as cuneiform sources (Rdanu), Aramaic (Radan) and Arabic sources (Al Rathan). The lands that were irrigated by Al-Adhem Dam were known in the Sassanid era as "Kora Shad Hormuz" or "Tusuja Al-Rathanin", as they irrigated the wide area on both sides of the Adhem River, known today as Khan Al-Ghurfa on the eastern side and Al-Aith land on the western side. The dam is a witness to the great

Iraqi engineers built the archaeological Al-Adhem Dam after studying the topography of the area and the water level and making the most of the water in agriculture. The remnants of the current dam are represented on the left side of the dam with a length of (48) m, and it consists of 4 oval pillars (3), which are visible between two openings. Small bricks were used with dimensions of 20 * 20 * 6 cm; the length of one pillar is 10.5 m in width and 4.5 m in width. The opening between one pillar and another is 225 cm on the right side, and they are built over a rocky tooth. As for the central part of the dam, part of it was destroyed due to various factors. The oldest reference to the site goes back to the trip of Joseph Rousseau in 1834, as well as the traveller Felix Jones.

The dam was built in the Sassanid era (637-226) Before Christ and continued to fulfil the purpose for which it was established until it collapsed in the late twelfth century After Christ after a crack occurred in it. Some believe that the reason for the dam collapse was the wars and invasions that took place during the last Abbasid era when the Al Adhem River was the most important defensive fort at that time. During the construction of the modern Al-Adhem Dam, maintenance work was carried out for

awareness of the ancient Iraqi man to protect his cities from the dangers of torrential rains and floods. The idea of constructing the current Al-Adhem Dam in 1990 is a revival of the idea of the old

the archaeological dam, which is separated by a distance of 2 km south of the modern dam, by the Ministry of Culture, Antiquities and Tourism / the General Authority for Antiquities and Heritage headed by the archaeologist, Mr. (Burhan Shaker) in the years 1993-1994.

6.2 HINDIYA BARRAGE

Name	Hindiya Barrage
Location	Babil Governorate, Iraq
Latitude	32° 42′ 46” N
Longitude	44° 16′ 02” E
Category of Structure	Barrage
Year of commissioning	1913
River Basin	Euphrates River / Shatt Al-Hindiya / Shatt Al-Hillah
Irrigated/Drained Area	550,000 ha

History

The heritage dam was established on the Euphrates River, South of Baghdad, at the place where the Euphrates River divides into the Hindiya and Hilla branches, to replace an old (weir) dam called the Shundervarkan Dam, which was established there about 25 years before the construction of the barrage and the latter began working in February 1911.

After two years and nine months, the barrage was completed and it was officially inaugurated in December 1913, and the purpose of establishing the barrage was to raise the water level in the head of the dam to secure water to the Hilla branch. The barrage was named Hindiya after Al-Hindiya River south of the dam, whose name went back to YahyaAsif al-Dawla, Bahadur al-Hindi, who was a minister with the King of India (Muhammad Shah al-Hindi) who opened and implemented a stream that took water from the right bank of the Euphrates River to deliver water to the city of Najaf, whose people were suffering from drought and this stream was later on known as Al-Hindiyah River in relation to the Indian Asif al Dawla.

Description

The original design of the Hindiya barrage was done by Sir Willem Wilcox, who was brought in by the Ottoman government to study irrigation affairs in Iraq and establish projects there. It was established by Sir John Jackson Company Ltd.The Hindiyabarrageis similar to the oldest regulators in Egypt in its construction method.

Sir William Wilcox set the design of the Hindiya barrage in two parts: the first is the main barrage and the second part is the barrage itself plus a submersible dam at its rear. As for the designs of the Hindiya barrage and its submersible dam, they were done based on the following details:

- Building type: Bricks (brick).
- The width of the barrage: 237.5 m between the retaining wall on the right abutment and the exterior wall of the ship lanes (Lock) on the left side.
- The number of openings equals thirty-six arches divided into three basins, each of which contains twelve openings.

- The width of the opening is equal to 5 m.
- The number of abutments is equal to thirty-three, each of which is 1.5 m wide, and two main abutment piers each 3.5 m wide, which are the twelfth and twenty-fourth.
- The width of the barrage is equal to 3, 85 meters between the curtains.
- The ship lane (left bank) is equal to eight meters in width and one hundred and thirty-one in length, and a drawbridge has been erected above it, and there are three pairs of iron gates.
- Floor level (front and back) = 26.35 m
- The level of the submerged dam's top in the south of the barrage = 27.35 m
- The ground level in the south of the submerged dam = 24.85 m
- The level of the beginning of the arch = 32.35 m
- The crown of the arch = 33.35 m
- The highest flood level at the head of the dam = 32.60 m
- The highest flood level at the back of the dam = 32.35 m
- The highest flood level at the back of the submerged dam = 32.1 m
- The water level in summer at the top of the dam = 31.35 m
- The water level in summer at the back of the dam = 27.85 m
- Summer water level at the back of the submerged dam = 26.35 m
- The hydraulic gradient of the barrage = 1: 10.4
- Gate Type = Each gate has two movable shutters

Discharges across the Barrage: Sir William Wilcox guessed the maximum discharge of the Euphrates flood was 4,000 m^3/s, given that the largest amount that could pass from the Hindiya barrage was 2840 m^3/s. And the records of the discharges proved the correctness of what Sir William Wilcox went to concerning the amount that could pass from the barrage. As for the maximum discharge of the Euphrates flood, the aforementioned records did not support it, and based on the details according to which the barrage was designed with a coefficient of 1.25, and regardless of the velocity of approach, the highest discharge of water passing through the barrage without causing a danger to it, is about 3000 m^3/s.

He reached this conclusion considering the springing of the arch of 32.35 meters is the highest water level, and the highest recorded water discharge in the barrage was the flood in 1940 when it reached 2801 m^3/s on May 5 with an average speed of 3.09 m/s at a time when the water level at the back of the barrage was 32.28 meters.

Related structures:

Historical lighthouse: In commemoration of the construction of the Shunderer Dam (1890 AD), a high lighthouse was constructed near the left wing of the barrage that can be seen today, and the following is written on the plaque placed on one side of the lighthouse:

When the Euphrates River diverted from its course and adjusted to a different direction as you see it, we were commanded, to establish this strong and tight barrage and split this bay completely, by the one whose orders are strictly binding on the face of earth, the greatest of good deeds. The pride of the Sultans of Othman's family, the successor of the Messenger of Allah, the Ghazi Sultan (Abdul Hamid Khan), son of the Ghazi Sultan (Abdul Majeed Khan), whose victory was supported by Almighty Allah and associated success in obeying his command to revive the earth after its death, he who built Hilla and other districts which were completed in 1308 A.H. and may the blessings and peace of God be upon Muhammad the Prophet, his honourable family and good companions.

Water Heritage

Solving the Irrigation Problem: The proposal to build the Hindiya Barrage in its ancient site was a life ring, as the water was cut off from Shatt al Hilla in the dry season, and the situation became more critical than it was in 1889, that is, before the construction of the Shunderfer Dam, and that many villages were abandoned by their people after the palm groves tended to damage due to extreme thirst besides that the Shunderfer Dam did not fulfil its duties as a result of the erosion occurring in its back, wherein the situation worsened year after year until Sir William Wilcox, was assigned to organize the affairs of Iraq irrigation, who then developed new dam's designs in 1909.

The Barrage as a Water Regulator: The barrage was used to regulate the water and distribute it alternately on the streams located in the north of the barrage on one side and the river course located in the south of the dam on the other side, and this shift system differs according to the seasons of the year and the need for winters and summer's crops, and below is a table of levels, discharges and areas of Hindiya Barrage.

One of the most important factors that led to the survival of the facility in good condition is the periodic maintenance of the facility by the Iraqi Ministry of Water Resources, and it is worth noting that this ministry is carrying out in this year 2021, and at present in particular, the work of cleaning and dredging the watercourse from sediments at the head and back of the ancient Hindiya Barrage under the auspices and directions of the Iraqi Minister of Water Resources, Engineer Mahdi Rashid Al-Hamdani.

The most important maintenance work that has taken place on the aforementioned barrage since its construction until now is given below:

- 1917 – Repairing the Barrage's floor for areas where gaps occurred due to mismanagement as a result of the foreign occupation of Iraq.
- 1918 – Repairing the floor at the back of the barrage as a result of the sabotage that occurred in some parts of it.
- 1919 – The gaps in the barrage were filled with cement concrete, with the construction of two massive walls dividing the barrage at its rear into three sections.
- 1921 – Repair of floors due to erosion because of a flood that occurred in 1920.
- 1925 – Reconstruction of the floor with the construction of a new wall for the submerged dam and new openings connected to the gates with the construction of new gates and renewing of the exterior of the building.
- 1926 – The navigation lock's basin was dried up and the surface layer of its floor is removed and another layer of cement is built. In the years following 1926, regular maintenance work and minor repairs during the summer months continued.
- 1927-1989 – Mechanical, electrical and civil maintenance works were constant by the Ministry of Irrigation at the time
- 2017 – Rehabilitation of Hindiya Barrage's Heritage Lighthouse.
- 2021 – Cleaning and dredging of the stream of the Hindiya Barrage

6.3 WATERWHEELS OF HEET

Name	**Waterwheels of Heet**
Location	**Al-Anbar Governorate, Iraq**
Latitude	**33° 38′ 52”.09 N**
Longitude	**42° 49′ 26”.36 E**
Category of Structure	**Waterwheels**
Year of commissioning	**More than 2500 years ago**
River Basin	**Euphrates River**
Irrigated/Drained Area	**22.5 ha**

History

The Water wheels were constructed over the Euphrates River in Heet City and they occupy an area of (2500) m^2. The main goal of their construction is to irrigate agricultural lands and grind grains by connecting the mills to the waterwheels. Waterwheels were used to irrigate the agricultural lands of several farmers in the Turbeh Village until the '80s of the last century in a shape of a river strip with dimensions of (1500*150) m^2 i.e., 22.5 hectare.

Description

The waterwheel is a wooden wheel 11. 6 m in diameter installed on a structure (constructed from stone and limestone) in the middle of the river called Aldaliya which carries 4 waterwheels. The waterwheel is made of only wood and ropes and no other materials are used.

Waterwheel consists of the following parts: -

- Al ober:- it is the wooden axis around which the waterwheel rotates.
- Al sulban: - It is everything in the form of two intersecting lines that connect Al ober to the waterwheel perimeter.
- AlKefaf: - wooden sticks on which the waterwheel perimeter is made and on which Alqawaqa is fixed.
- Alqawaqa: - pottery jars that ladle the water from the river and pour it into the water stream.
- AlHufuf: - wooden nails used for binding waterwheel parts together.
- Alsubn:-wide nails, the length of each is two feet, placed between Al'ober and Alsulban.
- Alsadan:-wooden parts on which Al'ober is put.
- Al-karaked: a wooden piece used to complete the cross if it is short.
- Albethora:-a wooden square connected to the waterwheel tip to increase its rotational speed.
- Alrabtta: - a strong rope to which the waterwheel is tied to stop it for maintenance purposes and not be swept away by water current during flood season

Water Heritage

Water Shortage and Agriculture Degradation's Solution

The Akkadians settled on the western bank of the Euphrates River between the region of Aneh and Heet in the fourth millennium BC, where they cracked the streams from the Euphrates to the agricultural lands and practised agriculture based on free-flow irrigation. For hydrological reasons, the bottom of the Euphrates River fell, and the irrigation water receded from its courses, which led to the degradation of agriculture. The farmers faced this problem with the idea of inventing wheels that rotate with the force and speed of the water flow in the river, and they called it Na'oor (singular form for a waterwheel) and Nawa'eer (plural form for waterwheels).

The Waterwheels as a Cultural and Historical Heritage

The waterwheels certainly existed more than two thousand years ago, when a mosaic panel was discovered in the city of Anemia dating back to the year 469 BC, confirming the existence of the waterwheels before this period, as the human populations that inhabited these areas, especially between the city of Rawah and Heet, depended entirely on agriculture, which in turn needs the waterwheels to raise water from the river to the agricultural lands, in addition to using them to operate grain mills by connecting them to the wheels to become water mills. These activities require a close link between the groups of the community to manage it, especially the management and evaluation of the irrigation water, which is managed by the beneficiaries and not by the ruling authority, where farmers have become organized in the form of a family or village gatherings to build waterwheels on the river which are managed in a participatory system and within agreed-upon laws. These activities have contributed to the development of the economic situation and the increase in incomes for the beneficiaries by transferring the local surplus of crops and handicraft industries to other cities via the river and employing wooden rafts (Aklak) that resemble ships as they descend with the current of the river to the cities of the south to transport these goods. The return way is through dragging them with ropes by experienced men, as it is the opposite of the direction of the flow, and it is a safer and cheaper way than the land convoys at that time. This activity strengthened communication between communities in various cities.

The management of this system was carried out in the past by farmers, and there were no written laws for management and operation at that time whereby a group of farmers agree to establish several waterwheels after setting standards for water distribution and maintenance work among them. Due to industrial development, these waterwheels were replaced by mechanical pumps and mills.

Hence there is a need for preserving them and avoid becoming extinct as a token of gratitude and appreciation for their role, as it was the lifeblood for the residents of this region for thousands of years, considering it a heritage landmark, to be present and alive in the eyes of the current and next generations, and it can rise to resume its role at any time, especially in times of crises such as wars and majeure circumstances conditions that prevent access to energy (fuel and electricity).

To preserve them, the Iraqi Ministry of Water Resources is responsible for their operation and maintenance and they are subject to the irrigation laws and regulations, where the aforementioned ministry maintained these waterwheels at the beginning of 2020 as follows: -

- Constructing a reinforced concrete wall to support the soil.
- Raising the level of the waterwheels park one meter high to avoid being covered in water besides raising all its facilities, such as walkways, electricity poles, and others.

6.4 WHITE BRIDGE

Name	**White Bridge**
Location	**Holy Karbala Governorate, Iraq**
Latitude	**32°38′25” N**
Longitude	**44°4′49” E**
Category of Structure	**Dam**
Year of commissioning	**More than 450 years ago**
River Basin	**Al-Husayniyah River branched from the Euphrates River**
Irrigated/Drained Area	**NA**

History

The Holy Karbala Governorate is located in the Middle Euphrates region, southwest of the capital, Baghdad, at a distance of 105 km from it. It is boarded to the north and west by Anbar Governorate, to the south by Najaf Governorate, and to the northeast and east by Babel Governorate. It consists of three main districts: Karbala District, Hindiya District, and Ain Al-Tamr District. Karbala's climate is hot in summer and relatively cold in winter. It is surrounded by palm orchards and fruit trees. It is watered by the Al-Husayniyah River branching from the Euphrates River, which was ordered by the Ottoman Sultan Suleiman the Magnificent during his visit to the holy city of Karbala in 1550 AD, where the length of the river is 29 km.

Description

The White Bridge was built on the Al-Husayniyah River in the Husayniyah district, east of the holy city of Karbala, to connect the two banks of the aforementioned river. The bridge was built of plaster and bricks, and its length is (46) m. It begins with the runway from the side of the main street, and it is (11) m wide, then takes gradually to reach a width of (5) m at the top end of the bridge and then returns to the expansion on the second side of the bridge. The arch consists of a pointed arch surrounded by (4) eight-shaped beacons attached to its end on each side. Each beacon has a height of (4.25) m and a diameter of (1.2) m. It ends in a conical, lobed shape with (13) convex parts.

Water Heritage

The white bridge is like a port for transporting goods: For a long time, the white bridge was the water gate of Karbala, where the transport of goods was carried out through it to reach another bridge called Umm Hudayba near the door of Baghdad, meaning that it was more like a port for transporting goods to and from the city.
- The white bridge is a cultural and historical heritage: The white bridge is considered one of the historical monuments in the holy city of Karbala, which has not been eroded with time. It was established more than 450 years ago during the time of Ottoman rule in Iraq. It is still serving and standing on the river, represented by a brick bridge with one gate and two minarets on each side. It was also called the Imam Ali Bridge (The Fourth Rashidun Caliph of Muslims), where history wrote that during the construction of the bridges over the Husayniyah River, attention was focused on the current site of the bridge due to the presence of a sacred relic next to it, which is the place of prayer of Imam Ali (peace be upon him) when he passed through Karbala while heading to the Historic Battle of Siffin.

One of the most important factors that led to the structure's survival in good condition and its continuity of work so far, despite the passage of more than 450 years since its establishment, is the periodic maintenance of the structure. Maintenance work was carried out for the white bridge by the Ministry of Culture, Tourism and Antiquities at the end of 2020. According to the old specifications and the old building materials that were used in the construction of the white bridge, where the bricks were used in the construction, and the technical plaster as a binding material, and the implementation by construction workers specialized in ancient buildings.

7 ITALY

7.1 AQUA AUGUSTA AND PISCINA MIRABILIS

Name	**Aqua Augusta and Piscina Mirabilis**
Location	**Campania region (Benevento City), Italy**
Latitude	**41.892**
Longitude	**12.475**
Category of Structure	
Year of commissioning	**33 and 12 BC**
River Basin	**Serino river**
Irrigated/Drained Area	**12000 m3**

History

The Aqua Augusta is a complex system of aqueducts, 145 km long, including secondary canals, conceived under the rule of Roman Emperor Augusto. It was built during the second half of the First Century BC (commissioning date ranges between 33 and 12 BC) to collect water from the Serino river springs located near Benevento, in the Campania region (Southern Italy) and diverting it to the numerous towns scattered along the Gulf of Naples, for irrigation and civil purposes. These included Pompeii, Naples, Pozzuoli, Baia, and Misenum- a strategic naval base of the Roman Empire with the most prominent Roman fleet.

Description

The final destination of this sophisticated system of canals, underground conduits, and bridges was a reservoir known as the *Piscina Mirabilis* (or Magnificent Pool), with a storage capacity of more than 12,000 m^3. This cistern was capable of storing water for the more than 30,000 people living in the naval base of Misenum. An example of advanced engineering for the times, the system also has a high cultural value because of its contribution to the development of the main cities and, particularly, its water distribution in Pompeii, one of the most relevant World Cultural Heritage Sites.

From a preservation perspective, the system has been affected by natural disasters such as volcano eruptions (79 AD), and earthquakes (1980) besides physical phenomena such as bradyseism and subsidence. All of these have, unfortunately, significantly compromised this precious cultural inheritance. In the last few centuries, anthropic pressure (the area is characterized by one of the highest population densities in the whole European Continent), encroachments, unregulated overbuilding, vandalism, absence of maintenance, and negligence left the sites to decay, especially the Piscina Mirabilis in Misenum. Immediate action-oriented attention is required to conserve this heritage irrigation structure.

Water Heritage

Aqua Augusta and the Piscina Mirabilis greatly enhanced Roman Empire's livelihood avenues, agricultural production, and overall regional development. Important cities such as Naples and Pompeii prospered due to the services of the system. It is considered a unique turning point in ensuring food security and stability among the population in the area (more than 100,000 people), especially in Misenum, given the great strategic military importance of the Naval base.

Aqua Augusta is a unique example of traditional engineering skills, planning techniques, and hydraulic equipment used in Italy. It also sheds light on the native wisdom that the architects carried, which has been passed over many generations. New water conveyance and water distribution techniques were conceived and realized, showcasing the intelligence of Roman architects, engineers, and land surveyors. These skilled men employed simple tools and built a brilliant system, taking into account the variable altimetry profile (even for long distances). The water flow mechanism reaching the highest possible level in the route was designed to eliminate the need for galleries and create the necessary hydraulic load. Besides, the ingenious and careful study of the course allowed the positioning of galleries deep below the soil surface and, thus, significantly reducing labour and costs. With these techniques and thought-through methodologies, these structures can be called a masterpiece of humankind's ability. It was ahead of its time in terms of project formulation, engineering design, construction, and water diverted. Aqua Augusta and the Piscina Mirabilis left an indelible imprint on Roman history.

7.2 BERRA IRRIGATION PLANT

Name	**Berra irrigation Plant**
Location	**Ferrara Plain, Italy**
Latitude	**44.980**
Longitude	**11.999**
Category of Structure	**Irrigation System**
Year of commissioning	**1921**
River Basin	**Distretto Irriguo Berra Contuga**
Irrigated/Drained Area	**46000 ha**

History

Due to a plausible drought situation, declining groundwater, and increased extraction, the Consortium Chief Engineer, Pietro Pasini, recommended rebuilding the hydraulic reclamation system. To ensure a stable water supply, improve groundwater recharge, and eliminate severe consequences in humid periods, bringing in high volumes of water from the Po River was the most suitable solution.

The construction of sewers in the river embankment was rejected. Instead, an appropriate and convenient siphon derivation system was developed to consider Po River's influence on the reclamation basin even during lean periods. Four siphons were built in Guarda, Cologna (Contuga), Berra and Ariano, to have an equitable distribution of water intakes; each siphon supplied water from 200 to 205 l/s according to the lean of the river.

In addition to having architectural merit elements, the Berra irrigation Plant represents an important step in Italy's environmental improvement policy based on Eng. Pasini's hydraulic criteria, called the Pasini method, internationally known as the Italian method, define and calculate the hydraulic parameters necessary for the design of mechanical land reclamation.

Description

The Berra irrigation plant is the main water deriving centre from the Po River of the Ferrara Plain Consortium. The diverting set consists of 8 steel pipes, each one with an internal diameter of 1 m, placed at the edge of the right bank of the Po River. The highest part of these pipes is buried 5 m below the top of the river embankment, not to exceed the maximum height of allowable intake for the operation of siphons. The pipes' total measure is 91.15 m. The siphon operates with a static suction head equal to 6 m in case of minimum water flow. The flow meter Venturi pipe is located near the control room of the gate valves at the downstream section of the siphons.

The water level for the upstream section of the Derivatore di Berra canal and the surrounding reclamation network must be 0.5 - 1 m above sea level to have regular operation of the derivation system. The minimum water level (at which the Po can reach in the lean period) is only 35 cm above sea level. Under these conditions, it would be impossible to trigger the siphon, so a large tub was built just downstream of the siphons, with an altitude such that it could always create a sufficient hydraulic prevalence for triggering the siphons. A hydraulic lifting system was built downstream of the tank to bring the water to the regular canal derivation altitude. The hydraulic lifting system consists of four horizontal-axis propeller pumps coupled to four electric motors. The flow rate of the single pumps is 6 m/s with a prevalence of 1.5 m.

The plant, managed by the *Consorzio di Bonifica Pianura di Ferrara* (Ferrara's Plain Land Reclamation Consortium), is still in operation and is the most important of the province in terms of water suction from the Po River (around 200 MCM/year).

Water Heritage

The Berra irrigation plant redefined the irrigation technologies for Italy as well as for the world. The invention of Pasini's method and specific hydraulic criteria began a new phase of technological advancements and influenced the environmental policy of the time. The plant has withstood many challenges, natural disasters like the 2012 earthquake, and urban developments but is still functional today.

Fig. 1. — I sifoni di Berra sul Po.

The Ferrara Plain Consortium had a stable water supply used for agricultural practices, animal husbandry, cattle rearing, and domestic uses. The large land reclamation area of 54,000 ha where the siphon intake systems from Po River (Berra, Contuga, Guarda and Garbina) were implemented received good quality water, used for the production of animal fodder, agricultural fields and later for the vital irrigation supply services of over 40,000 ha.

The Berra Siphons (and of Guarda) buildings are still framed in the Umbertino style, and the top of the buildings, the pillars walls, and the colours also have elements from Art Nouveau.

7.3 MIGLIARO WATER DIVERSION GATE

Name	**Migliaro Water Diversion Gate**
Location	**Ferrara Area, Italy**
Latitude	**44.791**
Longitude	**11.969**
Category of Structure	**Water Diversion Gate**
Year of commissioning	**1868**
River Basin	**Po river/ Po do Volano**
Irrigated/Drained Area	**2750 ha**

History

The Migliaro *Chiavica* –Migliaro water-diversion gate is the fourth of the 7-water diversion structure for irrigation, constructed in 1868 as inscribed on a walled tombstone. It was made by the second District Consortium (a Drainage Board of that period, now united with other Districts in the *Consorzio di Bonifica Pianura di Ferrara*). The water diversion gate was provided for an area of 2.750 ha that is still under irrigation today.

Description

Migliaro's water-diversion structure is composed of a sluice gate and a building structure inserted into the river embankment for water diversion from the Po di Volano River to the countryside. The technique of constructing buildings to close and open the canals was known to the ancient Romans. Initially, they constructed gates for

controlling the drainage of the countryside into natural waterways. The same terminology then extended to the control of derivation, which - vice versa – diverts water from natural watercourses: the direction of water flow is the opposite, but the hydraulic control function remains. The overflow water was initially regulated by a cataract in wooden planks, placed one above the other as a barrier, fixed at a level lower than the water in the river.

The derivation occurred due to gravity, and the flow rate was discharged into a culvert (which crosses the embankment) and then conveyed and distributed along a branched canalization to supply a large surface of cultivated agricultural land. The building structure consists of:

- A small brick cabin, inside which – in the past - the operator raised and lowered the gates in wooden planks
- A culvert, at the base of the embankment, built-in bricks with a vaulted section
- Four brick structures, inside the embankment, with an anti-siphoning function

The flow rate varied from 150 to 300 l/s: the average total flow was around 1.8 MCM in the four years. The maintenance has slightly changed the structure, i.e., the tiled roof is now a terrace, the barrier in wooden planks was replaced with a steel gate, and to reduce the risk of infiltration, the Consorzio di Bonifica Pianura di Ferrara built a barrier with a new steel sluice-gate, detached from the old structure. The water diversion takes place by gravity, but now the flow is beneath the gate, under free conditions.

Today, the water diversion structure serves 2.750 ha, providing an average of 18 MCM of water each year. It is maintained and repaired periodically, especially the sluice gates mechanisms. To avoid the risk of infiltration into the embankment, in 1993, the Water Board installed a barrier detached from the building to regulate the flow. Although in 2012 the Ferrara area was affected by earthquakes, there was no damage to the structure.

Chiavica di Migliaro is a small and simple structure but with great territorial value. Many modifications, renovations and repair work has been done, but the diversion structure stands still. The structure's design and construction were excellent. The asphalted road on the top of the embankment has existed for many years, bears discrete traffic, even heavy vehicles but still exists and resists the aggression of time.

Water Heritage

Water is a guarantee of production and income. The Migliaro water diversion sluice gate ensured both whiles representing the other six diversion structures all centuries old. It was only renovated externally- terrace instead of the tiled roof and the old wooden gates replaced by steel gates. But its heart, the culvert crossing the embankment body, is original in brick with a vaulted section. The structure is still functioning and continues to meet the territory's needs, and its constructive simplicity has proved to be a guarantee of durability.

After the Risorgimento Independence War, the Unitary State of Italy was born in 1861. The society focused on agricultural development-, agricultural economy and achieving food security. With the construction of the seven water diversion structures, Ferrara province became the first countryside with an ensured water supply and stable agricultural production, followed by many irrigation projects in the region.

It is simple but revolutionary considering the period of its construction - in the second half of the 1800s, when drainage and land reclamation were discussed more than irrigation. The gate led to agricultural development in the province. As an extension of the structure, materials were developed. Maceri were small artificial basins similar to rectangular pools, about 2 m deep, large 1.000 – 2.000 m^2, built in the most depressed areas of the countryside. The surface drainage waters flowed into them and supplied water for livestock and vegetable gardens. Maceri was also used heavily in the production of hemp, especially in the summers.

With the construction of the diversion gates, territorial characteristics, agrarian settlements, productive economy, and local entrepreneurship intertwined, supporting a balance of land and water that has always characterized the province of Ferrara. Today, the need for irrigation water is widespread and essential- for all fruit crops (pears, apples, peaches), field-scale vegetables (tomatoes, carrots, onions, garlic, potatoes, salad) and rice fields (6,000 ha) in the province of Ferrara which is provided for by the diversion structure. Although steam-driven machines and mechanical tools were popular in the 19th century, the designer paid particular attention to energy-saving tools, as explained in old writings.

7.4 PANPERDUTO DAM

Name	**Panperduto Dam**
Location	**Italy**
Latitude	**45.671**
Longitude	**8.683**
Category of Structure	**Dam**
Year of commissioning	**1884**
River Basin	**Ticino River**
Irrigated/Drained Area	**35265 ha**

History

The complex of works constituting the hydraulic node of the Panperduto is subjected to protection by the Superintendency of Cultural and Architectural Heritage as a monumental asset. Completed in 1884, the building rests on 16 diaphragms that support 30 sluice gates on 15 lights. Panperduto Dam allows Ticino water through the Villoresi Canal or the Navigli system up to Pavia, irrigating part of the dry plains of the Basso Varesotto and the Alto Milanese.

Description

The intake structure, located in Somma Lombardo (Varese), amid the Lombardy Valley Ticino Park, consists of an overflow dam with a hydrodynamic profile crossing the entire Ticino riverbed, with a height of 4.75 m, 70 m long intake building connected to the dam, with 30 sluice gates measuring 1.50 m x 3 m high, navigation basin to the left of the intake building, water collection basin derived from intake structure with a sand light arrester with four lights: 2.50 m high and 1.5 m wide, spillway with 36 lights 3 m long, bottom trap, remains of the navigation basin with the river and intake building of Visconti di Modrone irrigation ditch, regulating building or incile for the derivation of the Villoresi Canal and the derivation of the Industrial Canal, the beginning of the Villoresi Canal with the annexed navigation basin and the navigation basin on the Industrial Canal, a hostel and a Water Museum. In particular, the downstream prospect is characterized by vaulted arched grouped in pairs, originating from a three-light window in the centre.

The whole area is protected and open to recreational activities. The building on the left of the intake structure, originally used as a hydraulic tollbooth, is now a hostel and support structure. On the right, reachable only through routes inside hydraulic structures or by water, the complex has been transformed into the Museum of Italian-Swiss Waters. An underground hydroelectric power plant is also built on-site, managed by the Est Ticino Villoresi Consortium and the Enel Green Power company. It illustrates the origin, history and functionality of the Italo-Swiss Ticino water basin. An Ecomuseum is located in the centre of the artificial island of Confurto as part of navigable itineraries. The museum reflects the architecture of the original building through a conservative restructuring. The Geography Room has a map showcasing the route from Sesto Calende to the Dams. A Garden of water has been created to the south of the museum and along the canal. The Garden has interesting water games. Along with the intake, the structure is positioned as a didactic itinerary that illustrates the construction.

Today the plant is in a good state of maintenance. In recent years, the structure's safety has been a subject of concern, the static consolidation of the wall structure of the dam's building (exposed over time to water pressure and weather conditions), and the improvement of the hydraulic functionality and efficiency of the work. After the replacement of 25 gates and automation, the foundations are strengthened. An impermeable screen with concrete columns was also injected by high pressure using the jet grouting engineering technique for security reasons.

Water Heritage

The complex of hydraulic works irrigated parts of the dry plains of the Basso Varesotto and Alto Milanese, geo-morphologically arid, not suitable for agricultural development, and characterized by contractual types that favoured impoverishing cultivation systems. In fact, before the construction of the hydraulic system, it was not possible to carry out intensive agriculture there. Undoubtedly the construction of the intake structure has allowed crop expansion, such as corn requiring large quantities of water. It improved the living conditions of the local population. Today, through the Industrial Canal, the intake structure feeds the Milanese Navigli System (Grande, Bereguardo and Pavese), leading to world-renowned Lombard agriculture's prosperity.

The intake structure and the projects had a long gestation period and involved a rich cultural and technological exchange between technicians and engineers. Lombardy led the dynamics of technology transfer that guided European industrialization. For the dam alone, 22,000 m^3 of concrete was used, a quantity normal today but a big deal for an irrigation project at the end of the 19^{th} century.

At the time of construction, new techniques were also traced in addition to substantial financial resources. Important figures like Eugenio Villoresi, and the engineer Cesare Cipolletti, who studied a particular instrument to measure the water flow to be distributed to the users, named Cipolletti weir, worked on the structure. The technologies acquired on-site were also exported outside national borders. In Argentine Patagonia, Cipolletti's projects were used as a reference for reclamation projects on Rio Negro. The structure was an engineering marvel of its time. The structure's engineering design is why it is functional and standing today after resisting natural disasters like floods and social developments like urbanization while providing water supply.

Irrigation and the consequent agricultural development of the area with the introduction of new crops allowed optimization of food production, generating a surplus that improved the living conditions of local farmers, in a historical moment characterized by the crisis of the traditional silkworm.

Panperduto Dam bears the stamp of a cultural change and historical heritage. The complex of works constituting the hydraulic node of the Panperduto is subjected to protection by the Superintendency of Cultural and Architectural Heritage as a tremendous asset. Historically also, due to the stable water supply, Lombardy was an economically relevant region. Even at the end of the 18^{th} century, the irrigated countryside represented an obligatory reference for agronomists (not only Italians) as an extraordinary example of an age-old artificial agricultural landscape. The realization of the intake structure is followed by tradition.

8 JAPAN

8.1 ASAKASOSUI IRRIGATION SYSTEM

Name	Asakasosui Irrigation System
Location	Inawashiro Town & Koriyama City, Fukushima Prefecture , Japan
Latitude	37.491
Longitude	140.150
Category of Structure	Irrigation System
Year of commissioning	1882
River Basin	Lake Inawashiro in the Agano River system
Irrigated/Drained Area	8641 ha

Jurokkyo Sluice (current photo)

Jurokkyo Sluice (photo taken in 1882)

History

To channel irrigation water (5.5 m^3/s) into the Asaka wilderness, the Asakasosui Irrigation System Project was launched as the first national farm irrigation project in 1879, and the Jurokkyo Sluice, the Yamagata Intake, the Numagami Tunnel (591 m) and a canal (127 km) were built. This construction continued for three years until 1882: the total project cost was 407,000 JPY (3664.85 USD), and approximately 850,000 workers were involved in its completion. However, the pre-modern traditional technology wasn't sufficient for this complex project, so a Dutch engineer was hired for the canal's construction in 1878.

Koriyama region in Fukushima prefecture suffered from poor water supply because of low annual precipitation and steep river basins leaving the area uncultivated since ancient times. Given its great potential as fertile farmland, the government implemented a land development project in 1873 to reclaim the barren land by drawing water from the Inawashiro Lake as the first national irrigation project of modern Japan. Soon after, neighbouring wealthy merchants joined the reclamation work by establishing Kaiseisha, an investment company. Two years later, Kuwano Village, with 216 ha of arable land and a population of 700, was born.

Description

Today, the Asakasosui Irrigation System has three cities (Koriyama, SukaGawa and Motomiya), one town (Inawashiro), and one village (Otama) in its jurisdiction that covers approximately 8,600 ha, 10% of the entire Fukushima prefecture, and takes in up to 15.179 m^3/s of water from Lake Inawashiro as irrigation water. Its waterway has been extended by about 470 km.

In 1876, the Home Minister, Toshimichi Okubo visited Koriyama and, impressed with the canal's success, planned a land reclamation project in Koriyama to solve geographic and social issues faced at the time. The lack of jobs, poor harvest and the need for industries led to the implementation of the project in Asaka. Moreover, this region had long suffered poor rice harvests due to a lack of irrigation water. Therefore, the government planned to draw water from Lake Inawashiro and initiated a project to develop a canal in Asaka. Under the project, Lake Inawashiro was embanked to secure irrigation water and was channelled into the Koriyama region without causing problems for the Aizu region which had been already obtaining irrigation water from the lake. For the project, 2,000 people moved into Koriyama from nine domains across the country, including the domain of Kurume in Kyushu at a distance of 2,000 km from Koriyama.

To secure new irrigation water without interrupting the lake's conventional water use, a sluice gate called *Jurokkyo* was constructed in 1880 at the mountain's opposite side, at the intake of the conventional system and the riverbed of the source river was lowered to secure a stable supply. With the construction of Jurokkyo, the lake was transformed into a dam to supply new irrigation water to the Koriyama region through the mountain tunnel. This Jurokkyo sluice is the oldest among the sluices currently operating in Japan and has a significant historical value.

The newly constructed irrigation system increased the arable area in the Koriyama region from less than 3,000 ha to 5,600 ha, generating significant economic benefits. In 1898, hydraulic power generation stations were constructed by leveraging height differences in waterways, contributing to the area's industrialisation by supplying power. Water provided by the irrigation canal was used not only for industrial purposes but also as city water and served as a driving force for the region's development.

Since its completion in 1882, no renovations were conducted for the Asakasosui Irrigation System and the facilities decrepitated. Consequently, around 1926, prefectural and national renovation projects started- the waterways were revamped, and headworks were built as part of modernization. In 1942, the Koishigahama sluice was constructed about 1 km to the south of Jurokkyo to increase the amount of water for power generation, which marked the end of the role of the Jurokkyo sluices as an irrigation facility. To help alleviate food shortages

Bronze Statue of Dutch engineer
Cornelis Johannes van Doorn

Numagami Power Station (current photo)
*Multilateral use (hydraulic power station)

Numagami Power Station (past photo)
*Koriyama City History Museum Possession

after World War II, a new major waterway was built in 1954, leading to about 1,500 ha of new paddy fields and significantly contributing to Japan's rapid economic growth.

Significant renovations were conducted from 2002-2004 to cover the natural deterioration with time and comply with the current laws and regulations. In light of the historical value of Jurokkyo (the oldest in-service sluice in Japan), an approved historical structure by the Minister of Land, Infrastructure, Transport and Tourism was kept out of the renovations and is still conserved today. The upgrades did not impair the scenic view of the structure. After the renovations, the structure was put into service in 2005.

Water Heritage

In the early Meiji period, Koriyama was one of the post stations on Oshu Road. With steep river basins and the height difference between the most prominent river (Abukuma River) in this region and reclaimed land between 20 m- 30 m, the river water could not be used as irrigation water, coupled with annual droughts. While there was 3,800 ha of paddy fields at the time, rice yields obtained from them were less than half of those obtained from paddy fields in other regions.

For the first time in Japan's history, western construction technology was applied when a shaft method of constructing a tunnel was adopted. The shaft method is a split construction method designed to shorten the construction period by installing inclined and vertical shafts that connect to the top of a tunnel.

In November 1878, the government, in collaboration with the Dutch engineer, Cornelis Johannes van Doorn, launched the Asakasosui Irrigation System Development Project to draw water from Lake Inawashiro to the Asaka wilderness. Based on the success of the Otsukihara reclamation project, a collective name for the reclamation efforts by Fukushima Prefecture and those by Kaiseisha, this large Land Development Project catered to the economic, social, and social as political needs of Japan at the time. The project employed the conflict-ridden warriors and created several thousand ha of irrigable land, including reclaimed land.

The completion of the Asakasosui Irrigation System enabled water drawing from Lake Inawashiro to Koriyama, making a significant contribution to rice production. In 1898, the Asakasosui Irrigation System was used for hydraulic power generation, capitalizing on the height difference in waterways. Today, the Asakasosui Irrigation System is utilized by the power stations of Numagami, Takenouchi, and Marumori. The Numagami Power Station, the first long-distance high-voltage transmission ever achieved in Japan, was complicated to do at the time. This success in power transmission gave birth to a large number of spinning companies that required a large amount of inexpensive electricity and promoted industrialization and commercial development, leading to the rapid growth of Koriyama. In 1908, part of the canal's water was supplied to Koriyama which did not have enough city water. This water was also used as industrial water for a while, laying the foundation for the future prosperity of Koriyama.

The completion of the Asakasosui Irrigation System transformed the wilderness into beautiful paddy fields and promoted the development of the local economy by providing water for power generation and supplying municipal water. Koriyama, which once was a post station in Tohoku, has developed into one of Tohoku's major urban cities with a population of 3,20,000 in a little over a century.

While calculating the required amount of water, Cornelis Johannes van Doorn considered the soil and climate of Koriyama and compared them with irrigation cases in foreign countries located at approximately the same latitude as Koriyama (Spain and Italy). He based his calculation on the statistically obtained water requirement rate (amount of water consumed via percolation and evaporation) and the assumption of water supply for 1,800 ha (about half of the ordinary paddy fields at that time), and 1,000 ha of paddy fields to be reclaimed and obtained 5.56 m^3/sec as the required amount of water.

Ways to take in water for the Aizu region and the Asakasoui Irrigation System while not undermining the vested rights and interests of Aizu and maintaining the current water level were devised. The consequent result for the required amount of water for the irrigation period of 90 days was 43 MCM: The area of Lake Inawashiro is 103 km^2, and the amount of water for 1 cm is 1 MCM. 43,000,000 m^3 /1 MCM = 43 cm. The required water depth was set at 60 cm to ensure safety. In light of discharges into the Nippashi River, the required amount of water was secured by scraping the river bed by 60 cm, and the lake was embanked while giving due consideration to the environment. A sluice with a depth of about 1 m was constructed to facilitate water intake, and adjustments were made to the gradient of the Tonoguchi Weir waterway and that of the Futo Weir waterway, both of which Koriyama had the vested rights.

The water requirement rate computed by the Dutch engineer 100 years ago is still valid today as the unit water requirement calculated by Cornelis Johannes van Doorn (0.00195 t/s) is almost equivalent to that for the National Asakasosui Irrigation System Farm Irrigation Project (0.00185 t/s).

Building the Numagami Tunnel was a demanding task due to its muddy soil containing water and steep, solid bedrock. New foreign technology and construction methods were introduced and tried for Numagami Tunnel to shorten the construction period. A method that gave due consideration to airflow, lighting, the pumping of spring water and, the removal of drill waste was adopted, and shafts for the operation, such as inclined and vertical shafts that connect to the top of the tunnel, were built. The drilling operation for the Numagami Tunnel hit a roadblock, 36 m long, and was stuck due to blue clay, collapsing ceilings and walls, muddy water, and dirt. It took seven months to drill through the tunnel while injecting mortar and reinforcing walls and ceilings with iron poles. Throughout the process, compressors were used.

The Asakasosui irrigation system is characterized by a sustainable operations and management model. After 2004 renovations, an agreement was concluded between Fukushima Prefecture and Asakasosui Irrigation System Land Improvement District for maintenance, management, and repairs. Fukushima Prefecture established an administration office to implement annual inspections and repairs systematically to ensure sound governance. According to the agreement, the management costs are shared between Fukushima Prefecture and Asakasosui Irrigation System Land Improvement District. Moreover, monitoring of headworks and waterways is delegated to 100 members of the Asakasosui Irrigation System Land Improvement District, who conduct the management and maintenance of the waterways in collaboration with residents.

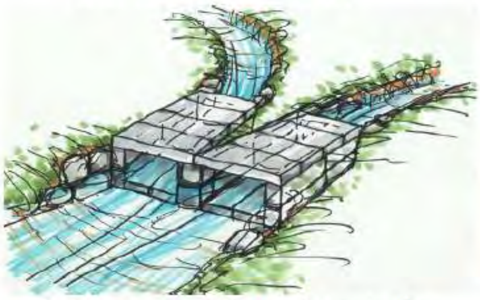
From a historical perspective, the Asakasosui Irrigation System is an important emblem representing the cultural and social traditions of different times and ages. It was an excellent engineering piece as well as a cultural icon. It has received several recognitions and influenced literature. In 2002, it was designated as a Civil Engineering Heritage site by the Japan Society of Civil Engineers. In 2006, it was designated as one of the Top 100 Irrigation Canals by the Ministry of Agriculture, Forestry and Fisheries and was selected as one of Japan's Top 100 Heritage Sites. The year 2007 marked its selection as one of Fukushima's Top 100 Heritage Sites. Designated as a Heritage of Industrial Modernization by the Ministry of Economy, Trade and Industry in 2009, it has been selected as one of the Water Culture of Fukushima sites. Moreover, the history of the irrigation system is taught to school students via textbooks like Furusato Koriyama.

8.2 ASUWAGAWA IRRIGATION CANAL

Name	**AsuwaGawa Irrigation Canal**
Location	**Fukui City ,Fukui Prefecture , Japan**
Latitude	**36.019 N**
Longitude	**136.296 E**
Category of Structure	**Irrigation Canal**
Year of commissioning	**1710**
River Basin	**Kuzuryu-Gawa River system (Sub Basin: Asuwa-Gawa River)**
Irrigated/Drained Area	**1997 ha**

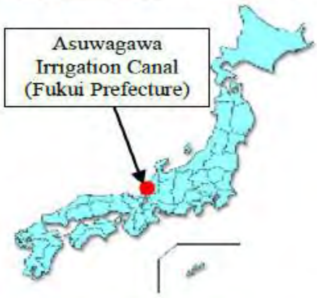
Ancient document recording the details of the canal dimensions (1710)

The picturesque cityscape created with the irrigation canal



Joseki stones installed to regulate water flow (Artist's rendering based on historical accounts)

Biotope made by drawing irrigation water into a schoolyard



Location in Japan

History

Built in the 7th century as a primitive waterway made of soil and piled stones, the AsuwaGawa Irrigation Canal took its current shape in the 18th century after the unification of intakes. Initially, the watercourses constructed at different periods withdrew water from the river individually, making it challenging to ensure equitable water distribution and causing repeated water disputes. To solve this problem, a wooden mattress division weir, a unified intake gate and irrigation canals were built in 1688, creating an ample irrigation canal drawing water from the Asuwa-Gawa River.

In addition, Joseki stone structures (2 m in length) made of sturdy stone surrounding each side of the canal were installed at the canal's diversion points to prevent excessive water intake caused by the eroded canal bottom. Joseki stone structures assured equal water distribution for farmers and eliminated irrigation disputes. Historical records like 1710 surveys show that the irrigation canal's fundamental dimensions are almost identical to the original ones in the 7th century, indicating the advanced engineering of the original plan and design of the canal.

With this canal, the irrigation area increased from 400 ha to 1,997 ha, and the area became one of the foremost rice cultivation zones in the prefecture. However, the irrigation canal and the division weir suffered frequent floods and were periodically repaired by farmers requiring large amounts of labour. Major disasters like the 1807 floods and the 1948 earthquake majorly destroyed the irrigation system. Therefore, in 1963 the Asuwa-Gawa headworks were built to ensure the stability of the irrigation system. Currently, a water management organization operates the canal system and supplies irrigation water appropriately. Additionally, this water has been used by local inhabitants and schoolchildren to create a biotope by drawing water into a schoolyard, which serves as a recreational place for children.

Description

The Asuwa-Gawa Irrigation Canal consists of seven main canals drawing water from the Asuwa-Gawa Headworks in the southeast area of Fukui City. The canal extends for 22 km, providing irrigation water for 1,997 ha of agricultural paddy fields. A remote-control system in a management office is used to control the division works and headworks, distributing water appropriately into the seven main canals. With this stable water supply, this land is now a prosperous area for paddy rice cultivation.

The Asuwa-Gawa River is one of several rivers flowing through the plains of Fukui. In the past, this river often overflowed because of drainage problems. Still, after forming an alluvial fan drainage pattern about 2,000 years ago, paddy rice cultivation began in the area. The irrigation canals feed into a residential area and have long been used as a crucial water source for daily life.

Today, this irrigation canal continues to contribute to community revitalization meaningfully. Local traditional events are often held utilizing and incorporating this irrigation water, for example, a walking event where people walk alongside irrigation canals and create a biotope in a schoolyard with water drawn from the canal by inhabitants and schoolchildren. The biotope is used as the base of environmental education for children to enjoy water and nature.

Restoration and maintenance: From its remodelling in the 18th century, the canal has witnessed many natural disasters and severe damages. A devastating earthquake in June 1948 destroyed the canal. The riverbed also collapsed, making downstream water intake impossible. Modern headworks and irrigation canals were built in 1963, with further intake unifications planned. The current headworks were built in 2008, with the irrigation canal being repaired in the same year. Today, the water supply system is managed via a remote-control facility, and a stable water supply irrigates a vast paddy field area.

Water Heritage

The AsuwaGawa Irrigation Canal was a turning point in irrigated agriculture and transformed into one of Japan's most prominent rice-producing areas. The stable water supply also increased people's standards and the aesthetic value of the region. The region developed socially with more harmony among the settlements that used to face water conflicts earlier. A primitive waterway initially to the large-scale irrigation project with a division weir, intake gate, and the main irrigation canal, the irrigation system achieved a steady water supply and thriving paddy rice cultivation. Standing and functioning efficiently even after 300 years and severe disasters, the irrigation canal increased the irrigation area from 400 ha to 1,997 ha, giving the community an economic boost and social security.

According to historical documentation, before the 18th century, the irrigation system faced water distribution woes that were solved by a unique installation. A firm wooden mattress division weir, a unified intake gate, and irrigation canals were installed to unify water intake from multiple division weirs. This idea was exceptional and innovative in those days, which reduced water conflicts and increased distribution efficiency. The AsuwaGawa Irrigation Canal was the largest in the area; however, water disputes existed and aggravated. Therefore, the local administration installed Joseki stone structures in diversion points of the canal for equitable water distribution.

The AsuwaGawa Irrigation Canal stands out in the history of Japanese civilization. Everything reflects society's ethos and value over the centuries, from the engineering techniques used to the water distribution models. As a city canal, it provided irrigation water and contributed to community revitalization by catering to domestic uses as well as beautifying the region and maintaining an ecological balance. The cityscape and irrigation canal come together in harmony alongside the Togo-kaido road, a historical area where generations have lived over the ages. This area prospered as a post town until the 16th century and flourished as a castle town from the 17th century. The irrigation canal flows through the middle of the road and has long been known as the Doden-Gawa River and is loved for its beautiful riverside scenery.

Regarding the historical city landscape, in 1998, the irrigation canal was repaired while the road on either of its sides was carefully preserved. It restored a local living environment abundant in harmony between people, nature, and history. The beautiful cityscape created by the irrigation canal became the subject of a novel by the famous historical writer Ryotaro Shiba. Traditional events are often held locally, utilizing and incorporating this irrigation water. Thus, the AsuwaGawa Irrigation Canal has both tremendous historical and cultural value.

8.3 BIZENKYO IRRIGATION SYSTEM

Name	**Bizenkyo Irrigation System**
Location	**Kumagaya City, Saitama Prefecture, Japan**
Latitude	**36.223**
Longitude	**139.248**
Category of Structure	**Canal System**
Year of commissioning	**1604**
River Basin	**Tone River, Tone River system**
Irrigated/Drained Area	**1400 ha**

History

Since the early 17th century, the Bizenkyo Irrigation System has been serving the water needs of the residents in the Northern Saitama Prefecture. The canal draws water from the midstream area of the Tone River, which has the largest basin area in Japan and irrigates approximately 1,400 ha of agricultural land along the right bank of the Tone River. Before the canal was constructed, residents in this area relied on rainwater, spring water, reservoirs and other water resources to cultivate rice and agricultural management was quite unstable. In 1604, the Governor of Bizen Province, Ina built a canal called Edo Shogunate within a year. The canal is one of the oldest canals in Saitama Pref. and has long been nicknamed 'Bizen moat', after the official title of Ina. After investigating the topography and the water availability of the Karasu River, a tributary of the Tone River, the irrigation canal was excavated, and a water intake was constructed.

Description

The Bizenkyo Irrigation System, 23 km long, involved constructing the Yajima weir, a reservoir system using part of the Oyama River, to distribute water through the main and branch canals. This water distribution system was later called "Kantouryu (Ina Style)" and was used to irrigate the right bank of the Tone River, which previously had no irrigation canal. In addition, the downstream flow into the KitaGawara and Hanyuryo canals, located in the uppermost stream of the Naka-Gawa River System, contributed as a critical water resource to irrigate paddy fields in south-eastern Saitama Prefecture, lacking any water resources from the mountains.

In 1604, Ina surveyed the water volume and topography, formulated a plan and finished excavating the irrigation canal of about 23 km in one year. During excavation, native techniques like the "Kanto Style" (Ina Style) irrigation technique were used, drawing on natural methods such as the "Tamei method," whereby the Karasu River was used as the water source to fill the Koyama River temporarily, the Yajima Weir installed downstream to ensure a heightened intake water level and water flowing down the Koyama River channel was stored to realize a stable the water intake. Its downstream flows into the Kitagawara and Hanyuryo Canals of the Naka-Gawa River System, lacking freshwater water sources and helping paddy cultivation. Overfall weirs secured the water level to stabilize the intake volume. In 1828, the first sluiceway was installed upstream of the intake port, and the second sluiceway was installed downstream to eliminate conflict between villages over floods and water shortage measures. This double sluiceway system was used for 131 years until 1959. In 1887, the intake port was relocated to the Kuguu area in Honjo City, which became the first brick-built watergate in Saitama Pref. designed by Mulder, a Dutch civil engineer.

The Bizenkyo Irrigation System serves as an agricultural irrigation canal supporting regional agriculture and a fundamental water-supplying structure to a vast agricultural land area in northern Saitama Prefecture. Even after 400 years, the same flow paths are continued while many sections remain unlined, marking its historical relevance and providing a glimpse into history. The Canal being maintained unlined helped in multiple functions like replenishing groundwater, maintaining rural landscapes, conserving ecosystems and preventing floods. Environmental conservation activities with active participation from residents in weeding and cleaning led to land improvement and maintenance.

Water Heritage

The fertile land in south-eastern Saitama Prefecture was formed by flooding and was too high to draw water, which forced the residents to rely on rainwater, spring water and reservoirs, etc., for rice production. Accordingly, in 1604, after studying water availability and topography, an irrigation canal of about 23 km was excavated by installing an intake port in the river within a year. The Canal stabilized the supply of agricultural water.

Currently, the Canal channels water for 2.2 km through the riverbed in the foreland after taking in water. The water enters the protected inland via the third sluiceway at the Tone River embankment in the Kuguu area, Honjo City. This is a unique form of irrigation, whereby water channels are installed in the foreland, and the sluiceways are left unlined when moving the intake port upstream of the Tone River. Diversion weirs installed in the main canal divert the water to branch canals by raising the water level (a reservoir function) so that each weir maintains its characteristic form, such as the inclination of a weir to the centre of the stream and weir structure, etc. At Suzumenomiya Weir installed in the Ehara area of Fukaya City, a weir is installed diagonally to the centre of the stream and the centre of the stream is directed toward the water intake port of the branch canals. The Canal remains unlined to this day, as well as embankments are constructed around bridges, weirs, and vulnerable parts of slopes, also use natural stones in natural environments and landscapes. The Yajima Weir and diversion weirs have been reconstructed into sturdy structures such as gates made of reinforced concrete or steel to adjust the intake volume and ensure the safe flow of floods.

It was a groundbreaking project that involved surveying the water volume and topography, formulating a structured plan and periodic customised advancements—completing the work in one year so that the river could be used for irrigation rather than relying on rainwater, spring water, and reservoirs. From an engineering perspective, the irrigation system was revolutionary. Native irrigation technique "Kanto Style (Ina Style)" was developed into a full-fledged concept. Ina developed the "Kanto Style (Ina Style)" irrigation technique as an excellent civil engineer. The technique, which is an efficient irrigation plan, utilizes the natural topography, where water is taken from a river. Yajima Weir employs the reservoir system utilizing the Koyama River is installed, enabling the use of drainage water in the weir's upstream area.

The project led to economic prosperity, increased satisfaction among the residents and environmental sustainability in the long run. It completely revitalized the local economy by increasing rice production by 10,500 tons. The fertile area in Saitama Pref. led to the combined production of paddy and "Fukaya green onion" as the main crop in the upland field. Water level and volume in the rivers were stabilised using weirs and reduced spring water and rainwater dependence. In the upland field areas, unlined canals replenished groundwater and conserved the aquatic ecosystem and natural environment.

The Bizenkyo Irrigation System bears the stamp of a cultural tradition and civilization. In the Joshikimen area, Fukaya City, a railway dedicated to transporting bricks was constructed in 1895, and the Bizenkyo iron bridge was named after the irrigation system was built. The plate girder bridge is designated as an important national cultural property as the adjoining brickwork arch bridge. Eiichi ShibuSawa's stone monument in the Harago area conveys the expansion of paddy fields in the upland fields. Even now, after many years after its construction, it is considered a historically valuable irrigation system, helping in replenishing the groundwater, preserving the landscape, conserving ecosystems, and preventing flooding.

The Bizenkyo Irrigation System is being taught at school as an important component of regional and cultural infrastructure, with periodic surveys held at various levels in schools to raise awareness among future generations. Regular surveys and field visits are also held for students.

In 2006, the Bizenkyo Irrigation System was registered as one of "Japan's fine 100 canals" by the Ministry of Agriculture, Forestry and Fisheries, recognising its long history and incredible landscapes. The traditional "floating lanterns on the river" were revived by residents in 2009 when developing the amenity embankments using natural stones.

8.4 DOEN IRRIGATION SYSTEM

Name	**Doen Irrigation System**
Location	**Aomori City ,Aomori Prefecture , Japan**
Latitude	**40.808**
Longitude	**140.383**
Category of Structure	**Irrigation System**
Year of commissioning	**1644**
River Basin	**Iwaki River system**
Irrigated/Drained Area	**8300 ha**

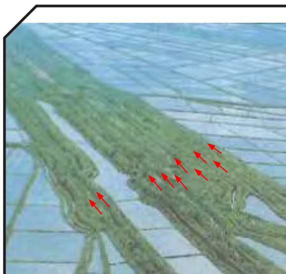
The Present and the Past of the Doen Irrigation System


The Improvement Work of the Doen Irrigation Canal (1944～1968)


The Doen Irrigation Canal and Mt.Iwaki
(Recognition of the Best One Hundred Canals in 2006)


The Nogi Division Works of the Doen Irrigation System（1944 ～1968）


The Present Division Works
(The Nogi Division Works)


Canals after Setting up the Nogi Division Works


The Present Canals Improved


In the early 1900s, the erratic and constantly changing water levels would cause hardship when planting rice


The Present State of rice paddy fields

History

Doen Irrigation System is a large irrigation canal that promoted the development of the Tsugaru Plain. The Tsugaru Plain, which expands over the Iwaki River Valley, was barren for many years, below 20 m above sea level and the harsh winter climate. To create water availability, in 1644, Tsugaru Clan Lord Tsugaru Tamenobu built irrigation headworks, an irrigation reservoir, and an open channel for new rice paddy fields. These structures are collectively known as the Doen irrigation system. Presently, the system contributes to the regional economy and develops regional agriculture with irrigation water for 8,300 ha of farmlands.

Around 1875, the irrigation commissioner set up the water delivery mechanisms and repaired the irrigation system. As a result, the Doen irrigation system maintained stable irrigation water with complete management of the water delivery and maintenance of the open channel.

Description

The Doen Irrigation System is composed of 12 weirs in the lower reaches of the Iwaki River. The weirs were designed to ensure equitable water allocation to the mid and lower reaches of water users. At the upper stream weir, large rocks were placed in the river stream at regular intervals to allow enough water to flow through the gap of large rocks. At midstream, weirs of wooden boxes filled with smaller rocks were installed to allow enough water for the lower stream area to flow through the smaller gap. Finally, at the lower stream area, weirs were constructed with rice straw bags filled with soil to dam up the water stream fully. The system with detailed guidelines solved the water shortage problem around the lower reaches.

The total length of the open channel extends to 16 km, located at the lower reaches of the Iwaki River. In the absence of standardised survey methodologies prevalent today, a technique called "Sekisuji Kenbun" (Checking the water flow direction) was used. The paths of old rivers were surveyed by joining these tracks the direction of the water flow, and the slope of the channel was determined. The western area of Tsugaru spreading at the lower stream area of the Iwaki River is around 0.3□10m above sea level. Drainage canals were used repeatedly because of constant water shortages, and the area was often flooded due to rainfall. In 1875, a senior officer was appointed to manage the water supply and use water efficiently. The system supplied stable irrigation water with appropriate water management and system maintenance. At present, the community undertakes the operation and management of the irrigation system. The irrigation control system, which controls the water levels, is effectively used to help prevent disasters in the area.

The large irrigation reservoir called "Mawarizeki Otameike" provided supplementary irrigation water for the open channel. The reservoir was rehabilitated and expanded over the years with the expansion of an irrigated area. At present, the length of the embankment (4,100 m) is the longest among irrigation reservoirs in Japan.

In 1941, the Irrigation System was improved, and the embankment of the "Mawarizeki Otameike" large irrigation reservoir was raised. Eleven weirs, including the Doen irrigation system, suffered damage from the melted snow in spring and the typhoon in 1958. As a result, all 11 weirs upstream were combined as a united headwork, and the main irrigation canal of the Doen irrigation system's upper stream area was expanded into 27 km to supply water for 8,300 ha of the fields. A canal network of 4,900 ha was formed, exponentially increasing the yields to 1,000 m^2, about 660 kg, or an average of 11 bags of rice. As time passed, the irrigation system degraded with age, and with a drought of the Iwaki River, the Doen irrigation system relied on the Tsugaru Dam to replenish irrigation water. The irrigation system was then restructured, and the facility was repaired in 1996. Presently, the Doen irrigation system supplies irrigation water for 8,300 ha of paddy fields and contributes to the regional economy and has become one of the leading granaries in Japan.

Water Heritage

Despite technical constraints like no surveying methodologies, the engineers of the time developed techniques from native wisdom. They created a surveying system by joining the paths of old rivers and by controlling the slope and direction of the water flow. When rice and vegetable fields were found in the construction sites of the open channel, a counterplan of preparing substitute rice and vegetable fields was created, and the community was relocated post-construction. In 1648, the rice yields grew from 13,000 tons to 48,000 tons from 32,046 ha paddy fields in the Tsugaru Plain. The structure not only contributed to food production but also created livelihood opportunities. In 1641, when the irrigation system was built, employment opportunities were generated for many years to come.

In the 1800s, the Doen irrigation system supplied water for the fields of about 2,840 ha, which increased to 4,700 ha during the 1940s. While eliminating the environmental impacts on local habitats for fish and other ecosystems, the Doen irrigation system was improved with the help of residents and professionals in the 1990s. The Doen irrigation system has taken over as the central system to support regional agriculture.

The structure holds a cultural sentiment among the local population. An annual praying festival is held in May, and the people pray for stable irrigation water and the harvest season. People share an emotional bond with the festival, showcased in their contribution to the system's maintenance and upkeep. The irrigation reservoir called "Mawarizeki Otameike" is maintained with the community's support and used as a recreation and relaxation place for the residents.

The Doen irrigation system was selected as one of the best canals by the Ministry of Agriculture Forestry and Fisheries. It is recognised as a historical property of the community. The Land Improvement District mainly manages the maintenance of the Doen irrigation system. The residents and elementary schools in the area volunteer to help maintain the environment and the system.

8.5 FUKARAYOUSUI IRRIGATION CANAL

Name	**Fukarayousui Irrigation Canal**
Location	**Susono City, Shizuoka prefecture, Japan**
Latitude	**35.230 N**
Longitude	**138.984 E**
Category of Structure	**Irrigation Canal**
Year of commissioning	**1670**
River Basin	**Kano River basin**
Irrigated/Drained Area	**527.2 ha**

History

Located in the Kano River Basin, the Fukarayousui Irrigation Canal is an irrigation structure completed in the 17th century which brings water from Lake Ashinoko (located in Hakone, Ashigarashimo-gun, Kana-Gawa Prefecture) through a tunnel to the Fukara district in Susono City (Shizuoka Prefecture). It then flows through the Fukara River to the Kise River, thereby delivering water for irrigation.

The Fukara district is located in the western foothills of Mt. Hakone, to the southeast of the Mt. Fuji foothills. Volcanic eruptions covered the area with volcanic basalt, so despite high precipitation levels, the water from different sources such as rainfall and snowmelt from upstream seeped underground, making the river flow low. Water channels carried insufficient water even for everyday activities, let alone for large-scale agriculture. Fukara villagers were unable to grow rice, the main crop in Japan, and were forced to rely on grains that could withstand droughts, such as barley and soybeans. The shortage of water exacerbated many other social issues like poverty and conflicts leading to unrest. To resolve chronic water shortages and develop new rice fields, the village headman, Ohba Gennojo, planned to divert water from Lake Ashinoko in Hakone to the village of Fukara through a tunnel. Due to limited machinery, and rugged topography, the progress was slow. It was impossible to dig straight through some cliffs manually because of ground collapses and Mt. Hakone's soft and fragile ground. Ultimately under the supervision of Tomono Yoemon after 3.5 years, the work was completed in 1670. A cumulative total of 840,000 workers were deployed and incurred a total cost of 7,400 Ryo (6 billion yen today).

Description

The tunnel has a total length of 1,280 m with a height differential of 9.8 m between the sluice gate of the Lake and the tunnel exit and an average gradient of 1/130 over the length of the tunnel. The tunnel is also characterized by breathing holes above it that are large enough for an adult person to enter. These were dug for ventilation. There are also two vertical shafts connected via side holes, each about 30m in length and connecting the tunnel to the ground's surface. The original wooden sluice gate was replaced with a stone and steel one in 1910, and a supplementary concrete gate was added in 1989 to alleviate age-related degradation.

The water flow capacity of the tunnel is the same as when it was first dug. The canal is still used for irrigation (of rice paddies). When the structure was first built, it was used solely as an irrigation canal, but since the Taisho Period (1912-1926), it has also been used for hydropower generation.

The canal is still used for agricultural irrigation of rice paddies. During ploughing, it can cover up to 527.2 ha of the area and deliver 5 m^3/s of water, during irrigation between 1.5-4.0 m^3/s, and non-irrigation season between 1.2 and 1.5 m^3/s._When the structure was first built, it was used solely as an irrigation canal. However, since the Taisho Period (1912-1926), it has also been used for hydropower generation, powering three generators at three power stations on the Fukara River of 3100 kW, 1400 kW and 1000 kW, respectively. For the last 340 years, Fukarayousui Irrigation Canal has played a vital role as an irrigation structure, providing water for agriculture and household use and hydropower generation in recent years. The Fukarayousui Irrigation Canal delivers irrigation water for rice paddies in a large area measuring 527.2 ha and spanning four municipalities (the cities of Susono and Gotemba and the towns of Nagaizumi and Shimizu).

Maintenance: Currently, a water management committee established in 1688 manages the Fukarayousui Irrigation Canal. The committee plays a vital role in determining the volume of water taken from the lake and its distribution. The distribution area is divided into three blocks (upper, middle, and lower), with two representatives from each block forming a committee of six. Twice a year, before and after the irrigation season, water flow is stopped, and the committee inspects the tunnel. Additionally, the waterways and sluices are inspected throughout the entire system twice a year to maintain and conserve them.

Water Heritage

Fukarayousui Irrigation Canal is a crucial marker in the irrigation history of Japan. Its unique techniques, radical construction design and detailed implementation, are exemplary. Even after 340 years of its construction, it is still providing irrigation water and water for domestic uses and hydropower generation. The canal enhanced the regional economy, and agricultural production and changed people's lives for good.

The 17th century saw the development of new rice paddies throughout Japan, and rice cultivation became the backbone of the economy. However, in this region, the lack of a stable water supply hampered agricultural production in the Kano River Basin. After several petitions from the Fukara villagers, the Fukarayousui Irrigation Canal was finally constructed in 1670. The Fukara region was reborn as one of Shizuoka Prefecture's most abundant rice paddy districts, and people grew dramatically affluent.

The canal was an engineering marvel. In the absence of machines, the tunnel was dug by hand using chisels and didn't go straight but followed a meandering course according to the ground's rock formations. Rapeseed oil was used to light the interior and shelves to place the lights at intervals of 5-10 m. In the 1,280 m long tunnel about 520 m from the sluice gate, there is a drop where the tunnel-digging workers from both ends met in the middle at slightly different heights. Considering 17th-century measurement techniques and tunnelling mechanisms, a height differential of only a single meter is a fantastic feat. An alternate explanation is that the drop was created intentionally to alter the force of the water flow.

The Fukarayousui Irrigation Canal plays an essential role in the region's social, cultural, and historical fabric. There is a historical museum in the district paying tribute to the great labour involved in making the structure, with illustrations that convey its history to children in an easily understandable form. It is also an important tourist attraction. The irrigation canal system is an asset treasured by the entire community. In 2005, the Ministry of Agriculture, Forestry and Fisheries selected the Fukarayousui Irrigation Canal in Japan's 100 most important artificial waterways list. Students at the local junior high school annually put on a play entitled Canal of Life at the historical museum celebrating the ancestor's achievements and appreciating the structure. An annual canal festival is also held to commemorate the Fukarayousui Irrigation Canal beginning in 2015.

8.6 GENBEGAWA IRRIGATION CANAL

Name	**GenbeGawa Irrigation Canal**
Location	**Mishima City,Shizuoka prefecture, Japan**
Latitude	**35.122**
Longitude	**138.912**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**16th century**
River Basin	**GenbeGawa Canal**
Irrigated/Drained Area	**142 ha**

History

Located in Nakazato, Mishima, GenbeGawa Irrigation Canal was constructed in the 16th century primarily for rice production at a slope of 1/200 between two rivers. It was named after an influential leader, Genbe Terao of the Mishima district. The canal transported spring water from Kohama Ponds to irrigate agricultural fields. GenbeGawa Irrigation Canal had been and is still used for more than 400 years for distributing water to 11 villages within 142 ha, as a stable water resource. It runs through the urban area of Mishima City now and is maintained by the Nakazato Canal district.

Description

GenbeGawa Irrigation Canal, with a 1,500 m length and an 8 m elevation difference, gets its water from Mt. Fuji's spring water coming from Mishima city park Rakujuen-kohamaike pond, which is registered as a Japanese national nature treasure and a beauty spot. The water comes to the Nakazato-onsuichi pond at the lower part of the basin to raise its temperature and is then distributed to the rice field of the Nakazato district. The canal from Kohama Pond to Nakazato district is created considering the geographical features fully, so water runs at the high points of the land. Therefore, during heavy rainfall, muddy water doesn't enter the canal. Moreover, the upper part of the canal is wide and shallow, warming up the cold 15° C water. Riverine residents use the canal's spring water for cooking, cleaning and washing.

However, since the 1960s, with increased groundwater use upstream, the canal's water drastically decreased. Additionally, wastewater from households and indiscriminate dumping polluted the canal. In response, during 1990-1997, ecology-up and water roads between city and village projects were executed by the local authorities. Shores covered with concrete blocks were replaced with original shore protection with stones and soil. Given the restoration of the unique waterfront ecosystem and the relationship between people and water, the Neo-Natural River Reconstruction Method was used. The canal's original condition and value were established among locals by a water amenity facility, irrigation facility and a waterfront ecosystem.

NPO Groundwork Mishima was founded in 1992 to promote cooperation among various sectors and provide skills for water improvement. The efforts culminated in the current water environment with rich biodiversity and a diversified agricultural facility. For the sustainable conservation of the GenbeGawa Irrigation Canal, its biodiversity and the experiences which people can gain from it, all sectors are making an effort to cultivate the next generation and re-construction the river maintenance system with the whole riverside area's involvement.

Water Heritage

The agricultural drainage system with GenbeGawa Irrigation Canal enabled stable water distribution to the whole Nakazato district. Before the canal, with no irrigation facilities and challenging topography, the Nakazato district faced water scarcity. With the expansion of rice-growing areas and the holistic regional growth, the canal proved to be a blessing for the local population. Excavated in the 16th century, the GenbeGawa Irrigation Canal was designed to irrigate a broad area with multiple sub-channels by making the most of geographical elevation from several water resources to the Nakazato district. It ensured stable water distribution, and a stable income and improved the living standards of the people.

Many bank-protection made of block lava on ditch was constructed by the lava extrusion from Mt. Fuji, a world heritage site. As the spring water from Mt. Fuji snow runoff was cold, the ditch's upper part was broadened, and the water depth was reduced to raise the water temperature. A flow channel was built at a high altitude to prevent frowning in muddy water by heavy rain. These pioneering techniques transformed the region into an extensive paddy field area and inspired future irrigation facilities. The reservoir was also constructed in the recent repair works. GenbeGawa Irrigation Canal has been utilized for more than 400 years and has an ecosystem. The canal has been actively maintained by the riverine residents themselves with their unique methods. In 1952, to increase rice crops, after WWII, the water's temperature was increased using *onsuichi. This water-heating pond* warmed up cold spring water at the lowest part of the GenbeGawa Irrigation Canal.

From the Nakazato-onsuichi pond, several sub-channels were built with complicated water division systems using innovative civil engineering technology. The GenbeGawa Irrigation Canal reconstruction project is a model case of Neo-Natural River Reconstruction, where the citizens participated in the amenity park's planning and construction. Groundwork-environmental preservation and improvement practice was carried out with local communities with citizens, NPOs, corporations, and the local authority. GenbeGawa Irrigation Canal's ecosystem was developed and restored its rich waterfront environment to keep the water currency through the years without stopping in winter.

The historical canal carries forward the legacy and engineering achievements of the people of its time. In the upper part of the GenbeGawa Irrigation Canal, along the riverside, shrines of water gods and wooden piers called *Kawabata* were built. These piers, with their rites, purify the souls by releasing bowls in the river at the time of the Hamaori bowl, releasing the tradition of Bon week (Japanese ritual week for the worship of ancestors' souls).

The canal is an outstanding example of Operation and Management, which has been sustained even today. Community cooperation and zone management manual for water, biodiversity and landscape preservation were prepared for each of the eight zones of the GenbeGawa Irrigation Canal. The community cooperation system reduced the farmers' financial burden to pay the annual maintenance fee and developed a participatory approach. To maintain environmental sustainability, water restoration, front landscape conservation, and ecosystem revitalization were considered throughout the reconstruction of the canal. There was a time that urbanization substantially deteriorated the water quality, but the approach to environmental conservation efforts, including environmentally conscious repair works, restored its quality. In charge of the facility, Groundwork Mishima held more than 200 workshops in 3 years to establish a collaborative water management system.

Daily maintenance of GenbeGawa Irrigation Canal and Nakazato-onsuichi pond is held by residents and citizen groups such as NPO Groundwork Mishima, The Group of GenbeGawa Lovers, and The Group for Fire Flies in Mishima. They also cooperate with farmers and the Nakazato Canal district. Citizen-led activities like Treasures of the water city Mishima have helped in the recovery of waterfront ecosystems. Precious species such as firefly (Luciola cruciata), loach (Lefua echigonia), a kind of aquatic plant (Ranunculus nipponicus var. japonicus), which disappeared once, came back to the water area. Notably, the number of fireflies increased in the region and has become a tourist attraction. The local authority and citizen groups also participate in the cleaning GenbeGawa canal on the first Sunday of May every year. To maintain the momentum and spread awareness, NPO Groundwork Mishima organizes environmental lectures and waterfront nature observation sessions for children and parents with the cooperation of Mishima City and Nakazato Canal district.

8.7 GOROBE IRRIGATION CANAL

Name	**Gorobe Irrigation Canal**
Location	**Saku City ,Nagano Prefecture , Japan**
Latitude	**36.259**
Longitude	**138.401**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**1631**
River Basin	**Shinano-Gawa River system**
Irrigated/Drained Area	**416 ha**

History

During the 15th and 16th century, in Japan, domestic turmoil, social instability, hunger and poverty, and family isolation was caused by war. Before the development of the Irrigation Canal, there were no construction methods for lengthy irrigation facilities or accurate surveying techniques.

Thus, Gorobe Ichikawa, the village leader, constructed Gorobe Irrigation Canal in 1631 and stabilized people's lives. To rehabilitate the Saku area in Nagano prefecture, Ichikawa Gorobe, the region's lord, built a 20 km long irrigation canal between 1626-1631, which turned the impoverished region into 40 fertile paddy fields. Before the canal's construction, the area suffered from wars, natural disasters- volcanos causing conflicts, and other issues like hunger, poverty, and family separation. With the Gorobe Irrigation Canal, the area became fertile and peaceful, enabling people to subsist on rice farming. The sub-alpine zone with an altitude of 2,080 m was used as a water source for the canal built down to the cultivation area with a height difference of 1,200 m.

Description

The overall length of the canal in 1631 was 20 km which was reduced to 13.3 km in 1971. Initially, the main structures were Hand-dug Tunnels, *Kakebi* (wooden aqueduct bridge), and an Earth canal which was later

Waterway drawing at the time of construction (1712)

Community money (Ninsokufuda)

Tsukiseki Ground level of this section was low, so Gorobe constructed a high embankment and excavated a waterway through it.

Tunnel was dug by man power using a chisel. It was dug from both sides and then joined. (Designated as Historic Site of Nagano Prefecture in 1981.)

Location map in Japan

supported with a Concrete Lining, Syphoning (RC), Open channels and Calvert (RC) in 1971 after the restorations. The main canal had one intake gate, which facilitated a total length of 9 Hand-dug Tunnels 892 m in length, with 2 *Kakebi*, 2 *Hakoiribi* (inverted wooden siphon), 5 *Ishiiribi* (inverted stone siphon), 18 *Ishizumi* (masonry), 4 *Iwakiriire* (cliff-hanging canal), and 20 *Wakutate* (water distribution facilities). The length of the Barrage (earth canal by embankment) is 1.1 km, with a height of 1.5 m-2.4 m, supported by 3 Waterwheel facilities using water hydraulic power for rice mills and flour mills situated downstream. After the canal's completion, 439 ha of new paddy fields were developed, which expanded to 870 ha in the coming years, ultimately leading to regional development and revitalization.

The location of Gorobe's headworks (intake facilities from the water source river) remains unchanged. However, large-scale improvements have been made from the entrance to the middle of Gorobe, by the local government from 1959 to 1971. The maintenance and management efforts were reduced using advanced technology. A significant detour around the four mountains was conducted on a digging tunnel which was potentially collapsible earlier but was improved after the reconstruction of a canal.

Due to the repeated collapse of Horinuki and the emergency restoration work, the tunnel's section became narrow, and the discharge capacity markedly declined. However, it remarkably improved after the restorations. Gorobe headworks currently intake up to 3.5 m^3/s as irrigation water.

Initially, village inhabitants voluntarily maintained and managed tasks of the constructed irrigation canal (called *Yosui Bushin*). In addition, they also engaged in conserving the forest area of about 4,500 ha, which supplied the water source (called *Yama Bushin*). Community money, called *Ninsokufuda*, was created and used for management expenses like worker payments. This unique community money system existed in the region for an extended period from the 1600s to 1950. It provided mutual benefits to the feudal lord/ system manager by reducing labour costs, the villagers receiving remuneration for their work, and the regional merchants selling their products.

For maintenance and repair, over 7,000 to 9,000 beneficiary farmers worked every year from 1631 to the major renovation in 1971. They monitored the repairing of the nine tunnels and the long irrigation canal. The construction was done skilfully on unstable ground. Locally available materials were used in maintenance to manage costs making the farmers self-independent.

Water Heritage

In the early 17th century, Gorobe's irrigation facilities changed the village from a poor area to a prosperous town centred on rice cultivation. Referencing the canal's success and the precise construction method, 40 new irrigation facilities in the Saku Basin were developed at the time. Until 1953, people engaged in maintenance work were paid with the local currency, which contributed to the revitalization of the regional economy and reduced the financial burden of water management administrators.

The irrigation canal is a valuable cultural relic that changed people's lives financially, and socially and wholly transformed the region into a peaceful and stable state. The area previously riddled with starvation, poverty and warfare, became one of the most granary areas in this region, Sakutaira (basin terrain zone located in the central part of the main island of the Japanese archipelago), due to the establishment of paddy field irrigation facilities. Cultural and traditional activities like flower arrangement and tea ceremony, sumo, village kabuki, literary poetry, haiku and Chinese poetry flourished in the region. New settlements developed, and prosperity prevailed due to stable water supply, agricultural production and economic stability. After 1971 renovations, water from Gorobe Irrigation Canal was diverted to the adjacent drought-hit Mimakigahara Plateau, transforming with stable farmer management. Over the years, the canal underwent restoration and improvements many times but has retained its original engineering design.

Moreover, the traditional wisdom of the residents was utilized, such as crossing the lower elevation zone by building a high embankment (*Tsukiseki*), overcoming soft ground by alternately stacking shrubs and soil for compaction (*Dengakuzumi*), equivalent to the contemporary geotextile construction method. Additionally, to overcome water leakage, like the modern grouting method, cotton flowing was observed in a turbulent manner. The leak was repaired by filling it with earth and sand.

The Gorobe Irrigation Canal was constructed with innovative ideas at that time. For example, the 1.1 km at the end of the canal called Barrage had several creative ideas. The water development for the Gorobe Irrigation Canal succeeded with accurate surveying technology, a reliable construction plan, and strategic management of the construction site. For the canal's water inlet, the earth was removed first, and sand flowed upstream. Next, the mainstream's eccentricity was shifted to the opposite side with the Gabion water system. And all measures were taken to prevent sediment inflow into water facilities. In addition, the control technique to change the water level was used with the jetty and weir installed in the mainstream. This intake technique from this ancient Japanese mainstream river was also applied in Afghanistan to the Gamberi desert agricultural land.

The irrigation water main line was built as a section of 20 km distance with a gentle slope of 2 to 3/1000, beyond the four mountain masses, the construction of nine Hand-dug Tunnels along the way, cross-linking of two aqueducts, sedimentary zones of volcanic ejectable for leakages, and construction of reliable facilities in the soft ground which was an ancient lake bottom in an irrigation facility- all are great examples of construction.

The farmers have been hitting maintenance and management of irrigation facilities for 385 years since completion. The construction was done so skillfully that the maintenance and repair work required very little technical expertise. According to folklore, the *Dengaku-zumi method* which is similar to the geotextile method and the *Mawata-Nagashi* method (using the same principle as the Grout method), was adopted by Gorobe the idea by his wife Kiyo. This is a unique case that ingenuity in life has been applied in large-scale civil engineering works.

Gorobe Irrigation Canal depends on natural water from the river. Laws have been established right at the beginning of the canal to conserve the water source and the forests (*Sanrin Hatto*). A dedicated community called *Yama Bushin* was set up for forest conservation, preservation, maintenance and management annually. In this way, Gorobe Irrigation Canal conserved the watershed protection forest. This spirit is still inherited, and conservation activities of the water source forest are continued, mainly by the water improvement manager for Gorobe Land Improvement District.

People organize various folk events as a form of appreciation for the leader Gorobe. Traditional events inherited in the area include a thanksgiving festival for the bounty of water, a celebration to calm the wind, memorial service for Gorobe, among others. Because of its historical importance, the facility was designated as a historic site of Nagano prefecture by the Cultural Property Protection Law on December 26, 1983. It is currently preserved as a landmark structure.

For over 385 years from the beginning of the irrigation canal, Murakamata Monjo (Official documents related to demography, industries, tax, official notices, and especially the record of canal maintenance management) created by successive village mayors are almost perfectly preserved to date. It is a unique historical material that conveys the village's demographics, cultivation, work situation, and administrative trends, from the earliest stage to the present day. Research Institute for History of Rural Development has been set up and publishes reports and findings every year.

Currently, the long-lasting forest conservation activity and the preservation of the Gorobe Irrigation System are mainly undertaken by the Gorobe Land Improvement District in cooperation with local communities. Presently, the Improvement District does forest conservation activities such as tree planting and undergrowth mowing to maintain a steady spring water flow. Furthermore, educational programs on the importance of irrigation water or rice farming are taught to students at local elementary schools to pass on the historical heritage from early childhood.

Many historical remains showcase the cultural value of the irrigation system. Some of them are

- Sui-jinja Shrine: In 1644, the Sui-jinja shrine was founded near the headworks. The annual spring festival is held here when the canal starts passing water every year.
- Sanechika-Jinja Shrine: In 1764, people in the Saku, in gratitude towards Gorobe Ichikawa, erected the Sanechika-Jinja Shrine. Thanksgiving Festival for bountiful water and Festival to calm the wind are held annually.
- Gorobe Memorial Hall: In 1973, Gorobe Memorial Hall was founded and now exhibits water resources to visitors from across the country.

- Gorobe-ato (ruins of the Gorobe Irrigation Canal): In 1982, the Waterway facility was designated as a Nagano Prefecture Historic Site from the beginning of development.
- Sosui Hyakusen: In 2006, Gorobe Irrigation Canal was selected as one of Japan's top 100 fine canals in Japan by The Ministry of Agriculture, Forestry and Fisheries.
- Wasangaku: In 1999, Wasangaku (Framed picture with mathematical problems and answers written on it and dedicated to shrines.) was designated as a Tangible Cultural Properties by Saku City.

8.8 INAOIGAWA IRRIGATION CANAL

Name	**InaoiGawa Irrigation Canal**
Location	**Towada City, Aomori prefecture, Japan**
Latitude	**40.983**
Longitude	**141.150**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**Since 1859 (Ansei 6, Edo Period)**
River Basin	**Sanbongihara area (left bank of Osaka River)**
Irrigated/Drained Area	**5,253 ha**


Sanbongi before development


Current scenery


A surveying instrument ·level·

Location in Japan

History

Located on the left bank of the Osaka River, Japan, the InaoiGawa Irrigation Canal is known as the agricultural lifeline of the Sanbongihara area. It transformed the Sanbongi area in Japan from a barren plain into a leading rice-producing site. Serving as a spiritual and cultural relic, the canal has been inherited from generations since its inception in 1859.

Description

Sanbongihara, the area's former name including Towada City, was an alluvial fan covered with volcanic ash generated from Mt. Towada. The volcanic ash impaired the soil's ability to retain water resulting in immediate rainwater seepage into the ground. Moreover, regional rivers running at lower altitudes kept the region from smooth rice cultivation. The rivers running in the surrounding area of Sanbongihara lay at lower altitudes and thus had few fields. They reclaimed small fields in lowlands along the rivers or highlands relying on spring water. Sanbongihara had too severe conditions for humans to live in. In summer, *Yamase wind* from the Pacific Ocean (cold and wet northeast wind brought by a high-pressure system over the Okhotsk Sea) caused cold weather damage to agricultural products. In winter, *Hakkoda Oroshi* (cold and dry northwest wind) blew up a snowstorm making agricultural production difficult.

Tsuto Nitobe, a samurai of the Nanbu Clan, planned Sanbongihara's large-scale reclamation of Sanbongihara to divert water from the Oirase River with a canal system reaching the Pacific coast to make farming feasible in the vast highland. However, the highest place in Sanbongihara was 30 m higher than the Oirase River. So, an intake was built upriver and a canal through a tunnel weir to Sanbongihara.

In 1855, Tsuto launched a large-scale reclamation project in Sanbongihara in cooperation with like-minded merchants. In the project, two tunnel weirs, including the Kuradeyama weir (2,540 m from KumanoSawa to Yagami) and Tenguyama weir (1,620 m from Horyo to Dannodai) and a land weir (7.2 km from Yagami to Sanbongi) were bored through. Tsuto shifted to Edo during the project due to work assignments, and his son Jujiro Nitobe took over. Water was passed through the canal on a trial basis in 1858, but parts of the canal were broken. After repair work, in 1859, about four years after the beginning, water was successfully taken to Sanbongihara. In 1860, the canal was named the InaoiGawa irrigation canal by Lord Toshihisa Nanbu.

Though the Irrigation system was completed, it did not have sufficient water supplies to reach the Pacific coast. Accordingly, another plan was developed to build an intake further upstream, comprising three tunnel weirs and an additional canal meeting the InaoGawa irrigation canal. The plan included the Lake Ogawara reclamation project, such as excavation work on Mutsu Canal (a canal running from Lake Ogawara directly to Mutsu Bay) and other reclamation projects covering Noheji, Tanabu, Shimokita and Ohata areas. Tunnelling work was started from the north side of the Kuradeyama tunnel weir but could not be completed.

Subsequently, the second water diversion plan was undertaken as a national reclamation project and finally completed in 1866. The project faced many technical hurdles requiring highly advanced engineering skills, such as constructing two tunnel weirs and a land weir.

The project has undergone several changes over the years. Modernization and development projects have been implemented, converting Sanbongigahara into one of the most productive rice production areas in Aomori Prefecture, covering approximately 5,300 ha of field. The canal reaching the Pacific Ocean was completed during the period 1937 to 1966. Then, from 1978 to 2006, the national farm irrigation project on the left bank of Osaka River was implemented to solve constant water shortage and poor drainage, ensure a stable water supply, and reduce the operation and maintenance workload. The farmers, residents, and relevant organizations such as the National Federation of Land Improvement Associations are currently working together to take the canal's new operation and maintenance measures.

With increased population, agricultural production and subsequent water demand, water distribution woes have emerged. Sanbongihara area appears to be a flat plain, but it has a rugged hilly terrain. The fern leaf-shaped terrain has many windings, hills, and a chasm faced with a steep slope or cliff. This results in distributed beneficial areas and difficulties in agricultural water management. The central management system under the national farm irrigation project allows for close-knit water management. However, with changing situation nationwide, an increase in the number of part-time farmers is seen in the Sanbongihara area with increased demand for water. Accordingly, area representatives discuss and pre-decide the water-taking rotation for equitable distribution and collective growth.

The irrigation canal is a dual-purpose canal for irrigation and drainage. With an increased number of people, the agricultural land is converting into residential areas, resulting in a mixed settlement of farming and non-farming residents, which subsequently lead to sewage flowing into the canal and a negative impact on drainage. With the local government's efforts, the sewage and village drainage systems seem to be in control. But the effects of the mixed settlement have also surfaced in the form of increased rainwater drainage. With the changes in the meteorological environment, such as torrential rain, precise drainage management such as the operation of gates and suspension of water-taking is being practised. The water level is managed meticulously to prevent effects on farming by diversion of irrigation and drainage canals, water level adjustments and early warnings for changing weather conditions in cooperation with local governments.

Water Heritage

The history of the InaoiGawa irrigation canal goes back to the time of reclamation by the three generations of Nitobe more than 160 years ago. When civil engineering works in Japan were dependent on foreign engineers, the reclamation project was carried out primarily by *Nanbu Tsuchikatasyu*, a group of construction technicians and completed with Japanese techniques, only showcasing the advanced native Japanese skills. According to a record, the project cost the Nanbu Clan 165,000 Ryo (currency units in Edo Period) and 220,000 man-hours. The Nitobe project faced many hurdles requiring due to the topography and almost non-existent mechanical support. However, the genius of the engineers and workers helped the construction of two tunnel weirs and a land weir which required embankment and cut earth to provide irrigation water.

In Sanbongihara, new fields were developed in parallel with the irrigation project, which started in 1855. In addition to Sanbongihara, new areas came up in the villages of Osaka, Fujishma, Orimo, Yoshida, and Momoishi, which was an additional 2,500 chobu (approximately 2,500 ha) of paddy fields and 3,000 kokus of rice yield. The total length of the InaoiGawa irrigation canal up to the Pacific coast is about 70 km with 5,900 ha of paddy fields (as of 2006). Today, Sanbongihara covering two cities and four towns has become one of the leading rice-producing areas in the prefecture.

The irrigation canal was a turning point for present-day Towada City, formerly known as Sanbongihara, in irrigation infrastructure, agricultural development, social and cultural exchange, and holistic growth. The canal enhanced food production and brought prosperity to the region.

The InaoiGawa irrigation canal was progressive considering the strategic planning, design, construction skills, engineering techniques, structure dimensions, and impact. All the methods and tools from surveying, measurements, tunnel digging, weir construction, and subsequent repairs were borrowed from Japanese ancestors. In 1852, Tsuto Nitobe, the founder, conducted land surveys with five technicians, including surveyors and construction workers (a tunnel builder). Particularly in building the tunnel weirs, Tsuto arranged a group of tunnelling workers with special techniques in the Domain and carried out construction in a highly organized manner. From the level, the Azimuth instrument, and the rope measure used then, the technician group used traverse calculation using the *Hassen* table (a Japanese trigonometric function table).

The two weirs, a fundamental of the reclamation project, were dug completely with a workforce for 2,500 Ryo. The total length of the Kuradeyama tunnel was 2,540 m, and that of the Tenguyama tunnel was 1,620 m. According to a record, branch tunnels were used in the tunnelling work. The Kuradeyama tunnel had 16 branches, and the Tenguyama tunnel had 8. These branch tunnels were dug individually to be connected and completed as tunnel weirs. The weirs at that time had an extremely winding structure. They have undergone a renovation to be a linear structure with lining concrete.

The embankment section has *Itakozuka* constructed by a single-sided hill method. It is a hill built on the single side of a mountain slope to build a canal on the upper area of the mountain. The mountain's soil with high volcanic ash content allowed the digging of tunnels like Tenguyama and Kuradeyama. Accordingly, the method was adopted, but the ditch had two meandering points side to side. The ditch was a hurdle in the project and leaked in five out of six water passage tests.

On the other hand, Kyonodate was the most challenging part of constructing the cut earth section. Kyonodate was located at a higher altitude, and the canal needed to be built by digging the ground about 10 m deep. A record says that it was challenging to maintain the gradient in the Kyonodate section, and seven were spent on the gradient's adjustments. In the section, 300 workers were engaged in construction at a time in the reclamation project. They carried large amounts of sand and earth to the ground from the canal deep under the ground.

The project made innovative attempts at that time, such as including opinions from academic experts, and residents into improvements in consideration of the environment and commissioning construction, operation and maintenance of the canal. Field development was started along with the launch of the reclamation project. Irrigation ditches were built in the town area, and the land was redistributed into residential, agricultural and commercial districts from the perspective of hygiene and disaster prevention. The project is a pioneering example of modern urban planning.

The InaoiGawa irrigation canal has witnessed a participatory and sustainable operation and maintenance model since its beginning. The Land Improvement District (LID) is currently responsible for the main canal through programs such as the main irrigation facilities management project. Members of the LID manage branch canals, and both farming and non-farming residents in the community work together to manage the beautiful park area. A continuous cooperation framework has been established with private companies under a river management agreement in recent years.

The canal and Tsuto Nitobe's philosophy have been handed down to the present generation, including the implementing public works, management bodies of the canal system and residents. The completion of the canal and its predecessors' achievements are commemorated and honoured in Taiso Festival every year. "InaoiGawa irrigation canal" is beloved by local people as a spiritual home serving as a place of communication, study and peace of mind.

A vital cultural relic representing the glory of the past civilization, the InaoiGawa irrigation canal has gained renewed attention as a community asset. It was selected as one of the best 100 canals in Japan by the Ministry of Agriculture, Forestry and Fisheries and ranked in the general poll for selection in 2006. In 2011, the river was registered as the 3rd Project Heritage for the Future of the National Federation of UNESCO Association in Japan. In 2013, selected as a Civil Engineering Heritage of the Japan Society of Civil Engineers. InaoiGawa irrigation canal is beloved by local people as a spiritual home serving through communication and education.

8.9 IRUKAIKE RESERVOIR

Name	**Irukaike Reservoir**
Location	**Inuyama City,Aichi prefecture,Japan**
Latitude	**35.338**
Longitude	**136.992**
Category of Structure	**Water Storage Structure**
Year of commissioning	**1633**
River Basin	**Kiso River**
Irrigated/Drained Area	**624 ha**

History

Located in Inuyama City, Japan, the Irukaike Reservoir was constructed in 1633. About 400 years ago, in the early Edo Period, the regional government (called *Owari-Han*) focused on increasing rice fields. However, the region faced an ongoing water shortage due to small-scale storage ponds as the primary water source and mainly barren. To overcome this situation, farmers and authorities 1628 planned to dam the Kiso River in Iruka Village. They built the Irukaike Reservoir navigating the water to develop the new rice fields. Finally, this plan was implemented as one of Owari-Han's projects in 1633.

Before its construction, a detailed investigation of the topography and geology was conducted. Accordingly, the Shelf-Construction Method (*Tanakizuki* method) was employed to dam the river. Developed by a Japanese reservoir expert, this method employed building the mound on both sides of the river to form the narrowest river section for easier closure, then a temporary wooden bridge was built over the river, and a massive soil mound was placed on that bridge, the bridge was then burned to collapse, and the soil fell in to stop the river flow. This method was an excellent success for dam construction and was used for many future projects in Japan.

Description

Irukaike Reservoir is located in the central part of Japan with a dam height of 25.7 m, a dam length of 724.1 m, and an effective storage capacity of 15,180,000 m^3. It is one of the largest scale irrigational reservoirs, supplying irrigation water to the farmland of 6.24 km^2 covering four municipalities.

Furthermore, in 1957, under the Aichi Canal Project: Japan's first large-scale comprehensive development project to increase food production post World War II, a concrete intake tower was constructed in Irukaike Reservoir, and the central connecting canal was refurbished with pipelines to improve the efficiency and ensure a stable water supply. After Aichi Canal's construction, the reservoir's surplus water during winter is distributed to the fields fulfilling winter irrigation demand.

The reservoir's performance (water storage capacity and conducting ability) hasn't changed much since its inception in 1633. Even the original structure is retained with some renovations over the years. The wooden intake facility was repeatedly improved in the first 30 years of its completion. The present concrete intake facility was constructed in 2002 as a subsidized project, which supplies 2.93 m^3/s of irrigation water to farmlands spread across 6.42 km^2. There were no spillways in the early years of construction, and it was installed after the 1868 *Iruka*-Gire accident when the dam body collapsed. The present spillway was constructed in 1991.

At first, Irukaike Reservoir was constructed for only storing and utilizing water. However, the reservoir was redeveloped with a flood mitigation function in 1991. Nowadays, the reservoir functions for both water utilization and disaster prevention, contributing to safe and secure regional development.

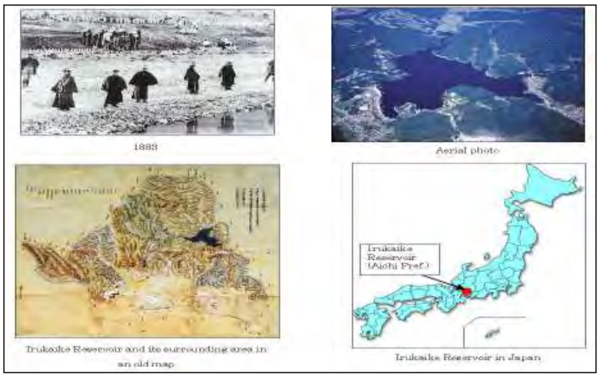
Restoration and maintenance: Since its completion, Irukaike Reservoir has contributed to the local agricultural development but has been hit by many natural disasters in the last 400 years. It has heavy rainfall, large earthquakes and subsequent repair and improvement work. Three noteworthy catastrophes followed by large-scale improvement works are explained below.

In May 1868, the embankment of Irukaike Reservoir collapsed in a historical catastrophe known as *Iruka-Gire*. The water level of the reservoir was full due to the continuous rain from the end of April. Sandbags were piled up into 12 layers, and water was discharged from the fully opened outlet simultaneously to prevent the dam body from collapsing. However, a portion of the dam body collapsed. Turbid water from the collapsed portion turned into a debris flood that destroyed the downstream villages, deserted 2.1 km^2 of broad farmland, and killed over 1000 people. About 1600 workers carried the impervious cohesive soil and elaborately compacted the soil with mallets carefully for restoration. The discharge canal was constructed in 1879, and the restoration work was finally completed in 1884.

In October 1891, an 8.6-magnitude earthquake, the largest earthquake caused by inland active faults in Japan, hit the reservoir's area. Riverbanks collapsed almost beyond recognition with large cracks and significant subsidence of slopes. Fortunately, Irukaike Reservoir didn't face colossal damage but only a few cracks showcasing the reservoir's remarkably high seismic bearing capacity.

In 1961, a torrential rain-induced landslide affected the dam's body for approximately 200 m long, and water leakage was detected downstream. In response, dam body reinforcement was implemented, such as grouting in the dam body and slope protection works and expansion of the spillway. In addition, the water intake facility has been automated, enabling remote control from the management office.

In March 2011, Japan was hit by the Great East Japan Earthquake, causing tremendous damage; however, the Irukaike Reservoir remained undamaged as its embankment was the epicentre of this earthquake. Nevertheless, future earthquakes can cause grave damage to the reservoir and the community. University professors verified the reservoir's seismic performance against possible large earthquakes in 2012-2015. As a result, it was verified that the embankment's deformation is minimal in such earthquakes, and the dam's body has sufficient seismic bearing performance. Moreover, detailed investigation and high construction management technology are worth evaluating.



Aerial photo
Irukaike Reservoir and its surrounding area in an old map
Irukaike Reservoir in Japan

Irukaike Reservoir enhanced agricultural production increased farmers' incomes and converted the uncultivated land to new rice fields. Consequently, agricultural areas there had tremendous development. Nowadays, those areas are very eager to be engaged in such regional improvements as the conservation of landscape and ecosystem.

Water Heritage

Irukaike Reservoir was a technological milestone for Japan in the irrigation industry. Built with fine engineering techniques and strategic planning, it has remarkable seismic bearing performance. In the early Edo Period, the government focused on developing rice fields, and large rivers with their tributaries were capitalized upon for irrigation. But in the elevated areas along the mountain like Inuyama City, small storage ponds were the only water sources that were insufficient for irrigation water.

The construction of Irukaike Reservoir enabled stable irrigation water distribution, which subsequently helped new rice field development. An old historical document stated that the agricultural harvest reached 2,300 tons, illustrating the reservoir's outstanding contribution to the local agricultural development.

During the feudal age, it was rare to acknowledge the residents' knowledge and act on their opinions during construction which was essentially practised for this government project.

Advanced technology like Shelf-Construction Method (*Tanakizuki* method) was adopted for constructing the dam's body under the instruction of a reservoir expert. In recognition of his efforts, *Owari-Han*, then regional government, named a part of that dam body after his birthplace. A detailed investigation was conducted to determine the best position of the dam body foundation, but compacting work was implemented with high construction management technology. Even after severe damages and facing disasters, the reservoir is still operational today. Irukaike Reservoir At that time, the construction required a lot of costs to dam the river, install gates for water distribution control, and compensate relocated residents.

Irukaike Reservoir contributed to the evolution of efficient and contemporary engineering theories and practices. The dam's location was determined after a thorough investigation and review of the foundation's surrounding topography and geology. The foundation is formed of excellent geology, such as the alternation of chart and mudstone. The dam is also utilizing an upheaval of solid geology as a part of the body. These intelligent techniques improved the dam's efficiency, prevented leakages after construction, and mitigated the dam's body's seismic impact.

The soil was required to fill the dam's body to be secured by the neighbourhood mountains. Therefore, a valley with an upheaval of solid geology was selected as the dam body site to reduce the amount of soil required for filling and digging with consideration to reducing the environmental impact caused by the construction.

The reservoir's operation and management practices have lasted many centuries and continue to function smoothly following a participatory approach. After construction, Irukaike Reservoir's water distribution was managed by a government-appointed operator, who dived into the water to operate the delivery tap of the intake facility installed on the natural ground below the water surface. The operator was provided land, and its descendants played the operator's role for a long time. Afterwards, the operations changed, and currently, Iruka Irrigation Canal Land Improvement District, established in 1952, is implementing operation and maintenance while coping with the changing water demands.

On the other hand, Irukaike Reservoir as a regional property is protected and conserved with the efforts of the residents. Every September, about 100 locals participate in the cleaning activity. Visitors can now enjoy the reservoir's beautiful scenery with cherry blossoms and azaleas in bloom and enjoy fishing at the pond. Irukaike Reservoir is used as an area for recreation and leisure activities throughout the year.

In addition, the reservoir is used for rescue drills by fire stations and educational visits for elementary schools. By studying Irukaike's history and its role, students acquire historical and scientific knowledge about water and agriculture, biodiversity in the reservoir, along the reservoir's technicalities.

Irukaike Reservoir performs multiple functions by providing irrigation water, promoting exchange between regional communities, disaster prevention, and education activities. In 2010, the reservoir was appreciated for its contribution to agriculture and its historical relevance to the region's development. It was selected as one of the Best 100 Reservoirs in Japan by the Ministry of Agriculture, Forestry and Fisheries.

8.10 JIKKASEGI IRRIGATION SYSTEM

Name	**Jikkasegi Irrigation System**
Location	**Azumino City,Nagano Prefecture, Japan**
Latitude	**36.281**
Longitude	**137.915**
Category of Structure	**Irrigation System**
Year of commissioning	**1816**
River Basin	**Narai-Gawa and KarasuGawa River Basins**
Irrigated/Drained Area	**958 ha**

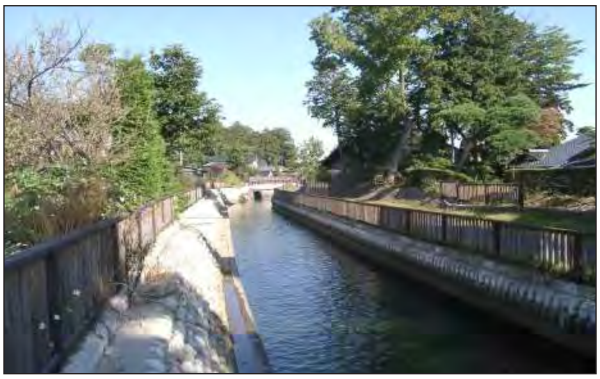
History

Located in the Matsumoto area in Nagano Prefecture, the Jikkasegi Irrigation System was excavated 200 years ago in 1816 over the Narai-Gawa and KarasuGawa River basins. Initially constructed by heaping up the earth, the system has gone through several renovations and is a modern canal with concrete lining now.

Description

Jikkasegi extends to about 15 km after taking in its water from the Narai River to irrigate an area of 958 ha, consisting mainly of rice fields.

Before the excavation of the Jikkasegi Irrigation System, the Azumino area did not have many cultivable lands because of the highly infiltrated soil with less water retention levels. Farmers faced water shortage, consequent poverty, and conflict. Even though the Azusa-Gawa River floodplains were fertile, a large amount of subsoil water and unstable course flow-induced, raging torrents eliminated the possibility of a steady water supply.



Magoichiro Todoroki, the village head, then planned the canal's construction to get irrigation water from the Narai-Gawa River, which was beyond the Azusa-Gawa River. After overcoming technical challenges during excavation, including improving soil quality, drawing water crossing the raging Azusa-Gawa River, designing a slow-gradient canal, and crossing 36 existing canals on different levels, the 15 km canal was completed.

After careful preparations, cutting-edge technology such as newly developed wooden pipes and built-up canals was used. The farmers completed the excavation with an average incline of 0.3% in three months, a brief period. The farmers provided funds as well as labour.

Post Jikkasegi's construction, agricultural production in the Azumino area improved dramatically, which led to a higher income for the then-provincial government. The government honoured the Todoroki family with kamishimo attire, which was usually worn only by high-ranking people. At the time of its completion, Jikkasegi provided water to an area of about 300 ha. However, with continued efforts, the benefitted area is now extended to about 1,000 ha.

In recent years, after the 1983 typhoon, the Azumino Wide Area Drainage Project, a national and prefectural undertaking, improved Jikkasegi's drainage function. The drainage has increased due to the regional development and road construction in the area. Each local government has a wide-area administration union to manage the drainage. After the drainage project, no flood damages were reported. Moreover, the improved drainage enabled the systematic production of diversified crops such as wheat and buckwheat.

Maintenance: Irrigation is managed by Nagano Prefecture Jikkasegi Land Development District and its attached water user associations. The farmers contribute funds for the management of facilities. The Azumino City Government is also constructing a participatory system where both the government and residents are involved in the maintenance and management of Jikkasegi and the preservation of its landscape by starting a Jikkasegi Landscape Creation Project as a particular section of the Azumino Design Brand Conference which is conducted in cooperation with the Azumino City Brand Promotion Office and its citizens.

Furthermore, water control is done using the latest agricultural engineering facilities. They include the Narai-Gawa River headworks, which controls automatic water-taking, the Azusa-Gawa River Siphon, where the canal crosses the river and canals with triple-sided reinforced concrete lining, and the Wide Area Drainage Control Offices, which manages water gates to drain the wastewater into the river efficiently. These facilities efficiently distribute and supply irrigation water to the area and function as disaster prevention facilities in the community.

Jikkasegi is important in historical worth and agricultural productivity, but its impressive appearance flowing in the lush countryside is indispensable in creating the Azumino area's beautiful landscape. Masonry waterways and safety fences called Azumino Model are installed around the canal considering the surrounding landscape. In addition, waterfront parks and cycling roads have been built for easy access to water and as a tourism resource. Both the residents and tourists enjoy these facilities.

In recent years, the farmer's organization managing the Jikkasegi Canal has been working with elementary schools in Azumino City to teach school children the history, mechanism, and importance of the canal to pass on this cultural heritage in all its bounty to the next generation. Several educational tours have been held since 2014, while the canal has been made part of the school curriculum.

Water Heritage

Jikkasegi provided irrigation water to an area bereft of local water supplies. It contributed to the development of local agriculture, improved economic conditions for local farmers, and increased food production. About 300 ha of new rice fields were developed immediately after its construction. Persistent improvement, maintenance, and management of the canal expanded the rice fields to about 600 ha in 1918. At present, about 1,000 ha are cultivated. Thus, the Jikkasegi irrigation canal strengthened the area's food production and, above all, increased rice production, which played a central role in the economy of the time. Jikkasegi continues to supply water to the Azumino area as the region's crucial main irrigation canal.

Jikkasegi draws water from the Narai-Gawa River, located beyond the Azusa-Gawa River, which required the canal to cross the river. Besides this advanced technology, Jikkasegi shows the culmination of other remarkable construction technologies at that time, including conveying water at an incline of 1/3,000 for 15 km in a canal located at a high bank and crossing 36 existing canals on different levels. Hollowed wooden pipes and assembled waterways were devised to allow this. Thus irrigation water was secured while existing irrigation customs were followed. Given the need for precise surveying, a new device was developed. Four years were spent surveying and drawing up a plan. Preparations also included securing funds, labour force and timber. The construction plans had revolutionary ideas considered an impossible dream at that time, such as the canal crossing the river and an alluvial fan that easily absorbs water. These developments were pioneering for Japan and its irrigation infrastructure.

The canal was designed with a holistic understanding of the topography and geology, considering the environmental impacts. For the canal to cross the AzusaGawa River, a water-control device called a rock crib was devised using wood and natural rocks. During a flood, the device was broken, minimizing flood damage and its impact on the environment. The canal has its unique characteristics. The ground was raised for a long distance to create a slow incline on complicated topography. In addition, cushioning materials such as cotton and rice straws were used to prevent water leaks and sinkage. The technology using cushioning materials is still used in canal repairs even in modern times.

The canal's smooth functioning is an outstanding example of operation and management over a long period. During the last 200 years, the canal has been adequately managed by a water user's association of local farmers. In 1951, the Jikkasegi Land Improvement District combined the associations, which strengthened the maintenance and management system.

Japan continues to cherish a beautiful traditional culture where natural phenomena are considered God. People pray for peaceful seasons without natural disasters and an abundant harvest. Therefore, people also erected a statue of a water god by the Jikkasegi canal, still maintaining the tradition of gathering in front of it to worship the water god before farming begins each year. A historical and cultural relic, the Jikkasegi canal system is an integral part of the region's people and traditions. The Azumino city designated the canal's name as Jikkasegi regulating outdoor advertisements within 300 m of the canal under the exterior advertising code to protect and preserve it. Another ordinance by the city, Azumino City Ordinance Regarding Maintenance, Development and Proper Usage of Groundwater, has a preamble stating, "*Jikkasegi filled with abundant water, the surface of rice paddies reflecting the Northern Alps with remaining snow, and springs gushing out to a rapid stream are all-natural features of the season representing the city of Azumino*," recognizing Jikkasegi as an irrigation canal and local resource representing Azumino.

Moreover, Jikkasegi is recognized as an essential local property by some academic societies. The Land Development District and its related organizations received the Ueno Award for their maintenance efforts involving farmers and residents.

8.11 JUKKOKU-BORI IRRIGATION SYSTEM

Name	**Jukkoku-bori Irrigation System**
Location	**Kitaibaraki City, Ibaraki Prefecture, Japan**
Latitude	**36.777 N**
Longitude	**140.655 E**
Category of Structure	**Irrigation System**
Year of commissioning	**1669**
River Basin	**Ookita River**
Irrigated/Drained Area	**78 ha**

History

The Jukkoku-bori Irrigation System was constructed in 1669 on a water-scarce plateau after the village chief's petition. The aim was to eliminate water scarcity and develop newly irrigated paddy fields. The farmers found the water sources along the branch streams of the Ookita River in the deep mountainous area in cooperation with each other. They made a plan of constructing an irrigation canal of 13 km from the water sources making skilful use of the natural geographical conditions. Construction work was completed in eight months in March 1669 and provided irrigated paddy fields in three villages. Moreover, the construction cost was only one-tenth of the initial cost estimated due to farmers' participation and voluntary procurement and preparation of construction materials from their forests.

The Jukkoku-bori Irrigation system has contributed to the sustainable development of rural areas and agriculture. It is a treasure produced by farmers' wisdom regarding planning and constructing essential facilities and a sophisticated irrigation system to continuously deliver stable irrigation water for more than 350 years without undertaking any big-scale rehabilitation work.

Description

The irrigation system comprises an irrigation canal (about 13 km long), two intake gates, and two-division works. It irrigates 78 ha of paddy fields with a maximum water intake of 0.36 m^3/s. Although several portions of the canals have been renovated to concrete lining types, canals at least 2 km from the upper intake facilities have remained unchanged over the last 350 years.

The farmers sought the water source in the mountainous area higher than their paddy fields; one in Takino-Sawa Valley, 2 km away from their village, and another in Karo-Sawa Valley, 4 km away with a catchment area of 1.6 km^2 and 2.9 $km^{2,}$ respectively. The farmers developed the water resources for the area of 4.5 km^2 combining the two catchment areas by constructing a connecting channel between two valleys resulting in water resources development and an increase of water flow volume at the point of Takino-Sawa Gate by 180%. It drastically changed the farming system from a rainfed to irrigated system with two irrigation canals which were very innovative at that time.

After the construction of Jukkoku-bori, the region's poor farmers achieved food self-sufficiency and their poverty was alleviated due to the removal of water scarcity. Realizing such poverty alleviation, neighbouring farmers replicated the idea and constructed 15 irrigation schemes using the same technical method. Consequently, a base infrastructure for agricultural production in Kitaibaraki City was formed with a paddy field of 1,050 ha, which achieved wealthy rural development without poverty. In the hillside village of Hitana, the habitants began to produce Gaerome Clay made of weathered granite pounded by waterwheels using the water flow from Jukkoku-bori, and it led to the establishment of the new pottery industry, named Matsuoka-yaki Ceramics that helped farmers increase their income and contributed to the development of Hitana village. As it was well-received in Japan's capital city, a wealthy regional economy was formed by managing and distributing Matsuoka-yaki.

Irrigation water management is conducted by the Jukkoku-bori Operation and Maintenance Committee, comprised of farmers from three villages where the irrigation water is directly used. Contributions of the villages cover the management expenses of the system. Daily maintenance of canal clearing and regulating water volume is carried out by the gate operator and the canal watcher, selected among the Committee members. In the annual maintenance activities of canal clearing, the farmers carry out the traditional preservation activities, utilizing excavated soils in bags and piling them for reinforcement at the road shoulder. Bags are made of straw as a part of the paddy field soil. This tradition has been unchanged for 350 years to reduce the transportation cost of reinforcement material and unused excavated soil. These traditional measures of canal maintenance with rice-husk ash and clay for water leakage have been carried forward since the 1920s.

Recently, Jukkoku-bori has been used as teaching material for elementary school pupils, who often visit the system as a part of social education to foster interest and willingness to preserve it in the future. In 1996, the Waterside eco-park was established to spread awareness about Jukkoku-bori, and many hikers have visited the park. Furthermore, voluntary activities on the history of Jukkoku-bori and geological heritage have been carried out. Jukkoku-bori, therefore, provides an important resource for education and sightseeing in the area.

Water Heritage

The farmers achieved food self-sufficiency, and their poverty was alleviated due to the removal of water scarcity. Agricultural production in Kitaibaraki City with a paddy field of 1,050 ha increased the incomes. In the hillside village of Hitana, a new pottery industry helped farmers increase their revenue and contributed to socio-economic development.

Since the survey technology was primitive and adequate survey equipment was not popular at that time, it was not easy to achieve such canal construction work in the mountainous area, which required sophisticated technology. For the levelling survey where good foresight was not secured, the farmers adopted an effective levelling method of using hunting bullets. Such innovative, accurate and cooperative survey works undertaken by the farmers with effective use of the various gears and tools and the detailed work plan passing through day and night led to the completion of the entire construction within a short period of 8 months.

The main geological feature of the Takino-Sawa and Karo-Sawa watersheds (1.6 km^2 and 2.9 km^2, respectively) is their formation, which uses weathered granite to hold abundant groundwater. Furthermore, the farmers developed more stable and abundant water resources by combining two different watersheds via the connecting channel. The technology without large-scale geographical change has realized more effective construction by using small construction materials and attained maintenance-free facilities than current technologies.

Developed water is conveyed to the plateau via new irrigation canals, which were constructed by excavating hard rocks of granite at the mountain slopes and resulted in almost no leakage from the canals. Such plans for selecting canal routes considering the geographical and geological conditions can be a model of modern technology.

After the Horiwari channel to the Takino-Sawa Gate, a natural stream was used as a conveyance canal, and canals were constructed by excavating the mountain slopes from the Takino-Sawa Gate to the plateau. The drop works to reduce water power were designed and built with the effective use of natural geographical conditions. Around 15% of the total length of the Jukkoku-bori System effectively used natural geographical and geological conditions, and their selected routes and construction methods have resulted in less load on the natural environment with significant resistance against natural disasters. Jukkoku-bori is unique in terms of adopting cutting-edge technologies at that time. At the same time, the natural environment has been carefully adapted and preserved. It drastically changed the plateau where agriculture previously relied only on rainfall into profitable irrigated paddy fields.

From the ancient days in Japan, there has been a cultural tradition that gods are believed to exist inside irrigation sources spiritually. Hence, people are accustomed to respecting gods who provide water resources. In Matsui Village, a piece of poetry composed in the same era of the construction of Jukkoku-bori has been shared until today. The shrine of the village chief has been kept active. It is a part of the traditional regional culture to present gratitude to god and the people involved in its execution.

Irrigation water management of Jukkoku-bori is conducted by the Jukkoku-bori Operation and Maintenance Committee comprised of the farmers from three villages (Matsui, Hitana and Awano) where the irrigation water is directly used. Such operation and maintenance system carried out by farmers themselves was formed as a result of succeeding the system developed at the time of the construction where the farmers carried out a study to find the water sources deep inside the mountains working together and performing each role by themselves. This is an outstanding example of long-run operation and maintenance.

The functionality and the management system of Jukkoku-bori haven't changed for 350 years. Although the beneficiary area directly using this irrigation water is 78 ha, irrigated water in drainage canals has been reused since the 1960s in five villages downstream via newly developed trunk canals of the irrigation scheme. The beneficiary area of this reused water is around 200 ha. The main idea and compositions of the irrigation system, such as watershed, watercourse, intake points and division point, retain their original features. The irrigation system is currently being used just as it was in the ancient days, showcasing the system's sustainability.

8.12 JYOSAI-GOKUCHI IRRIGATION SYSTEM

Name	**Jyosai-gokuchi Irrigation System**
Location	**Toyama City, Toyama Prefecture, Japan**
Latitude	**36.609**
Longitude	**137.307**
Category of Structure	**Irrigation System**
Year of commissioning	**1893**
River Basin	**Joganji River Basin, Joganji River**
Irrigated/Drained Area	**3381 ha**

History

The Jyosai-gokuchi Irrigation System is around a 12 km length of an irrigation canal in Toyama City, Toyama Prefecture. It runs parallel to the Joganji River, which is one of the world's most rapid rivers. The canal is vital for irrigation and supports local life because it irrigates around 3,300 ha of agricultural land and provides domestic and industrial water supplies and hydroelectric power.

Until the end of the 19th century, the Joganji River had many irrigation intakes but mainly were destroyed or buried under sediment after every flooding. This caused significant damage to local agriculture. To prevent repeated flooding, a Dutch civil engineer, Johannis de Rijke, developed the Joganji River Project to unify intake (called 'gokuchi' in Japanese) for irrigation canals at a safer location upstream by closing all 12 irrigation intakes on the left side of the river together. It was the first intake unification project of such magnitude in Japan.

Description

The irrigation project came with a main canal 12 km long, two tunnels, settling basins, and many more auxiliary works. This intake unification helped further stabilize the water supply to the Josai Unified Intake Irrigation Canal, which saw peak intake water volume go from 33 m^3/s (at the time of construction) to the current 35 m^3/s. Later, several intake unification projects flourished in the prefecture, which helped eliminate water disputes and stabilize the water supply. The rice production increased throughout the prefecture and resulted in Toyama Prefecture becoming one of Japan's leading agricultural regions and accelerating similar intake unification projects in Japan. Moreover, to deal with the sediment taken downstream of the canal due to repeated flooding, the Shinjo Anti-sediment Sluice was constructed in 1900. This canal was one of the first nationwide to be developed as a calming waterfront. Its historical and scenic value makes it a key facility for citizens.

Three hydroelectric power plants using the irrigation canal were also constructed in 1961 to ensure the co-existence and co-prosperity of agricultural irrigation and hydroelectric power generation. Furthermore, the land improvement area installed a small-scale hydroelectric power generator using the irrigation canal. They have also partnered with Toyama City to install a micro-hydroelectric power generator using the irrigation canal for environmental awareness and the production of low CO_2 green energy-reducing environmental loads. As of December 2019, Toyama Prefecture had 30 small-scale hydroelectric power plants using irrigation canals in most of the nation. Small-scale hydroelectric power generation initiatives on the Joganji River were pioneering projects in Toyama Prefecture and nationwide.

Presently, as the region has become increasingly urbanized and crowded, as well as a declining population and the ageing farming population, maintaining land improvement facilities has become more complex. The irrigation association has been planning to restructure the irrigation management system more efficiently to ensure rational use and labour-saving using remote-controlled facilities, camera surveillance and management, and measuring and recording precipitation, water level and current data.

The creation of the first water lovers' promenade in an area around the irrigation canal in the country and taking care of the historical remains and sights have made this facility well-known and popular with residents. This project became an opportunity for the government to create "Water Environment Establishment Projects", and similar facilities was designed around the country.

Water Heritage

The structure was a revolution for Toyama Prefecture. The first large-scale national intake unification project further spurred other similar projects around the prefecture, eliminating water disputes and enabling a stable water supply, boosting rice production, and making Toyama one of Japan's leading agricultural regions.

With a large irrigation area of around 5,000 ha and the unification of 12 complex irrigation canal systems, this project was the first of its kind nationwide, and the most advanced in terms of the scale, facilities, and area served. Furthermore, focusing on the large volumes of sediment from the Joganji River, a large settling basin upstream to remove sediment and an anti-sediment sluice were constructed as part of advanced anti-sediment measures for this project.

Josai Unified Intake Irrigation Canal was a trailblazing project that transformed water use in Japan, making the Joganji River one of the steepest nationwide. Known as Japan's most overflowing river, the river would flood almost annually with strange debris flow. Large volumes of sediment penetrated the system and prevented the adequate distribution of water, which had a tremendous negative impact on local agriculture. This intake unification project helped agriculture develop significantly by becoming a force to prevent disasters, protect people's lives and livelihoods, and improve food production productivity by ensuring a stable water supply.

The project was considered once the intakes were unified, floods and sediment influxes fell sharply, and a stable water supply was ensured, which allowed the creation of a farmland ecosystem network.

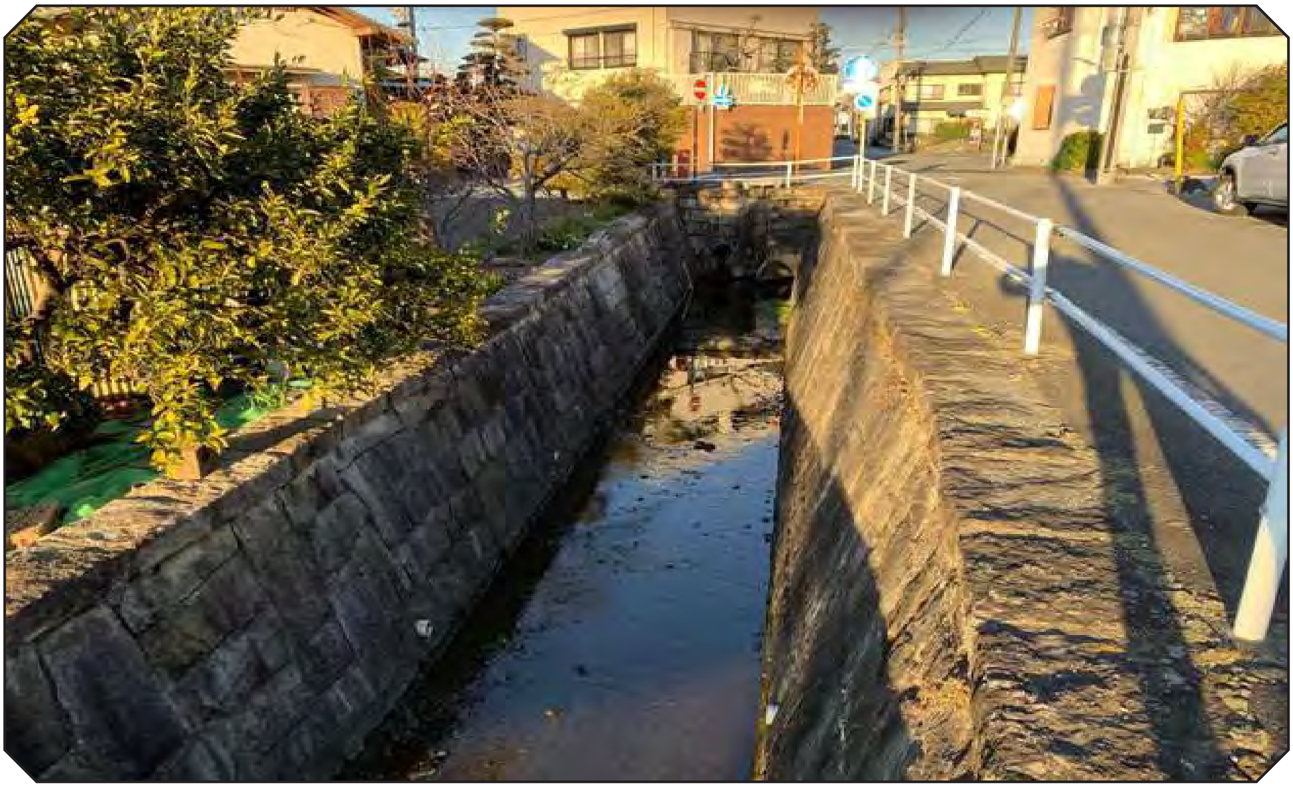
Ever since the Hietsu Earthquake in 1858, technologies for surveys, flood control and disaster relief for the Joganji River had been nurtured in the region, and many highly precise planar and discharge surveys of various irrigation networks, including the Joganji River, had been commissioned. The project predecessors used these documents as the basis to create accurate water utilization calculations, which were unheard of at the time, and their effective and fair irrigation water distribution plan meant they could make a more stable irrigation system.

The first intake tunnel was created by boring through the Takadomari Cliff, a challenging rock wall plunging into the river and chosen for its capacity to withstand the Joganji River's large floods. The rock wall was pierced in multiple places to provide a stable water supply to deal with the rising river bed or water level changes during flooding and blockages. All this, including the fact that all was completed with the workforce, shows the intelligent planning and execution of the project.

The warrior Sassa Narimasa's levee is still visible to this day in the bed. Over 100 trees from 1760 Pine Forest remain and continue to protect the area from flooding damage. These heritage pieces show vestiges of the civilization around the Joganji River and underline the high historical and technological value of the Josai Unified Intake Irrigation Canal.

8.13 KANUKI IRRIGATION CANAL

Name	**Kanuki Irrigation Canal**
Location	**Numazu City, Shizuoka Prefecture, Japan**
Latitude	**N35.09862484**
Longitude	**E138.8724876**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**1620-1629**
River Basin	**Kano-gawa River, Kano-gawa River System**
Irrigated/Drained Area	**7.13 ha**



History

Before 1620, agriculture in the Kanuki area suffered from chronic water shortages, with rainfall and reservoirs as the only water sources. Therefore, Ueda Naizen, who lived in Kamikanuki Village, made a plan to build an irrigation canal using the Kano-gawa River that ran nearby as an intake and began construction work on the project.

In the 1620s, when the Kanuki Irrigation Canal was constructed, the Edo shogunate (national government) and the various clans (local authorities) were encouraging the development of new rice paddies throughout the country, and the same was true in the Kanuki area. Under these circumstances, solving the water shortages through the establishment of the Kanuki Irrigation Canal system marked an important turning point in the development of agriculture in the Kanuki area.

Comparison of before and after the completion of the Kanuki Irrigation Canal at that time

- Before completion: Paddy field area: 191.27 ha (harvest: approx. 267 tons)
- After completion: Paddy field area: 224.73 ha (harvest: approx. 306 tons)
- (1777 Kamikanuki Village Record Book, 1777 Shimokanuki Village Record Book)

Agriculture in the Kanuki area had been suffering from chronic water shortages, but with the completion of the Kanuki Irrigation Canal from around 1620 to 1629, the Kanuki area became free from drought, which laid the foundation for the development of agriculture known as the "2,000 koku of Kanuki." The total yield was 306 tons, consisting of 153 tons in Kamikanuki Village, 135 tons in Shimokanuki Village, and 18 tons in Zendayu-shinden. Water from the Kanuki Irrigation Canal was also directed to Ganyudo Village, and the four villages of Kamikanuki Village, Shimokanuki Village, Zendayu-shinden, and Ganyudo Village benefited from the Kanuki Irrigation Canal. In addition, land with a yield of 21 tons in Kamikanuki Village was opened up as new rice paddies due to the Kanuki Irrigation Canal.

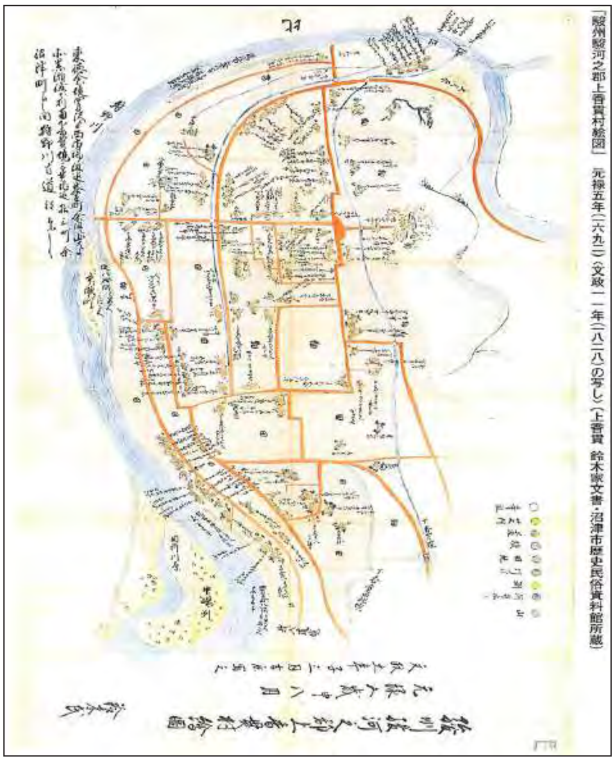
Description

The irrigation canal extended from east to west on the north side of Kanuki-yama mountain, with an upper canal extending from Yazakinohana to Kamikanuki (about 1,200 m long and 3.6 m wide) and a lower canal to Shimokanuki (about 3,818 m long, 3.6 to 5.5 m wide, and 1.5 to 4.5 m deep). Water was successfully drawn despite the difficulties involved in the construction, such as building a stone weir at the intake to raise the water level, together with work such as mixing furnace ash with earth to prevent water from seeping into the sandy soil irrigation canal. As a result, the Kanuki area became free from drought, and it became the foundation of the agricultural development known as the "2,000 kokus of Kanuki" (with one koku being about 150 kilograms of rice). Currently, although the area under irrigation has decreased with the urbanization of the region, it now plays a stronger role in local disaster prevention as a drainage canal during heavy rains and the like. As a result of the progress of repair work such as culverting, it has lost its former appearance, but it has been passed down in the region for about 390 years.

- An overview of the Kanuki Irrigation Canal as it currently remains is as follows.
- Structure: Concrete canals (U-shaped, box-shaped, etc.)
- Irrigated area: 7.13 ha
- Extension: 19.85 km (irrigation canal: 9.96 km; drainage canal: 9.89 km)
- Water level control facilities: 9 locations.

Water Heritage

Today, the city, the agricultural cooperative, and local water commissioners attend a memorial service for Ueda Naizen, which is held every year on August 15 at Reizanji Temple. In addition, the facility contributes to providing a good living environment for residents, such as the maintenance of the local community through waterway cleanup activities by neighbourhood residents, and plays a role in preventing ambient water pollution and preserving the beauty of the landscape.



A crescent-shaped stone weir was set up at the water intake, and a "Kawakura" structure (three logs assembled in the shape of a triangular pyramid, with a bamboo rope stretched over it, on which grass or straw mats are hung) was placed as an extension of the stone weir to raise the water level. In addition, three places called "Sunaharai" (sand conduits) were established in the stone weir where the stones were lower than the ones around them as a measure to prevent the accumulation of sand. During the rice planting season, it is necessary to take in a lot of water, so a sand conduit about 1 m wide near the bank was covered with boards to dam the water flow, and the two sand conduits about 5 m wide far from the bank were covered with horizontal log poles, on which bamboo was placed vertically like stakes with grass and straw hung to dam the water flow. This was an ingenious way of securing the water level at the intake.

Initially, when Ueda Naizen built a weir at Otaki on the Kano-gawa River and constructed an irrigation canal to draw in water, the water did not flow because of the sandy soil near the water intake sluice gate. Therefore, at a time when cement was not widely used, furnace ash was mixed with soil and spread on the irrigation canal to prevent water from seeping in, which succeeded in bringing long-awaited agricultural water to the Kanuki area.

Due to flooding of the Kano-gawa River in June 1945, the upstream bend of a 50-meter section of the bank of the stone weir collapsed over a width of about 10 meters, preventing water from entering the irrigation canal, so an axial-flow pump was installed at Zentokubo, where the Kise-gawa river joins the Kano-gawa river. Since the water is now pumped, there is no longer a need to repair the stone weir or insert the "Kawakura" structure.

Due to a land readjustment project in the Nakase and Nakahara areas that began in FY 1968, the upper and lower canals of the irrigation canal in some sections were backfilled, and a levee was constructed along the Kano-gawa River. As a result, the lifting pump at Zentokubo was removed, and its location was moved downstream on the Kano-gawa River, where the current Kanuki pumping plant was established, and water is taken year-round as water to maintain the irrigation canal. The water intake method has changed since its construction, the irrigated area has decreased, and its role as a drainage canal has increased, but it still plays an important role as agricultural water for the area and contributes to the promotion of agriculture in the area.

Operation and inspection of the Kanuki irrigation pumping station and water level control facilities (such as the Futasegawa sluice gate and Miyahara pump) and repairs to other sluice gates are performed by the Numazu City facility manager. Otherwise, daily management of the irrigation canal (patrols at ordinary times and removal of garbage, etc.) and sluice gate operation (at times of heavy rain) are carried out by the Kanuki Irrigation Canal Committee, which is organized by local farmers. In addition, Numazu City responds to requests and suggestions from residents through onsite inspections, repair work, and so on.

8.14 KIKUCHI IRRIGATION SYSTEMS

Name	**Kikuchi Irrigation Systems**
Location	**Kikuchi City, Kumamoto Prefecture, Japan Tsuiji-ide Irrigation System; Haru-ide Irrigation System; Imamura-ide/Houei-zuido Irrigation System; Furukawahyodo-ide Irrigation System**
Latitude	**32.988 N (Tsuiji-ide Irrigation System); 3.008 N (Haru-ide Irrigation System); 32.975 N (Imamura-ide/Houei-zuido Irrigation System); 33.016 N (Furukawahyodo-ide Irrigation System)**
Longitude	**-229.171 E (Tsuiji-ide Irrigation System); -229.116 E (Haru-ide Irrigation System); -229.174 E (Imamura-ide/Houei-zuido Irrigation System); -229.106 E (Furukawahyodo-ide Irrigation System)**
Category of Structure	**Irrigation System**
Year of commissioning	**1615–1835; 1615 (Tsuiji-ide Irrigation System), 1701 (Haru-ide Irrigation System), 1705 (Imamura-ide/Houei-zuido Irrigation System), 1835 (Furukawahyodo-ide Irrigation System)**
River Basin	**Kikuchi River Basin**
Irrigated/Drained Area	**615 ha; 85 ha (Tsuiji-ide Irrigation System), 210 ha (Haru-ide Irrigation System), 190 ha (Imamura-ide/Houei-zuido Irrigation System), 130 ha (Furukawahyodo-ide Irrigation System)**

History

The Kikuchi Region is located in the middle area of Kyushu Island, the most western of Japan's four main islands. The Kikuchi River is 71 km long, and the area of the watershed is 996 km^2. The Kikuchi Irrigation Systems consists of four irrigation systems sequentially constructed in the watershed in 1596–1835: 1) Tsuiji-ide Irrigation System, 2) Haru-ide Irrigation System, 3) Imamura-ide/Houei-zuido Irrigation System, and 4) Furukawahyodo-ide Irrigation System. ("ide" means an irrigation system, and "zuido" is the tunnel in Japanese)

These irrigation systems represent the developmental process of agricultural engineering in the pre-modern period of Japan (from the early 17th century to the 19th century). In particular, unique techniques for excavating canals and tunnels can be seen in the irrigation systems because these irrigation structures were constructed in mountainous areas. The management rule of irrigation water was also affected by the sequential construction of the irrigation systems because the new ones dealt with more river water restrictions.

Description

The salient features of each irrigation system are as follows.

1. Tsuiji-ide Irrigation System (KIS-No.1) was constructed by a ruler to develop about 230 ha of rice fields in 1596–1615 (about 400 years ago). Although the irrigated area decreased due to urbanization, the irrigation system currently has multi-functional roles. The irrigation canals provide a beautiful townscape and act as a drainage facility for flood water.

2. Haru-ide Irrigation System (KIS-No.2A) was constructed in 1698–1701, about 100 years after the construction of KIS-No.1. A village leader planned and built the irrigation system. This proves that the community was democratized during the 100 years since the construction of KIS-No.1. The irrigation system was constructed to develop about 70 ha of rice fields, and excavation of an approximately 11-km irrigation canal with a 450-m tunnel in the mountainous area was required. The system is an irrigation facility and an important regional resource that vitalizes the local community. Canoeing using the irrigation canal is a good example.

3. Imamura-ide/Houei-zuido Irrigation System (KIS-No.2B) was constructed for 220 ha of rice fields in 1705. This irrigation system was planned almost at the same time as KIS-No.2A. The main irrigation canal is about 6.5 km, and there is a 300 m tunnel (height = 2 m). Currently, the tunnel is also used as an educational tool for history and agricultural engineering.

4. Furukawahyodo-ide Irrigation System (KIS-No.3) was constructed to develop 180 ha of rice fields in 1813–1835, about a century after the construction of KIS-No.2A and No.2B. The excavation of about a 2.4-km water channel through a mountain was conducted to obtain water from the adjacent watershed because the flow volume of the river was not sufficient for the additional development of rice fields. A 19-km irrigation canal was also excavated in the mountainous area.

The Kikuchi Irrigation Systems (KIS-No.1, No.2A, No.2B and No.3) have been maintained and used by the local communities for a long time. However, the irrigation structures were destroyed many times by disasters such as floods and earthquakes. For example, Kumamoto Earthquake in 2016 destroyed the wall in the tunnel of KIS-No.2B. However, the irrigation canal (tunnel) of KIS-No.2B was repaired. Many irrigation structures, especially irrigation tunnels, have been conserved in the irrigation systems in their original state. However, steel weirs have replaced the inlets (weirs) of the irrigation systems, and the irrigation canals are partially paved with concrete.

The irrigation structures and cultivated lands in the Kikuchi River watershed have been selected as “Japan Heritage” because they can be considered a miniature model of the historical record and culture of Japanese rice farming. Kikuchi Irrigation Systems is one of the most critical components of heritage.

The Kikuchi Irrigation Systems are mainly managed by a single organization (Kikuchi Land Improvement District). The organization employs professional staff members. The organisation mitigates water conflicts among the irrigation systems due to droughts, which frequently occurred in old times.

The irrigation structures are used not only for irrigation but also for the revitalization of the local community. For example, the old tunnel of KIS-No.2B is used as an educational tool for primary school children. Canoeing in the irrigation canal of KIS-No.3 is also an excellent example of the multi-use nature of the irrigation system. This activity was selected as a recipient of the “Sport and Culture Tourism Award 2018” by the Agency for Cultural Affairs of the Japanese government.

Water Heritage

The Kikuchi Irrigation Systems (KIS-No.1, No.2A, No.2B and No.3) were sequentially constructed starting in the early 17th century, and finishing in the 19th century. The first irrigation system (KIS-No.1) was planned around the end of the civil wars in Japan. The irrigation canal of KIS-No.1 was constructed using sophisticated techniques in the early 17th century. The second and third irrigation systems (KIS-No.2A and No.2B) were built in the early 18th century. Long irrigation canals and tunnels were excavated to develop the mountainous area.

Additionally, the construction of KIS-No.2A and No.2B was not planned not by a ruler but by a village leader, reflecting the democratization of the local society in Japan. The last irrigation system (KIS-No.3) was constructed to develop rice fields in the most upstream river watershed in the 19th century. Therefore, it can be said that the location of the irrigation systems represents the development process of the river watershed. The developmental process of agricultural engineering in the pre-modern period of Japan can be seen through the irrigation systems. In particular, excavation techniques of canals and tunnels, which were evolved in the construction of irrigation systems, were substantial. Those techniques were widely applied to other irrigation systems in later years.

The Kikuchi Irrigation Systems have provided an outstanding contribution to the development of rice fields in the river watershed. The irrigation systems developed about 700 ha of rice fields. Also, the irrigation systems, KIS-No.2A and No.3 supplied irrigation water and drinking water. The irrigation systems did a lot to alleviate poverty in the mountainous area because it was hard for the villagers to obtain water. The irrigation systems have been reinforced and supply irrigation water to about 615 ha of rice fields in the river watershed.

When the villagers planned the last irrigation system (KIS-No.3), they had to find another water resource because the previous irrigation systems had used the river water. They planned the construction of the water channel that connects the river to the adjacent river through a mountain to abstract additional irrigation water. The length of the water channel was about 2.4 km. Also, the main irrigation canal of KIS-No.3 is about 19 km long. It took more than 11 years to construct the irrigation system. In addition, it cost 5.8 million USD. This cost indicates the difficulties of the construction and the innovative nature of the idea.

Sophisticated techniques of excavation of tunnels were necessary to develop the mountainous area. Three irrigation systems (KIS-No.2A, No.2B, and No.3) have more than a hundred meters long tunnels. Those tunnels are good examples of agricultural engineering at the time. In particular, the tunnel of KIS-No.2B was about 300 m long and was excavated in a short time (only 100 days).

The Kikuchi Irrigation Systems (KIS-No.1, No.2A, No.2B and No.3) still have a crucial role in rice production and have kept their original functions for several hundred years. The irrigated area of the irrigation systems is 615 ha today. The locations and scales of the irrigation systems are almost the same as when they were built.

However, there are many disasters such as typhoons, heavy rainfall and floods, earthquakes, and volcanic eruptions in Japan. After some of these disasters, parts of the irrigation structures have been repaired and reinforced with concrete or steel. Droughts can also cause severe water conflicts in the river watershed. All inlets of the irrigation systems were repaired to intake water efficiently. Also, the irrigation canals were partially paved with concrete to prevent water loss. The water channel of KIS-No.3 has not been used since a large concrete dam was constructed in the river watershed.

8.15 KITADATE IRRIGATION SYSTEM

Name	**Kitadate Irrigation System**
Location	**Syounai Town, Yamagata Prefecture , Japan**
Latitude	**38.782**
Longitude	**140.022**
Category of Structure	**Irrigation System**
Year of commissioning	**1612**
River Basin	**Tachiyazawa River**
Irrigated/Drained Area	**2880 ha**

History

Shonai area in Yamagata prefecture lay in flat terrain on an alluvial fan and was 5 m higher than the surrounding rivers, making it barren land and poor water supply until the 1600s. The feudal lord, Kitadate Toshinaga, established a plan for Kitadate Irrigation System to divert water from the Tachiyazawa River in an adjacent basin, delivering the water around the mountain ridges to help the impoverished population.

The construction, which began in 1612, encountered many difficulties, such as canal construction next to a cliff and landslides. However, the Kitadate canal of about 10 km was completed in only four months by mobilizing 7,400 workers in a day, using lanterns in the dark and accurate and detailed design. The success of this construction led to new irrigation canal constructions in the region, an additional 5000 ha of paddy fields were developed, and 46 villages were established in the following 57 years.

In addition, efficient and organized water management for distributing irrigation water to a large beneficiary area increased the rice harvest in this region by about seven times. The farmers' incomes were secured, leading to the development of the regional economy and the formation of farming villages. This management system for distributing irrigation water was administered by a district magistrate, an administrative body of that time. Then it was transferred to a farmer's organization in 1885, and now, the organization of the land improvement district is conducting appropriate water management in cooperation with residents.

Today, the Kitadate irrigation system provides abundant water to rice fields and forms a beautiful landscape. The development history of the system has also been used as teaching material for local elementary schools, and the system has been recognized as an important historical asset of the Shonai Plain.

Description

The Shonai area was a challenging area to secure irrigation water because the altitudes of the surrounding rivers were low compared with the left bank area of the Mogami River located in the Shonai plains. The Kitadate irrigation system, which consists of headworks and an open canal, was constructed in 1612. As a result, about 5000 ha of new rice paddies were developed, and the construction of the Kitadate irrigation system contributed to development in the left bank area of the Mogami River enormously.

As part of the system, a canal was set up on a steep slope of a mountain to take irrigation water from the Tachiyazawa River, but the construction was tough. However, they conducted an accurate survey and completed the construction of a 10 km canal in only four months. Following this, the canal was extended by 30km, and many new rice paddies were developed, leading to the development of many new villages. After constructing the Kitadate irrigation system, there was a shortage of irrigation water and growing obstacles due to cold water in the Tachiyazawa River. From 1954 to 1972, a new inlet was established in the Mogami River, and a reorganization of irrigation canals was carried out to construct a 3 km tunnel and two pumping machine stations. As a result, the irrigation water shortage and the problem of cold water were improved.

The canal of the Kitadate irrigation system has been repaired suitably and is useful for preserving aquatic habitats, and the creation of a rural landscape harmonized with beautiful rice paddies. This is why the canal was selected by the Ministry of Agriculture, Forestry and Fisheries as one of the 100 fine canals in Japan.

The irrigation system is praised as a local historical asset. The organizations of the MogamiGawa Land Improvement District have accepted foreign trainees through JICA's training program, introducing the structure of the canal, maintenance methods, and water control systems. A Shinto shrine was built in 1778 by the fief population, praising the achievements of Kitadate Toshinaga, and it was revered as a god of water. Following its construction, the maintenance and renovation of the shrine were undertaken by farmers, and a new shrine was built in 1973 at its current location near the ruins of Karikawa Castle as "Kitadate Shrine". A festival is performed every May, and residents gather around and appreciate the benefits of their predecessors' virtues.

A high-ranking district magistrate undertook the maintenance of the Kitadate irrigation system until around 1875, and after that, it was transferred to the farmer organization. The MogamiGawa Land Improvement District was established in 1955, and large-scale changes to the irrigation system and repair works are performed appropriately. Water for irrigation is supplied to 2,880 ha of rice paddies at present. Such steady work is contributing enormously to the development of the agricultural economy in this region.

The MogamiGawa Land Improvement District appropriately maintains the maintenance and management of irrigation facilities. Efforts have been made with residents and local elementary schools for environmental improvement and environmental conservation activities.

Poor drainage decreased rice harvesting, especially in the lower elevations of the downstream land; the Mogami River's water level rose, causing floods and enormous damage. Therefore, a drainage improvement project was started from 1965 to 1977; drainage pumping systems and drainage canals were improved, reducing flood damage. However, due to the lack of drainage capacity and frequent flooding from the recent increase in rainfall and a change in land use, a project was started to restructure the drainage system and strengthen the drainage function in 2017. Since drainage measures are an important issue for agriculture and residents' lives, a new water management system is planned to enable accurate and rapid drainage operations.

Water Heritage

The completion of the Kitadate irrigation system led to the development of new rice paddies left of the Mogami River. For example, the construction of the Yoshida irrigation system, which consists of headworks and a canal located downstream from the Kitadate irrigation system, was completed in 198. New rice paddies of about 1200 ha were developed and contributed to agricultural development. Forty-six villages were opened by 1669, and it began to look much like the current landscape of villages. Along with this, the population also increased markedly.

Moreover, the construction of the Kitadate irrigation system fostered a strong agricultural spirit on the foundation of rice cultivation. From around 1890, farmers became more motivated to cultivate rice, and the government and people carried out an agricultural improvement project. Kandenbakou - a method of improving farmland by draining the paddy and tilling the field with a horse-drawn plough - and private breeding of rice plants became established. Private breeders created Thirty-eight new rice varieties in Yamagata Prefecture. Six of them were by seven breeders in the Amarume district, found on the left bank area of the Mogami River. This contributed significantly to the history of good-quality rice in Japan.

There were two main ideas on how to take irrigation water from the Tachiyazawa River - setting up a canal in the mountainous area and setting up skirts along the Mogami River. However, because it was challenging to construct a canal in a mountainous area with the technology, a survey and a design were executed using the latter method. The plan was suggested at a clan's conference, but it was vehemently opposed because its feasibility was questionable and required enormous costs. However, the accuracy of the survey and the design were confirmed at the site. Despite difficulties, the workers completed the 10 km canal in four months.

In addition to celebrating the achievements of Kitadate Toshinaga and the festival held in May every year at the Kitadate shrine, ceremonies were held in 1911 – to mark the 300th anniversary of the construction of the Kitadate irrigation system, and in 2012 which marked the 400th year. These ceremonies reflect the virtues of the ancestors carried forward for posterity. The tomb of Kitadate Toshinaga, near Karikawa Castle, was designated as a designated cultural property in 1952, and a bronze statue was erected in the Tateyama Park of the Castle ruins in 1973, and many people still revere it.

8.16 KOUNOMIZO-HYAKUTAROUMIZO IRRIGATION SYSTEM

Name	**Kounomizo-Hyakutaroumizo Irrigation System**
Location	**Yunomae Town, Kumamoto Prefecture, Japan**
Latitude	**32.272**
Longitude	**130.982**
Category of Structure	**Irrigation System**
Year of commissioning	**1705**
River Basin	**Kuma River system**
Irrigated/Drained Area	**2822 ha**

History

Kounomizo Old Weir was constructed across the Kuma River, one of Japan's three most rapid rivers. Its construction started in 1696 and took nine years to complete. Even at the upper stream during the relatively dry season, the construction was challenging, considering the poor civil engineering technology. A distinctive feature of the Kounomizo Irrigation System is its three irrigation tunnels with a total length of 2,524 m. It was the longest in Japan through the Edo period (1603-1867). The inside of the two tunnels was strengthened by an A-frame structure called Gassho-Zukuri with stone pillars of 110 kg apiece. There exist only three such tunnels in Japan, and Kounomizo's tunnel, which adopted this method in 1729, is the oldest.

About Hyakutaroumizo, the most salient feature is that it was hand dug by farmers from children to the elderly through five construction periods over several hundred years. Unlike Kounomizo's construction, which a feudal lord ordered, there was no governmental support, special instructors, or leaders. Therefore, it can be said that Hyakutaroumizo is the product of farmers' blood, sweat, and tears. The exact year of the first excavation is unknown due to the lack of the document, but it is believed that its construction started sometime in Kamakura Period (1185-1133). The second construction began in 1677, and the fourth was completed in 1710.

Description

An irrigation system with weirs, tunnels, and canals was constructed in 1705 to develop new paddy fields. The water source of the system came from one of the three most rapidly flowing rivers in Japan. Before its completion, the weir was washed away twice by floods. Therefore, the weir structure became L-shaped, combining Yoko-Zeki (horizontal weir) and Tate-Zeki (longitudinal weir). This type of weir structure is unique and rare. In addition, a giant rock was placed in front of the weir to avoid the direct impacts of the torrent and flowing tree trunks. After its completion, only partial damages were registered; however, the foundation and the weir itself were kept intact. Also, small ditches called Ikadanagashi and Akusuihaki were constructed at the weir. The former was opened so that the logs from the upper stream forest could flow through the weir, and the latter was opened to avoid the sedimentation of sand or gravel at the intake gate.

Three tunnels were excavated in this system. After just digging naturally, one of the tunnels was fortified by the stone Gassho structure. This structure is rare and is the oldest in Japan, but strong because the tunnel has not collapsed so far. The total length of the tunnels was 2,524 m, which was the longest in Japan until the 19th century.

The structure of Kounomizo's old weir was uniquely L-shaped. It combined Yoko-Zeki (horizontal weir with dimensions, height–6.7 to 9 m, length–36 m and width–22 m), which crossed the river from North to South, with Tate-Zeki (vertical weir which was 84 m long), vertically connected to Yoko-Zeki from the downstream.

Irrigation canal systems are divided into Hyakutaroumizo and Kounomizo. Hyakutaroumizo was hand dug and constructed by farmers with no government supports or instructions. On the contrary, the construction of Kounomizo was conducted by the feudal clan. It is said that the success and the civil engineering methods of Hyakutaroumizo construction were primarily followed.

Due to the construction of those facilities, the food production in the area increased by as much as 10,000 kokus, which is equivalent to 10,000 people eating in one year. Currently, 2,822 ha of farmlands benefit from this system, and various crops such as rice, tobacco, melon, and green tea leaf are cultivated.

Since the water source of Kounomizo and Hyakutaroumizo is one of the three most rapid rivers in Japan, during every rainy and typhoon season, a considerable amount of water overflows from the canals. It is necessary to check and control the amount of water flow every day during the seasons not to cause fatal damage to the whole irrigation system.

At Kounomizo Land Improvement District, three water distribution and repair staff members and 24 facility administrators ensure fair water distribution. About 30 water leakage repair works a year and dredging of the canals are conducted by the district members. A lighting system was installed so that the facilities management can be carried out more carefully and enable safe guiding for visitors.

After repairing the Hyakutaroumizo project because of its aged dry masonry causing frequent water leakage, the total length of reconstruction is 5,000 m. As a consequence of the environmentally low-impact technique taken, the number of fireflies that had previously decreased year by year increased. An area in Asagiri Town is designated as one of the Top 100 Firefly Spots in Kumamoto Prefecture.

Water Heritage

Before constructing the Kounomizo-Hyakutaroumizo Irrigation System, this region could produce only upland rice and sweet potatoes. But because of the irrigation system, the region produces various products; rice, wheat, tobacco, pear, tea leaf, horticultural crops like melon, and animal husbandry. Due to the structure, the production jumped up to 53,000, increasing 10,000 kokus (1 koku meant the amount of rice consumed by an adult per year). Those facilities currently irrigate 2,822 ha (about 40%) of the paddy fields in the region. A new village came into being called the New Rice Field Village. The first batch of immigrant settlers was 333 households, including Miyazaki Prefecture, to escape poverty. After the canal's construction, the number of migrant families gradually increased to 474 between 1789 and 1800. Kounomizo and Hyakutaroumizo have significantly contributed to the region's development, the increase in food production and the decrease in poverty.

Water needs to be elevated up to the plateau at first to irrigate the undeveloped lands. However, it was impossible with the civil engineering technology, so Kounomizo's three tunnels were excavated under the plateau. The old tunnel of 1,451 m in length was built in 1696, and the new tunnel of 664 m was constructed in 1705. In the same year as the old tunnel, the third tunnel 409 m in length was excavated. Combined with the three tunnels, the total length is 2,524 m, and it was the longest irrigation tunnel in Japan through the Edo period (1603-1867). These tunnels were originally all hand-dug unlined and vulnerable to floods. In 1729, 23 years after its completion, the project to fortify the New Tunnel in the soft ground of a pyroclastic mixture called Shirasu started. (Shirasu is a pyroclastic flow deposit, which covers most of southern Kyusyu). Two third of 664 m was reinforced with 110 kg apiece stone pillars, using an A-shape structure called Gassho-zukuri.

In the same year, Old Tunnel was also fortified by the Gassho structure. The Gassho structure works like a truss structure. Its inclined ceilings are sturdier and more stable against weight than a flat ceiling. The Third Tunnel, which was not improved with the Gassho structure, collapsed and is no longer used. There are only three Gassho-style tunnels in Japan; Kounomizo's Old and New Tunnels and Kawabaru Tunnel in Ooita Prefecture. Kawabaru Tunnel, built around 1854 and extends 52 m, is not an irrigation tunnel. Since Kawabaru Tunnel adopted the stone Gassho-zukuri more than 100 years later than Kounomizo, Kounomizo is still the oldest tunnel with such a rare construction method. Since the construction of the Kounomizo weir and two floods, the L-shape was eventually adopted, suitable for resisting rapid streams and the impact of flowing rocks and tree trunks.

In the construction, eight holes were drilled into the bedrock of each bank of the Kuma River. Next, the holes were inserted by sawtooth oak trunks (20 m long and 1 m in diameter) connected to make joists of Yoko-Zeki. After that, approximately 3.6 m long thick pine trees crossed the river to surround it with boxes of trunks. People placed many giant rocks in the boxes to construct the foundation of Yoko-Zeki. The function of Tate-Zeki was to support Yoko-Zeki from the downstream side. Six holes were drilled at the bedrock of the left side of the river, and giant trees were put in them, as for Yoko-Zeki. With these two structures together, a stronger weir was constructed.

The structure is an important cultural icon that represents the hard work of people. This unique native wisdom led the system to stand today after facing floods and other natural disasters. It also paved the path for modern engineering theories and practices. The system witnessed a sustainable operations and management system which has been sustained and developed over the past several centuries through farmers' water management organization and conserved 125 ha of forests.

In 2006, Kounomizo-Hyakutaroumizo Irrigation System was designated as one of the Top 100 Canals in Japan. In addition, both of their facilities appear in elementary school textbooks as the region's agricultural heritage. Hyakutaroumizo Irrigation System is still operating. Its management and maintenance are in charge of Land Improvement Districts.

8.17 KUMEDAIKE RESERVOIR

Name	Kumedaike Reservoir
Location	Kishiwada City, Osaka Prefecture, Japan
Latitude	34.456
Longitude	135.416
Category of Structure	Water Storage Structure
Year of commissioning	738
River Basin	Ohtsu-Gawa
Irrigated/Drained Area	27.7 ha

History

Kumedaike Reservoir meaning 'an eternal paddy field reservoir', was constructed following a unique method called *Shikiha*, in the 8th century. It's construction and subsequent renovations took 14 years, from 725 to 738, to give its original shape as seen today. Over the last 1300 years, it has continued to contribute to agricultural production in the Kishiwada City area.

Kishiwada City is located in the south part of Osaka prefecture, has no large rivers and little rainfall, and many of its ponds were constructed in ancient times. Rice cropping started around the 2nd century BC in the region and likely earlier in the Yagi area, Kumedaike's irrigation command area. This area relies on the Amano-Gawa water system with a small amount of water. Therefore, the spread of farmlands caused a severe water shortage problem during droughts in the Yagi area. Witnessing the plight of the people, the Buddhist priest Gyoki, who is known for his commitment to the construction of the Great Statue of Buddha in Nara, made a pact with Tachibana no Moroe, petitioned the emperor, organized the residents, and constructed the reservoir.

Description

Kumedaike Reservoir, with a 4.4 m embankment height, 2,650 m perimeter, 45.6 ha reservoir area, and 1.57-million-ton reservoir capacity, geographically straddles two neighbourhoods, Ikejiri and Okayama, in Kishiwada City. It has the largest water area in Osaka Prefecture and has the third-largest capacity, following Komyike and Sayamaike. Currently operational, it is irrigating 27.7 ha of farmland.

Kumedaike Reservoir at that time was constructed by integrating adjacent small ponds. The initial water source was not the current Gyutaki-Gawa River but the Haruki-Gawa River located southeast of the reservoir. The embankment was constructed by alternately compacting argilliferous soil layers and sand gravel layers and sandwiching leaves in between, which is called the *Shikiha* method. The method originated in Japan from technology exchange with East Asia, and for this reason, the Kumedaike reservoir is also an important historical site. After that, the Kumedaike reservoir was upgraded several times by merging with adjacent smaller ponds in the 13th - 14th centuries.

The Kumeda Temple near the reservoir is one of the 49 temples Gyoki established. It was erected for the operation and maintenance of Kumedaike Reservoir in 738. At first, the scale of Kumedaike Reservoir was smaller, but with increasing demand, it was expanded with new embankments. With the new higher embankment built during these renovations, it became difficult to take water from the Haruki River. For this reason, the water source was changed to the Gyutaki-Gawa River. Additional canals—Sakae-Gawa and Izeki were also built at the same time. However, the Gyutaki-Gawa River had already been irrigating the farmlands of its original water rights holders. Since the actual water rights holders drew water from the Gyutaki-Gawa River during the irrigation season, Kumedaike Reservoir could draw only during the non-irrigation season until its storage capacity got full. Despite its large size, it was difficult for Kumedaike Reservoir to meet the water needs of its large beneficiary area. Thus, farmers depended on the muddy water from heavy rains during the irrigation season to secure enough water.

While the Ohtsu-Gawa River system to which the Gyutaki River belongs often experienced floods during heavy rains, causing considerable damage, the Kumedaike Reservoir were traditionally allowed to draw the muddy floodwater from the Gyutaki-Gawa River. This water allocation rule is still valid today. The water managers of Kumedaike Reservoir have continued opening the intake gates during heavy rains, getting soaked in the process, and closing the gates after the rains. Kumedaike Reservoir has played a role in flood control because the floodwaters from the GyutakiGawa River are diverted into the Haruki-Gawa River system. The function of flood control is as essential for the residents as agricultural water.

Management and Distribution: Kumedaike Reservoir had been managed by Kumeda Temple. In the 1200s, the management body was transferred to a water users' organization involving 14 villages. Water distribution and renovation work have been done by this group ever since. There used to be precise rules for drawing water and the cost allocation of water dues among these 14 villages. Although there are no extant records of the details of the rules, the cost allocation was determined based on the area of paddy fields owned since the 19th century or so. After World War II, the Land Improvement Law was enacted, enabling the Kumedaike Water Users' Group members to join the Kumedaike Land Improvement District cooperative. Due to the Land Improvement Law and subsidy from the national government, the cooperative conducted large-scale embankment renovation projects from 1960 -1965.

Kumedaike contributed as a vital food provider for a very long time, more than 1200 years, from its construction. However, due to dietary changes and urban expansion in the rapid economic growth era around 1960-1980, the irrigation area decreased from its peak area of 370 ha to 27.7 ha. The decrease in the number of farmers' population who maintain the facilities has shifted the responsibility towards residents.

Now non-farmers and children voluntarily contribute to the maintenance of the reservoir, not only as an irrigation facility but also as a precious wetland. As a necessary fixture in the community, it is cleaned and managed by a citizens' group established in 2002, drawing members from more than 100 organizations such as schools or residents' associations in collaboration with the land improvement district. As a result, the burden on farmers has been greatly alleviated, and the reservoir is well-managed.

Kumedaike Reservoir is recognized as an irrigation facility and precious property as a scenic spot, recreational site, and valuable local heritage with a profound history and long tradition.

Water Heritage

Kumedaike Reservoir was a turning point in irrigated agriculture, food production, and the improvement of farmers' economic conditions. Kishiwada City, with no large rivers and little rainfall, expanded its farmlands after the reservoir's construction. The integration of the existing small ponds into the Kumedaike Reservoir secured a stable food supply through consistent irrigation. After subsequent renovations according to the demands of each era, the reservoir continued to play an important role as a precious agricultural water resource in the area. Moreover, it has created new income avenues like fish farming for the people.

The reservoir's embankment was constructed following the *Shikiha* method, in which layers of leaves are sandwiched in between. This unique method can also be found in another reservoir constructed in the same era, like the Sayamaike Reservoir. The structure was innovative in its ideas at the time of its construction. It was renovated over and over to accommodate expanding farmlands. With the new higher embankment installed during these renovations, it became difficult to take water from the Haruki-Gawa River. For this reason, the water source was changed to the Gyutak-Gawa River to maximize water volume. Furthermore, the reservoir area of 45 ha is the widest in the prefecture despite its location on the plains.

As interest in environmental aspects and demand for creative preservation of wetlands and greenery increased throughout Osaka prefecture, the Osaka prefectural government formulated the Oasis Plan in 1991, aiming at comprehensive development as an ecological resource underlying a charming community that "*preserves the structures' agricultural character while bringing 'comfort' and 'richness' to city life, involving the residents of Osaka Prefecture in the process.*" Under the plan, many renovation projects such as bolstering banks to 376 m, adding 2,640 m of levees, one spillway, two intake structures, sediment removal, and other environmentally friendly projects such as footpaths, water purification structures, and greenery, etc. were implemented to make full use of the historic vistas and resources, allowing the site to be better enjoyed by residents and farmers.

The first project funded through this plan was implemented from an environmental perspective between 1991 and 2001. It added updated water usage and emergency protection devices and scenic levees that blend into the surrounding scenery, beautiful vistas in all directions, paths for enjoying history, zones for aquatic biodiversity, water purification facilities, and so forth. It contributes not only to farmers but also to ordinary citizens as a source of comfort and recreation.

Kumedaike Reservoir was registered as a Prefectural Historic Site in 1941, while Kumeda Temple had been recorded in 1936, and its scenic view was registered as a Scenic Zone. In addition to its role as a source of irrigation water, it also provides an aquatic environment for diverse creatures. Carp, gudgeon, and shrimp are farmed, and approximately 100 kinds of migratory birds annually visit in the winter, giving the reservoir the nickname Birds' International Airport.

Kumedaike Reservoir bears the stamp of a cultural tradition. It has been proven that the origin of the *Shikiha* method, which was used extensively in the reservoir's construction, lies in East Asia. The reservoir is an essential social, cultural and political structure. Several events are organized in the region to appreciate the reservoir and its contribution. The traditional Danjiri parade festival has been held annually in the Yamate area in October in Kishiwada City for 300 years. People from the Yagi area, which has traditionally benefitted from the reservoir, visit Kumeda Temple and the shrine to express their gratitude towards Gyoki for building the reservoir.

Kumedaike Museum displays numerous historical artefacts from the Nara period and serves as a place where urbanites and farmers can mingle. In 2010, the reservoir was included in the list of The Best 100 Reservoirs in Japan chosen by the Ministry of Agriculture, Forestry and Fisheries. Furthermore, Kumedaike Reservoir figures prominently in the following five annual festivals and events: Great Dondo Festival (January); Gyoki Founder's Memorial (February) Kumedaike Cherry Blossom Festival (April); Kumedaike Summer Festival (August); Kumedaike Ecological Seminar (August).

8.18 KURAYASU AND HYAKKEN RIVERS IRRIGATION AND DRAINAGE SYSTEMS

Name	**Kurayasu and Hyakken Rivers Irrigation and Drainage Systems**
Location	**Okayama City, Okayama Prefecture, Japan**
Latitude	**34.719**
Longitude	**134.095**
Category of Structure	**Irrigation and Drainage System**
Year of commissioning	**1679 (The Kurayasu River (irrigation canal), Yoshii Locks) 1687 (The Hyakken River (drainage canal))**
River Basin	**The Kurayasu River: The Asahi River basin; The Hyakken River: The Yoshii River basin**
Irrigated/Drained Area	**2,472 ha (Irrigated) and 2,845 ha (Drained)**

History

About 360 years ago, people in Okayama suffered from food shortages, population growth, and frequent poor harvests in the early Edo period. Mitsumasa Ikeda, the feudal lord, undertook a large-scale project to develop newly reclaimed fields in 1656 to improve crop productivity, offer stability, and raise the living standards

of farmers. In 1657, a Bay Area Land Reclamation Plan was established for the Kojima Bay area, located between the Yoshii River and the Asahi River estuary. However, the project was temporarily abandoned due to difficulties securing a sufficient amount of irrigation water for the newly reclaimed rice fields and controlling drainage from medium and small rivers in the area.

Description

Afterwards, Nagatada Tsuda, a *Gundai* (a type of magistrate in feudal Japan), embarked on a project for an irrigation canal that was 19.9 km in length, with a width of 4 to 7 m. This project aimed to secure an adequate water supply for the new fields from the Yoshii River. This canal was called the Kurayasu River. This canal became the source of the water supply for the new land of the Kurata-Shinden district, which was 329 ha in total (reclaimed in 1679). The Kurayasu River also turned out to help supply water to the new land of the Oki-Shinden district (built later) along with other rivers, one being the Suna River. The canal was also quite convenient as a waterway, connecting the Yoshii River and Okayama Castle over the shortest span. On the Okayama plain, people relied on irrigation facilities, especially in the newly reclaimed areas. The Kurayasu River was an epoch-making project.

The Kurayasu River continues to be appreciated even today, as its essential role in the lives of the people who live in the district remains unchanged. Yoshii Locks at the intake of the Kurayasu River, being a perpetually protected historic landmark, are the oldest such remains in Japan. Yoshii Locks consist of two stone sluices constructed of robust granite and one elliptical lock chamber. With advanced technologies, Yoshii Locks enabled the boats to pass. Presently, Yoshii Locks are designated as an Okayama Prefecture Historical Site. At the same time, Nagatada Tsuda built 11.7 km of sea dikes at the Hyakken River estuary. He then built a huge retarding basin on the inland side and five drainage gates made of granite, completed in 1687. These were substantial assets to rice farming as they extracted residual water from the rice fields, which was harmful to crops and was the most technologically innovative project of its time.

Restoration: The Kurayasu River has been connected to the Yoshii River and the Asahi Rivers for more than 300 years since it was built in 1679; however, it was divided by a major renovation of the Hyakken River in 1985. Since then, the Asahi River has become a water source for the west side of the Hyakken River, while the Yoshii River has remained the same, providing water to the east side of the Hyakken River.

Both sides of the Kurayasu River have been well protected. They have maintained their original appearance, while with several rivers related improvements, they have continued to be an essential part of the area's irrigation system. Also, the Hyakken River has undergone several modifications since it was first constructed, yet it has maintained its function as a flood control and drainage system.

Presently, many civil societies such as the Okayama Clan Nagatada Tsuda study group and Tomiyama Nature's Club have been working on preserving these facilities by engaging in clean-up activities and honouring ancestors, respecting these rivers as well the Mother River of Okayama. These projects are adopted as reading materials for school students in Okayama Prefecture, such as *Reclamation in Okayama* and *The Story of the Hyakken River.*

Water Heritage

Kurayasu and Hyakken Rivers Irrigation and Drainage System was a milestone in irrigation infrastructure. By providing irrigation water, the system enhanced the region's food production and contributed to the region's holistic development. Over the years, the Hyakken River as the main drainage canal has assisted in developing the Oki-Shinden land reclamation district, which was Japan's most significant area of land development at that time. It was 1,918 ha in total area when it was completed in 1694. Through the concept of combining the functions of flood control and land development, the Hyakken River, 12.9 km in length from the point where it branches off from the Asahi River, has prevented or reduced the detrimental effects of floodwaters from the Asahi River. The completion of these projects resulted in the sea-land reclamation of over 2,200 ha in the area. Thus, these projects increased food production, developed regional agriculture, and improved the quality of farmers' lives. Furthermore, the concepts and advanced technology applied in these projects have greatly influenced both the theory and practice in developing similar facilities across Japan.

The Kurayasu and the Hyakken River helped complete land development by increasing the crop productivity of the existing farmland. The system eliminated the shortage of land, strengthened the crop production system, contributed to poverty reduction, the development of stability, and improved the quality of farmers' lives. As a result of this process, farmers were provided land per the size of their families.

The construction of the Kurayasu River started in February 1679 and was completed in August 1679. Just conceiving the idea of connecting both the Yoshii River and the Asahi River is astounding, but what is even more incredible is the construction itself, which only took six months to complete. This is a testament to excellent planning and the use of existing small and medium-sized rivers, water channels, and wetlands for most of the connection process. At the same time, the Kurayasu River featured small water channels crossed with stone siphons at 23 crossing points. Also, Yoshii Locks, which serve as the intake of the Kurayasu River, were built with robust granite and were placed on top of a rocky hill that is solid and stable.

Furthermore, the Hyakken River had a drainage system that combined five stone drainage gates at the estuary and a retarding basin on the inland side. This was to reduce the detrimental effects caused by water by utilizing high and low tides. In this way, the concepts and advanced technology from this period have influenced technological innovation and future generations. From ancient times to the present day, Okayama has always been a leader in rice farming. Several extraordinary ideas and methods were created here and adopted in other areas across Japan.

Using innovative technology, the Kurayasu River brought abundant water to the Asahi River from the Yoshii River, 15 km away from the Kurata-Shinden district, connecting the two rivers. Finally, it was used as both an irrigation canal and a waterway for boats. Furthermore, they built another river called the Hyakken River, installing a drainage system that combined a retarding basin and many sluices made of stones at the estuary. These are the innovative ideas that Nagatada Tsuda made a reality.

The Kurayasu and Hyakken Rivers Irrigation and Drainage System were advanced and excellent engineering that completely revolutionized the irrigation industry in Japan. Regarding the Hyakken River, the precise design and techniques that combined a huge retarding basin and drainage gates were adopted in other land development projects completed in 1819 and 1852 in what is now Kumamoto Prefecture. Regarding Yoshii Locks, the Fukuoka feudal clan also adopted techniques related to lock placement, the structure of double sluices, and its granite stone pillar in the building of their sluices, called *Nakama-Karato*, completed in 1736. Furthermore, the Kurayasu River later became a model for *The Aiba River,* which was built by the Hagi feudal clan in Yamaguchi Prefecture and completed in 1744. These are prime examples of the definition of outstanding technology, as these were developed over 330 years ago.

For over 270 years, the stone drainage gates at the Hyakken River and the sea dikes by the estuary played complementary leadership roles in water transportation for flood and tidal defence. Although the structure of the river locks has been changed gradually, owing to several renovations, the system has greatly influenced both the theory and practice in the development of drainage systems. The creation of the irrigation system also established the use of stone foundations and associated techniques, allowing for elaborate structures.

The excavated sections of the Kurayasu River are over 4.3km in length, which is 22% of 19.9km of the total length, and were built on existing small and medium-sized rivers, water channels and wetlands. This was done to preserve the environment. The Hyakken River ecosystem includes many wild species of plants and animals, and it has been designated as a natural treasure of Japan.

To construct the Kurayasu and Hyakken River irrigation canals and many other water area reclamations, a financial fund called *Shasoumai* was established. It also played a role in providing famine relief by offering funds at low interest. Furthermore, there were many individuals and masonry technocrats whose efforts completed all the projects. These projects were realized as a result of their efforts, exemplary techniques and the availability of funds. The fact that this undertaking has stood the test of time for almost 300 years points to the unique nature of the construction.

Each component of the system represents a part of the agricultural heritage of the region. Stone locks, stone seawalls and stone drainage canals are the basis of the technology. The Okayama clan's strong will and solid philosophical grounding allowed the completion of such a formidable task. This system was built with great attention to spirituality; it reflects traces of tradition, culture and civilization. This system is one of the most precious assets of the region and serves as a model for humanity in tackling agricultural crises throughout the world. Assessing cultural heritage values, Yoshii Locks have been selected as an Okayama Prefecture designated Historic Site, even though they no longer serve as intake gates due to the construction of the Sakane Weir in 1980. However, they remain the oldest existing lock gates (flood gates) in Japan and have maintained their original appearance for 340 years.

The drainage and irrigation system has continued to function and provide multifarious facilities due to its robust operations and management model. The Kurayasu River has a stable water flow provided by the Sakane Weir and is managed by the YoshiiGawa-Karyu Land Improvement District and Okayama City. A water-use adjustment organisation comprises local farmers to ensure the system's optimum condition and water efficiency. The revetment is a two-sided waterway with all sections consisting of natural stones and blocks. Still, in some areas, some river spaces are formed with double-sided natural stones by revetment improvement. The Kurayasu River is protected by local people carrying out regular clean-up events out of respect for their Mother River, allowing their maintenance until today after three centuries. Some communities have formed organizations like the Tomiyama Nature's Club, which shares the historical and cultural background of the Kurayasu River by holding events such as historical walking tours.

As the Hyakken River has undergone several major renovations since it was selected as a designated first-class river in 1966, its capacity for flood control and drainage has been strengthened even more. For example, during the deadliest floods in West Japan (in July 2018), the Hyakken River fulfilled the functions it was designed to, even 330 years after its completion. This is proof that the Edo era was a period of advanced technical prowess. People in Okayama Prefecture recognized again the crucial role that the Hyakken River played. At the same time, the renovations have created space for holding events and festivals for locals to visit and enjoy. The Hyakken River has nurtured the natural environment of the districts through which it flows. Furthermore, it has been designated as a natural treasure of Japan by the Forest Culture Association.

Yoshii Locks are well maintained and preserved by the Yoshii Locks Conservation Society, which the Okayama City Board of Education supervises. Residents and children also participate in workshop events to see the locks' solid and stable stone foundation.

8.19 MANNOU-IKE RESERVOIR

Name	**Mannou-ike Reservoir**
Location	**Manno Town, KaGawa Prefecture, Japan**
Latitude	**34.163**
Longitude	**133.873**
Category of Structure	**Water Storage Structure**
Year of commissioning	**701**
River Basin	**Kanakura River**
Irrigated/Drained Area	**3003 ha**

History

Mannou-ike Reservoir was initially constructed as a large-scale water source for Kagawa Prefecture in 701 when paddy fields began to spread rapidly in Japan, and the then ruler systematically promoted the cultivation of new paddy fields for expanding production capacity of the newly formed nation.

Description

Mannou-ike Reservoir boasts a bank height of 32.0 m, a bank length of 155.8 m, a water storage volume of 15,400,000 m^3, and an irrigation area of 3,003 ha, Japan's most prominent and one of the oldest agricultural reservoirs. After the initial construction, the embankments collapsed due to heavy flooding in 818. The famous high priest Kukai, who studied the latest civil engineering

technology in Tang Dynasty China, reconstructed the reservoir using three advanced construction methods.

1. Use of arched banks which took water pressure into account where banks were positioned, slightly curved to the inside of the narrowest sections of the valley allowed for smaller external slopes even with high banks and reduced the soil fill volume.

2. Creation of spillways by excavating base rock as an anti-flooding measure. The use of arched banks had the additional benefits of narrowing the embankment's top widths and shorter spillways length.

3. Installation of specialized revetments made of brushwood fence at the water's edge to prevent both erosion and landslides of the internal slope of the embankment.

The reservoir repeatedly collapsed and was rebuilt in the following periods. When the reservoir was reconstructed in 1631, a vertical pipe equipped with five intake holes was installed to allow warm surface water intake for better paddy growing. This original structure is still regarded as a model of a standard reservoir today and is highly esteemed as an excellent practical technology. In the year 1870, the wooden bottom intake pipes were replaced by a tunnel intake structure by digging a tunnel in the rock at the western corner of the embankment. Since then, this intake structure improved the efficiency of maintenance and management, which didn't require repair to this day, demonstrating the high technical standard of those days.

Today, the beneficiary area is divided into 16 designated water supply districts with water supply control members determining the water demand for each district and a committee making the final determinations for overall water supply with division works in 250 locations, reservoirs in 59 locations, and special affiliate members who are familiar with the complex water supply customs are appointed to assist water supply control members to form an efficient water supply management system.

In addition, Mannou-ike Reservoir is considered a special and peaceful place that possesses a genuinely universal heritage value in historical, cultural, traditional, technical, and maintenance aspects as one of the world's preeminent agricultural reservoirs. Many tourists gather to view the water flowing forcefully from the irrigation outlets during the *Yurunuki* pulling out of reservoir plugs to release water. Over 1300 years, Mannou-ike Reservoir has continued to preserve civil engineering feats.

Water Heritage

Mannou-ike Reservoir transformed the irrigation industry with its unique approach and advanced technological achievements. With the reservoir's construction, food production increased, water and food supply became stable, and the regional economy flourished. In the year 821, Kukai reconstructed the reservoir using methods from the Tang Dynasty China. The reconstruction utilized landfill techniques such as the rammed earth method, where the earth is piled up inside a framework made of boards while being compacted into place using mallets. The design also utilized three construction methods that would have been considered state-of-the-art at the time. The first method was arched banks which took water pressure into account where banks were positioned slightly curved to the inside of the narrowest sections of the valley. This allowed for smaller external slopes even with high banks and reduced the soil fill volume. The second method was the creation of spillways by excavating base rock as an anti-flooding measure. Arched banks had the additional benefits of making narrower widths at the top of the embankment and shorter spillways length. The third method was the installation of specialized revetments made of brushwood fence at the water's edge to prevent both erosion and landslides of the internal slope of the embankment.

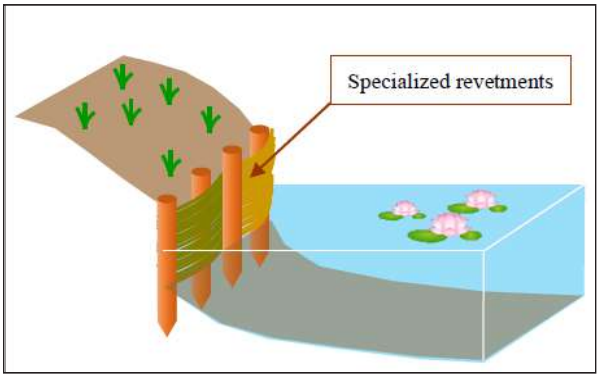
At the time of the reconstruction, Mannou-ike Reservoir is estimated to have had a bank height of 22 m, a bank length of 109.2 m, a bank width of 10.9 m and a reservoir water volume of over 5,000,000 m^3. The reconstruction required a labour force of 3,80,000 people compared to about 2,00,000 inhabitants in Kagawa Prefecture in those days. The structure's scale, reservoir water volume, and irrigation area were all on an unprecedented scale at that time.

Seto Inland Sea coast has little to no rainfall throughout the year due to its geographical conditions as being between mountainous areas to the north and south. The area has suffered from drought since ancient times. In addition to contributing to alleviating these water shortages, which often severely affected the lives of people, Mannou-ike Reservoir was constructed during a time when rulers systematically promoted the development of agriculture to improve food production, with farmers carrying out the construction of the reservoir and being supplied with fixed meal rations and wages from rulers, and can thus the structure which has also contributed to the livelihoods of farmers.

The 1631 reconstruction utilized practical techniques which have become the basis for modern reservoir preparation, including the use of a structure where vertical pipes were linked with bottom irrigation pipes inside the banks using wooden box-shaped pipes, and the installation of 5 water intakes making for a structure that allowed for intake of water from the top of the reservoir according to the water level. The depth of the reservoir at the time is estimated to have been 20 m; however, because there is a difference in the temperature of the water at the top and bottom levels of the reservoir, the cold water closer to the bottom of the reservoir bed is not well suited for paddy rice cultivation. Thus, a method was introduced for gradually collecting water that was closer to ambient temperatures from near the water's surface. Design drawings related to the repair and reconstruction of the reservoir from the year 1700 onward remain today. In addition to establishing the irrigation outlets and spillways based on highly precise plane surveying, these documents also show that the landfilling work was maintained uniformly. The remaining illustrations also show large numbers of people compacting and using mallets to tamp down the banks. Even from these earlier times, work was carried out using efficient construction methods under the instruction of a site foreman.

The Reservoir's basic structure where irrigation water is collected from the surface is still used as a model for modern reservoirs and is primarily based on the original concept, showing that Mannou-ike Reservoir has dramatically contributed to the development of reservoir technologies.

During the *Yurunuki* ceremony held in June, prayers are offered to the enshrined gods and benefactors at Kanno Shrine, located on a hill on the eastern side of the bank. Once all of the ceremonies are concluded, it is customary for all participants to light ritual fires at Kanno-Ji Temple and pray for abundant water. As large numbers of tourists gather to view the water forcefully flowing from the irrigation outlets when they are opened, the ceremony has become a valid symbol of the arrival of summer.



A variety of materials are on permanent display at the Karin Hall and Kagawa-Yosui Museum to convey the history of Mannou-ike Reservoir and the great works of our forerunners, and children study about Mannou-ike Reservoir in prefectural elementary schools as part of studies about their home region, showing a continued sense of reverence and respect for the ancestors.

The reservoir is constructed and renovated with due consideration of its environmental surroundings in terms of design and construction. It runs for a total length of over 20 km and produces a variety of waterfront spaces, making this a critical structure for preserving rich natural environments in which a variety of aquatic organisms, birds, animals, and other creatures thrive. Sanuki Mannou National Government Park has also been established in the hilly area adjacent to the reservoir and is visited by many visitors throughout the seasons who come to see various flower events.

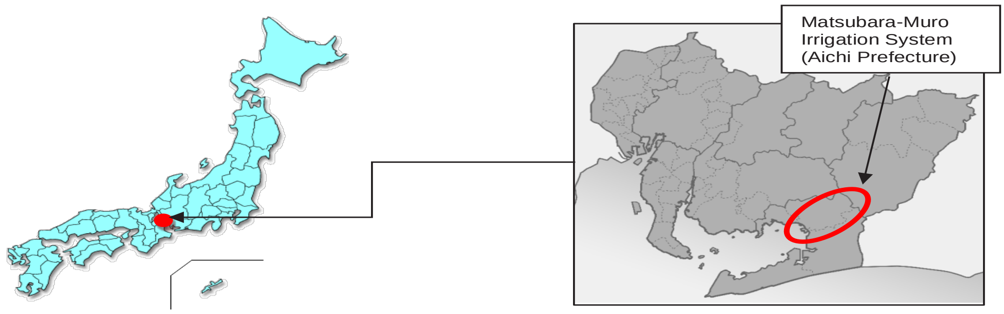
Of the facilities, the wood deck installed on the side of Mannou-ike Reservoir has become a trendy walking area where visitors can enjoy spectacular views. There are also a large number and variety of other activities centring around Mannou-ike Reservoir, including the planting of cherry blossoms in the woods and parks around the reservoir by mainly volunteer organizations, the provision of history guides to visitors to the reservoir, lakeside concerts, health marathon events, and more, demonstrating that the reservoir is both a tourism resource and cultural symbol for local society.

The Mannou-ike Reservoir's management and operations mechanisms played a vital role in its efficient service provision and continued its function for centuries. From its initial construction in 701 until the Mannou-ike Reservoir Land Improvement District in 1951, the reconstruction and maintenance of the reservoir were carried out by farmers who were provided with fixed food allowances and wages. Actual water supply and facility operations were carried out by *Mizuhainin* (water coordinators) and managers called *Ikemori* (reservoir protectors), who worked to ensure a fair water distribution to prevent disputes and maintain order and discipline.

The establishment of the Mannou-ike Reservoir Land Improvement District resulted in the entire shift of management to a collegial agency. Following the newly established Water Supply Control Committee Regulations, 16 designated water supply districts were established, with water supply control members predicting the water demand for each district and the committee making the final determinations for the overall water supply. Recently, measures have been implemented to reduce the labour required for water management and fortify disaster prevention measures, including introducing the latest equipment, which allows for remote opening and closing of intakes, remote switching of live cameras and the assignment of publicity patrol vehicles.

8.20 MATSUBARA-MURO IRRIGATION SYSTEM

Name	**Matsubara-Muro Irrigation System**
Location	**Toyohashi, Toyokawa and Shinshiro City, Aichi Prefecture , Japan**
Latitude	**Matsubara: 34.80229469 north** **Muro: 34.87383971 north**
Longitude	**Matsubara: 137.39597145 east** **Muro: 137.4746295 east**
Category of Structure	**Irrigation System**
Year of commissioning	**Matsubara: 1567, Muro: 1888**
River Basin	**ToyoGawa River Basin**
Irrigated/Drained Area	**1612 ha (Matsubara: 642 ha and Muro: 970 ha)**



Location

Muro-Matsubara Head Works
(Present)

“Ichimonji Seki” with a boat-way
(Kusakabe Head Works constructed in 1693)

The Conduit No.1 (Muro Irrigation System)

Present

Completion(1894)

Automatic Tumble gates (Muro Irrigation System)

Present

Original after Completion(1896)

History

Originally, Matsubara-Muro Irrigation System was two independent irrigation systems. The systems were merged to supply water to the beneficiary areas of about 1,600 ha through open canals and a pipeline system.

Aichi Prefecture had been suffering from drought because of a lack of water sources. Despite such a condition, with a growing population, developing new rice paddies became necessary, and water was taken from the Toyo River. So, the feudal lord installed Matsubara Irrigation Canal on the right bank. On the other hand, Muro Irrigation Canal was constructed by the private sector on the left bank. Both canals significantly contributed to forming a huge farmland zone with a stable water supply at that period.

Description

For Matsubara Irrigation Canal, headworks were constructed in 1567, but they were later destroyed by the flood and re-constructed in 1693. The reconstructed headworks were called *Ichimonji Seki* (a straight line crossing weir with a boat-way). It had a boat way in the middle of the weir to deal with the vulnerability against flooding, in addition to the original purpose of navigation. It discharged excess water and prevented the weir from being washed away as the discharging facility and flushing sediment retained the functions and contributed to the system's long life. Around 400 years ago, it was proved that this design concept was effective for flood control and water use and long life and functions.

Muro Irrigation Canal, a weir with about 320 m in length and an average width of 36 m, was completed in 1887. People suffered from repeated earthquakes, floods, and typhoons and were subjected to poverty. They finally got over such a situation by applying new technology, Automatic Tumble Gates and Artificial Stone Construction Methods.

Automatic Tumble Gates- It was a kind of weir with semi-automatic gates which opened automatically to release stored water when the water level upstream came to an off-balance point during the flood. The gates were installed at the intersection of a branch river and the Muro Irrigation Canal.

Artificial Stone Construction Method- This construction method enabled the structure's construction with strength and water-tightness. It adopted a mixture of weathered granite soil and limestone powder. By adjusting water content and compaction, the mixture got strong and water-tight enough to make the structure sturdy in the water. This method was applied to relevant structures, and some of them are still working. With the installation of this irrigation system, the development of new paddies proceeded relatively smoothly, and the number of farmers increased steadily.

Restoration: Since the Toyogawa River repeatedly changed its course due to flooding, Matsubara Irrigation System had to change its location and design of its head works. Muro Irrigation System also had repeated rehabilitation and modification work due to frequent floods. For stable water taking, two independent head works for the respective canals were integrated into one in 1968 as Muro-Matsubara Head Works, which was newly constructed with a modernized design.

With the integration of headworks, the canal system was also renovated. Matsubara Irrigation System and Muro Irrigation System currently share Muro-Matsubara Main Canal for around 5 km in the upper reach. From the middle reach to the lower reach, water is passed through Matsubara Irrigation System for approximately 10 km and Muro Irrigation System for about 18 km. Both are irrigating respective farmlands in their beneficiary areas. Upon renovation, the canal system was given another role of sending urban water. The canal system was initially constructed for irrigation, but it was renovated to provide domestic and industrial water and irrigation water. Among them, Matsubara Irrigation System was reconstructed into a pipeline system for rational water use. The reconstruction work was completed in 2004.

With proper operation and maintenance work, the beneficiary area of the Matsubara-Muro Irrigation System has become a leading agricultural area of 1600 ha. In addition, a hydropower station, using the difference in elevation of the canal, and the first of its kind in the East Mikawa region, was constructed on this canal system in 1895. The eco-friendly electricity generated by the irrigation water also contributes to the development of the local economy.

Water Heritage

The Matsubara-Muro Irrigation System was a revolutionary system for developing irrigated agriculture food production and income generation for the people. Completing the Matsubara Irrigation System in 1567 enabled the new development of 7 km^2 of quality paddies, and the canal still irrigates 6.4 km^2. A new design concept of headwork brought this outcome. On the other hand, Muro Irrigation System irrigated both existing paddies with a water shortage problem and newly developed paddies by land reclamation in the coastal areas. Its total beneficiary area was 12 km^2 as of 1907. Such success came from applying advanced technologies of the Artificial Stone Construction Method and Automatic Tumble Gates. Muro Irrigation System constantly saved farmers and paddies from droughts, and the canal water improved farmers' rice harvest. It enabled the additional development of 11 km^2 of new rice paddies, which led to the total settlement of 1,300 farmers. Matsubara-Muro Irrigation System provides a stable water supply for paddies, irrigating newly reclaimed lands and forming a vast farmland zone.

Steep and flood-prone ToyoGawa River caused head works failure located in the lower reach. Therefore, Kusakabe Head Works was constructed in 1693. *Ichimonji Seki*, a kind of weir, was built in a direction transverse to the current to make it the shortest distance from an economic standpoint. A 5.5 m wide boat way was installed in the weir to manage the flood. In addition to the original purpose of navigation, it prevented the weir from being washed away by flooding and flushed sediment to retain its functions. The headworks that have endured for 180 years show that the technology was effective as the countermeasure for flooding and sedimentation.

The construction of the Muro Irrigation System was tough due to frequent storm attacks- hitting and breaking the facilities. As a countermeasure, Artificial Stone Construction Method was introduced. This method was an Innovative technology that made the structures highly durable and water-resistant even though cement was not standard back then due to its high cost. The Automatic Tumble Gates were adopted at the Muro Irrigation System crossing and a branch river to counter flooding. The design concept of the weir was modified to open its gates automatically when the river water level became too high to solve the frequent weir failure. This was a technological breakthrough against flooding and led to a stable water supply at a low cost.

ToyoGawa River Basin sometimes had heavy rainfall, failing headworks. To solve the problem, a new design concept to have an opening in the weir was employed to construct Kusakabe Head Works. Since the opening was helpful in boat navigation, a transportation method was newly confirmed and prevented the failure of the weir by reducing the load on the weir by discharging excess water. Moreover, it also had the function to flush sediment deposited on the upstream side of the weir. The structure was an example of engineering excellence. The Automatic Tumble Gates installed at Muro Irrigation System was a kind of semi-automatic operation system which automatically opened gates during flooding preventing damage. In those days, gates were manually operated, and these automatic gates reduced workforce and rehabilitation costs. It could be said that the Automatic Tumble Gates were an outstanding technology to manage floods.

Artificial Stone Construction Method was exceptionally eco-friendly because it was developed of weathered granite soil, limestone powder, and rocks for raw materials, all of which were local produce. A hydropower station, the first of its kind in the East Mikawa region, was constructed on Muro Irrigation System in 1895. The concept of using irrigation canals for clean energy was adopted 130 years ago and is widely used today. It was remarkable to see this development a century back, a visionary structure in itself.

Conduit No. 1 of the Muro Irrigation System made with the Artificial Stone Construction Method is conserved on-site and is still used as part of the present canal system. Remains of a power station are also maintained in the lower reach of the Muro Irrigation System, as the first one to use a canal in the East Mikawa Region.

The Matsubara-Muro Irrigation System maintains a sophisticated operations and management model. The Matsubara Irrigation System has been operated and maintained by Matsubara Irrigation Canal Land Improvement District. The canal was reconstructed into the pipeline system to meet fluctuating water demand, fulfilling advanced water demand by certificated farmers. As for Muro Irrigation System, Japan Water Agency operates and maintains the section shared for irrigation and urban water, while Muro Irrigation Canal Land Improvement District is in charge of only irrigation purposes. In the multi-purpose aspect, the canal is composed of two independent waterways to separate the canal water from drainage from neighbouring watersheds so that the water quality can fulfil the standard of urban water.

The lower reaches of the canal run through the residential district and add to the scenic beauty of the region. The residents and volunteers clean up the canal in return. This mutual relationship between the canal and the residents has lasted for many years.

8.21 MEIJI-YOUSUI IRRIGATION CANAL

Name	**Meiji-Yousui Irrigation Canal**
Location	**Okazaki City, Toyota City, Aichi Prefecture , Japan**
Latitude	**35.047**
Longitude	**137.177**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**1880**
River Basin	**Yahagi River basin**
Irrigated/Drained Area	**4,744.40 ha**

History

Unlike other Japanese canals named after their locations, the Meiji irrigation canal was named after the Meiji era, representing the beginning of the modern era in 1868. Even today, this system irrigates one of the most extensive granaries in Japan.

Aichi Prefecture, located higher than the river, was a vast barren plateau called *Anjo-ga-Hara*. Conflicts among farmers often occurred over limited and insufficient water supply. One farmer named Tsuzuki initiated the canal's construction about 200 years ago to cope with such difficulties. After his sudden death, the building was taken by the local facilitators, Messrs Okamoto and Iyoda, under the government's instruction. Starting in 1879, the 52 km long canal with its four main canals was completed in March 1880. Afterwards, 160 km of secondary canals and 140 diversion structures were constructed, and the sterile plateau flourished into more than 8,000 ha of paddy fields. The canal system was completed with a budget of approximately 2.3 billion JPY (20 million USD), which was raised privately (farmers) entirely, a first-of-its-kind event in Japan at the time.

Description

Intake of the Meiji-Yousui Irrigation Canal is located at the Yahagi River, which flows in the centre of Aichi Prefecture, Japan. The beneficiary paddy field area of 4,740 ha covers eight cities, mainly on a diluvial plateau on the right bank of the Yahagi River.

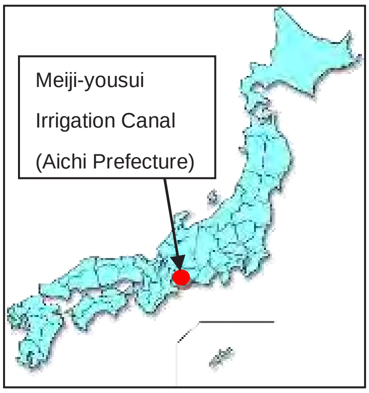
Meiji-yousui Irrigation Canal
- Philosophy of environmental conservation is still intact -

Many of irrigation canals in Japan were named after their locations, but this canal had the name of the Meiji era, which represents the opening of modern era in 1868. Even today, this system irrigates one of the biggest granaries in Japan. However, this area used to be a vast barren plateau and is located higher than the river flow. Conflicts among farmers often occurred over limited and insufficient water supply. To cope with such difficulties, one local private farmer initiated the construction of the canal system about 200 years ago, and 52km of the canals were completed in 1880 with the budget of approximately 2.3 billion yen (US$20 million), which was fully provided by the private fund, making it very unique in those days.

For the construction of diversion weir and tunnel, the manufactured stone called “Jinzou Seki (human produced stone)”, which was the advanced technology of those days, was utilized. This stone was manufactured by mixing soil with lime, gravel and water with special combination, which created an extremely strong structure of the times without using cement. The structures constructed with these stones are still in use. This material has also been used for the tunnel constructed to intercross under the irrigation canal, so that no collapse of irrigation canal could result.

Development of agriculture after construction of this irrigation system was outstanding. Paddy fields in this area before construction was approximately 2,300ha which increased to more than 8,000ha after the construction. In addition, farming with multidirectional agriculture was realized taking advantages of good drainage condition of the plateau and stable supply of water. . With completion of the system, various agriculture related institutions were established successively in this area, which have further contributed to the improvements of farming techniques and education of farmers.

Farmer’s Water Management Organization, which maintains the Meiji-yousui Irrigation Canal, has been conducting forest conservation and watershed management activities in the watershed areas of the system since the early 1900’s, because the Organization has a basic philosophy “ water users should produce their own water”. It now owns 543ha of forest in its watershed area, and this philosophy still attracts nationwide attention as an advanced environmental thinking.



Meiji-yousui Irrigation Canal

Meiji Head Works and Yahagi River

Agricultural Event with Local People

Previous Head Works made by the manufactured stone

Watershed Conservation Activities “Let’s Take-care of Our Forest”

For constructing the diversion weir and the tunnel, the uniquely manufactured stone called *Jinzou Seki* (human-produced stone) was used, quite an advanced technique for its time. This stone was manufactured by mixing soil with lime, gravel, and water in a unique combination, creating a robust structure without using cement. The structures constructed with these stones are still in use. This material has also been used to avoid collapses in the tunnel built to intercross under the irrigation canal.

After the canal system's construction, the region experienced an agricultural boom, from 2300 ha to 8000 ha of paddy fields. In addition, farming with multidirectional agriculture was realized, given the plateau's good drainage condition and stable water supply. Various agriculture-related institutions and research centres like Anjo Agricultural School, founded in 1901, and Aichi Agricultural Institute in 1920, were established successively in this area, which further contributed to improving farming techniques and farmers' education.

Restoration: Meiji-Yousui Irrigation Canal has undergone several repairs and renovations to maintain its efficiency, cater to changing demands and industrial growth and feed in incessant irrigation water in the region. Since the original headwork installed in the Yahagi River was a simple training levee consisting of wooden stakes and broken stones, water often leaked, and the headwork was repeatedly damaged. Therefore, a diversion dam was constructed to replace the original training levee in 1901. Under the prefectural project in 1932, concrete bank protection works were carried out, and old facilities were repaired drastically. After a series of rehabilitation and maintenance works, the current headworks were completed in 1958, and the related irrigation and drainage canals were also repaired simultaneously.

The region's high economic growth with new factories and houses caused the flow of industrial drainage and domestic wastewater into the canals, seriously impairing the water quality and rotting rice roots. This led to the transformation of open irrigation canals into pipeline systems in 1970. Out of approximately 300 km of canals, 80% of the lines are now changed to piped canals. Water is conveyed from the headworks to downstream by gravity, and modern water management systems such as remote monitoring and control device are installed in the Water Management Office. The modernised diversion dam is well equipped with a passage gate for ships, considering the shipping industry.

The Meiji-Yousui Irrigation Canal Land Improvement District maintained the environment by leaving a trace of the past. Grounds above the pipeline canals are utilized as bicycle tracks, walking courses, green belts, and waterfront. As one of the advanced uses of canals, a micro power plant is being constructed to utilize vertical intervals of the canals. In 2014, the National Irrigation and Drainage earthquake-resistant project began as the region is most vulnerable to a devastating earthquake.

The Meiji-Yousui Irrigation Canal has become an educational hub for irrigation, water, agriculture, food and the environment. The Environmental Study Facility of Water built by the Meiji-Yousui Irrigation Canal Land Improvement District witness many visitors annually. The educational paddy field for children named 21 paddy fields as Station of Water was opened for awareness.

Water Heritage

The Meiji-Yousui Irrigation Canal represents the beginning of a new era, an era of modernization, advanced technology, up-to-date machinery and excellent engineering skills in the irrigation industry and the whole society. From the beginning of the canal's use, the irrigated area increased manifolds. The development of agriculture after the construction of the Meiji-Yousui Irrigation Canal was remarkable. The Paddy field in this area, which was approximately 2,300 ha in 1879 before the building, increased to 4,300 ha in 1883. By reconstructing the headworks in 1900, water intake from the Yahagi River became stable, and land reclamation rapidly increased. The grid network of the branch canals achieved outstanding development. The previously barren area changed into the great grain belt that exceeded 8,000 ha in 1907. The irrigation canal enhanced the region's income, environment, and, in general, people's living standards by establishing harmony and satisfactory living conditions. The plateau's good drainage conditions promoted the joint shipment management and expansion of multidirectional agriculture to produce poultry farming, sericulture, vegetables, and fruit trees during the winter season. In addition, canal digging and the overall construction brought additional income to the farmers who became labours during the slack season on the farm, and their team spirit was heightened.

During 1910-1940, this area was called Japan Denmark, as its agricultural level was as high as Denmark, the world's most advanced agricultural country at those days. It appeared in textbooks as a Japanese model farm village and became Japan's most famous village that hosted study tours from all over the country. The construction was backed by a detailed survey, and planning considering the regional topography. A 2.3 billion Yen worth of irrigation system entirely financed by private avenues like water supply charges from the newly developed paddy fields and local capitalists was a big feat in itself. To manage natural disasters, a strong intercrossing tunnel was installed under the canal, making it sturdy and functional as a river structure. The canal system was developed using unique native techniques like using the *Jinzou Seki* (human-produced stone), which was replicated in all future irrigation dams. The canal's diversion dam built in 1901 received the authorization of a Public Works Heritage from the Japan Society of Civil Engineering in 2007. Today, the Meiji-Yousui Irrigation Canal has been well operated and maintained by the Meiji-Yousui Irrigation Canal Land Improvement District by its dues. Initially, a non-profit farmers' organization was established in 1882 as an organization of the farmers, by the farmers, for the farmers that managed the facilities cooperatively. In 2016, with more than 13,000 beneficiaries, it was proposed by the World Bank as an advocated irrigation maintenance system. This pioneer Participatory Irrigation Management model was the origin of the Land Improvement District, the most prominent part of Japan's world-famous management system today.

The organization has been conducting forest conservation and watershed management activities in the region since the early 1900s, following the philosophy *water users should produce their water*. After implementing large-scale afforestation with flood control in the forests since 1914, the owned forest area has reached up to 543 ha in its watershed. This philosophy is hailed all over Japan as advanced environmental thinking.

Furthermore, waterfront and water parks are maintained to provide relaxation spaces. Triggered by the provision of such rural facilities, collaborative maintenance and management of the Meiji-Yousui Irrigation Canals by rural communities together with farmers themselves have been accelerated.

The Meiji-Yousui Irrigation Canal marked the beginning of a new era for Japan quite literally. It is embedded in people's memories, social practices, traditions and lives. The people involved in its construction are still worshipped every year as Gods in the Meiji River Shrine established in 1884. Around 40 memorial monuments from the time of construction can be found in this area. In 2006, the Meiji-Yousui Irrigation Canal was chosen as one of the Top 100 Irrigation Canals in Japan," which includes typical irrigation canals supporting agriculture in Japan. In the west Mikawa area around Anjo City, it is widely adopted as teaching in primary schools. These annual festivals related to the canal are eternally etched in the irrigation system's achievements in the pages of history.

8.22 MINAMIIEKI-KAWAGUCHI-YUSUI IRRIGATION SYSTEM

Name	**Minamiieki-Kawaguchi-Yusui Irrigation System**
Location	**Tsu City, Mie Prefecture, Japan**
Latitude	**34.614**
Longitude	**136.316**
Category of Structure	**Irrigation System**
Year of commissioning	**1190**
River Basin	**Kumozu-Gawa River**
Irrigated/Drained Area	**360 ha**

History

Located at the southern foot of the central Aoyama plateau, Minamiieki-Kawaguchi-Yusui Irrigation System was established in 1190, the Heian Period and Minamiieki-yu and Kawaguchi-Yu irrigation systems were combined in 1792 as they continue to function even today. Built in the 12th and 17th centuries respectively, these systems were integrated for their utilization networks.

A brief outline of the construction is provided below:

- 1190: Minamiiek-Iyu Established
- 1664: Kawaguchi-Yu Established
- 1729: Unification of Minamiieki-Yu and Kawaguchi-Yu (Headworks and canal changed to current location)
- 1925: Big-scale rehabilitation of Headworks
- 1950 - 1966: Rehabilitation of the main canal
- 2000 - 2004: Reinforcement of the weir
- 2004 - 2010: Rehabilitation of the main canal and gates in the Minamiieki-Kawaguchi-Yusui irrigation system
- 2006: Certified as one of 100 fine canals in Japan called Sosui Hyakusen

Minamiiekikawaguchiyusui Irrigation System

～ Rock excavation and Water utilization system that has two histories ～

Those channels have two histories. One of the histories goes back in the 12th century and the other goes back in the 17th century. The reason why they have different histories is because former two water utilization networks combined.

This organization was accomplished in 1729. It decided detailed rules about water management because channels followed some territories of those days. Those customs of water management have been inheriting and keeping up for several hundred years up to the present.

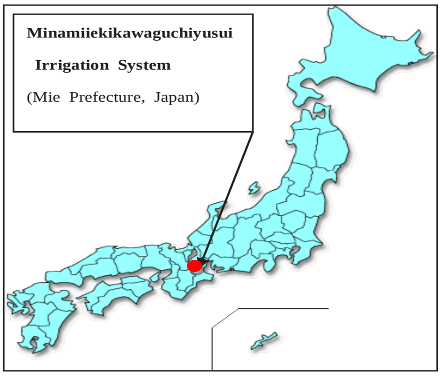
Channels were constructed with ingenuityaccording to the natural topography. They were long sections to construct by excavating rock only using chisels and hammers to reduce leakage of water. In the time of no machine, rock excavation was very difficult task. Now there has been about 1km of canal of those days. According to the record, the construction was extremely hard and it spent three years, so Yamanaka Tametsuna, construction leader, had never come home during this interval.

This water management organization has very positively managed. Main canal has gone without saying it has been still an important local irrigation. It has appropriately managed together with non-farmers from the different of view having the multifunctionality without food products, for example water for fighting fires. It delivers lectures to elementary school children on a history of main irrigation canal at regular intervals. It has been thinking it is an important duty to hand pioneer's hardships on to next generation, and being extremely active.

Canal remaining trace of rock excavation

Current canal

Hammer and chisel at that time



Position of the site in Japan

Description

With a headwork in the midstream area of the Kumozu-Gawa River, it is categorized as class A (the most crucial class of rivers in Japan's irrigation system). The current combined system is composed of the headworks, the main irrigation canal (about 7 km) and diversion works. It supplies water to agricultural paddy field areas of 360 ha and community livelihood and fire-fighting water activities.

Minamiieki-yu and Kawaguchi-yu were combined in 1729, and the headworks and the canal were changed to the present route. Channels were constructed with ingenuity according to the natural topography. Long sections were built by excavating rocks only using chisels and hammers to reduce the leakage of water. In the absence of machinery, rock excavation was a challenging task. Even today, 1 km of the original canal remains. According to records, the arduous construction work was completed in 3 years under Yamanaka Tametsuna's leadership.

Over the years, the headworks and the canal have been repaired and renovated to maintain efficiency and stay updated with the technology. The main canal structure was changed from an earthen canal to a concrete lining from 1950 to 1966 to prevent water leakage, which improved the passing water capacity. Although Minamiieki-yu's headwork opened as the weir in 1190, it was severely damaged by every passing typhoon. It was therefore rehabilitated between 2000-2004. The headworks became stronger, ensuring a steady water supply and reducing the operation and maintenance fees; however, the water intake capacity remains unchanged. The irrigation system's area has unique shape rocks approaching both the sides of Kumozu-Gawa River, a scenic area of the Ieki Line creating a beautiful valley. The system's headworks, after modifications, harmonize with the landscape of the fixed-crest weir of stone veneers and form a view. In addition, there is a policy that nature restoration should be conducted considering the ecosystem network in the targeted area, not just in the restored part. There is a lot of emphasis on preserving natural diversity, conserving the environment for ingenious living organisms and holistic environmental sustainability.

Water Heritage

The Minamiieki-Kawaguchi-Yusui irrigation system made after combing two historic structures is an essential milestone for irrigated agriculture and regional development in Japan. It provides irrigation water, enhances the paddy fields, and maintains the natural ecology of the region. The flood prevention improvements in the Setogafuchi region enhanced the region's agricultural production. A weir was constructed upstream of Kasaiwa, and then excess water was discharged through the riverside to the back of Suwa. This is called Kawaguchi-yu, where the irrigated area was 3,997 koku (1 koku = about 180 l; rice yield unit). The agreement was that the area should be spread from Todo to the Kishu clan, and the deal is still effective. After that, Minamiieki-yu and Kawaguchi-yu were combined in 1729, and up to now. Minamiieki-Kawaguchi-Yusui has multi-functions, agricultural water supply, land conservation, village formation, livelihood and fire-fighting water supply, water purification, groundwater stabilization (well water), ecosystem conservation, and aesthetic value creation.

With the construction of the system with bare hands and chisels to shove off deep rocks, the workers created history, and their efforts are still celebrated and honoured. The historic site of Kawaguchi-yu presents an example of natural land's optimum utilization with reduced water leakages. Complex tasks like excavating bedrocks shaved by chisels only, pillar holes in bedrocks, installing logs in the holes, and sidewalls of the canal were made with mixed reddish soil and lime, a unique native technique.

The Minamiieki-Kawaguchi-Yusui Irrigation System witnessed a participatory management model since its construction and until now. The first irrigation association with farmers and non-farming members was established in 1917 to manage the facilities. The association was reorganized into the Hakusan-Cho Land Improvement District (Minamiieki-Kawaguchi-Yu Section) in 2006, the current management authority. The irrigation system has been managed following a communal approach together with the irrigation association. This also reflects the joint funding model as residents finance the running costs of the facilities for its provision of agricultural water, livelihood water, and fire-fighting water.

The Minamiieki-Kawaguchi-Yusui Irrigation System is a social, historical, economic, and cultural emblem of the Mie Prefecture. It transformed people's lives, brought prosperity and created harmony among different water users. Minamiieki-Kawaguchi-Yusui was selected as one of the 100 fine canals in Japan called Sosui Hyakusen by the Ministry of Agriculture, Forestry and Fisheries (MAFF). There is a monumental stone to commemorate people's arduous construction work with bare hands and chisels.

To preserve this cultural legacy, the Chief Director, Mr Matsumori delivered lectures to elementary school children on the history of the irrigation system every year since 2006. These irrigation facilities were constructed after overcoming many challenges, and all efforts should be made to maintain them and pass them on to the next generation.

8.23 MINUMA-DAI IRRIGATION SYSTEM

Name	**Minuma-Dai Irrigation System**
Location	**Syoubu Town, Saitama Prefecture, Japan**
Latitude	**38.185 N**
Longitude	**139.471 E**
Category of Structure	**Irrigation System**
Year of commissioning	**1728**
River Basin	**Tone River basin**
Irrigated/Drained Area	**11340 ha**

History

The Minuma-Dai Irrigation System, Japan's largest irrigation project with advanced civil engineering technology, was constructed in 1728 and has been irrigating a vast amount of farmland (about 11,340 ha at present) in the Saitama plain extending to the north of Tokyo, the capital city. Its main canal has a length of about 80 km, diverting water at the middle reach of the Tone River, the largest river in Japan in terms of the catchment area.

At the beginning of the 18th century, Yoshimune Tokugawa, the 8th Shogun of the Edo government, promoted paddy field development to improve the financial condition of the feudal government. In the Saitama plain, large and small ponds called tamei were the main water source for paddy irrigation, while no supplementary water sources were available for additional paddy field development. Yasobe Tamenaga Izawa, the famous civil engineer from Kishu-Ryu (Kishu school), developed a radical plan to solve this problem.

Description

Izawa abolished the Minuma *tamei*, the biggest pond in this area that supplied water to about 5,000 ha of paddy fields. By draining the pond, 1,200 ha of new paddy fields were reclaimed. To substitute Minuma *tamei* water and improve water availability in the surrounding region, the Minuma-Dai Canal was constructed to divert Tone River's water, approximately 60 km away from the pond. The Minuma-Dai Canal Project was a national project that created a large-scale irrigation system providing a stable water supply to 15,000 ha of existing and newly reclaimed paddy fields. This irrigation system made a significant contribution to the increased food production and the government's financial restoration.

Originally it was an earth canal. *Fusekoshi* (inverted siphon), *Kakedoi* (aqueduct bridge), diversion work and water gates were carved out of wood. After numerous repairs and maintenance, it was finally remodelled into a concrete canal (except for the preserved section of the original canal) and provided an adequate water supply. The original *Motoiri* (intake gate) was integrated with other water intakes of irrigation and domestic water into Tone Barrage, completed in 1968. As a result, water intake stabilization has been achieved. As a result of irrigation water use rationalization and modernization of facilities from 1963 to 1995, part of the irrigation water was diverted to urban water. This water use diversification now contributes to the increasing water demand in the Tokyo metropolitan area.

The benefitted area has decreased from approximately 15,000 ha to 11,340 ha now. However, about 37 m^3/s of water is still taken from the Tone River and supplied to paddy fields located in the farming area from the Saitama plain to suburban Tokyo. Even 300 years after the initial construction, the System has the same system design of intake, canal routes and gravity water delivery. It delivers water to the Saitama Plain, and in 2006 it was registered as one of the 100 fine canals in Japan by the Ministry of Agriculture, Forestry, and Fisheries.

The main canal is managed by the Japan Water Agency (JWA), and other main canals and lateral canals are now managed by the Minuma-Dai Yosui Land Improvement District. It monitors 31 canals over a length of 192 km, irrigating 11,340 ha of farmlands. A 1.1 km stretch of the eastern route still retains the original earth canal structure. The prefectural government owns and manages this zone as the preserved section of the original canal, along with the bordering forest on a slope away from urbanization.

Progressive urbanization has created many issues such as illegal garbage dumping, domestic wastewater, and flooding caused by abnormal weather and torrential rain. To promote close cooperation among canal operators and local municipalities, the Land Improvement Districts set up the Minuma-Dai Yosui Cooperative Council with related municipalities as its members in 1979. There are over 20,000 members, with 90 community representatives and 25 officers guiding the initiative. Efforts are made for the proper maintenance and conservation of the canal, including its clean-up, with mutual assistance.

Water Heritage

The Minuma-Dai Irrigation System was a landmark for the region's economy, agricultural production, and water availability. The system provided a stable and abundant water supply to the approximately 15,000 ha of paddy fields. In addition, *Tsusenbori* (navigation lock) constructed 180 years before the Panama Canal contributed to the economic prosperity by providing an interregional boat transport system for transporting farm produce, including rice, to Edo (former Tokyo) and delivering daily commodities and fertilizers to rural areas from Edo. The system pointedly contributed to the rural areas' development, including reinforcing food production and vitalization of the local economy, and the government's financial restoration.

Minuma-Dai Irrigation System was based not only on the innovative vision and construction technology but also on the innovative planning of its facility arrangement. The location of *Motoiri* (intake gate) at the Tone River was selected in consideration of the direction and force of water flow, and so on. When the Tone Barrage was constructed in 1968 with modern civil engineering, its selected location was where the original Motoiri was built, showing quality engineering standards. When the Minuma-Dai Canal route was planned, it was designed to partly utilize the existing river as the canal to shorten the work period to a large extent and utilize the inflow water of the current river as an additional water source.

The successful completion of the national project of the Minuma-Dai Irrigation System was attributed to the innovative plan and the civil engineering techniques used- the accurate levelling method by using *Mizumoriki*, the design and construction technology of *Motoiri* (intake gate), *Fusekoshi* (inverted siphon) and *Kakedoi* (aqueduct bridge). It was one of the largest wooden structures of the day in Japan. *Tsusenbori* (navigation canal with wooden lock) was also constructed before the completion of the Panama Canal. As a result, Japan's most extensive irrigation system was developed with an irrigation area of approximately 15,000 ha. The intake and river-crossing on the way were some of the most significant wooden structures in Japan with an outstanding level of technical skills. The intake gate of the *Minuma Motoiri* (3.6 m wide and 1.5 m high) had a box culvert structure with wooden framed packs of stones placed to prevent sediment influx and scours. The box culvert structure provided improved safety features of suppressing buoyancy under their weight on the upper side. When the canal needed to cross the Moto-Ara River, the inverted syphon of the Shibayama Fusekoshi (47 m long) was constructed. On top of the Fusekoshi, an earthen bridge was made to prevent the siphon from surfacing. Such an inverted siphon structure is still adopted now.

The characteristics of *Kishu-Ryu* were the separation of irrigation and drainage canals and the fixing of the river and canal route with the strong embankment and revetment. A drastic change of engineering method from *Kanto-Ryu*, which fully utilized the natural topography, to *Kishu-Ryu* contributed to the stable water supply, drainage improvement in farmland, and flood damage reduction. The combination of those separate water supply/drainage and fixed channel route methods is today's pioneering technology in water utilization and flood control. For accurate level surveying, *Mizumoriki* was used. Its accuracy was proven with a margin of error of just 6 cm for the total length of some 80 km, which was almost equal to the present measurement accuracy levels.

The excavation work was conducted with minimum alteration of the natural environment, maximizing the use of the existing river in the area for the canal. The canal constructed along the contour line with the woods on the slope constituted a beautiful landscape of the rural area. Even in the face of urbanization, part of such a peaceful landscape is still preserved. Furthermore, drainage water after regular irrigation is returned to the downstream rivers; thus, an extensive water recycling system is organized. More recently, a relaxing waterfront was made for residents and holidaymakers with 57 km long walking trails and over 40 km of the canal lined with cherry blossoms by the local municipalities and voluntary groups. Thus, the irrigation system is performing multiple water supply and recreation functions in the suburbs of Metropolitan Tokyo.

By employing all of the latest techniques and mobilizing a large number of local people by adopting a unique work allocation and payment method (village contracting), this enormous construction project was completed within a brief period of 6 months, from September 1727 to March 1728. The project covered 115 diversion works and water gates, 130 bridges, 84.5 km long channelling, and the total excavated soil accumulated to 1,440,000 m^3. The total number of workers reached 900,000. To proceed with the big project within such a short period, the government promoted villagers' participation, and then adopted a *Murauke* (village contracting) system of a labour work payment method. Work sections were divided by the village, and all tasks were performed virtually altogether. Additionally, for the wooden facilities made of combined wooden sluice pipes and gate materials, carpenters processed them based on the drawings and carried them to the construction sites for installation.

At key construction spots and the Minuma-Dai Irrigation System, small shrines were installed with Benzaiten (Japanese Goddess of water) statues to pray for safe construction work. Such a Benzaiten statue in a shrine was placed on the three spots along the canal. Even nowadays, a festive event is held, praying for a stable water supply and a rich harvest every year. *Tsusenbori* was recognized as a designated national historic site in 1982 as the oldest wooden lock canal in Japan for its historical and cultural value. At the end of August every year, lock opening and closing demonstrations are carried out with restored facilities. The Minuma-Dai Irrigation System and its engineering achievements are taught through textbooks in schools and local municipalities in Saitama Prefecture to carry forward the legacy. The Minuma-Dai Yosui Land Improvement District erected a bronze statue of Izawa, the originator of the canal in 2005, in Minuma Nature Park to honour him for this feat and showcase the importance of the irrigation system as a local resource.

8.24 MURAYAMA ROKKAMURA-SEGI IRRIGATION CANAL

Name	**Murayama Rokkamura-Segi Irrigation Canal**
Location	**Hokuto City, Yamanashi Prefecture, Japan**
Latitude	**35.597**
Longitude	**138.424**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**Nearly 1000 years ago**
River Basin	**Sio-kawa basin Fuji-kawa River system**
Irrigated/Drained Area	**550 ha**

History

Built nearly 1000 years ago, the Murayama Rokkamura-Segi irrigation canal is located at the southern foot of Yatsugatake Mountain and provides water for irrigation and domestic use. This steep area is located at 600- 1,000 m elevation with no large rivers. The average yearly temperature is 11 degrees Celsius, and the annual rainfall is 1,150 mm. The primary water sources are springs and Doryu waterfall at a 1,200 m of elevation. The area faces severe water shortages with unfavourable agricultural conditions.

Description

The canal was built in this steep sloping land to slow down the flow velocity of the waterway and divert water for irrigation and domestic uses. With its diversion gate, an aqueduct bridge, the canal was built with a holistic technical understanding of the topography and supported current efficient water use. It was a problematic construction due to the steep slopes and hard rock base. One of the construction directors committed suicide while working on the project. Now, the canal supplies water to 550 ha of farmland and many villages as a necessary irrigation facility.

Despite the severe agricultural conditions in the area, the farming community prospered, and their living standards improved along with solid water management protocols. The incomes were improved by highly valued highland vegetables, which could not be possible with the irrigation water provided by the canal. Besides agricultural production, water is also provided for domestic uses and disaster management.

Irrigation rules among 30 communities were established in the 1700s about maintenance, repair, water conflict, water fee, governance, and annual events. In addition, agricultural planning and the amount of harvest of rice, wheat, soybeans and other millet are pre-decided in the arrangement. It is noteworthy that water quantity and water fee based on the plan are scientifically determined.

Murayama Rokkamura-segi Canal

~Excellent water supply system has improved the poor land～

This area is located at 600 to 1,000 meter elevation, steep sloping land, and there is a paucity of rivers. In addition, the average yearly temperature is 11 degrees C and annual amount of rainfall is 1,150mm.As just described, Agricultural requirement of this area was very demanding.

It is described as the canal was first built in a thousand years ago in this steep sloping land. In order to efficiently use of irrigation water, there was a need for facilities to slow down the flow rate of the waterway, diversion gate, an aqueduct bridge and so on. This canal has such a technical consideration for its steep sloping land and it has supported current efficient water use.

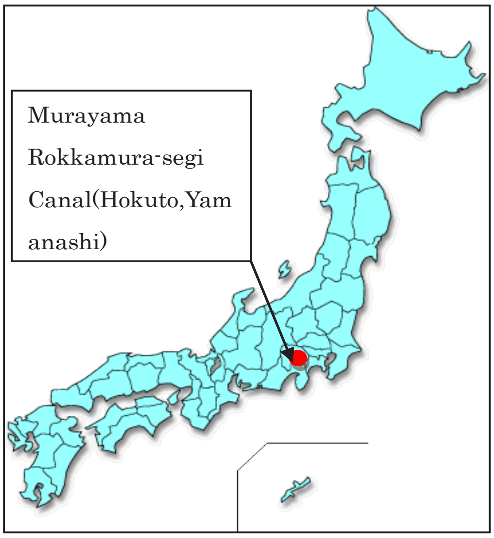
Also, it was described that a matter of arrangement between 30 settlements which covers things related to maintenance and repair, cost of water concession and administrator was made in the 1700s. In addition, agricultural planning and amount of crop of rice, wheat, soybeans and other millet are described in the arrangement, and it is noteworthy that water quantity and cost of water concession based on these plan are finely defined.

Although agricultural requirement of this area was very demanding, the farming community was well developed and its living was improved with their solid management. As well as Murayama Rokkamura-segi canal continues to improve the level of the facility with maintenance and repair, they have placed a small hydroelectric generation system to reduce running cost.

The stairs waterway

The aqueduct bridge

The natural type waterway



Position Figer

Currently, Murayama Rokkamura-Segi Irrigation Canal Land Improvement District continues to improve the canal with maintenance and repair, renovated 3.3km in the last five years, and installed a small hydroelectric generation system to reduce running costs in 2007. Furthermore, they launched an NPO organization with residents for passing down the value and beautiful scenery around the canal to the next generation. They have conducted many events such as walking events for primary school children or experience-based activities of traditional matters. In February 2006, the canal was included in Japan's best 100 selected canals due to its agriculture promotion, collaboration, cultural value, and ecosystem, including the aquatic creature.

Given the canal's geographical location, maintenance and operation have become problematic. Despite leased prefecture-own land for management around the canal area, most of the sediment flows into the canal from the mountainside, creating an enormous burden for maintenance. More recently, the cost of repair and system maintenance is also increasing year by year.

Water Heritage

Murayama Rokkamura-Segi irrigation canal was the region's turning point, which experienced agricultural production, increased incomes, and an unprecedented boost to the local economy after the Murayama Rokkamura-Segi irrigation canal's construction.

Historically, residential areas developed near the spring water, with hunting and collecting as the primary activity. With the canal, farming settlements were established. *Samurai* groups resided in the main street with many posting stations around the area, as seen today. In recent years, the canal has contributed to the region's socioeconomic development by supplying water to rice and highland vegetable farms. After constructing the canal, at least 30 villages were formed in the 1700s. In the 1900s, the average sales amount per farming household reached more than 10 million YEN.

The structure was advanced in terms of construction techniques, topographic understanding and the size of the command. The construction in the steep slope area was a substantial achievement of its time. Tokushima-Segi, Asao-Hosaka-Segi and Tate-Segi, the three significant weirs of Yamanashi Prefecture, were built in the 1600s. In contrast, Murayama Rokkamura-Segi was constructed approximately 1,000 years ago.

Although the age is unclear, headworks, tunnels, diversion gates and aqueducts were built in the mountains. Considering the time and the rugged terrain, the techniques used for surveying and construction were exemplary and were the starting point for Japanese engineering methods. For efficient water use, decreasing the flow velocity was essential. So, the canal was precisely designed to conform to contour with the unlined tunnel, diversion gate, aqueduct bridge and so on.

Murayama Rokkamura-Segi irrigation canal irrigated 350 ha in 1890, which was a record of its own. The installation of tunnel lining and diversion gate increased the water flow capacity to meet the development of agriculture and village settlements.

8.25 NAGANOSEKI IRRIGATION CANAL

Name	**Naganoseki Irrigation Canal**
Location	**Takasaki City, Gunma Prefecture, Japan**
Latitude	**36.357**
Longitude	**138.947**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**Before 1645**
River Basin	**Tone-Gawa River System (Sub Basin: Karasu-Gawa River)**
Irrigated/Drained Area	**430 ha**

History

Built about 100 years ago, Naganoseki Irrigation Canal is depicted in a hand-drawn map of Gunma prefecture from 1645 (National Diet Library Collection), confirming its existence nearly 400 years ago at the latest. Two inverted siphons were built in 1814, passing more than 2 m below the bed of the Haruna Shirakawa River, as evident in another hand-drawn map from around 1830. The canal system not only increased agricultural production but also contributed to public hygiene and improved people's living standards by supplying city water, particularly to public bathhouses in the city centre and the castle's moat, to improve the landscape.

Despite the modernization and rehabilitation works for increasing the water supply, water disputes persisted in the downstream area until the cylindrical proportional distributor was completed in 1962.

Description

The Naganoseki Irrigation Canal passes through the middle of Takasaki City from west to east. The headworks draw irrigation water from the KarasuGawa River with a

Naganoseki Irrigation Canal
- A long history of water supply to Takasaki's agricultural land and castle town -

It has long been told that construction of the Naganoseki Irrigation Canal began about 1000 years ago. The canal is drawn clearly in a hand-drawn map of Gunma Prefecture dating back to 1645, confirming its existence nearly 400 years ago at the latest.

Two inverted siphons were built in 1814, passing more than 2 meters below the bed of the Haruna Shirakawa River as evidenced in another hand-drawn map from around 1830.
This proves that the people of the time possessed a high knowledge standard and advanced engineering technique. The technical standard of the work involved in constructing the sinphon was very advanced and large scale at the time.Withdrawing additional water from Haruna lake through a tunnel of 283 m and going through the modernization, the sytem irrigated over 1,700 hectares of paddy fields in 1904, and also supplied drinking water for people living in the town through 120 public water taps in 1887. Commemorating the construction of the system, stone monument was erected in 1901, which inscribes a thanking message for the hard work of predecessors, saying "Thanks to the water supplied by the Naganoseki Irrigation Canal, a harvest of 7500 tons of rice is possible, and more than one hundred thousand people live on its water."

The canal system was very important not only for increasing agricultural production, but also for contributing to public hygiene and improved living standards of people in the area by supplying city water, particularly to public bathhouses in the city center and to the moat of the castle for improving the landscape.

In spite of the modernization and rehabilitation works for increasing water supply, water disputes persisted in the downstream areauntil the cylindrical proportional distributor was completed in 1962.

Although paddy fields area has been on the decrease owing to urbanization in recent years, the canal system now fulfils the function of regional drainage by collecting urban drainage water in the canal. The staffs of the Land Improvement District work hard to manage the canal system not only for irrigation but also for drainage purposes all year round. As such residents of Takasaki City join together to keep the canal and surrounding area clean, demonstrating the appreciation for the the Naganoseki Irrigation Canal.

maximum water intake capacity is 6.8 m^3/s. The main irrigation canal is 8.6 km from the headworks to the cylindrical proportional distributor and distributes water to 15 beneficiary areas by branch irrigation canals. Moreover, the cylindrical proportional distributor divides the water into four downstream regions in proportion to their extent.

Withdrawing additional water from Haruna Lake through a tunnel of 283 m and going through modernization, the canal irrigated over 1700 ha of paddy fields in 1904. It also supplied drinking water for people living in the town through 120 public water taps in 1887. Though paddy fields in beneficiary areas are decreasing due to urbanization, it irrigates about 430 ha these days. It also fulfils the function of regional drainage.

Following a cooperative management model, the Naganoseki Irrigation Canal was managed by a water users' association called Naganoseki Suiri-Dokou-kai before 1890. In 1890 the Naganoseki Futsu-Suiri-Kumiai (General Irrigation Association) was formed under the General Irrigation Association Act to manage the canal until the Land Improvement Act was enacted in 1949. After passing that Act, the association was restructured to its current version of the Naganoseki Land Improvement District.

While the structure changed from unlined canal to concrete lining in 1979, stop-logs to the gate or automatic weirs replaced diversion weirs, and the management became more accessible in recent years. However, with urbanization and increasing settlements, a more concerted approach was required to manage rains, typhoons, and floods. Takasaki City residents also work together to keep the canal and surrounding area clean, demonstrating appreciation for the Naganoseki Irrigation Canal. People participate in cleanliness drives. Elementary school students in Takasaki City are taught the history of the canal and its contribution to agricultural products and improved living standards of people in the area. In 2006, the Naganoseki Irrigation Canal was listed as one of Japan's Top 100 Irrigation Canals.

Water Heritage

Naganoseki Irrigation Canal was a significant development for agricultural production in the region; it boosted the local

Old Gunma Prefecture map from 1645
(National Diet Library Collection)

Location of the site


Head works at Karasugawa River


Cylindrical proportional distributor

Hand-drawn map of diversion weirs from around 1830
(Takasaki City Historical Document Division Collection)
This map clearly shows that the NAGANOSEKI irrigation canal passes under HarunaShirakawa River by way of the Shirakawa inverted siphon.


NAGANOSEKI around 1934
With the stone monument commemorating the construction


Canal system at present

economy and increased incomes. Given the plateau terrain, irrigation from rivers was complex earlier. Still, the Canal allowed for the first time the irrigation of fields, thus contributing significantly to the development of local agriculture. The Canal irrigated 1700 ha of paddy fields while more and more paddy fields were planted. Its' importance as a local water source is evident from its depiction in the hand-drawn map of Gunma Prefecture from 1645.

Public waterworks were developed, and the Canal began providing drinking water through 120 public water taps in 1887. From around 1600, water from the Araiseki Canal which branches off from the Naganoseki Irrigation Canal was used to fill the moat surrounding Takasaki Castle and bring water to the centre of town. Many public bathhouses were built in an area near the town's inns due to the Araiseki Canal. In this way, the living environment and sanitary conditions improved. Furthermore, water from the Araiseki Canal still flows into the moat where Takasaki Castle once stood. Seasonal trees and flowers create a beautiful environment that citizens love today. In 1901, commemorating the construction of the system, a stone monument was erected next to the canal, which inscribes a message, "*Thanks to the water supplied by the Naganoseki Irrigation Canal, 7,500 tons of rice can be harvested, and more than one hundred thousand people live on its water*". This monument confirms that the canal was essential for developing agriculture and the improvement of the living standards of people in the area.

The Naganoseki Irrigation Canal takes its water from the first-class KarasuGawa River. It is necessary to pass under the smaller Haruna Shirakawa River to do so. The Gunma-gun Shi (a historical report of Gunma County) records that in 1814, a cross culvert was constructed 2.1 m under the bed of the Shirakawa River (present-day Haruna Shirakawa River). Siphoning and other advanced agricultural engineering techniques were being used to supply water 200 years ago at the latest. With the river's width at the time, the length of the culvert passing under the riverbed is estimated at around 50 m. Together with temporary diverting canal construction, the construction scale is guessed substantially large.

Furthermore, in 1887 excavation of a tunnel began that drew water from Lake Haruna 22 km upstream into the KarasuGawa River. In 1904, the 285-m-long tunnel (H1.8m x W1.4m) down the mountain was completed as a supplementary water source for the KarasuGawa River. Even after completing the tunnel from Lake Haruna, there were repeated water disputes in the downstream areas every time a water shortage occurred. The local farmers took turns watching each diversion weir to avoid stolen water by others. These disputes over water distribution dating back several hundred years were not solved until 1962 with the installation of the cylindrical proportional distributor that allowed for water distribution in proportion to the extent of downstream areas. These complex techniques and engineering designs testify to Japanese traditional wisdom and showcase that the canal was ahead of its time.

According to documents, the Naganoseki Irrigation Canal construction dates back to 1645 at the latest. Other records show that the construction may be in the mid-900s. Paddy fields remain found along the canal under the volcanic ash layer (Mt. Asama eruption in 1108). As evidenced by several hand-drawn maps from 1645, the canal was one of the largest projects of its time. It has progressed from being unlined to cobblestoned, and today the canal is concrete-lined, but in some sections, cobblestones from prior eras are still visible outside. The scale of the canal has hardly changed from its original state. Hence, the canal has been passed over many generations and has provided irrigation water from time immemorial.

8.26 NASU IRRIGATION SYSTEM

Name	**Nasu Irrigation System**
Location	**Nasushiobara City, Tochigi Prefecture , Japan**
Latitude	**37.038**
Longitude	**139.987**
Category of Structure	**Irrigation System**
Year of commissioning	**1885**
River Basin	**Nakagawa Basin**
Irrigated/Drained Area	**2600 ha**

History

Constructed in 1885 at the Tochigi Prefecture, the Nasu Irrigation System transformed a 40,000 ha area of barren land into a flourishing town with 1,71,000 people and a healthy 2600 ha of paddy fields. It was a national project conducted by 150 Japanese engineers under the direct control of the central government.

Description

Located between the NakaGawa River to the north and the HokiGawa River to the south, Nasunogahara is a vast alluvial fan with another two rivers, the KumaGawa River and the SabiGawa River running underground through the central area; the fan geologically consists of accumulated sand and gravel layers and loam layers of volcanic ash. In the past, it was a wilderness with no surface water and deep groundwater and suffered from drinking water shortage, let alone irrigation water. The government constructed an irrigation system with a main canal and diversion canals to enrich this barren area.

The construction of the main canal (with a total length of about 16 km) was completed in a short span of 5 months. In 1886, 4 diversion canals (with a total length of about 59 km) were also opened in the following year. The construction project involved tunnel excavation on fragile ground and siphon installation to cross rivers, both of which required highly advanced techniques at that time. Masonry structures with a pentagonal cross-section were adopted in the entire section to secure the tunnel's strength cross-sections. Similar pentagonal structures were also adopted for siphons, where resin and cement were used as reinforcing material. An innovative longitudinal diversion method was invented to overcome disputes over insufficient water, enabling equitable diversion of precious water.

Post-system construction, paddies were gradually developed, but the area did not increase as expected due to a geological problem, where water infiltrated the ground. Initially, the canal withdrew water from the Naka Gawa River at a maximum of 5.5 m^3/s and irrigated paddies in a 40-ha area. About 30 years later, Nasu Irrigation System

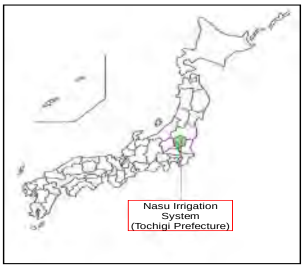
- Canal network greatly contributing to the development of Nasunogahara -

This area is an alluvial fan with an area of approx. 40,000 ha that was once covered by wilderness. It used to be barren land, where life was difficult to sustain. This was because surface and ground water was unavailable and even drinking water could not be secured owing to its geology consisting of highly permeable sand and gravel layers and loam of volcanic ash. In order to transform this land into paddies and fields and promote agriculture, the government started to construct the main canal and diversion canals in 1885 at the request of the region. This construction was a national project conducted by 150 Japanese engineers under the direct control of the government.
The construction project involved tunnel boring on fragile ground and intersection with rivers through siphons, both of which required highly advanced techniques at that time. To secure the strength of cross-sectional surfaces, the tunnel adopted masonry structures with a pentagonal cross-section in the entire section. The siphons also adopted similar pentagonal structures, and resin and cement were used as a reinforcing material. Furthermore, as disputes over insufficient water occurred, a then-innovative longitudinal diversion method was invented. Thanks to this method, a diversion system that could allocate precious water equally was established, and water disputes were reduced.

Through renovation works to extend the canals and expand the cross-sectional area, the irrigation area, which was initially 40 ha, has now increased to 2,600 ha. The farmer-based organizations are conducting proper maintenance and management focusing on effective water use, reasonable water allocation, facility conservation, and so on. This irrigation system has greatly influenced the promotion of farming that utilizes well-drained soil conditions. By developing an area with a population of about 171,000 into a major agricultural producer, where not only paddy rice but also local specialties such as pears and strawberries can be produced with diversified farming, the irrigation system has made a great contribution to the growth of the local economy, in areas such as food production and in the farming community.

Moreover, the former intake facilities, which were designated as national Important Cultural Properties in 2006, are highly important facilities with great historical value.


Main canal of the Nasu Irrigation System



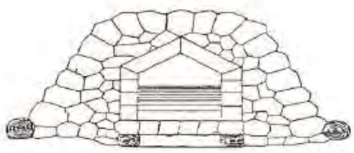
Location map of Japan


Rice planting


Longitudinal diversion method


Former Iwasaki Tunnel


Structure of a siphon


Cross-sectional diagram of a siphon


Former Nishiiwasaki Intake

the irrigation area was 255 ha in 1913. In the 1920s, it increased to nearly 500 ha. Therefore, after 80 years of its construction and suggestions from the Nasu Irrigation System Land Improvement District and the National Nasunohara Development, the reconstruction began in 1967, which the government subsidized. In this project, the main canal and diversion canals were renovated, and Nishiiwasaki Headworks was constructed as an intake of the Nasu Irrigation System in 1976. These facilities are still in operation today.

Since then, the canal has withdrawn irrigation water from the Naka Gawa River at a maximum quantity of 8.6 m^3/sec. The main canal is divided into eight sluices to deliver water to many more diversion canals. Now, it supplies water to fields with an area of 2,600 ha and provides water for domestic purposes, fire protection, flood prevention and other public amenities.

Nasu Irrigation System is included in the three major irrigation canals in Japan. In February 2006, the Nasunogahara Canal centring on Nasu Irrigation System was recognized as one of the Top 100 Irrigation Canals in Japan by the Ministry of Agriculture, Forestry and Fisheries. Moreover, in July of the same year, the former intake facilities of the Nasu Irrigation System that played a central role in the Nasunogahara Canal were listed under the National Important Cultural Properties by the Ministry of Education, Culture, Sports, Science and Technology. They are the first to be recognized as the Heritage of Modernization in Tochigi Prefecture.

Water Heritage

Nasu Irrigation System was a turning point for Tochigi Prefecture, Nasushiobara city, for the development of agriculture and increase in food production. The system was constructed with due consideration to the geological features of the region. Besides poor water supply, the area didn't have a transport root making life difficult for the people and pushing them into poverty. After the irrigation system, with abundant water supply, water reached every corner of the city with its diversion canals developed and renovated as and when required. Nasu Irrigation System's canal network transformed the vast wilderness into paddies and fields and enabled domestic water supply. The system serves as the driving force for developing the regional economy in areas such as agriculture and has a ripple effect on the entire economy. Now, Nasushiobara City and Ohtawara City are the largest agricultural producers in Tochigi Prefecture and continue to develop as the two leading cities in the northern area of the prefecture.

In the 1880s, withdrawing water from the Nakagawa River was an absolute necessity for irrigating reclaimed land and securing the domestic water supply to Nasunogahara. Although the irrigation area was still small, the completion of the Nasu Irrigation System enabled a secure supply of domestic water. Each household was equipped with a washing place, and waterwheels were built in various places and used for timber processing and milling. The irrigation system dramatically improved people's lives. The canal network renovated by the national project has been used to irrigate paddies and fields for local specialities such as pears and strawberries, forming the basis of the agricultural production infrastructure for the metropolitan area. It also contributes to dairy farming, which is the city's pride in producing an enormous amount of raw milk on Japan's main island.

The construction of the main canal was led by Japan's 150 best civil engineers of the time who worked on designing, surveying and constructing the canal. With a total length of about 16 km, the canal has two tunnels and two siphons. Masonry was adopted for 484 m of the two tunnels (about 60% of their total length) and 313 m of the siphons. Some masonry works were conducted in sections totalling 3,346 m, which accounted for about 25% of the entire construction site. In particular, advanced techniques were employed in masonry works for tunnels and siphons.

The former intake facilities of the Nasu Irrigation System are a valuable civil engineering heritage that was among the most extensive works at the time of their completion around 1885. The first intake was constructed by boring a tunnel on a cliff of the Nakagawa River. As this intake did not have an opening and closing function to regulate water and prevent sediment inflow, it was repeatedly damaged by floods. Therefore, in 1905, the second intake was constructed about 200 m upstream of the original one. The first intake was later modified with masonry as a backup sluice. Later, the river's flow changed, and the intake was relocated to its original place in 1915 (third intake). In 1928, the water regulator was installed, and the masonry arch was added on the top. This masonry sluice is still functional today.

There were two tunnels with a total length of about 1.1 km; one was Iwasaki Tunnel leading to the intake in Nishiisasaki, and the other was Kameyama Tunnel between Nishiisasaki and Kameyama. For better ventilation and smooth progress, the 922 m Kameyama Tunnel construction was conducted separately in three sections divided by two adits. Iwasaki Tunnel was bored from the exit. As the rock was easy to collapse due to its fragile volcanic features, the entire tunnel was constructed with ashlars to have a pentagonal cross-section (160 cm wide and 165 cm high)). The masonry walls on both sides were reinforced by cementing.

For intersections with the KumaGawa River and the SabiGawa River running in the middle of the alluvial fan, 46 m and 267 m siphons were respectively used to connect the canal. The siphons were masonry structures with a pentagonal cross-section (136 cm wide and 167 cm high)). The siphons had considerably deep structures with the inlet 5 m deep and the outlet 7 m deep to connect the canal below the rivers that run underground without surface water. This masonry works required highly advanced techniques. The irrigation system is an excellent piece of engineering, capitalizing on the topography and using locally available materials, which showcases Japan's advanced skills even in pre-modern times.

The Nasu Irrigation System has witnessed robust operations and management mechanisms since its inception. The participatory approach followed in its management is still visible today. Today, the Nasunogahara Land Improvement District Association is responsible for the direction of the irrigation facilities on consignment or transfer from the national government. In 1905, the Nasu Water Association moved the system's intake to about 200 m upstream according to the changed riverbed. In 1915, the Nasu Irrigation System Common Irrigation Association relocated the intake collapsed by floods caused by a rainstorm to its original location. Again in 1940, the intake collapsed because of a heavy rainstorm. Ultimately, in 1953, the Nasu Irrigation System Land Improvement District conducted erosion control work to prevent sand and gravel from flowing into the intake. Since the Nasu Irrigation System was renovated by the national project, economic and optimal facility management plans, have been formulated, and management systems for proper water control have been studied to promote essential functions for area-wide water control, such as effective water use, reasonable water allocation, facility conservation, disaster prevention, and management cost reduction.

The association established a management committee for long-term and comprehensive operation and management for each main canal and branch canal. These committees conduct daily regimes with the local farmers. As a unique and equitable cost-sharing model, the association operates a reserve fund system for the maintenance and management of medium and long-term projects. Additionally, the Association conducts regular inspections and patrolling to conserve, protect and maintain the entire irrigation facility. The Canal Protection Days are fixed every year when residents, the associations, and other members work together for grass mowing and cleaning activities. To spread awareness about renewable energy, activities for disaster prevention, environmental sustainability, and city-wide conservation are organized.

Considering their historical value, the former intake facilities of the Nasu Irrigation System have been preserved as historical structures. In 2002, Nasu Irrigation System Park was developed around the facilities with the cooperation of the Tochigi Prefectural Government and Nasushiobara Municipal Government.

8.27 ODAI IRRIGATION CANAL

Name	**Odai Irrigation Canal**
Location	**Kinokawa City , Wakayama Prefecture , Japan**
Latitude	**34.283**
Longitude	**135.448**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**1710**
River Basin	**Kinokawa River basin**
Irrigated/Drained Area	**567 ha**

History

The Odai Irrigation Canal takes the water from the Kinokawa River that runs through the northern area of Wakayama Prefecture and irrigates the farmland of 567 ha on a river terrace along the right bank of the Kinokawa River. Due to its topographical feature as an undulating river terrace, water could not be withdrawn directly from the Kinokawa River. Therefore, farmers in the area used to suffer from water shortages and consequent conflicts over water. Thus, in 1707, the government constructed the main channel (32.5 km) in parallel with the river under the supervision of the engineer, Ohata Saizo. The channel was built along contour lines with a low gradient to deliver water to distant areas. Nine siphons and eight aqueduct bridges were also built on the canal. By supplying water to new rice fields of approximately 1,000 ha, the canal significantly contributed to agriculture and the local economy.

Description

In the early 18th century, canals were made of stone and earth, and aqueduct bridges were wood. During heavy rainfall, they were damaged and repaired repeatedly. Therefore, in the 1910s, *Toi* (aqueduct bridges) and *Fusekoshi* (inverted syphon) were reconstructed with brick and stone pitching to reinforce the structures. In 1710, the canal that took the water at Odai Sluice on the upper stream of the Kinokawa River and stretched 32.5 km was completed. In the 1950s, renovation works were implemented as a postwar recovery project to increase food production. These included the renovated Oda Headworks with concrete sluices and spillway gates, a substantial water supply for a stable supply, and other maintenance facilities.

The canal's completion enabled the development of rice fields over an area of 1,000 ha and contributed to the local agricultural development. Since then, the canal has continuously supplied agricultural water for 300 years while being repaired repeatedly.

Today, the Odai Irrigation Canal is a concrete-built water canal (29 km) that runs almost the same route as the original one taking the water from Oda Headworks. Now, the canal irrigates the farmland of approximately 570 ha on the right bank of the Kinokawa River and supports various forms of agriculture, such as the cultivation of fruits, vegetables and rice. Since its establishment, the canal has been familiar to local people as a structure that irrigates the land and serves as an oasis for the area.

Currently, Odai Land Improvement District is in charge of the operation and maintenance of the canal. Water is taken from Oda Headworks at a speed of 7 m^3/s and supplied for a 567 ha area on a river terrace along the right bank of the Kinokawa River. The residents maintain the area around the irrigation canal and branch water canals.

Over the years, increased population, industrialization, migration, encroachments and urbanization have affected the canal's surroundings. Some contemporary challenges are decreasing farming population and farmland, deterioration of existing agricultural facilities, domestic and industrial wastewater inflow into canals, declining water quality and rainwater drainage. Tackling these would require a coordinated effort from all the stakeholders with a common management goal.

Some of Odai Land Improvement District's ongoing initiatives are awareness building regarding management status and the system's multifunctional role among residents, periodic water canal tours for elementary and junior high school students to develop sensitivity and other environmental preservation activities around the water canals with the active participation of the residents. In the elementary school curriculum, the great accomplishment of Ohata Saizo is introduced with a supplementary social studies textbook in Wakayama Prefecture. In August 2016, Ohata Saizo Network Wakayama was established by local volunteers. They are engaged in various activities (preserving the facilities, and disseminating the system's historical knowledge) with cooperation from the Land Improvement District.

Water Heritage

The vast river terrace on the right bank of the Kinokawa River often suffered from droughts due to the area's high altitude and the limited scope of available small reservoirs for water supply. The Canal enabled the development of 1,000-ha farmland and contributed to the development of local agriculture. The canal still serves as a critical infrastructure to support agriculture in the region.

A total of over 100,000 farmers joined the construction of the Odai Irrigation Canal. The canal's completion enabled the development of rice fields over 1,000 along with the income generated from the construction work. In appreciation of the canal, people celebrate Ohata Saizo

Kensho-sai Festival to honour the great accomplishment of Ohata Saizo, the engineer.

The Odai Irrigation Canal conducts water from the Kinokawa River to the vast area of the river terrace. Therefore, it needed to be equipped with an intake upstream, and the canal with a total length of 32.5 km required to be developed with a low gradient. Based on the accurate surveys and field study design, the construction was completed in 4 years only. During this project, a unique construction method was invented based on detailed field surveys, accurate techniques, and project planning by precise designing, and calculation to streamline construction costs. This revolutionary method, called *Kishu-Ryu*, became the basis for rice field development in Japan. This method influenced the future advancement of rice field development techniques. In this method, a survey instrument called *Mizumoridai* was invented to enable accurate levelling. This instrument was used to determine the route of the channel along contour lines and realize a gentle flow of the channel with a gradient of 1/3000 to 1/5000. This method was also employed in the construction of wooden aqueduct bridges and syphons intersecting the rivers. Moreover, in the survey-based project planning the survey results, the construction site was optimally divided into sections, and minimum materials and workforce were allocated to each section to streamline the work. As a result, the construction period was shortened, and construction costs were reduced.

In particular, a 30 m long wooden bridge called Tatsuno Toi employed the most advanced techniques of the times, such as a flood-proof structure without a post in the centre, which was enabled by utilizing the bedrock on both banks. Wooden aqueduct bridges and syphons were repaired every time they were damaged. In the 1910s, these facilities were modernized by reinforcements with brick and stone pitching, representing the technical transition of the times. These brick aqueduct bridges and syphons, which are still available today, have been adequately maintained and managed by the farmers' organization to date.

At that time, terrace irrigation at a high altitude depended on creek water from the mountains and small reservoirs. The idea of the Odai Irrigation Canal was revolutionary as it planned to take the water directly from the Kinokawa River and conduct it to the vast area. As the Kinokawa River system has many tributaries, the following measures were taken to solve this issue:9 syphons with wooden canals were built under the bottom of the tributaries for the water to intersect the tributaries, eight aqueduct bridges were built to convey the water with a wooden bridge, the tributaries' water was dammed for a level intersection to supply canal water and *Tatsuno Toi*, an aqueduct bridge was built on the river with a width of 30 m The same bedrock is still used as the foundation of the present aqueduct bridge constructed with brick and stone pitching, which shows the accuracy of the field surveys at that time.

In addition, techniques to enhance the maintenance function of the canal were introduced, such as forming sand layers under the bottom of the canal and behind its wall on the mountainside to drain percolating water from the mountain, as well as making some fragile portions on the banking walls of the canal by design to minimize collapse caused by flooding in heavy rains. Moreover, the canal was designed with a low gradient so that it could store water for droughts.

The system contributed to the evolution of contemporary engineering practices like the *Mizumoridai* surveying method. This method was innovative at that time and was later adopted widely for water use and flood control. *Kishu-Ryu* construction, invented during the system's construction, contributed to rice fields in Japan. It involves straightening meandering rivers, building solid embankments to prevent floods, developing new rice fields from retarding basins, and building dedicated water canals to irrigate from the upper river basin. The irrigation system was revolutionary by all means, right from the radical idea to the construction methods, the surveying techniques, and the implementation strategy.

The canal was planned and is still maintained with its with due consideration to the environmental aspects. The undulating terrace forms the beautiful rural landscape on the right bank of the Kinokawa River. The Odai Irrigation Canal was built in parallel with complex contour lines, harmonizing with the local landscape. The irrigation canal stretching 32.5 km creates a rich waterfront environment that provides habitats for various water creatures. The reconstructed aqueduct bridge *Tatsuno Toi* adds to the natural landscape.

The Odai Irrigation Canal is a cultural relic and an important part of people's lives. It bears the stamp of a past civilization and the present irrigation facilities of the region. In recognition of its role to form beautiful landscapes and serve as an oasis for the area, the Odai Irrigation Canal was selected as one of the Top 100 Irrigation Canals in Japan by the Ministry of Agriculture, Forestry and Fisheries in February 2006. In the 1910s, three aqueduct bridges (*Tatsuno Toi, Koniwatani River Toi* and *Kozumi River Toi*) and Nakatani River Sluice were reconstructed into modern structures using brick and stone. Valued for contributing to the formation of historical landscapes in the region, these facilities were registered as national cultural properties in March 2006. The Canal is not only an essential agricultural infrastructure but also the pride of residents. Efforts are made to pass on this historical legacy and the wisdom from this system to future generations.

8.28 OGAWAZEKI IRRIGATION CANAL

Name	**Ogawazeki irrigation canal**
Location	**Kanra Town, Gunma Prefecture, Japan**
Latitude	**36.233**
Longitude	**138.919**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**Unknown (estimated about 400 years ago)**
River Basin	**Ogawa River, Class A river**
Irrigated/Drained Area	**104 ha**

History

The Ogawazeki irrigation canal is a significant heritage structure in the Kanra region, located in the southwestern part of Gunma, 100 km away from the Tokyo metropolitan area. It is estimated that the main canal of this masonry irrigation structure was constructed over 400 years ago, followed by a branch canal system. Still, the exact year of construction is not known. It has been used for different purposes by residents, such as household use, emergency use and irrigation in downriver paddy fields.

Gunma, Obata area, Kanra Town is a small castle town with many former samurai residences from the Edo Period. In the central area of the town, the Ogawazeki irrigation canal runs below a row of cherry blossom trees offering a scenic view. In 1615 (Genwa Gannen), Ieyasu Toku-Gawa provided Nobukatsu Oda, the second son of Nobunaga Oda, with large rice fields. According to a record, Nobukatsu and his family governed Yamatonokuni for 26 years until their relocation to Obata in 1642 (Kansei 19); the Clan had been based in Fukushima. The Clan residence was planned according to the allotment of land, irrigation canals and water supply. Obata was chosen as a relocation site because it had a cliff approximately 20 m high on the west of the Ogawa River, which was expected to serve as a fortress and secure sufficient irrigation water from the Ogawazeki irrigation canal. Thus, Obata became the heartland of the Clan. The current land allotment of the Obata area was decided around the time of the relocation of Jinya. Since the 152-year-old history of the Oda Obata Clan, the irrigation canal's management has been passed over many clan generations.

Branch canals were constructed by Nobukatsu Oda, the second son of Nobunaga Oda when Nobukatsu inherited the family estate, including Yamatonokuni Matsuyama (Nara Prefecture) with 30,000 *kokus* (a unit of crop yield) and Joshu Obata with 20,000 *kokus* for the recognition of his distinguished service in summer siege of Osaka. He established Jinya (a Clan administrative building) as the head of the Oda family in 1615 (Genwa Gannen). Two families of Oda and Matsudaira, a successor to Oda, established the position of Goyo Mizubugyo (water

OGAWAZEKI IRRIGATION CANAL
Multiple functions of agricultural water contribute significantly to improving the livelihood and developing the industry in the region

The Ogawazeki Irrigation Canal was constructed about 400 years ago. It has contributed to the development of agriculture as well as improving the living standard of the people in the region, by using water not only for irrigation but also domestic water and emergency purpose. Construction of an irrigation channel running through a community enabled to use irrigation water for domestic water in the community, leading to the establishment of washing places, and 47 of which are still in use today.

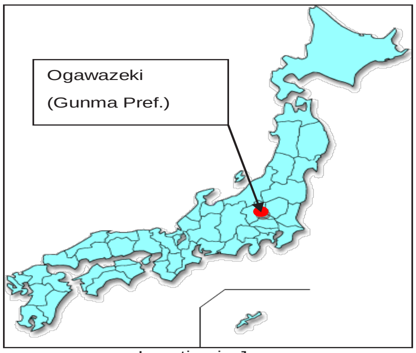
In addition, a water wheel was installed in this irrigation channel, which had been used as a power source for the facilities of the silk industry in the early part of the 20th century. These silk industry related facilities have just been designated as a World Heritage site. Accordingly, this irrigation channel system is an excellent example of multi-purpose uses, and contributes to the region in many ways.

On the other hand, water quality in the channel had deteriorated due to the use of synthetic detergents in the 1960s, the period of rapid economic growth in Japan, making multiple uses of irrigation water difficult. Residents of the region then rose up against contamination with the resolution to "restore the clean water channel of olden times". Since then water quality has been improved due to their cleaning activities of the channel, and knowledge dissemination about water pollution. In 1985, the Ogawazeki Irrigation Canal was designated as one of the best 100 water in Japan.

Although the system was constructed 400 years ago, it had the highest technical standard of that time, including a masonry channel preventing leakage of water, and elaborate stone structures. The system is highly recognized, registered in several heritage systems in Japan, and contributes significantly to improving the livelihood of the people in the region.

Mansonry canal

A washer using water in past Ogawazeki



Location in Japan

administration officer), who spread awareness about the importance of water among the public and managed the Ogawazeki irrigation canal facilities. This centuries-old administrative system became the premise for the existing operations and management model of the canal system today.

The historic Ogawazeki irrigation canal has been the foundation of the region's development. By capitalizing on the geology, the canal added to the natural landscape, historical sites and cultural properties in Kanra town and beautified it further.

Description

The water to the Ogawazeki irrigation canal is diverted through a 7 m high barrage on the Ogawa River running from Mt. Inafukumi and located below Ohgi Bridge 3 km away to the south from Obata, an area in Kanra Town. The water intake called a large gate regulates the amount of water flowing into the canal according to rainfall. The total length of the Ogawazeki irrigation canal is approximately 20 km. Both the main and branch canal is covered with lining material. Space from 2.5 m to 3 m wide and 1.5 m to 2 m deep was dug under the ground, and a mixture of clay and lime (lining material) was applied on the inside with a width of 1 m to be firmly hardened to build just a 50-cm barrage. Then, rocks were piled up on the surface to prevent the barrage from being washed away by the stream.

The Ogawazeki irrigation canal is also called the main canal. A stream runs down to the north on the east side of the former samurai (warrior) residential area. It is split into 2 to divert Yokomachi and meet again in front of Otemon. Then, it passes through the former commercial area to paddy fields in the downriver. Ogawazeki irrigation canal offers agricultural water for 104 ha of paddy fields in the northern area of Kanra and contributes to stable rice production.

Several unique techniques were developed in its construction based on native wisdom and traditional hydraulic and technical knowledge. Some of them are described below.

The main canal has three intakes, including, from the upriver, Ichiban-Guchi (No.1), Niban-Guchi (No.2) and Sanban-Guchi (No.3), which divert water to branch canals in the samurai residential area. The intakes have the same size as a 1-sho cup (1 sho = 1.8 l), a 5-go cup (1 go = 180 ml), and a 3-go cup individually to distribute water to each residence evenly. The branch canals are installed in a grid pattern taking water from three intakes from the main canal, which are a contrivance of predecessors and called, from the upriver, Ichiban-Guchi, Niban-Guchi and Sanban-Guchi. The branch canals have ensured a stable water supply and supplied household water used in Jinya.

There is a *Fukiage* stone gutter approximately 650 m away from the intake that takes water from it. It is 7.7 m long and 1.2 m wide and made of greenschist stone material. The base was made of two stones which were processed sophisticatedly without gaps left between them. The gutter consists of seven stones, including two on the bottom, two on the right wall and three on the left wall, in addition to four stones that hold sidewalls. Instead of the wooden gutter constructed in years, the stone gutter was built in seven months from August 1865 to March 1866 by 250 workers under Tadahiro Matsudaira, the last Lord of the Obata Clan.

Rakuzanen was built by Oda and named after a saying of the Analects of Confucius "*The wise find pleasure in water; the virtuous find pleasure in hills.*" It is a circuit-style garden from the early Edo Period and has the same characteristics as Katsura Imperial Palace in Kyoto. It is the only large-scale famous garden left in Gunma and had undergone a 10-year restoration work until March 2012.

The masonry construction method allowed the masonry canal to supply sufficient water to the downriver area without leakage. The main canal running through the commercial area is 1.2 m to 1.7 m wide and 1.1 m to 1.7 m deep (the height of the masonry barrage). It was built by piling up 5-8 greenschist stones the size of a human head in a Yabanezumi style and, in most parts, a stone 30 cm long, and 50 cm wide was placed on the top of each pile. In some parts, greenschist stones 20 cm long and 30 cm wide, or 20 cm long and 40 cm wide, were piled up in a *Yabanezumi* style. The main canal had 47 washing places, including eight on the right side of the barrage and three on the left side in Yokomachi, and 18 on both the right and left sides of the commercial area individually. Barrage supplied critical domestic water waterworks systems that were installed after World War II. Water was used at each household for washing vegetables and farming tools, and bathing.

Over the years, the canal system has undergone some renovations such as replacing the masonry structure with a concrete embankment, expansion of a road and reinforcement by working concrete grout into joints, which has maintained its appearance since the old days. The efforts of residents have also maintained water quality.

Obata area, located in the upper reaches of the river, takes water from the canal for household use while the downstream areas of Fukushima and Niiya draw water for irrigation. In 1957, Obata private water supply system was completed. Since then, the Ogawazeki irrigation canal has been used as a drainage canal, not just as a household water canal, resulting in water pollution. Since the late 1960s, the increased use of synthetic detergent has aggravated pollution levels. The Ogawazeki irrigation canal was heavily contaminated, which was later cleaned up in the 1970s and 1980s through various interventions such as the installation of trash screens. After considerable efforts from the community and the public sewage system's improvement by the local administration, the irrigation canal has been restored to its original status of a clean canal.

Water Heritage

The Ogawazeki irrigation canal was a milestone irrigation infrastructure that transformed the region and accelerated economic growth. It has been functional for more than 400 years and continues to render services in irrigation, domestic use, and emergency works, and adds to the aesthetic value of the region. Built following traditional construction designs and renovations over the years, it reflects Japanese civilization. A brief historical overview is presented below, along with a timeline of developments.

The construction method allowed the masonry canal to supply sufficient water to the downriver area without leakage. It is worth noting that such high civil engineering techniques were used when no construction machinery was available. The Ogawazeki irrigation canal represents the wisdom predecessors and the durability of the ancient structures, which are still functional today.

The Ogawazeki irrigation canal played an essential role in enhancing the economy not just through agricultural production but also by promoting other livelihood avenues, leading industrialization in the region, and improving people's living standards for years to come.

The canal system was the driving force in milling rice, barley, and wheat by waterwheels and silk reeling factories from the Meiji Period until around 1945. In particular, the Obata Silk Reeling Company, founded in 1878 and the Ogami Silk Reeling Company in 1878, was based near the Ogawazeki irrigation canal for the hydraulic power drawn from the canal. The two companies merged into Kanra Obata Gumi in May 1898. A large-scale reeling factory taking advantage of hydraulic power from the Ogawazeki irrigation canal established a base of regional development. It contributed to the silk industry in Gunma, which is registered as World Heritage today. In the agricultural field, Kanra thrived with silk cultivation. The canal was used to wash silk-raising tools such as silkworm baskets made of bamboo. Even today, the Ogawazeki irrigation canal offers agricultural water for 104 ha of paddy fields in the northern area of Kanra and contributes to stable rice production. Overall, the Ogawazeki irrigation canal not only contributed to the town's industrial development, but it has also played a multi-functional role from irrigation to silk production to domestic uses and other activities.

Managed over generations by the clan, the canal system always had strategic operations and maintenance models in place. With changing times and increased involvement of the water user, it is now managed by the government in association with farmers and residents who take care of its maintenance and scenic beauty. OGawazeki irrigation association consists of farmers who use irrigation water for their paddy fields in the downriver area. They discontinue the supply every year at the end of April to clean the canal system and remove sand and earth accumulated on the intakes. Sweeping river sand and waste accumulated on the barrage in the past year ensured the water passage function of the entire canal, allowing for a smooth stream of water to the downriver area. The residents with clean-up activities have also maintained water quality. The local government body performs the operation and maintenance of the canal facilities. Facilities renovation is implemented every year with cooperation from national and prefectural governments. OGawazekin Irrigation Canal taking off from the Ogawa River in Japan is recognized for the active participation of farmers. The Town has pledged to make continued efforts to maintain and restore the functions of the canal system and hand it down to future generations.

The canal system has been a witness to centuries of social, political and cultural change. A renovation monument of Ogawazeki irrigation canal water intake (built in 1943) bears the inscription saying "It was told Ogawazeki irrigation canal was constructed by the ancients" and therefore confirmed the canal's existence since ancient times. It is an old Ogawazeki irrigation canal passed over many generations since pre-clan times. No historical remains or material specify the objectives of the system at the time of construction.

Ogawazeki irrigation canal is a precious historical facility with critical cultural properties of Kanra Town. It is selected as one of the best 100 water quality canals in Japan (by the Ministry of Environment), one of the best 100 water spots in Japan (by the National Land Agency), one of the best 100 canals in Japan (by the Ministry of Agriculture, Forestry and Fisheries) and a Civil Engineering Heritage of Japan Society of Civil Engineers. The historical transition of the canal layout can be tracked by comparing past drawings such as the picture map of Obata Jinya (the year of creation unknown)", the Hitofudekagiri (traversable) map (1876), and the current passage route.

8.29 SAYAMAIKE RESERVOIR

Name	**Sayamaike Reservoir**
Location	**Osakasayama City, Osaka, Japan**
Latitude	**34.500**
Longitude	**135.533**
Category of Structure	**Water Storage Structure**
Year of commissioning	**616 A.D.**
River Basin	**Yamato River**
Irrigated/Drained Area	**331 ha in Osaka**

History

Sayamaike Reservoir on Nishiyoke River, serving the large-scale irrigation area of Osaka Plains, is the oldest artificial agricultural reservoir in Japan dating back to 1,400 years and continues to be in use to this day. The irrigation system has been used for a very long time and has been rehabilitated and modernized repeatedly since its operation. Many of the technologies adopted for the reservoir construction were brought from the Korean Peninsula, from China, especially in the renovation work carried out about 800 years ago. During the repairs carried out 800 years ago, the size of the reservoir was not changed except for the banks, which were raised to approximately 10.2 m. However, the gutters beneath the banks, formerly made of wood, were now made of stone to stabilize the water supply. The irrigated area now is double that of 1,400 years ago, increasing downstream crop production.

The current size of the Sayamaike Reservoir was attained during the repairs carried out about 400 years ago when the water supply was increased to approximately 2.50 MCM. Provisions were also made to supply water to the 80 downstream villages. The water supply system, management and organization established during these repairs are still in use today. Within the past 100 years, repairs were carried out using concrete and heavy machinery to create a more stable water supply. During the recent repairs, disaster prevention functions and measures were taken to ensure that the reservoir could be used in urban conditions.

With the rapid economic growth after World War II, large landslides flowed into the Sayamaike Reservoir due to the development of dormitory towns in the upstream areas of Osaka, now a metropolis. The surrounding areas have continued to be developed after the dam was constructed, and the Sayamaike Reservoir is now used as a recreational area for the citizens. The reservoir is cleaned every month by a civic organization, and festivals are also held in the area.

SAYAMAIKE RESERVOIR

Japan's oldest reservoir constructed 1,400 years ago, and its irrigation system

The Sayamaike Reservoir was constructed about 1,400 years ago by the order of the Emperor of the time, who said, "There is a shortage of water in Sayama area, which is likely to pose an obstacle to farming. Dig more ponds to promote agricultural development". This event is recorded in the oldest history book in Japan. The Sayamaike Reservoir, which is the oldest artificial reservoir in Japan, and whose irrigation system have been used for a very long time, has been rehabilitated and modernized repeatedly since its operation. It is still in use as an agricultural water system. Many of the technologies adopted for the reservoir construction were brought from the Korean Peninsula, and technologies brought from China were also used in the renovation work carried out about 800 years ago. As such, the reservoir is a valuable heritage constituting evidence of technology exchange and transmission in East Asia region in that period.

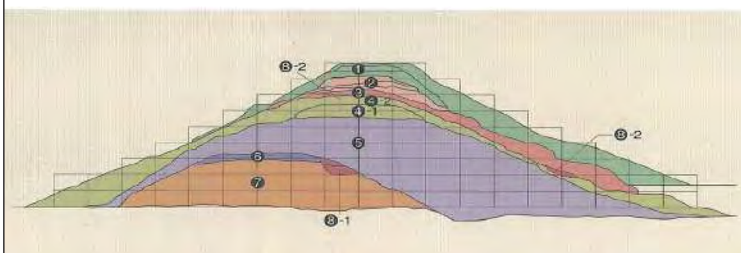
The history of the Sayamaike Reservoir irrigation system, dating as far back as 1,400 years, mirrors that of the development and renovation of irrigation systems in Japan. When a large-scale renovation was carried out recently, traces of past renovation works, including 57 pieces of wooden sluices, were found in the dam body. In the Sayamaike Historical Museum located on the edge of the reservoir, people can learn how the reservoir and its irrigation system have changed through many renovations over the period of 1,400 years. In particular, the museum exhibits a cross-sectional surface of the dam body which shows the history of renovation, as well as articles which have been unearthed, so people can see the historical transition of renovation and technological development.

In the 1600s, in order to ensure functional distribution of water to its beneficiary area from the Sayamaike Reservoir, the management of the reservoir, irrigation canals, and other small reservoirs located along those canals were systemized. Its management records for 400 years since then have been preserved. At present, the land improvement district is responsible for managing and maintaining this system.

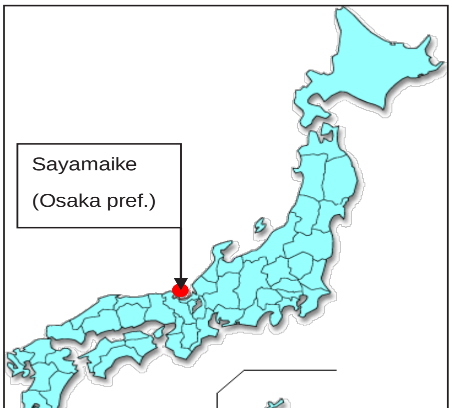
Further, the 57 pieces of wooden sluices excavated from the dam body is going to be designated as a nationally important cultural property, thus there is no doubt the system is recognized as an extremely important cultural heritage.

Sayamaike reservoir from the sky

Trace of repeated renovation (found wooden sluices) (Upper: Edo period (after 1600s) Under: Nara period (nearly 8th Century))



History of renovations and upgrades during 1,400 years



Location in Japan

Description

The Sayamaike Reservoir is an artificial reservoir using the natural geographical features of the valleys and their rivers. The dam was built to stop the flow and store water. The name is written in the *Kojiki* (Records of Ancient Matters) and the *Nihon Shoki* (Chronicles of Japan), two of the most ancient books on the history of Japan, which record that the pond was built under the emperor's orders. As the area lacked irrigation water, many ponds and ditches were constructed to improve the situation. Some of the characteristics are below:

- Ponding Area: 36 ha
- Pondage: 2.8 MCM
- Circumference: 2,850 m
- Length of Northern Bank: 997 m
- Area of Basin: 44.39 km^2 (reference point)

The Osaka Plains, the reservoir's location, is a large-scale irrigation area. When the reservoir was constructed, artificial twig mattresses (*Shikisoda*) were used to reinforce the banks. This technology used widely in the East Asian region, was introduced to Japan through the Korean Peninsula. The 60 m-long gutters, which drained the water from the pond, were made by hollowing out Japanese umbrella pines, and the gutter connections were designed to prevent the water from leaking.

Records on repairs made 600 years later(in the year 1200) describe how the latest technologies of the day were used, including shaping stones to form stone gutters. A stone monument, discovered during an excavation of the reservoir, states that these repairs were done by people living in the 50 or so villages around the Sayamaike Reservoir. It also says that the construction was carried out by many people—the young and old, men and women—pulling stones. Stone materials used for the gutters of the reservoir have been discovered. They carried a tumulus sarcophagus buried in a grave of an ancient leader and reprocessed the stone to drain the water. Stone materials, reused during the repairs made in the 1600s, were discovered recently in the reservoir.

Another major large-scale repair of the Sayamaike Reservoir was made when Japan became a modern state. Shakuhachi gutters, large water supply structures, were laid in two areas. Systems to prevent floods and bank collapse were also built. The name of the valleys, including the Sayamaike Reservoir, now known as the Nishiyoke River, was given during this period. After the 1600s during the Edo Period, the Sayamaike Reservoir management system was organized to supply water efficiently, consisting of reservoir managers, daily managers of the reservoir, and village leaders living in the surrounding irrigation area. Management records of the past 400 years have been preserved.

Large-scale improvements and repairs were carried out under the government budget to modernize the system from the beginning of the 1900s. The banks were raised, and dredging and concrete spillways (flood prevention) were added. During the repairs after the devastating drought of 1921, reinforced concrete was used to draw water from the river for the first time.

The 1,400-year repairs to the Sayamaike Reservoir continue today. After the 2001 repairs, the area surrounding the reservoir has been developed by planting over 1,000 cherry trees, and public festivals are also held in this area. The area was selected as one of the best 100 reservoirs in Japan and has become a valuable recreation spot.

During the recent repairs and cultural property excavation at the Sayamaike Reservoir, 57 items were discovered and are now showing at the Osaka Prefectural Sayamaike Museum. The first Japanese umbrella pine gutters, the stone gutters used during the repairs 1,200 years ago, the monument, the wooden gutters used during the repairs 400 years ago, and other items were designated as valuable cultural properties in July 2014.

Significant repairs from 1988 to 2001 were conducted to prevent water damage in downstream areas. Even with urbanization, the loss of farmland, and changing functions, the Sayamaike Reservoir is still maintained and managed as a valuable source of water for agriculture to be handed down to future generations.

Water from the reservoir is used for 331 ha of agriculture. Amid the urbanization, land improvement district activities continue to maintain rice fields in the southern part of Hirano in Osaka.

Water Heritage

The oldest artificial agricultural reservoir in Japan, Sayamaike Reservoir, represents a milestone in irrigation infrastructure and agricultural development for Japan and the entire world. While the reservoir has elements of different civilizations, its sustainability is a testimony to the engineering marvel it truly is. It was found that the first gutters were carved in 616, matching the estimated period using dendrochronology. As it was built around this time, it is concluded that the reservoir has been in use for 1,400 years. It was improved to increase production, and its functions have been maintained through several repairs. The twig-mattresses (Shikisoda) method used when it was built is known to have been introduced in East Asia. It is an important heritage that proves the technological exchanges made with East Asia during those days. In addition, for the repairs made 800 years ago, the technologies for processing stones and constructing large structures were introduced in China. As written in the articles on the construction of the Nihon Shoki (Chronicles of Japan), the reservoir was built to promote agriculture.

When a large-scale renovation was carried out recently, traces of past renovation works, including 57 pieces of wooden sluices, were found in the dam body. In the Sayamaike Historical Museum located on the reservoir's edge, people can learn how the reservoir and its irrigation system have changed through many renovations over 1,400 years. In particular, the museum exhibits a cross-sectional surface of the dam body, which shows the history of renovation and articles that have been unearthed, showing the historical transition of renovation and technological development. Further, the 57 pieces of wooden sluices excavated from the dam body are designated as a nationally significant cultural property; thus, there is no doubt the system is recognized as a critical cultural heritage.

In the 1600s, to ensure functional distribution of water to its beneficiary area from the Sayamaike Reservoir, the management of the reservoir, irrigation canals, and other small reservoirs located along those canals were systemized. Its management records for 400 years since then have been preserved. At present, the land improvement district is responsible for managing and maintaining this system. The rotational irrigation water delivery system that began in the 1600s is still used today. The downstream leader (*Mizushimo-Soudai*) was the leader of the villages and later became the manager of the Sayamaike Reservoir. After 400 years, this leader still maintains and manages the Sayamaike Reservoir Land Improvement District today.

Improvements and repairs of gutters and banks at the Sayamaike Reservoir have continued since it was first constructed. On the cross-section of the banks, traces show that the banks were raised, which increased the volume of the water supply. When the reservoir was built about 1,400 years ago, the height of the banks was approximately 5.4 m, the bottom width was 27 m, and the length is estimated to have been 300 m. The maximum water supply was about 800,000 m^3. Downstream excavations have shown that villages developed one after the other within a 3 km range from north to south and a 2 km range from east to west. During the repairs carried out about 1,250 years ago, the height of the banks was raised to approximately 9.5 m, the bottom width to 54 m, and the length to 54 m, giving an estimated water supply of 1.70 MCM. During the repairs carried out 800 years ago, the size of the reservoir was not changed except for the banks, which were raised to approximately 10.2 m. It is considered that the current size of the Sayamaike Reservoir was attained during the repairs carried out about 400 years ago when the water supply was increased to approximately 2.50 MCM.

8.30 SHICHIKAYOUSUI IRRIGATION SYSTEM

Name	**Shichikayousui Irrigation System**
Location	**Hakusan City, Ishikawa Prefecture, Japan**
Latitude	**36.433**
Longitude	**136.617**
Category of Structure	**Irrigation System**
Year of commissioning	**1903**
River Basin	**Tedori River Basin**
Irrigated/Drained Area	**4806 ha**

History

The Shichikayousui Irrigation System derives water from the Tedori River, which arises on Mt. Hakusan, traditionally considered sacred. The system delivers water for irrigation of rice paddies in a large area spanning four municipalities (primarily the city of Hakusan, Ishikawa Prefecture, the cities of Kanazawa and Nonichi and the town of Kawakita). Shichikayousui means seven canals and refers to the Togashi, Goh, Nakamura, Yamashima, Taikeiji, Nakashima, and Shin-Sunagawa canals that feed on the main and tributaries of the Tedori River, known since ancient times as a raging river.

Each of the Shichikayousui Irrigation System canals draws water from 5 barrages built at suitable places by placing gabions and skeletal groins in the river Tedori which arises in Mt. Hakusan, traditionally considered a sacred mountain that was also flood-prone.

The project's planning and execution were based on Dutch civil engineer Johannis de Rijke's observations and recommendations of the Tedori River. One of the recommendations was to consolidate the scattered water intake structures into a single structure built on sturdy ground (in an area with steep riverbanks) that would divert the water into waterways in tunnels. Another recommendation was to conduct the diverted water through a single main canal from which it would flow into each of the irrigation canals in turn, from upstream to downstream. A third was to construct a main canal along the Tedori River so that excess water or tainted water could be ejected back into the river.

Description

Over approximately five years from 1899 to 1903, a cumulative total of around 100,000 people worked on this massive project, erecting large sluice gates at Akudogafuchi on the main Tedori River and digging three tunnels through cliffs, and building barrages and sluice gates connecting the 7.8 km main canal of the Shichikayousui Irrigation System to each of the irrigation canals.

Consolidation works were executed wherein the feed-water inlets for the seven canals were united to take countermeasures against flooding, secure a stable supply of water for the System, and make it easier and more convenient to draw water from the river and improve the efficiency of water distribution operations. Large sluice gates and water inlets were designed to be strong, sturdy and stable. The large sluice gates were built on a cliff face with high stone pillars and brickwork. The feed-water inlets, a series of three arches, are the exits of three semi-circular arched water tunnels dug through the rock and lined with brick. The inlets feature cornerstones, pillars, and horizontal capstones made of stone, whereas the rest is made of brick. The large sluice gates positioned right in front of the tunnel needed to be the sturdiest of structures, making them a brick and stone exterior and a concrete-filled interior.

Drawing water from the river became more accessible, the water levels in the irrigation canals were stabilized, and water diversion and irrigation rotation procedures were simplified. Conflicts over water were resolved, and the

SHICHIKA-YOUSUI IRRIGATION SYSTEM

One of the Greatest Projects of Unifying Diversion Weirs for a Stable and Efficient Supply of Water

Irrigation developments have been conducted over 1,400 years in this region. The prototype of the present irrigation system was first constructed in 1869 by the initiative of a village leader who devoted all his wealth for the project. Since then, the area had been irrigated by seven diversion weirs made of gabion and robust materials in the Tedori River, which often flooded and gave damages to surrounding areas. Around 1900, the recommendation for improving the situation was made by a Dutch engineer, who was hired as part of the modernization policy of Japan in those days. Proactively adopting his advice and recommendations, a weir unification project, including floodgate, aqueduct tunnel, and water intake structure was completed in 1903, in which seven diversion weirs were unified into one diversion weir. This reduced the difficulty of water intake, stabilized the water supply, and allowed efficient use of water (procedures for diversion and rotational irrigation system were simplified). As a result, water shortage and dispute over water were resolved, and the area of approximately 6,500 hectares became fertile farmland, leading to successful agriculture and rural development.

To construct this irrigation system, more than 100,000 laborers were deployed and unique technical features of the project for rational and efficient water uses were as follows: (1) unification of scattered diversion weirs at one intake site, with solid foundation and diverted to the aqueduct tunnel; (2) water reuse was promoted for water saving; and (3) building of a main canal along the River Tedori to spill waste water or bad water (not suitable for irrigation) into the River Tedori.

With the weir unification, The Shichika-Yousui Irrigation Management Federation was created above the seven irrigation associations that had been independently organized for managing each irrigation system, leading to rationalized water management and efficient use of water. This Federation has continued until today, and controls and manages the irrigation system. Over the years, the system has been rehabilitated and modernized, including the modernization of the intake weir (1949), the construction of the Dainichigawa Dam (1968) and the repair of the waterway network (1982). Recently, improvement of the water channels has been carried out for better manifestation of multiple functions such as environment conservation, disaster prevention and local water supply.

Students of elementary schools and junior high schools in the neighborhood, members of local resident organization, and people inside and outside the prefecture visit these improved facilities, which now have become a place to study the history of agricultural water development. In addition, the system is also used for small hydroelectric power generation, and now regarded as an important system for energy aspects.

project was later known as the Great Meiji Improvement (about the Meiji period 1868-1912).

When the Shichikayousui Irrigation System was built, it had an overall water distribution capacity of 66.8 m^3/s. The series of three tunnels could draw water at a rate of 54.4 m^3/s, and the rest was made up by the intake from a supplementary sluice gate, feeding four feed-water inlets altogether.

In 1934, due to major flooding of the Tedori River, the riverbed fell, making it difficult to divert water from the river through the large sluice gates. A weir was erected, which was intended for a hydropower generation project being planned around the same time. After a hydropower generation canal was used, two tunnels were connected, and it became an easy task to supply irrigation canals with 30 m^3/s. Afterwards, a large-scale agricultural water utilization improvement project was implemented to bring the volume of water intake up to 76 m^3/s, discharge capacity up from 19 - 31 m^3/s, improving the ability to secure water, including supplementary water feed from in front of the large sluice gates and intake from the supplementary sluice gate. The weir was heightened by 50 cm, and new canals exclusively for irrigation were created separately from the hydropower generation canal in 1949. The Tedori River dam was completed in 1981, and the flow of the river was tamed. Today rotational irrigation (each canal receiving or not receiving water, in turn on determined days during times of insufficient water) has ceased to be conducted. However, irrigation is still carried out using the same system of irrigation structures.

Today, while the land area under agricultural cultivation has shrunk, the structures continue to be maintained and utilized and contribute to the supply of up to 60 m^3/s of water to agricultural irrigation canals. The opening and closing of the sluice gates are overseen by Hokuriku Electric Power Co., Ltd. and the operation of the weir. Still, this Land Improvement District carries out the conservation of the structures themselves, and they have been maintained in good condition.

The large sluice gates and feed-water inlets still have the original stone floors, stone walls, and brickwork and are adequately maintained with only visual inspections. Of the three large sluice gates, the one currently in use undergoes inspection once a year by a specialist contractor commissioned by the Land Improvement District. Once a year, the water flow is stopped, and the Land Improvement District employees perform inspections of the tunnels. If any abnormalities are found, measures are taken after discussions with the prefectural and central governments. There have been central government-led inspections of the large sluice gates, tunnels, and feed-water inlets in recent years, with instances of damage noted in detail and plans for reconstruction work. This work is currently underway as a central government project.

In 2009 the Japan Society of Civil Engineers listed these structures as Civil Engineering Heritage sites. Around 2,000 people visit it every year, including local elementary and junior high school students, local organizations from Ishikawa Prefecture, and outsiders. It is a popular spot for exploring the history of the familiar local agricultural irrigation canal system.

Water Heritage

The Shichikayousui Irrigation System's large sluice gates, tunnels, and feed-water inlets were commissioned in 1903 and are still used for irrigation today. The structures are primarily unchanged from their original form last 111 years after construction. Shichikayousui Irrigation System helped develop irrigated agriculture, increased food production, and improved the economic condition of farmers. The consolidation project had the following outcomes:

1. The trouble and cost of diverting water into all of the irrigation canals were alleviated. In particular, there were significant economic benefits as it became unnecessary to perform repair work after each time the river flooded.
2. Much labour was saved, and various problems afflicting the irrigation canals downstream were resolved.
3. As a result, labour could be devoted to other tasks such as land cultivation, and people of the region could improve their agricultural business or pursue side businesses, etc.
4. The supply of water via the irrigation canals was stabilized. The water intake of the irrigation canals, which had previously been a source of anxiety each time after heavy rainfall, could be controlled by operating the sluice gates, and the amount of water diverted to the canals was stabilized, eliminating conflicts over the water supply.
5. Rotating irrigation became easier. Intake procedures were streamlined, and water volume adjustment for rotating irrigation during summer months when the Tedori River level is low could be carried out simply by operating the sluice gates, rather than taking labour-intensive steps such as removing skeletal groins from the river.
6. A single irrigation association for the seven canals was formed from the previous independent associations for each canal. With the formation of the Shichikayousui Irrigation System Association, irrigation rotation and water distribution mechanisms were streamlined

and simplified. The disparities mentioned above between the upstream and downstream sections of the irrigation canal were somewhat mitigated.

7. Reduction in construction costs for water intake after consolidation created dramatic economic benefits.

Finished in 5 years with 100,000 workers, it reached an area of irrigated land up to 6,500 ha. Planning and execution were based on Dutch civil engineer Johannis de Rijke's observations of the Tedori River and recommendations.

The large sluice gates and feed-water inlets of the Shichikayousui Irrigation System are designed to be strong, sturdy and stable. The large sluice gates are built on a cliff face with high stone pillars and brickwork. The large sluice gates are positioned right in front of the tunnel. The original sluice gate doors were 3 m tall, 3 m wide, and 26 cm in thickness and were made of pieces of zelkova wood, fastened together with hardware mounted on the left, right and centre. Cast-iron hardware was also installed on the groove of the door and on the door's edges to heighten durability. Also, around wrought-iron spindle 4.5" in diameter was mounted on the door, which enabled it to be opened and closed with a turning motion similar to a potter's wheel. A wooden hut was built to house the opening and closing mechanism and prevent rusting due to rain.

The sluice gates were later motorized in 1924, and the wooden doors were replaced with steel ones in 1968. The roof of the hut was last redone in 1997. There are three tunnels dug through rock cliffs. Their interiors have a semicircular arch shape, with a height of approximately 3 m and a width of 2.7m, and are walled with a brick while the floors are of stone flags. Each tunnel is about 210m in length. The feed-water inlets at the tunnel exits have cornerstones, pillars, horizontals and capstones made of stone, while the rest is made of brick. There are four inlets, including one leading to the supplementary sluice gate noted for their picturesque appearance. These are all testimonies to Japanese rich heritage and knowledge of irrigation structures.

The Shichikayousui Irrigation System made an outstanding contribution to enhancing food production, livelihood opportunities, rural prosperity, and poverty alleviation. Irrigation canals were already in use in the region during the Heian Period (792-1194), and by around 1600, they were being managed under the system of regional fiefdoms. The system draws water from the Tedori River, on Mt. Hakusan, for agricultural irrigation canals that serve 7,400 ha of agricultural land.

A Tedori River Shichikayousui Irrigation System water utilization association was formed at the time of the consolidation project 111 years ago, which later took the form of a land improvement district, but continues the work of collectively representing the residents of the river basin and performing duties related to water utilization, just as in the past. Every March and September, the organization carries out periodic water flow stoppages to inspect the structures and perform necessary repairs to conserve them. The association has many members based on a delegation system. Budget, operations, and management are discussed at biannual general meetings.

In 1869, a local merchant and landowner, Eda Gonbei ordered the digging of a tunnel to draw water from Akudogafuchi on the Tedori River for the furthest upstream of the seven canals, the Togashi Irrigation Canal. This restored crumbled water intake structures each time there was water damage, reduced the influx of floodwaters, and enabled uninterrupted boat transport since there was sufficient water supply even during dry weather. Above the tunnels is the forest of Akudo, the former site of Shirayama-Hime shrine, and Mito Myojin shrine, the protective deity of the Shichikayousui Irrigation System. At Shirayama-Hime Shrine, rituals expressing gratitude for the water flowing from Mt. Hakusan are held twice yearly. A great Spring Festival offers prayers for an abundant harvest held each March and a great Fall Festival to give thanks each October.

8.31 SHIRAKAWA BASIN IRRIGATION SYSTEM

Name	**Shirakawa Basin Irrigation system**
Location	**Ozu Town , Kumamoto Prefecture, Japan**
Latitude	**32.875 32.875 N (Uwa-ide Irrigation System); 32.871 N (Shita-ide Irrigation System); 32.852 N (Babagusu-ide Irrigation System); 32.812 N (Toroku Irrigation System);**
Longitude	**130.943 130.943 E (Uwa-ide Irrigation System); 130.931 E (Shita-ide Irrigation System); 130.852 E (Babagusu-ide Irrigation System); 130.736 E (Toroku Irrigation System)**
Category of Structure	**Irrigation System**
Year of commissioning	**1606–1637; 1637 (Uwa-ide Irrigation System), 1618 (Shita-ide Irrigation System), 1608 (Babagusu-ide Irrigation System), 1606 (Toroku Irrigation System)**
River Basin	**Shirakawa River basin**
Irrigated/Drained Area	**1230 ha: 390 ha (Uwa-ide Irrigation System), 430 ha (Shita-ide Irrigation System), 160 ha (Babagusu-ide Irrigation System), and 250 ha (Toroku Irrigation System)**

History

About 400 years ago, four irrigation systems were constructed in the Shirakawa River Watershed in Kumamoto, Japan: 1) Uwa-ide Irrigation System, of which the main irrigation canal is 14 km long, constructed to develop about 330 ha of new rice fields in 1618–1637; 2) Shita-ide Irrigation System with 12 km of the main irrigation canal constructed for 270 ha of rice fields in 1589–1618; 3) Babagusu-ide Irrigation System with 14 km of the main irrigation canal constructed for 95 ha of rice fields in 1588–1608, and 4) Toroku Irrigation System with 2.6 km of the main irrigation canal and three lateral irrigation canals were constructed in 1596–1606. Overall, 1,083 ha of new rice fields were developed with irrigation systems.

Description

There is an active volcano, Mt. Aso, and its caldera in the upstream area of the watershed. Because the mean annual rainfall is above 2,800 mm in the caldera, flood control is one of the most critical concerns in the watershed. On the other hand, due to the steep slope of the river, the flow volume can decrease vastly when non-rainy days continue. Therefore, the best agricultural technologies such as an oblique weir, a spillway, and irrigation canals along the geographical contour were assembled to construct the irrigation systems. Additionally, since the active volcano produced a large amount of volcanic ash, the maintenance of the irrigation canals was also a paramount concern.

While water from the Shirakawa River in regular periods could be efficiently withdrawn despite its unstable flow conditions, during rapid floods, an effective discharge of excess water downstream was needed. An oblique weir was built at the bend in the downstream area of the river to fulfil this requirement. The weir had the minimum height to secure enough ponding depth to withdraw water. This configuration of the weir enabled water intake in regular periods and easy discharge of excess water at the time of floods by letting the water flow over the weir, preventing damage in surrounding areas. In addition, the main irrigation canal of 40 km in length was excavated along the contour line of the river terrace in three irrigation systems in the middle reach of the Shirakawa River, which was built by combining very advanced technologies of the time. The oblique weirs in the irrigation system in the Shirakawa River Watershed were almost the oldest in Kumamoto. Other irrigation systems widely adopted this structure in Japan.

Furthermore, a unique structure called Hanaguri was constructed in the canal to prevent volcanic ash accumulation, which continuously fell from the Volcano. The Hanaguri Canal was built by excavating rocks partially at about 5 m intervals to make walls. In the lower part, holes measuring 2 m in diameter were dug to prevent the deposition of earth and sand. The Hanaguri

Monument of the recovery from flood disaster

“Uwa-ide” irrigation canal’s selection as one of the 100 best canals in Japan

“Uwa-ide” irrigation canal

The irrigation canal is paved. (1)

“Uwa-ide” irrigation canal

The irrigation canal is paved. (2)

Plan view of “Uwa-ide” weir (past)

“Uwa-ide” weir (present)

still fulfils its functions demonstrating the innovative and advanced technologies of the time. These facilities were built with careful consideration of the local climate and the geographical and hydrologic features of Kumamoto. They have been voluntarily maintained and managed by local community members. They even now have not lost their essential functions since their construction 400 years ago, despite suffering damages from many natural disasters such as floods, volcanic eruptions and earthquakes.

In addition, newly developed rice fields by irrigation system formed groundwater recharge and cycle system in the middle to lower reaches of the Shirakawa River. This means that the unstable flow conditions of the Shirakawa River were successfully converted into stable groundwater resources by irrigation systems constructed in the middle reach of the river and the development of rice fields. In this way, the water utilization and water circulation system in the region of Kumamoto was created about 400 years ago. Currently, 1 million residents in Kumamoto depend entirely upon groundwater for their daily domestic water supply. Ninety million tons of groundwater recharge, accounting for about 15% of the 600 million tons of annual groundwater recharge, is from rice fields in the middle reach of the Shirakawa River basin. This water utilization and circulation system have been inherited continuously to the present times. All these systems were constructed based on the hydrological and geographical characteristics of the watershed. The Shirakawa Basin Irrigation system has been passed over many generations and has overcome challenges like urbanization, population, industrialization, and many natural disasters. The Uwa-ide Irrigation System' oblique weir was first destroyed by flood flow in 1796. Although the Uwa-ide weir was reconstructed, the weir was destroyed by floods four times (in 1828, 1884, 1900 and 1953). In particular, the 1953 flood destroyed both Uwa-ide weirs and Shita-ide and Babagusu-ide weirs. Right-angle weirs replaced the three oblique weirs. The irrigation canals were also repaired after the flood disasters. Today, the irrigation canals were partially paved with concrete to prevent water loss. In addition, the irrigation canals in Uwa-ide and Shita-ide Irrigation Systems were partially destroyed by Kumamoto Earthquake (Mw7.0) in 2016. Then, the irrigation canals were paved with concrete for reinforcement.

The irrigation systems are mainly maintained by three local organizations: Ookiku Land Improvement District, Babagusu-Zeki Land Improvement District, and Toroku-Zeki Land Improvement District. Seminars, symposiums, and other events are held for school children and the local community to spread awareness about irrigation systems and their role in food production and the environment. Rice farming and the irrigation system still have an important role in the regional water cycle and environment. On the other hand, the total irrigated area in Tohoku Irrigation System decreased by about 75% because the downstream irrigation system flowed through the urban area. However, irrigation canals have an enormous contribution to creating a water environment in urban area. Therefore, the residents in the metropolitan area join in to maintain the irrigation system, such as collecting garbage in the canals.

Water Heritage

Four irrigation systems; "Uwa-ide", "Shita-ide", "Babagusu-ide", and "Toroku" Irrigation Systems, constructed around the same time (1606-1637), made a significant contribution to rice production in the Shirakawa River Watershed. Before the construction of the irrigation systems in the Shirakawa River Watershed, the land was covered by reed. The irrigation systems enabled farmers to develop about 1,800 ha of new rice fields. In particular, the rice fields increased from 700 ha to 1,070 ha in the middle area of the watershed for 400 years.

This big irrigation project was started by the governor, Kiyomasa Kato, at that time. In the construction process, farmers and engineers also developed their autonomous organization. *Tenaga*- the independent organization, developed through the construction and the management of the irrigation systems continued even after the construction. The system's management practices were sophisticated and have been inherited for generations until now.

The engineers and the team overcame many challenges like the active volcano, Mt. Aso in the upstream area of the watershed produced a large amount of volcanic ash, and the maintenance of the irrigation canals such as dredging was an essential concern. Babagusu-ide Irrigation System, constructed by excavating a hard rock hill, was not easily accessible during the irrigation period due to its hilly topography. Therefore, a unique facility called the *Hanaguri* irrigation canal was invented, which prevents as well by creating partition walls with 2-m diameter holes at about every 5-m interval, which prevents sedimentation of volcanic ash and manages the water flow because of the vertical eddy, which is automatically generated.

In Uwa-ide, Shita-ide, and Babagusu-ide Irrigation Systems, the main irrigation canals were constructed along the geographical contour to deliver irrigation water efficiently. Additionally, the main irrigation canal of the Shita-ide Irrigation System flows in the lower place of and parallel to the Uwa-ide Irrigation System to receive and reuse the spilt water from the upper irrigation canal. This idea for efficient water use was inherited by other irrigation systems such as Tsujun Irrigation System, constructed in 1854, and Kounomizo-Hyakutaromizo Irrigation System, constructed in 1710. The irrigation systems still have a critical role in rice production by keeping their original functions for 400 years.

Uwa-ide Irrigation System was designated as one of the best 100 canals in Japan. The local organizations and communities were also commended by for their excellent management practices of the irrigation system by the national government and other organizations. Kumamoto City, which financially supports the paddy fields with irrigation systems, was given Water for Life Top Award from the United Nations in 2013.

8.32 SODAIYOUSUI IRRIGATION SYSTEM

Name	**Sodaiyousui Irrigation System**
Location	**Shimouchi City, Gifu Prefecture, Japan**
Latitude	**35.341**
Longitude	**136.554**
Category of Structure	**Irrigation System**
Year of commissioning	**1669**
River Basin	**Nagara-Gawa (Sub Basin: Kiso-Gawa)**
Irrigated/Drained Area	**929 ha**

SODAIYOUSUI IRRIGATION SYSTEM

Crossing Boundaries: A Canal born from The Hopes of the Local Farmers

As the rivers in the Sodai area were once shallow, and water could not be efficiently drawn from the main river, the local people suffered from annual droughts and low regional productivity. In spite of this, there were no large-scale irrigation systems in the area until the Sodaiyousui Irrigation System was constructed in 1669, and this was largely due to the political system at that time. The land in this region was divided up by several monarchs, and they were unable to work together to develop an irrigation system due to disagreements amongst themselves.

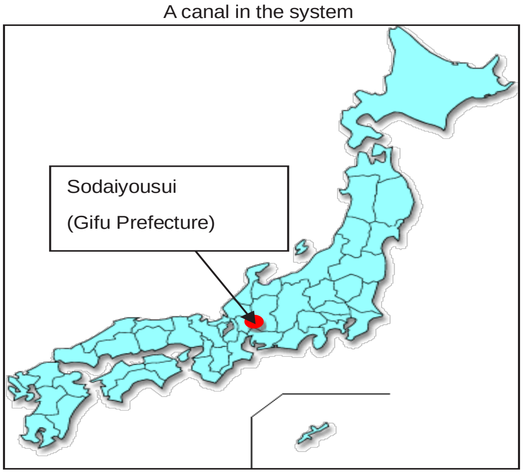
The local farmers of the area met together to discuss what to do about the situation, and came up with a plan for constructing the Sodai irrigation canal themselves. This entrepreneurial process was rarely seen at the time in Japan, and is an indicator of the extent to which people in this area desperately needed an irrigation system. Needless to say, the farmers did also have conflicting interests among themselves, but they were nevertheless able to resolve these issues through the assignment of new rice paddies, as well as through other means.

Construction was tough, with *tagane* and *nomi* (Japanese chisels) being used to dig into the bedrock, and the project was funded through generous investments made from the personal funds of local influential farmers. Ten years later, the 17km-long irrigation canal was completed, and the once barren area was transformed into beautiful new rice fields. It remains an important institution to this day, supporting a flourishing intensive agriculture industry. Nowadays, the local people have continued to work together to protect the canal system through community cleaning and weed-clearing projects, as well as by carrying out repairs. Further, the canals are studied by the local children in their environmental education lessons, and the history of the canals is explained in a supplementary textbook used by the local schools. In this way, work is being carried out to protect the irrigation system for future generations.

Canal diversion headworks

A canal in the system

Remains of the original rock excavation work



Map showing location within Japan

History

Sodaiyousui Irrigation System was constructed in 1669 in the Sodai area precisely in Mino and Seki City, the central region of Gifu Prefecture. Their geographical conditions range from the mountainous regions in the north and the east and open plains in the south. However, shallow rivers added to poor water availability, annual droughts and low regional productivity. When the monarchs were unable to come together and build an irrigation system due to internal disagreements, the local farmers, with support from *Samurais,* constructed the 17 km-long Sodai irrigation canal in 10 years. This entrepreneurial process was a rare occurrence at the time in Japan.

Despite poverty, rampant droughts, poor harvests, large-scale cultivation of mountains, forests and plains, and the construction of water utilization facilities shared by multiple settlements, it was virtually impossible due to socio-political reasons. At the time, local land was divided up into numerous *Hans* (Japanese feudal domains) as this fragmentation kept the political powers of each Han in check, and farmers were prevented from joining forces and forming more prominent groups. In addition, there was a strict class system, and the social climate was characterized by endless friction among the local people.

However, in 1663, a samurai called Kita Kichiemon and his brother provided their funds to a wealthy farmer, Shibuyama Ihee, who planned and constructed the irrigation system in collaboration with the farmers' community. Hurdles like a conflict of interests among individual settlements and opposition from upstream villages were managed through agreements and negotiations. Compensation and farmlands were provided to those who lost their lands in the irrigation system's construction.

The construction in 1667 was complicated, with no mechanical equipment or dynamite at the time. To resolve this, Japanese chisels *Tagane* and *Nomi* were used to dig into the bedrock. The rock was heated with fires built using coal and charcoal, and water was poured over the rock to make it easier to shatter. The construction costs reached up to 5,500 ryō (worth around 1.1 billion yen today), and the three men exhausted their assets. Despite financial difficulties, Kita Kichiemon and his brother later abandoned the project, but Shibuyama Ihee carried on construction.

As soon as the construction was completed, the results were outstanding. The once barren area was transformed into beautiful new rice fields. It remains an essential facility to this day, supporting a flourishing intensive agriculture industry.

Description

Sodaiyousui Irrigation System draws water from the Nagara River, the first-class river in Japan, and irrigates around 1,000 ha of farmland in the plains left to the riverbank. Its maximum water intake rate is 9.15 m^3/s, its length is around 17 km, and after flowing through the main canal, water is diverted into four channels. These channels irrigate paddy fields and a wide range of crop fields, including barley, soybeans, taro root and strawberries. As the Nagara River bed's elevation is low, water cannot be quickly drawn, which hampers the local agriculture that depended upon mountain streams for irrigation in the past. However, with Sodaiyousui's construction, the situation improved, and the region flourished.

A maximum of around 1,500 ha of farmland has been irrigated by the Sodaiyousui Irrigation System throughout its history and promoted residential development in the region by providing utilities and improving the living standards, and the environment for the people. Although there has been a slight decline in the area of farmland receiving irrigation from the system, it remains a vital regional facility that provides water for around 1,000 ha of agricultural land today.

The Sodaiyousui Irrigation System has undergone many improvements and renovations since its construction in the last 350 years and currently has remote control operation facilities. It continues to accurately and efficiently distribute irrigation water to farmland in the area, allowing local agriculture to flourish.

With the degradation of the riverbed at the sluice gates, the first major reconstruction project began in 1934. Further repairs and improvements on the canals and the diversion headworks were carried out in 1941, 1957, 1982, and 1997. However, some sections bereft of past improvement works are deteriorating and posing a severe problem with increased maintenance costs and water shortages. As a result, efforts are currently being made to extend the system's operating life through strategic conservation works.

Nowadays, the local people work together to protect the canal system through community cleaning and weed-clearing projects and by carrying out repairs. Further, the local children study the canals in their environmental and educational lessons, and the history of the canals is taught in supplementary textbooks in schools. Ancient wisdom and accomplishments of the irrigation system are passed to future generations.

Water Heritage

The Sodaiyousui Irrigation System was a landmark for Japan's irrigation infrastructure, the region's agricultural production, and an exemplary work of community spirit and joint management. It was formed entirely from people's money, hard work, and resilience and redefined the farmer's role in society.

According to historical records, the System led to a dramatic increase in rice paddies, from around 200 ha to approximately 500 ha of rice fields, and contributed significantly to a rise in the local population and the stabilization of livelihoods in the region. The agricultural land currently irrigated by the Sodaiyousui canal system practices a range of farming methods, including a rotational three-crop system of rice, barley and soybean crops that spans a 2-year cycle and intensive farming that combines vegetable, flower and livestock agriculture. In this way, the System continues to act as a vital facility for regional agriculture.

The irrigation system not only provides water for use in agriculture but also for recreation, as well as for extinguishing fires in case of emergency. There is a strong sense that the system is vital for agricultural producers and the local people. The Land Improvement District monitors the day-to-day management of the main canal, and the local people maintain the lateral canals by clearing weeds and removing mud themselves.

Over the years, with advancements and the emergence of automated facilities, the system witnessed many modifications with an entire basic premise. During the historical period, canals mainly were constructed out of earth and stone, and modern heavy machinery and technology were unavailable. As a result, the canals suffered from damages due to numerous natural disasters and were repeatedly repaired. Additionally, following the degradation of the bed of the Nagara River, construction work was carried out in 1934 to move the sluice gates 650 m upstream to their current location. At the same time, improvements were carried out along the canal, making the current water intake rate of 9.15 m^3/s possible. In 1945, the Irinoto diversion headworks were installed at the tip of the Sodaiyousui Irrigation System, and these circular tank shape diversion works were in use until 1989 when they were renovated. Circular tank-shaped diversion works are round structures out from which many canals flow. Water can be accurately diverted into these canals according to demand by dividing the circular tank. This technology was a pearl of wisdom in a historical period of ceaseless struggles over water. There are few circular tank shape diversion works remaining in Japan today. The Sodaiyousui Irrigation System was reconstructed as a slide-gate diversion system during its renovations around 1990, making precise water flow control possible through sluice gate operations.

The complex political system of the 17th century was the main reason why no water utilization systems were developed in the region before the Sodaiyousui Irrigation System. The region was complicated by multiple *han* divisions, causing conflicts and disagreements. Although disputes among settlements were generally internally managed by *Hans*, the plans for the Sodaiyousui Irrigation System were born from discussions and agreements made by farmers, which was highly unusual for this period. It was not an official public project but a rare accomplishment where a large-scale project funded entirely with private money in a conflicted region was booming.

A grave was built for the three founders of the Sodaiyousui Irrigation System within the Jinkou-Ji Temple grounds, which is in modern-day Seki City, to enshrine their spirits. The local farmers hold memorial services at the shrine and present their gratitude to the founders, worshipping them as water gods. In 1813, the I-jinja Shrine was also founded close to the shrine further to revere the three founders of the irrigation system, and their remarkable achievements have been praised throughout the ages. An annual festival is held at the temple as a reminder of the virtue of these three men to this day.

In this way, the irrigation system has been a necessary facility in the region for 350 years after its construction. History is taught in schools, ensuring that future generations inherit this rich history. Regional organizations are also working together to protect the forests surrounding the source of the Nagara-Gawa River, from which the water for the Sodaiyousui Irrigation System is provided by planting and growing trees in the area, maintaining an ecological balance.

8.33 TACHIBAIYOUSUI IRRIGATION CANAL

Name	**Tachibaiyousui Irrigation Canal**
Location	**Taki Town, Mie Prefecture, Japan**
Latitude	**34.450**
Longitude	**136.450**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**1823 (reconstructed in 1935)**
River Basin	**Kushida River**
Irrigated/Drained Area	**436 ha**

History

Located in the Kushida River Basin in Japan, Tachibaiyousui Irrigation Structure is recognized for laying out a system of canals and cross-drainage structures that required accurate surveying and measuring the elevation of land, which was considered innovative for its time in terms of both planning and execution.

During the Edo Period (1603-1868), the Seiwa district of Taki-cho was poorly situated in terms of water utilization, as although the Kushida River flowed nearby, the riverbed was low-lying, and water had to be brought to cultivated areas from far upstream, which made agricultural production vulnerable. For this reason, there were hardly any rice paddies, and most agriculture consisted of tilling the land, which was a heavy burden on the local people. Then in 1774, Nishimura Hikozaemon, from the Niu district of what is now Taki-Cho, poured his resources and labour into creating an irrigation canal to develop new rice fields and bring prosperity to the region. Nishimura's plan for canal construction was submitted to the Kishu Domain government in 1808, and construction began 12 years later in 1820. It was completed in 1823 at a total cost of 12,600 Ryo (4 billion JPY today), with a cumulative total of 247,000 workers engaged.

Description

Tachibaiyousui Irrigation Canal stretches to about 30 km, cutting a winding path using the digging technique used for mercury mining in the area since the Nara Period (710-794). The canal's central structural line runs through the town east-west, and the Kushida River, categorized as Class A (the most important class of rivers in Japan's system), flows alongside it. It went through several tunnels, mountain passes, and over valley embankments, all achieved through manual labour using only hammers and chisels. It was a gruelling feat. The fact that the Kushida River bed was at a lower elevation than the farmland to be irrigated and the volume of water in small brooks that flew out of the mountains was small and inconsistent meant that local people could not create rice paddies and faced severe water scarcity.

Digging the irrigation canal through the foothills at high elevation enabled water delivery to a broader area, increasing the rice paddies and ensuring a stable water supply. Also, the structure was designed so that water flowing down from the mountains after heavy rains were caught in the irrigation canal and discharged safely into the Kushida River, reducing the threat of water-related damage.

The canal follows a winding path that makes skilful use of the mountain foothills' geographic features. The great length of the canal provides a water storage function and supplies water to the irrigated region even during periods of little rainfall. When the irrigation structures were built, however, it enabled the creation of approximately 160 ha of rice paddies and improved the people's living standards. The five small villages in the area irrigated by the Tachibaiyousui Irrigation Canal all maintained the structures.

The Irrigation system now consists of one weir constructed on the Kushida River, 4.1 km of the waterway for shared hydropower use, 21.8 km of the main irrigation canal, 1.0 km of the Matsuyama tributary, 145 water diversion gates, 38 water discharge gates, and two storage ponds. The current Tachibai Weir is the fourth-generation weir constructed in 1935 and is a stone dam structure. Stone is said to have been used because tall boulders in the riverbed downstream were smashed up and used to build the facility. To the right of the centre (toward the right bank), there is a log chute used to float lumber over the weir, and the structure is a highly outstanding one in terms of both stonework and its picturesque appearance.

Tachibaiyousui Irrigation Canal is multi-functional, used not only for irrigation but also for other purposes as well. The irrigation canal takes in water at the weir, which is diverted along the way to the Hatase Power Station. From there, it flows down to the irrigated agricultural area lower in the basin at a maximum rate of 3.28 m/s governed by customary water utilization rights during the irrigation period from late April through late August. It also flows at a rate of 0.2 to 0.4 m^3/s during the non-irrigation period and is an indispensable part of life in the region.

The area irrigated by the Tachibaiyousui canal, which is inside the Taki-cho town limits, is roughly in the centre of Mie Prefecture. The region is hot and humid, with average annual precipitation of 2,500 mm and a yearly average temperature of 15.7^o Celsius. Taki-cho is a rural municipality, with forests and meadows accounting for 55% of the land area and agricultural land for 26%. There is 1,040 ha of land under cultivation (799 ha of rice paddies, 40 ha of other fields, and 201 ha of arboricultural land). Farm households total 1,170, with an average of 0.88 ha of cultivated land per household. Principal crops include rice, tea, cabbage, Chinese cabbage, leeks, barley, and soybeans. The percentage of persons aged 60 and above is high at 29%, compared to an average of 24% for Mie Prefecture.

There was little difference between the structure's utility during the planning stages in 1820 and when it went into operation after the completion of the work. However, the weir structure changed during repeated reconstructions after the work was completed in 1823 and during prefecture-led improvement work on the Tachibaiyousui Irrigation Canal between 1951 and 1971. The raw earth or unlined waterways canal sections were converted to concrete channels. This lining improved the water transfer capacity of the canal and reduced water loss. During this project, the zone stretching 1,100 m from the intake point at the weir was turned into a tunnel, and the canal route was partially modified.

TACHIBAI-YOUSUI IRRIGATION CANAL

Multifunctional Irrigation Canal Maintained in Cooperation with Local Residents

In this region, farmers had long suffered from the shortage of water supply and relied on upland cropping for their livelihood. Under such circumstances, regional leaders planned to develop new paddy field area in the region by excavating irrigation canal around early 19th century. Accurate surveys were conducted using surveying tools in those days made of logs and bamboos. A 30-km-long irrigation canal system was completed in 1823, mobilizing a total manpower of 250,000 workers and applying historically inherited excavation technique, which was initially developed about 1,300 years ago for mercury excavation. The canal was excavated at high altitudes of the mountain, and could catch runoff water from mountains when heavy rainfall occurs, thereby contributed to reducing flood hazards. In addition, it had relatively long length because it passed through winding mountainsides, and could store relatively large volume of water in the canal, which could be used supplementary during the drought period. In the latter period, improvements in diversion weir and canal (1951-1971) were carried out to facilitate modernization of the system.

The Tachibai-Yousui Irrigation Canal has long been managed and maintained by farmers and the land improvement district since its construction in 1823. However, people's interest in agriculture and water-use facilities waned against a background of the rapid economic growth after World War II. It has come to more difficult to properly maintain the facilities, which were the results of sustained efforts and devotion by their predecessors. As such, the land improvement district and local residents started a joint project called "10,000 Hydrangea Stock Campaign" to plant hydrangeas along the canal in 1993, and the total number of hydrangea stocks now exceeds 30,000. Since 1997, the "Hydrangea Festival" has been held to promote exchanges between urban and rural residents, and revitalize the area. The festival now attracts over 10,000 visitors every year. The irrigation system is also utilized as a site for education, which makes significant contributions to developing understanding of agriculture and rural areas.

Along with these efforts, various activities, including cleaning and repair of the water channel and environmental conservation, have been conducted by local residents in the region. In the end, an organization devoted to such activities has been set up, working with the land improvement district to manage and maintain irrigation facilities.

As stated above, the Tachibai-Yousui Irrigation Canal is not only supplying water for irrigation, fire-fighting and domestic use, but also has recently been used for such purposes as environmental education, tourism, and small hydroelectric power generation. This irrigation system contributes significantly to the development of agriculture and rural society through the participation of local residents in cooperation with land improvement district.

Water Heritage

Since the Kushida River bed was at a lower elevation than the farmland, the volume of water in small brooks that flow out of the mountains was small and inconsistent, and people faced water shortage and poverty. When the irrigation structures were built, they enabled the creation of approximately 160 ha of rice paddies and stable food and water supply. The canal was multifunctional. Part of the canal was set aside as a washing area, and people used the water for various daily tasks. It also provides water for firefighting and has enabled people to live safer lives.

The construction of the Tachibaiyousui Irrigation Canal, which goes through several tunnels and mountain passes and over valley embankments, achieved through manual labour, was a remarkable accomplishment of its time. As the canal was dug through the mountain foothills, the earth was piled up on one side, causing concern about water leaking out. For this reason, clay was extracted from the nearby mountains and applied around the canal to prevent leakage.

The weir was constructed on the Kushida River in 1823 by driving many wooden posts into the riverbed between two boulders that jutted out in the riverbed, then lining up sticks and stones to create the structure. The building materials for the weir were procured from the river and surrounding forest, all sustainable resources that could be easily replaced at times of maintenance or repairs after flooding. However, the entire weir was destroyed during floods in 1829, 1870, 1886 and 1919, and in 1921 the weir was moved to its present position 400 m downstream and replaced with a stone structure, with funding from Chubu Electric Power Company. Since then, the irrigation canal has provided a stable supply of water for 93 years.

The irrigation canal was dug using techniques developed for mercury mining in the region and the local digging technique, known as *Manbo*, which allowed it to be dug briefly. There are abundant mercury deposits in the region, which were mined as long ago as the Nara Period (710-794) and used in large amounts to apply gold leaf to the Great Buddha at Todai-Ji Temple in Nara. Kukai, the progenitor of the Shingon sect of Buddhism, also visited the region. Since ancient times the mercury mining industry flourished in the area and underpinned the progress of civilization here until the late Edo Period (1603-1868). The weir has been awarded and recognized through various selections, awards, and designations concerning its historical relevance. Structures designated as Taki-Cho municipal cultural properties include (1) the Tachibai weir, (2) the Yanagitani tunnel (an unlined tunnel), (3) the mountain pass, and (4) the Mebosotani embankment. All of them were designated in 2001, and all are still functioning to deliver water to the irrigation canal. Its structures are the first agricultural water-related structures in Japan to apply for designation as Registered Monuments of Japan" by the Agency for Cultural Affairs (registration scheduled to be approved in September 2014.

The Tachibaiyousui Irrigation Canal is an excellent example of joint operation and management over a long period. The maintenance and utilization of the irrigation canal are carried out by the Taki-Cho Seiwa Local Resource Conservation and Utilization Commission, an organization governing and promoting the conservation of farmland, water, and the local environment, in conjunction with the Land Improvement District (LID). To provide technical support for the effective implementation of action plans, 12 members selected from each village and the Land Improvement District formed the Mi-Do-Ri (water, land, community), Support Team in 2007. This group learns advanced agricultural structure maintenance techniques from experts to carry out work that farm households are incapable of and shares these with residents during joint activities to promote the longevity of agricultural structures.

The Tachibaiyousui Irrigation Canal Land Improvement District, which manages the canal as of 2013, represents an irrigated area of 436 ha. Chubu Electric Power handles the conservation and maintenance of the Tachibana Weir and the canal's section extending to Hatase Power Station. The irrigation and drainage coordination committee operates the main irrigation canal downstream from the power station, Matsuyama tributary, storage ponds, and water discharge gates. The gates to divert water for irrigation are operated by the full-time irrigation canal staff. In soil washing into the canal during floods or other natural disasters and breakage of facilities, restoration work is carried out directly by the Land Improvement District. As the irrigation canal flows through mountainous areas, dried leaves and other matter get into the canal with strong winds, and removing this is a highly labour-intensive endeavour.

One great conservation initiative of the LID and residents was the 10,000 Hydrangeas Project, 1993, where residents planted these hydrangeas along the canal, and their number now exceeds 30,000. Today, local people are actively engaged in the cleaning, repair, and maintenance of the structure and environmental conservation activities. The Taki-Cho Seiwa, Local Resource Conservation and Utilization Commission, works with the LID to maintain and utilize the canal. The Tokai Agricultural Administration Office of the Ministry of Agriculture, Forestry and Fisheries (MAFF) recognized the Tachibaiyousui Irrigation Canal and its hydrangeas in 2005 as one of the 100 beautiful rural community views of the Tokai region, and MAFF designated the canal in 2006 as one of Japan's 100 most important artificial waterways. In recent years irrigation structure management has been characterized by activities to deepen children's understanding of agricultural and rural village life. This LID was the first in Mie Prefecture to register a structure as part of this effort in April 2000 and designates August 1 of each year as Agricultural Irrigation Canal.

At this family event, people go down the Tachibaiyousui Irrigation Canal in boats. Going through the unlined tunnel along the approximately 300 m route, they appreciate the canal system and the hard work. Through such experiences, children learn about the history of the Tachibaiyousui Irrigation Canal, the role of such canals, the agriculture of the region, and water's role in the regional culture. By actively appreciating the canal's myriad benefits, people have deepened their understanding of the canal. Residents and the Land Improvement District are working together to maintain and utilize it.

8.34 TAKINOYU-SEGI AND OHKAWARA-SEGI IRRIGATION SYSTEM

Name	**Takinoyu-Segi and Ohkawara-Segi Irrigation System**
Location	**Chino City, Nagano Prefecture, Japan**
Latitude	**36.014**
Longitude	**138.234**
Category of Structure	**Irrigation System**
Year of commissioning	**1785/1792**
River Basin	**Kamikawa River Basin**
Irrigated/Drained Area	**771 ha**

History

The Takinoyu-Segi and Ohkawara-Segi Irrigation System is an agricultural canal system excavated in response to a head member of Tazawa Village, Yosen Sakamoto, to the Takashima Provincial Government over 200 years ago. The system continues to be appropriately maintained, managed and used as irrigation canals even now.

Yosen Sakamoto (1736-1809) devised an innovative irrigation system at the time, called a "Kurikoshi (pass-on)" irrigation system. In 1775, he started frequenting the provincial government to petition to develop such a system persistently. A *Kurikoshi* irrigation system connects several rivers flowing east and west with canals that send overflow from the fuller rivers in the north to those in the south with water shortages. This linking of waterways was a revolutionary strategy at the time for irrigating farms. In addition to agricultural use, the irrigation system offers water for fire-fighting, household use, and environmental use.

Takinoyu-Segi and Ohkawara-Segi Irrigation canals, excavated over 200 years ago, continue to be used for agricultural irrigation under the proper administration of Land Improvement Districts and local farmers after going through partial renovations. Beneficiaries of the irrigation system use it while admiring Yosan Sakamoto's accomplishment and appreciating the blessings of water. The Land Improvement Districts comprised of residents in benefited areas are responsible for managing the current irrigation system through fees collected from district members. Officials and residents share responsibilities in on-site management.

Description

Both Takinoyu-Segi and Ohkawara-Segi canals draw water from the Takinoyu River, which begins in Mt. Tateshina. The 10.4 km-long Takinoyusegi Canal was completed in 1785, and the 12.5 km-long OhGawara-Segi Canal in 1792.

Structural Features of Takinoyu-Segi and Ohkawara-Segi Irrigation System

- **Mechanism of the Kurikoshi structure:** Yosen Sakamoto proposed *Kurikoshi*, a new concept of irrigation system to the provincial government. The *Kurikoshi* irrigation was a pioneering approach of its time, connecting rivers running in an east-west direction with canals to convey surplus water in sequences such as from the Takinoyu-Gawa River and Shibu-kawa River with relatively abundant water in the northern area to the southern area suffering from water shortages, allowing for irrigating newly developed agricultural fields.

TAKINOYUSEGI AND OHKAWARASEGI IRRIGATION SYSTEM

Overview and Features of the Irrigation System

The Takinoyusegi and Ohkawarasegi irrigation canal system consists of agricultural canals excavated in response to a village head called Yosen Sakamoto’s petition to the Takashima Provincial Government in Nagano Prefecture over 200 years ago. The system continues to irrigate the farmlands in the area even now.

The water-supply system Sakamoto devised is called a “*kurikoshi* (pass-on)” irrigation system. In the system, several rivers flowing east and west are connected by canals to send overflow from the fuller rivers in the north to the ones in the south with water shortages. This was a revolutionary strategy at the time for irrigating farms within the water system.

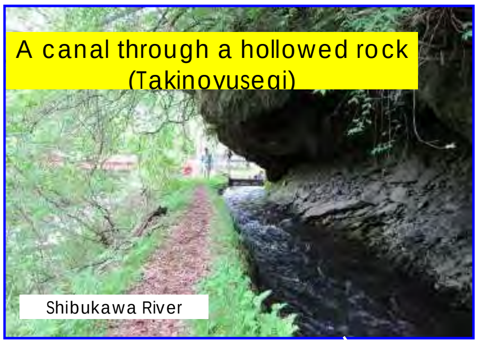
Both Takinoyusegi and Ohkawarasegi canals draw water from the Takinoyu River which begins in Mt. Tateshina. The 10.4km-long Takinoyusegi Canal was completed in 1785, and the 12.5km-long Ohgawarasegi Canal in 1792.

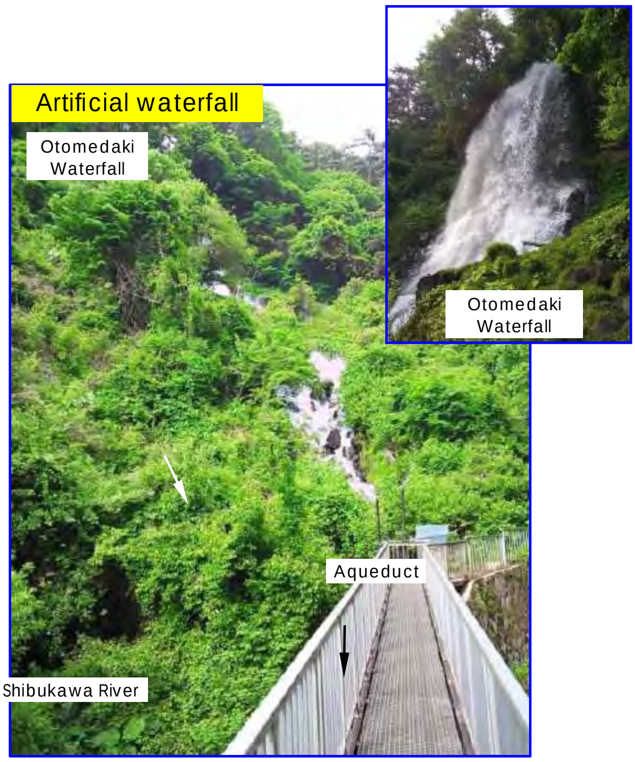
The structure of water intake from the Takinogawa River is called “*Shibatatae.*” When the water in the Takinogawa River feeds canals after being dammed by dikes built with wood and rocks, this structure allows some water to leak so that enough water flows downstream. Beneficiaries of the irrigation system maintain it in almost the same structure as it was at the time of excavation.

When the irrigation system was first excavated, the water conveyance structure used canals built with soil. This gave water rights to the farmers along the canals, who used the leaked water through the soil. Taking these farmers’ rights into consideration, renovations are done using a structure without a bottom lining even now.

On steep slopes along the river, canals were built through a hollowed-out rock to secure a cross-sectional area of flow, which shows the outstanding technology of the time.

When canals cross the river in a deep valley, artificial waterfalls were built on both Takinoyusegi and Ohkawarasegi canals, where the water gushes down along a steep cliff all at once. The collected slow water then crosses the river through aqueducts, flowing downstream with the water fed from the river. This is a unique irrigation structure taking advantage of the natural topography of the surrounding area.





- **Water intake structure:** The structure of water intake from the TakinoGawa River is called *Shibatatae*. When the water in the TakinoGawa River feeds canals after being dammed by dikes built with wood and rocks, this structure allows some water to leak so that enough water flows downstream. Beneficiaries of the irrigation system maintain it in almost the same structure as it was at the time of excavation.
- **Water conveyance structure:** When the irrigation system was first excavated, the water conveyance structure used canals built with soil, causing water leakage through long-distance conveyance to benefited areas, resulting in water rights for people who farmed using the leaked water. Renovations were conducted using a single-sided lining only on the valley side or a double-sided lining that did not cover the river bottom.
- **River crossing structure:** Drop structures were built to convey water from the Takinoyu-Gawa River across the Shibu-kawa River in a deep valley. Water runs down the steep slope all at once, is collected, and crosses the Shibu-kawa River through Kakehi (aqueducts). Water runs down the steep slope all at once, is collected, and crosses the Shibu-kawa River through Kakehi (aqueducts) and is conveyed downstream with the water fed from the Shibu-kawa River. The base of both waterfalls has been skillfully processed to slow down the water by natural rocks downstream.

On steep slopes along the river, canals were built through a hollowed-out rock to secure a cross-sectional area of flow, which shows the outstanding technology of the time. When canals cross the river in a deep valley, artificial waterfalls are built on Takinoyu-Segi and Ohkawara-Segi canals. The water gushes down along a cliff all at once. The collected slow water then crosses the river through aqueducts, flowing downstream with the water fed from the river. This is a unique irrigation structure taking advantage of the natural topography of the surrounding area.

Over the years, both Takinoyu-Segi and Ohkawara-Segi have had no major changes in the route since the time of excavation. Still, the canals in the downriver were extended with the expansion of benefited areas. The dikes also had no significant changes in their structure. However, recent development has brought about a massive inflow of surface water into the dikes running along contour lines during heavy rain, resulting in more overflow and failure of dikes in many places. This failure required the enforcement of disaster preparedness, such as increasing the height of soil canals and installing new overflow channels, which was not needed at the time of excavation.

Development in the upriver areas has brought about a massive inflow of surface water into the dikes running along contour lines during heavy rainfall, resulting in more overflow and the failure of dikes in many places. Accordingly, disaster prevention measures have been implemented, such as increasing the height of the soil canal and installing overflow channels not needed at the time of excavation.

Water Heritage

Takinoyu-segi and Ohkawara-segi Irrigation System represent a turning point in developing irrigated agriculture and increased food production. It connects several rivers flowing east and west with canals that send overflow from the fuller rivers in the north to those in the south with water shortages. This was a revolutionary strategy at the time for irrigating farms.

When 15 dikes were excavated under the plan proposed by Yosen Sakamoto, approximately 300 ha of new fields were in the record. The construction of the Takinoyu-Segi and Ohkawara-Segi Irrigation System brought about 150 ha of the new fields. The excavation of new dikes facilitated the cultivation of barren lands into rice paddies and created the basis of the present settlement. Furthermore, it contributed to agricultural development through increased production and commercial growth through modern industrialization. Rice production had dramatically increased after the excavation of the irrigation system, resulting in increased food production, and helped people in dire need during the Tenmei Great Famine (1782-1788).

On the other hand, small-scale hydroelectric power generation draws energy from falling water in Takinoyu-Segi. The Land Improvement District lends the irrigation system and canals to a private electric company and appropriates the usage fees. In Ohkawara-Segi, a study has been undertaken to introduce small-scale hydroelectric power plants. Tateshina Power Plant and Tateshina 2nd Power Plant currently function at the output values of 260 kW and 141 kW, respectively. Therefore, the irrigation system contributed to agricultural production, but hydropower generation has accelerated the region's holistic development.

As explained above, with ingenious engineering techniques, the mechanism of *Kurikoshi* and the river crossing structure were unprecedentedly innovative at the time. Canals built through hard, hollowed-out rocks also show outstanding technology for the time. Advanced technology was used to draw water across the Shibu-kawa River with artificial falls and aqueducts by using bedrock on the river bank. Also, an outstanding technology for the time was used to hollow out hard rocks along the rivers.

During an irrigation period, dike management members patrol the irrigation system in rotation every day. They assume the colossal responsibility for diversion control during droughts and drainage control during rain periods. The Land Improvement Districts are responsible for the main parts of the irrigation system. At the same time, individual settlements manage branch canals and those at the end of the system, other multipurpose activities to maintain agricultural land and environmental conservation.

The water intake, conveyance, and river crossing structures were constructed to consider the natural environment and ecosystem, including waterways. In particular, waterfalls that made the most of the natural terrain have been maintained in their original state since excavation. The upriver areas of both Takinoyu-Segi and Ohkawara-Segi are located in Yatsugatake Chushin Kogen Quasi-National Park with a rich natural landscape. Citizens often visit the canals, which pass through a cottage area in Tateshina Highlands. Renovations to masonry canals were implemented considering the surrounding landscape, and parts of maintenance roads were opened to the public as a footpath.

Educational initiatives and museum exhibits are organised periodically to establish historical importance and spread awareness about the irrigation system. Elementary school students all over Japan have been learning about the irrigation system and Yosen Sakamoto's project. Yatsugatake Sogo Museum, Chino City, has a permanent exhibition of Yosen Sakamoto and his project. The exhibition includes a water intake structure model, panels showing the *Kurikoshi* mechanism, and video presentations about the history and current usage of the canals. Moreover, to appreciate the structure, a statue of Yosen Sakamoto has been erected along the Takinoyu-Segi Irrigation Canal. A picture map of Kamisuji Shinseki and the irrigation plan by Yosen Sakamoto has been designated as tangible cultural property of Chino City in 1999. The Otome Falls in the system's complex have been recognized as one of the best 100 Hometown Landscapes of Chino City.

8.35 TANZANSOSUI IRRIGATION SYSTEM

Name	**Tanzansosui Irrigation System**
Location	**Inami Town, Kako County, Hyogo Prefecture, Japan**
Latitude	**34.791**
Longitude	**135.057**
Category of Structure	**Irrigation System**
Year of commissioning	**1891**
River Basin	**Kakogawa River**
Irrigated/Drained Area	**2500 ha**

History

Located in the KakoGawa River basin, Tanzansousi Irrigation System consists of OgoGawa and YamadaGawa Irrigation Systems, constructed between the late 19th century and early 20th century. The Construction of Ogogawa Irrigation System fed on the Ogo River in 1888, while YamadaGawa Irrigation System fed on the Yamada River in 1911. After its completion, the irrigation system initially irrigated 1,012 ha of new land, and now the beneficiary area of the system is expanded to 2,500 ha.

> **TANZANSOSUI IRRIGATION SYSTEM**
>
> **Western Technologies were Proactively Employed for Constructing a Modern Irrigation Network**
>
> The Tanzansosui Irrigation System was established in the late 19th century when Japan was in the midst of modernization. Before then, it had been difficult to irrigate the highlands with conventional technology, and people managed to survive by using rainwater and growing cotton resistant to arid conditions. However, people in the area faced worsening poverty by the import of cheaper cotton from foreign countries. To cope with such difficulties, the construction of an irrigation system was initiated.
>
> Based on the suggestions of Japanese engineers who had studied overseas and foreign engineers living in Japan, a plan was formulated to install a 735-meter-long siphon duct across the valley, applying various new technologies. The cutting-edge technologies that people could not even imagine in those days were the use of the world's most advanced iron pipes transported from the United Kingdom, and the siphon principle under which water flows up again once it flows down. The completion of the irrigation system made it possible to irrigate 1,012 hectares of new land initially, and now the beneficiary area of the system is expanded to a total 2,500 hectares.
>
> One of the remarkable features of the Tanzansosui Irrigation System is an integrated system of managing many reservoirs built along the irrigation canal (81 reservoirs) and existing ponds. Moreover, this irrigation system forms a huge water-use network connecting three dams by headrace channels of about 36 kilometers built later, and irrigates about 7,400 hectares of land in the region as a whole.
>
> At present, a monitoring system by the local association has been established not only to ensure proper water management, but also to respond to sudden heavy rain showers linked to recent extreme weather events. Further, the history of the irrigation system appears in supplementary textbooks for elementary school students as part of the history education of regional development. Irrigation facilities are also used as a learning site for elderly people. Facility managers show very positive attitudes toward enhancing multiple functions of irrigation facilities. With these efforts, this irrigation system is designated as several kinds of national assets, and is widely recognized in the country.

It uses a unique concept of the integrated operation of many storage ponds with the irrigation system that stabilizes irrigation and has resulted in a dramatic increase in productivity, ensuring rural prosperity and poverty alleviation. With the canals and reservoirs built as part of the irrigation system, many irrigation ponds were also constructed. The irrigation ponds store water taken from rivers during the non-irrigation season to be used during the irrigation season and are designed to work in an integrated manner. Initially, Tanzansosui Irrigation System took in water only from the Shijimi River, a tributary of the Kako River. Therefore, going upstream to the Tojo and Sasayama Rivers, a 36-km channel was constructed to connect the three dams and form a magnificent water network for irrigating farmland of 7,404.8 ha. Under the Toban Farm Irrigation Project Plan, formulated to assume that water would be taken from the Sasayama River of the Kako River upper stream, the State-run Toban Irrigation Project was set up. With the completion of the Toban Irrigation System in 1992, Tanzansosui Irrigation System was reshaped as seen today.

In the construction of the Tanzansosui Irrigation System, local people participated in huge numbers. They provided their funds, and Western technologies were introduced in Japan, such as surveying techniques, steel pipes, and bricks. Repairs and improvements were also carried out with state-of-the-art technologies of those days. Together with the canals, the irrigation project built a large number of reservoirs. The water network, composed of canals and ponds, forms a distinctive cultural landscape of the region.

Description

Ogogawa Irrigation System originated from Kizu, Ogocho, Kitaku, Kobe City (Ogo Headworks) towards Kandecho, Nishiku, Kobe City (Neribeya Division Works). The main and branch canal extension is a length of 26.3 km and now covers an irrigation area of 1,100 ha. With its construction, 700 ha of new rice fields were developed, and 27 irrigation ponds were constructed. One of the critical features of the Ogogawa system's construction was the construction of Misaka Siphon to cross over Misaka-no-Tani, a 700 m wide and 50 m deep valley at the Shijimi River. The water line was constructed with soft steel pipes produced with cutting-edge steel-making technology imported from the British Empire. The inner lining of the tunnels was built with bricks, and the entrance was stone-lined, which is the second oldest of this kind after the Biwako Daiichi Irrigation System, built in 1887. The capital required was collated as 45,000 JPY (406 USD) from the National Treasury and 24,000 JPY (216.69 USD) from local communities.

YamadaGawa Irrigation System originated from Yamada Cho, Kitaku, Kobe City (Diversion Weir) towards Miyaga Regulating Reservoir, of the mainline of the OgoGawa Irrigation System. The main and branch canal extension is a length of 57 km and now covers an irrigation area of 850 ha. With its construction, 850 ha of new rice fields were developed, and 54 irrigation ponds were constructed. YamadaGawa Irrigation System presents a unique example of a canal tunnel built with concrete bricks. It is one of the oldest cases of concrete bricks being used for tunnel construction in general in Japan. The three aqueduct bridges along the Moriyasu Branch

Canal adopted stone arches and railings and brick walls, a combination rarely seen around Japan. The capital required was collated entirely from local communities.

Another vital aspect making Tanzansosui Irrigation System different from others is a significant number of irrigation ponds constructed together with the Irrigation System to store river water when farmland needs no irrigation to be used during the high season for irrigation. Reservoirs are usually redundant upon the completion of an irrigation system. The Irrigation System and ponds are designed to work in an integrated manner in using water. It was also known for its water distribution model. Agricultural water was secured and distributed accurately according to ‘canal-water-only hectares’ only when a vast area of complicated terrains was overcome, a considerable engineering challenge of its time.

Restoration: Over the years, with regular usage, the passage of time, and natural disasters, the system was restored and renovated several times. In 1924 after severe droughts, ways to expand the water storage capacity of the canal system were studied. From the early 1930s, some undertakings were carried out, as listed below:

- **1933: Completing Yamada Pond:** The gravity dam was built with rubble and mortar as a supplementary water source for Tanzansosui Irrigation System. The surface of the dam was covered by granite, constructed in coursed masonry *Kenchiishi,* cuboid stone. Its intake tower and 3-strand-arch spillway have beautiful decorations over them. It was a stone dam with a capacity of 233,400 m^3, a height of 27.3 m, and a crest length of 78.3 m. It was revolutionary for its time as there were only a few gravity dams constructed for agriculture around Japan before World War II.
- **1935: Soogawa Offtake Canal:** Water is taken into the conduit from the Soo River to the north of the sluice gate for the Ogogawa Irrigation System to supplement water sources.
- **1936: Agreement for taking water to the Ogogawa Irrigation System out of the irrigation period.** A decision was made that, Water may be taken in during the non-irrigation period, from September to May next year. During the irrigation period, from June 10-September 19, water may be taken in upon consultation if and when it is determined that the water source district has any surplus water.
- **1937: Yamadaike Offtake Canal:** The offtake canal, a catchment area of 58 ha, was constructed to add to Yamada Pond’s water supply.
- **1940: Kanda Channel:** To supplement the water source for the OgoGawa Irrigation System, the Nishihata River basin, a tributary of the Osawa River, was adjusted to let it flow into the Ogo River.

Many years after its completion and wartime, Tanzansosui Irrigation System deteriorated and suffered a considerable loss of water flow capacity due to poor maintenance and damage by severe floods in 1945 and 1946. This shortage in irrigation water led to a significant number of paddies being left unplanted. The facilities of the Irrigation System were repaired, and a large-scale prefecture-run repair project started in May 1949. Major facilities of the Canal were improved- the headworks were fixed, the Misaka Siphon Bridge was newly constructed, the Neribeya and Oinokuchi Division Works were converted to cylindrical proportional distributors, and concrete walls of channels were reinforced, among others.

Water Heritage

Before the irrigation system, the Inamino Tablelands, the primary beneficiary of the Tanzansosui Irrigation System, located 30-40 m above surrounding rivers, wasn’t able to utilize river water and suffered from poverty and rampant water shortage. The completion of the Tanzansosui Irrigation System led to the region’s dramatic agricultural growth. Many irrigation ponds were dug, which reduced the seasonal and regional water use restrictions, and formed a network of rivers, channels, and ponds as a unique irrigation system. This additional water source resulted in an expansion of rice fields, higher productivity and yield of rice. In 1878, the year of the Land Tax Reform, the authorities recognized the average yield per tan (approx. 991 m^2) in the six villages of the Mori District as 1.62 *kokus* (approx. 290 litres) for rice paddies and 1.10 *koku* (approx. 198 litres) for another farmland. In newly developed paddy fields, the average yield jumped to 2.23 *koku* (401 litres).

- **Rise in land prices:** The expansion of paddy fields and improved quality of existing paddies provided increased harvest, leading to higher land prices in the Inamino Tablelands. (Land price changed from 3.95 JPY (0.036 USD) to 155.7 JPY (1.41 USD).
- **Development of farming village:** Unlike other state-funded projects, Tanzansosui Irrigation System was initiated and funded by local communities for construction. They prepared a canal plan and lobbied with the state and prefecture governments for its execution. They also contributed a significant number of expenses for the project.

Tanzansosui Irrigation System used Westernized technologies and implemented the project with native techniques. This engineering marvel was a true amalgamation of those times. Some of its unique engineering features are highlighted below:

- **Misaka Siphon, Misaka Shijimicho, Miki City:** The facility is regarded as a symbol of the Tanzansosui Irrigation System. It was designed and constructed on the advice of Henry Spencer Palmer, Major General in the British Royal Engineers. The critical challenge was passing Misaka-no-Tani, a 700 m wide and 50 m deep valley where the Shijimi River goes. Misaka Siphon was the answer; a water line of 752 m in full extension was constructed with imported soft steel. The pipeline was laid on a siphon bridge (often called *Megane-Bashi*) that goes over the Shijimi River o take advantage of a vertical drop of 2.45 m between the sides of the valley in carrying water according to the principle of siphon, which runs at the bottom of the valley.

- **Neribeya Division Works, Yuda, Kandecho, Nishiku, Kobe City:** It was constructed in 1891 to distribute water from the Ogo and Yamada Rivers to Neribeya's six districts downstream. After the flood caused damages, it was restored as a hexagonal structure. The facilities have a complicated layout to let the waterfall under it before springing out from its centre for maintaining a stable flow and depth of the water.
- **The main line of the OgoGawa Irrigation System, Katsuo, Ogocho, Kitaku, Kobe City:** The part of the mainline that runs around Katsuo, Ogocho, was laid on an earthwork, 130 m in total length and 5 m in height, constructed to let the pipeline go over a valley. The earthwork was equipped with wooden conduits and tunnels to avoid interfering with an existing river at its central part.
- **Kusadani Passage, Kusadani, Inami Town:** It is believed that a narrow tunnel was excavated around the completion of the OgoGawa Irrigation System, but no further information is available. The 120-m long passage, underground farming channels and tunnels were excavated without shoring to lead water from the Sigetani-ike, an upstream pond, to the Aza-Kawakita District, Kusadani.
- **Hiraki Bridge, Mizuashi, Noguchicho, KakoGawa City:** The aqueduct bridge was built with stone, with brick walls, near Hiraki Pond, located at the end of the Moriyasu Branch Line, to go over a ditch excavated during the Edo Period. It is a single-span bridge with a length of 16.2 m, equipped with tough railings and a granite arch. With the completion of a high-standard highway, the bridge has been relocated for preservation as a symbol of the local community.
- **Tenaka Bridge, Innami, Inami Town:** The stone-built aqueduct bridge with brick walls were constructed at an intersection of the Moriyasu Branch Line and a channel. Just like the Hiraki Bridge, it is a single-span bridge length of 4.7 m, equipped with tuff railings and a granite arch. It has been out of service since around 1989 when pipelines for farmland development replaced irrigation channels. At present, it is maintained and preserved as part of Tenakabashi Park.

Tanzansosui Irrigation System in its current form and functioning after a century is due to its robust operations and maintenance system. Currently, the OgoGawa & YamadaGawa Land Improvement District, Hyogo Prefecture, operates and maintains the Tanzansosui Irrigation System, composed of headworks, dams (Yamada Pond), main and branch canals, regulating reservoirs, and division works, for 120 years, supplying water to some 80 reservoirs to irrigate farmland of 2,000 ha. At present, day-to-day operation, such as water level monitoring, regulation of diversion gates, cleaning of channels, weeding, and simple repairs, is carried out mainly by technicians. Meanwhile, telemeters and other devices have been introduced to essential facilities for streamlining the Irrigation System. To cope with the frequent extraordinary downpours, neighbourhood associations set up schemes to monitor division works and other facilities.

The Ogo-Gawa and Yamada-Gawa Land Improvement District in Hyogo Prefecture set up Tanzansosui Irrigation System Exhibition Room on its office premises for visitors to learn about the Irrigation System and understand the history of the region and the role of farmers and the Land Improvement District. In addition, the Museum of Inamino Tameike, a forum for preserving and using irrigation ponds and channels connecting them as local treasures for passing them down to the next generation, is operated mainly by local farmers and other citizens. The Land Improvement District participates in the Museum as a member organization and actively engages in its operation by, for instance, setting up walking courses.

Tanzansosui Irrigation System is a historical structure with embedded cultural and social values. In 2003, the Canal was designated as an important area based on the Survey of Cultural Landscapes conducted by the Agency for Cultural Affairs. In 2008, it was recognized by the Ministry of Economy, Trade and Industry as the Heritage of Industrial Modernization, demonstrating growing recognition of the great historical and cultural values the OgoGawa and YamadaGawa Irrigation System have. Among other awards, the system was recognised as an important site among the Hyogo Prefecture Heritages of Modernization and a Civil Engineering Heritage in 2006 by the Hyogo Board of Education. It has also been listed in the Selection of 100 Fine Canals in Japan by the Ministry of Agriculture, Forestry and Fisheries.

8.36 TENGUIWA IRRIGATION SYSTEM

Name	**Tenguiwa Irrigation System**
Location	**Maebashi City, Gunma Prefecture, Japan**
Latitude	**36.409**
Longitude	**139.036**
Category of Structure	**Irrigation System**
Year of commissioning	**1604**
River Basin	**Tone River System, Tone River**
Irrigated/Drained Area	**1571 ha**

History

In 1601, feudal Lord Akimoto planned an irrigation canal to revive the barren lands and develop new paddy fields, especially on the right banks of the Tone River. In 1604, the Tenguiwa Irrigation Canal was completed and created an abundant water supply. After the paddy fields, the water flowed back into the Hachiman River (present-day Taki River). The excavation was recorded in old documents such as the Jōmō Densetsu Zakki (1774) and the Shukin Roku (1798) and is still passed down from generation to generation.

Initially, Tone River's right bank was unsuitable for rice cultivation. The land was at a higher elevation than the Tone River, which allowed easy water diversion from the river to the main area. Akimoto requested Honda, the feudal lord who ruled over the upstream region of the river and was granted permission to establish a water intake port in the upstream river area. Farmers were exempted from land taxes for three years and helped in constructing the irrigation canal. Over time, with people's support, an irrigation canal was also built over the downstream river area.

In 1605, the Tenguiwa Irrigation Canal's water intake port was expanded, excavating a new irrigation canal. In 1610, a canal about 23 km long, including the Hachiman River, was completed. The irrigation canal excavated by feudal Lord Akimoto was called the Tenguiwa Irrigation Canal, and the irrigation canal excavated by feudal lord Ina was called the Daikan Bori. The whole area, including these two canals, is now called the Tenguiwa Irrigation System. In 1893, Japan's fifth oldest hydroelectric power plant was constructed by exploiting a drop area in Tenguiwa Irrigation System. Even today, there are traces of the brick water intake port from that time.

Description

The Tenguiwa Irrigation Canal was an unpaved water canal completed in 1604, which was 0.75 m deep, 1.2

m wide and about 3 km long. Excavating the Tenguiwa Irrigation System expanded the paddy fields as well as increased the irrigated area. The canal was rebuilt as a reinforced concrete structure 2 m deep and 5 m wide to accommodate this expansion more effectively.

Although the rice harvest yield was 900 tons, it increased to 4,050 tons in the latter half of the 18th century and the region transformed into a rich paddy-producing area. Today, the Tenguiwa Irrigation System takes its water from Tone River and supplies it to 1,571 ha of paddy fields spread throughout Maebashi City, Takasaki City and Tamamura Town.

Even now, four centuries later, people appreciate the canal's contribution. It has overcome many hurdles like natural disasters such as floods and typhoons, especially Typhoon Kathleen (1947) and Typhoon Lone (1948), which caused severe damage to the structure. In 1948, a permanent agreement was formed on the joint water intake facility between the Tenguiwa Irrigation System and the Hirose Momonoki Irrigation System to stabilize the water intake, called the Bando Ōzeki Land Improvement District Association. In 1951, the Bando Ōzeki joint water intake port was created as a disaster recovery project. The Bando Ōzeki water intake port is managed by the Bando Ōzeki Land Improvement District Association.

Water Heritage

The rice harvest in this area increased from 900 tons to 4,050 tons due to the Tenguiwa Irrigation System. As per historical illustrations and records, approximately 70 villages in the early 19th century prospered due to the Irrigation System. Engravements are a witness to people's prosperity and gratitude towards the constructors of the system. The irrigation system accelerated a new growth pattern in the region which enhanced. Farmers petitioned to rank the feudal lord Akimoto's achievements, the mastermind behind the canal system. In 1912, Emperor Meiji granted Akimoto a new rank.

The Tenguiwa Irrigation System has been around for four centuries and has contributed to a stable water supply, stable income and overall development. It was built using a unique method created by feudal lord Akimoto, a modified version of Sengoku warlord Shingen Takeda's strategy to adapt to the fast-flowing Tone River. It was named *echūwaku,* after the feudal Lord Akimoto's official rank. *Echūwaku* was a structure whereby when the Tone River's main stem level rose, the wooden frame fixed to the river would automatically weaken the water's momentum. When the water level exceeded a certain level, the water intake to the Tenguiwa Irrigation System would be controlled and guided back into Tone River's main stem. Due to the unique technology, even if a flood occurs on one side of the Tone River, the land on the opposite side would remain undamaged.

Additionally, paper lanterns were used to measure differences in elevation between the land and the Tone River, which was frequently used in the early and mid-17th centuries. A rare form of measurement was when the Tenguiwa Irrigation System was excavated. *Chōken Inari* is a hillside shrine and a benchmark point of reference for measuring with paper lanterns.

Since 1990, an annual festival has been held honouring the Feudal Lord Akimoto, and both he and the Tenguiwa Irrigation System are held in high regard by the people. The irrigation system became the flagbearer of many cultural practices and fairs for years to come. Since Tenguiwa Irrigation System was completed, festivals have been held, and farmers offered rice to feudal Lord Akimoto's grave along with other activities such as Yabusame (horseback archery) and the traditional *Shishimai* Dance at the shrine to show their gratitude to Akimoto, the feudal lord who enriched their lives. Even today, 400 years later, this festival is held to honour him. At this festival, the Mayor of Maebashi City dresses up as the feudal lord and leads a warrior procession as they travel around the town and present their gratitude. In 1776, the farmers built a stone monument to show their appreciation for feudal Lord Akimoto. It is a rare sight in Japan, and its high historical value led to its recognition as a cultural asset of Gunma Prefecture in 1950. The history of the Tenguiwa Irrigation System is taught in elementary schools in Maebashi City, and students visit the site for educational reasons.

8.37 TERAGAIKE POND AND TERAGAIKE WATERWAY

Name	**Teragaike Pond and Teragaike Waterway**
Location	**Kawachinagano Town, Osaka,Japan**
Latitude	**N34.46541208**
Longitude	**E135.5595973**
Category of Structure	**Water Storage and Conveyance Structure**
Year of commissioning	**1649**
River Basin	**Ishikawa River, in the Yamatogawa River system**
Irrigated/Drained Area	**25 ha**

Teragaike Pond and Teragaike Waterway

— New Rice Field Development and Teragaike Pond/Teragaike Waterway —

Teragaike Pond stores valley water for agricultural purposes and is the largest reservoir in Kawachinagano City, Osaka Prefecture. It was built in 1649 for the purpose of developing new rice fields. Its water source is located at the headgate on the Ishikawa River, six kilometers to the south. The 8.2-kilometer-long Teragaike Waterway was built along it.

Development of the new rice fields was led by Yojibei Nakamura. Since the development resulted in a 100-fold increase in crop production, Nakamura has long been admired for his achievement and, even now, a memorial service is held annually on the anniversary of his death. The pond's construction resulted in some land being submerged; however, the owners of such lands received replacement land and traces of them remain as exclaves scattered throughout the city.

Although the benefits of Teragaike Pond and Teragaike Waterway have been decreasing due to increased housing development and urbanization, they still play an important role in providing a stable supply of agricultural water to the surrounding area. In recent years, Teragaike Pond has been further developed as a municipal park, to serve as a place of relaxation for the citizens, providing a venue for local festivals, illumination events and many other activities.

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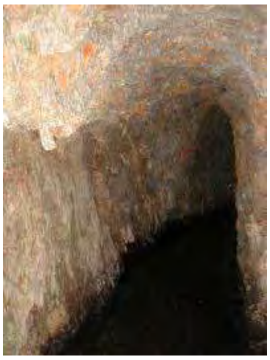
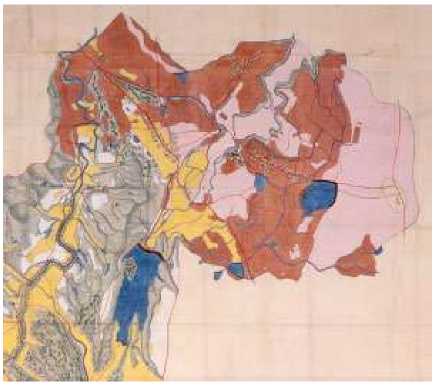
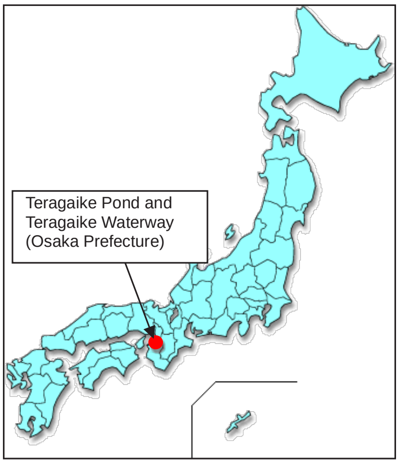


Tunnel at Teragaike Waterway

Teragaike Pond



Picture after the development of new rice fields in 1690



Location map in Japan

History

Construction of Teragaike Pond and Teragaike Waterway was completed in 1649 under a municipal plan to develop new rice fields in Ichimura Village. The original intention was to redirect water to newly reclaimed fields, by expanding a small pond into a much larger one by utilizing the natural terrain. The water source for the pond is the Ishikawa River, which is located 6 km to the south.

At that time, the Headmaster of Uwahara Village, Yojibe Nakamura, proposed to the Ryoshu (the ruling lord) a development plan for new rice fields. According to a document from that era, the Ryoshu handed over this newly developed agricultural land to the people whose original land was used to make the pond, as part of the aforementioned expansion work. They were also to be compensated if a bank of the pond failed. The construction of the Teragaike Pond was a topic in a supplementary textbook for elementary schools in the city. Its construction took 16 years, from 1633 to 1649.

Description

Teragaike Pond is the largest reservoir in Kawachinagano City, Osaka Prefecture. It is located on the Akamine Plateau in the northern part of the city. Teragaike waterways run from the Ishikawa River, the water source, to beneficiary areas via Teragaike Pond. Teragaike waterway is a general term for the waterways that are being drawn upon. Among the waterways, the section from the Ishikawa River to Teragaike Pond is the focus of the WHIS and is referred to as Teragaike Waterway.

It has been stated that a total of 40,000 people worked continuously on the project. The slope of the 8.2-km-long waterway was measured at night under the light of lanterns, while during the day the waterway was dug. Upon completion, crop production increased 100-fold. Owing to this accomplishment, Yojibe Nakamura has been admired by the villagers ever since and each year they hold a memorial service on the anniversary of his death. The new sections of land given to those who lost their land to the construction of the pond are scattered throughout the city as exclaves and still retain traces from that time.

The three most popular ponds in southern Osaka Prefecture are said to be Teragaike, Sayama and Izumi Kumeda Ponds (in that order). Teragaike Pond is also widely known for its depth. Although the number of beneficiary areas has decreased due to residential development, it still plays an important role in supplying agricultural water to local fields. Furthermore, the zone around Teragaike Pond has been developed as a municipal park and citizens enjoy it as a place to relax and as an interactive space.

(i) Specifications of Teragaike Pond

- Full watered area: Approximately 13 ha
- Water storage capacity: Approximately 600,000 metric tonnes
- Perimeter: 2,197 m
- Embankment height (north side): 15 m
- Embankment length (north side): 126 m

(ii) Specifications of Teragaike Waterway

- Length: Approximately 8.2 km.

From its construction through to the present, many renovations have been carried out on Teragaike Pond to maintain its function, mainly around its sluice gates and embankments. As the original metal parts used in the sluice gates were made of iron and tended to rust quickly, copper ones replaced them in 1744. In August 1854, due to a severe earthquake, about 34 m of the embankment was damaged. 945 workers took part in the repair work. A sticky soil, known as hagane, was used to reinforce the embankment and resist high water pressure.

A structure called a “throwing hole” was adopted for the intake of water to the reservoir, which enables a large pond like Teragaike Pond to take in water according to the height of the water’s surface. This system is said to have been first adopted in the nearby Sayama Pond in around 1600, and the present-day Teragaike Pond has the same structure.

Water Heritage

Teragaike Pond and Teragaike Waterway were constructed to develop new rice fields (referred to as shinden) in Ichimura Village by expanding the pond near Oyamada Village. Crop output after the development of the new rice fields grew about a hundredfold, increasing from about 6.72 koku* to approximately 615.47 koku.

This growth is described in a local history book, The History of Kawachinagano City, Volume 2, which states: “As a result of Teragaike Pond’s completion and the full use of its irrigation function as a reservoir, the irrigation conditions of the land have improved. In addition, the number of lands with intermediate grade and stable production of rice and grains/vegetables/fruits has increased significantly. In other words, the completion of Teragaike Pond contributed greatly to the improvement of crop productivity in the area.”

Hence, Teragaike Pond and Teragaike Waterway are public works facilities symbolizing an important historical stage of transformation in the development of irrigated agriculture in Japan.

The owners of land submerged due to the pond’s expansion work received replacement land in the newly developed area. A document dated April 11, 1649, sent to the residents from the village that would be newly developed to the village that would be submerged, still exists. The document states that, in addition to receiving replacement land due to the pond’s expansion, if the new bank of the pond broke and rice fields were damaged, it was agreed that the rice farmers would receive compensation for the rice that could have been harvested that year and that the damaged areas of the rice fields would be fixed.

Due to the achievement of developing the new rice fields, Yojibe Nakamura was gifted with land and promoted to the position of Acting Administrator. His achievements led to increased food production and the development of the village. He is still honoured today. A memorial service is conducted at his tomb every year on the anniversary of his death, August 8, and several monuments were erected on the embankment to commemorate him and his achievements.

The construction of the Teragaike Pond is an extension of the original small pond. The east and west sides of the pond utilized the hills on both sides as banks. The north and south banks, which are shorter in length, were constructed using soil to form a larger pond. Some village neighbourhoods were submerged due to the pond's expansion, which shows that developing the new rice fields was very much a priority at the time.

The History of Kawachinagano City, Volume 2, states: "We want to focus on the expansion and improvement of Teragaike Pond to secure the irrigation to the newly developed rice field. To maintain a good production environment in the newly developed rice field, the Zeze Local Domain was actively involved in creating irrigation ponds. In this area, the development of the new rice fields and construction of irrigation ponds are inextricably linked."

Following the intensive development of the new rice fields, earth and sand flowed from the surrounding hills into Teragaike Pond, which resulted in conflicts between the villages. As a result, they decided to install 20 stakes on the east side of the pond and 19 on the west to create a boundary and exchanged a document specifying the preservation and maintenance of the pond.

Teragaike Pond was filled with water between August and February of the following year. As an irrigation fee, about 4 koku of rice were customarily sent from Ichimura Shinden to Uwahara Village every year. Teragaike Irrigation Rules (1659) has various provisions regarding the diversion of irrigation water, and it describes penalties for violating the provisions.

Teragaike Pond was built on the land of Oyamada Village, and the owners of the submerged land received replacement land in Ichimura Shinden. As a result, the bottom of the pond became the territory of Ichimura Shinden. There were some Oyamada exclaves in Ichimura and some areas remain exclaves to this day.

With recent urbanization, the beneficiary areas of Teragaike Pond and Teragaike Waterway have been decreasing but the current state of the pond is being maintained, with renovations carried out by managers and beneficiaries for generations, and the pond is still providing a stable supply of irrigation water for agricultural lands. The current beneficiary area is estimated to be approximately 25 ha. The present Teragaike Waterway has a concrete three-sided structure along the entire line, and most of it is the present structure since the existing soil waterway was renovated in the 1970s.

About its management, the Uwahara Irrigation Association and the Nosaku Irrigation Association are responsible for the waterway from the intake point from the Ishikawa River to the dropping point at Uwahara, while the Teragaike Irrigation Association covers the waterway from Uwahara to Teragaike Pond. These three associations form an irrigation union, known as the Teragaike Pond and Waterway Union. They built the monument.

In addition, the area around Teragaike Pond is equipped with promenades and sports facilities. It is also maintained as a municipal park and is used as a place for citizens to relax and enjoy walking and running, etc.

8.38 TERADANI IRRIGATION SYSTEM (CANAL)

Name	**Teradani Irrigation System (Canal)**
Location	**Iwata City, Shizuoka Prefecture,JAPAN**
Latitude	**N34.77781**
Longitude	**E137.83540**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**1590**
River Basin	**Tenryu River**
Irrigated/Drained Area	**1504 ha**

History

The Teradani Irrigation System was built in 1590 and pioneered innovative irrigation technology, which integrated flood control and water utilization in large rivers. The technology had a significant impact on the development of irrigation in Japan. The system consisted of an intake, the main canal, some lateral canals, and an operating organization.

The irrigated areas served by this canal system were along the Tenryu River, which had sufficient flow

throughout the year. However, the farmers could not use the water and suffered from shortages. They had to take water from a small stream at the foot of the hill, which restricted the expansion of farmland due to the frequent flooding of the Tenryu River that changed course almost every year, depositing large amounts of sand and gravel.

The project to build the canal began at the behest of Tokugawa Ieyasu, the regional ruler who later became the commander-in-chief of the Edo shogunate (military government), to achieve economic growth through agricultural development. Under his orders, his vassal Ina Tadatsugu made the plan, and Hirano Shigesada, a magistrate, started the construction. They built a levee to separate the farmland from the floodplain, and the main canal, 4 m wide and 12 km long. The canal was completed in 1590, two years later after work started. It irrigated 2,000 ha of rice paddies, including 400 ha of newly opened rice fields. In general, overflow frequently occurs at canal intakes from large rivers during flooding. The intake in the project was a combination of a levee and a culvert buried across it, a new method in Japan. The levee was built over the culvert to protect the farmland from floods. The installed culvert was 4 m wide, 2 m high, and 21 m long, with sufficient capacity to irrigate the target area. After its completion, the revolutionary system of combining levees and culverts received high acclaim, and the Edo shogunate applied the method to many other projects.

With a series of minor improvements, this design concept was widely used for about 300 years until cement and bricks from Europe became popular in Japan. The Teradani Irrigation System pioneered the construction of large wooden culverts that accelerated Japan's agricultural development.

Hirano Shigesada also organized Igumi, a farmers' cooperative, to ensure smooth water distribution to 73 villages and maintain and manage the canal. Igumi spent a great deal of money and labour to relocate the intake upstream after the river changed its course drastically due to flooding. Today, the irrigation system takes water from a hydropower reservoir and is free from flooding problems. The Teradani Irrigation System Land Improvement District, the successor of Igumi, manages the irrigation canal, which has played a vital role on the same route since 1590 while earning respect for its contributions and history from the residents.

Description

Teradani Irrigation System attributes its success to the construction of a levee to control flooding of the large river and the installation of a large culvert that allows water intake while maintaining the function of the levee. Combining these two structures enabled steady water intake for the first time. The Edo shogunate highly valued the technology developed by Ina Tadatsugu and used it in many important projects throughout eastern Japan. The application of the new technology contributed to the development of rice paddy farming along large rivers, and it also greatly improved farmers' economic conditions.

This irrigation system adopted a large wooden culvert buried across a levee to protect farmlands from the flood-prone large river. The design was state-of-the-art. The wooden culvert installed at Teradani irrigation was 4 m wide, 2 m high, and 21 m long, an unprecedented structure in Japan at that period.

Teradani Irrigation System did not only solve the constant water shortage in the existing 1,600 ha of rice paddies but also opened 400 ha of new rice paddies, irrigating a total of 2,000 ha of arable land. It led to the establishment of 7 new villages, significantly improving the food production capacity and stability of 80 villages. Although the surrounding areas experienced food crises due to drought every ten years, in the 17th century, the irrigated area did not have a record of famine. The farmers in the irrigated area did not suffer from drought at all.

At the time of the construction of this irrigation system, most rivers in Japan had flood problems. People did not have the means to utilize water stably despite the presence of a large river nearby. It hindered the development of agriculture. This irrigation system was the first to apply the innovative combination of preserving farmland with levees and installing a large-sized wooden culvert to ensure sufficient water intake and levee functionality. Many examples of its application followed in Japan.

The beneficiary area of the Teradani Irrigation System used to be the floodplain of the Tenryu River. There were many oval-shaped and irregular-shaped rice paddies because of the undulations on the ground surface. Moreover, some farmland could not get irrigation due to differences in elevation. These problems resulted in a large area of unused land and low productivity in farming.

In 1891, Suzuki Urahachi, the secretary-general of the Teradani Irrigation System, persuaded farmers to readjust 43 ha of farmland, the first to be done in the country. It involved levelling the ground, rearranging the canals and adjacent roads in a grid pattern, changing the shape of fields into rectangular ones, and expanding the plots through an exchange of property rights. The readjustment not only increased the cultivated land area but considerably improved productivity. The central government officials visited to observe the improvements. They later enacted the Farmland Readjustment Act and used the highly-regarded readjustment in the area as an exemplary model for the nationwide expansion of farmland readjustment.

Generally, farmers will not exchange ownership of farms if water availability differs from place to place. One of the success factors in this farmland readjustment was the sufficient water supply to every farmland provided by the canal system. We could say that productivity improvement would not have been possible without the Teradani Irrigation System.

The canal was constructed by reshaping and enlarging existing small streams. This method minimized impacts on the environment and reduction of farmland. The design and construction of the system contribute to preserving the beautiful rural landscape.

The culvert adopted for the intake had an outstanding feature in terms of size. The cross-section was 4 m wide, 2 m high, and 21 m long, something that never existed before based on historical records. The culvert was constructed without nails, using an elaborate combination of numerous wooden pillars and boards. It was an outstanding and unprecedented work to build a structure that withstood the currents of a large river using wood alone in 16th century Japan, where modern engineering technology was still not developed.

The intake location was carefully selected to ensure a stable water intake. To avoid sedimentation at the opening of intake structures during flooding and maintain the intake function even during drought, the appropriate intake location was chosen at the cut bank closest to the streamflow on a wide river. The main canal was constructed on the route that allowed maximum channel gradient to minimize alluvial deposits. The first intake constructed in 1590 remained functional for 168 years. However, the intake location needed to be relocated upstream as the Tenryu River changed course. The farmers spent a lot of money and labour to move the intake in 1758, 3 km upstream from the original location. In 1884, it had to relocate again 5 km upstream. The selection of the appropriate intake location used the same criteria as the initial construction in 1590.

Water Heritage

This irrigation system was constructed approximately 430 years ago to supply water to 2,000 ha of rice paddies. Its capacity could fully meet the water demand according to existing historical documents. Even 430 years ago, they could measure the gradient accurately and build the canal properly.

At present, the beneficiary area is approximately 1,500 ha. Although the earthen canal was replaced with a concrete-lined structure after World War II, it remains on the original route maintaining its 7.4 m^3/s capacity. It continues to have a vital role in local agriculture by providing a water supply. One of the success factors is the appropriate route selection during its construction.

In the 20th century, dams were constructed upstream of the river, and sediments were trapped in the dam reservoirs, resulting in a significant drop in the riverbed downstream and making it difficult to draw water from the river. Therefore, the intake structure was relocated twice upstream, and water is now taken from the dam reservoir for power generation. It has restored stability to the water intake. During the second relocation, some upstream sections of the canal became a shared structure with domestic and industrial water. Teradani Irrigation System Land Improvement District currently outsources the operation and management of the shared sections to a local public corporation that supplies domestic and industrial water.

Since its establishment 430 years ago, the farmers' cooperative, an independent and democratic organization, has been operating and maintaining the irrigation system. Farmers share the necessary costs equally according to their acreage. The canal was rebuilt from an earthen canal to a concrete-lined structure which ensured safety and reduced maintenance costs. The farmers are satisfied with the results immensely. Though the Teradani Irrigation System Land Improvement District is an organization for irrigation, it also strives to work with the local community. Every year, many high school students studying agriculture are invited to learn about irrigation. The staff gives lectures on water management for irrigation and demonstrates the facility's operation. This activity is appreciated highly by high school students aspiring to become farmers as a practical, hands-on learning experience.

Also, the Iwata City government, which has jurisdiction over the beneficiary area, created a supplementary textbook in cooperation with the organization. The history and accomplishments of the Teradani Irrigation System are taught at elementary schools every year. It has significantly helped residents recognize the value and importance of the irrigation system. The farmers in the beneficiary area never forget their gratitude to the forested area upstream, the water source. The organization donates a portion of the harvested rice to public organizations in the forest area every year. The donated rice is used in school lunches and other purposes.

Furthermore, Teradani Irrigation System Land Improvement District has been paying voluntarily for the conservation cost and maintaining 45 ha of forest for more than 60 years. In 2003, it received the prestigious Merit Award in Water Resources from the Minister of Land, Infrastructure, Transport, and Tourism for its conservation efforts. Moreover, we received the Prime Minister's Award for the 2022 Greenery Promotion Movement. The local people created and passed on a unique tradition of expressing gratitude to the founder, Hirano Shigesada. Celebrations such as the Iwata City designated intangible folk cultural property, Kamo Dainenbutsu, a ritual of playing taiko drums accompanied by flutes and gongs and singing songs dedicated to the founder and offering prayers to the local deity for a good harvest, have been held for more than 250 years. In addition, the Teradani Water Festival is held annually on the founder's death, and the local people offer prayers and present offerings to him.

8.39 TERUIZEKI IRRIGATION CANAL

Name	**Teruizeki Irrigation Canal**
Location	**Ichinoseki City , Iwate Prefecture , Japan**
Latitude	**38.990**
Longitude	**141.109**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**1180**
River Basin	**Kitagami-Gawa River system (Sub Basin: Iwai-Gawa River basin)**
Irrigated/Drained Area	**1073 ha**

History

The Teruizeki irrigation canal, excavated over 800 years ago (1180 A.D.) and named after sovereign ruler Terui, is a UNESCO world heritage site. Traces were found initially during the excavation project of the historical monuments and sites of Hiraizumi, which achieved UNESCO world heritage site status in 2011. The irrigation system had a significant influence on the culture at the time. The origin of the Teruizeki irrigation canals dates back to the 12th century when the canals were developed to supply water to the nearby ponds in Buddhist temples. Severe droughts in 1623, 1643 and 1649, caused extreme distress among the local farmers and residents. To manage the situation, the sovereign rulers reduced the land taxes and provided emergency rice supplies. In addition, a large-scale expansion of the canal system was executed. The innovative idea of surveying at night by lining up lanterns along the canal route was adopted for straight and clear viewing. Over the decades, repairs and developments have been carried out by the land's rulers to countermeasure droughts. These developments over the years led to the construction of the canal with periodic modifications and have contributed to the fully operating Teruizeki irrigation system, which is still in use today.

Description

The total combined length of the eight canals is approximately 64 km and uses a diverse range of irrigation facilities, including unlined canal, stone canal, concrete canal, tunnels, elevated fumes, headworks, regulating gates, spillways, elevated flumes, inverted siphons, diversions and aqueduct bridges to distribute the appropriate amount of water to irrigate 1,073 ha of farmland. The system can be divided into eight principal canals, each maintained by an assigned channel guard, sluice guard and construction planner.

The Teruizeki irrigation canals are a cultural mark in Japanese irrigation history. Starting as a water supplier for the lakes of Hiraizumi, these rare underground water channels developed into a whole network of irrigation canals. In fact, up until the year 1600, only 500 ha of paddy fields were seen in the entire area. Following the canal's large-scale repairs, over 1,500 tons of rice was annually yielded from a total irrigated area of 830 ha. According to the records, in the face of severe droughts, further canal expansions were undertaken to supply water to inaccessible areas to enhance rice yields. Even now, the whole community comes together to manage the intricate system of canals and related facilities, which supplies water to 1,100 ha of paddy fields every day. The volume of water that flows through the canals varies from 1.023 m^3 to a maximum of 4 m^3 and even maintains an environment for underwater creatures. Above all, the water canals contribute to the natural scenery of the land, the nucleus of the natural environment.

Water Heritage

Although Teruizeki irrigation canals were primarily used to provide irrigation water, they also provided fresh drinking water and prevented fires. In the 1900s, the canals propelled water to turn into approximately 50 water turbines. These turbines were primarily used to mill rice and flour, contributing to the agricultural development and economic growth of the area.

The techniques used to construct the Teruizeki irrigation canal system were a starting point for the future development of canals in Japan. It was a significant technological achievement of its time. The sovereign ruler himself diligently examined and researched the river's course and executed the plan to build the irrigation system. The process of deciding a logical route to construct the confluence was determined by conducting various experiments such as placing lanterns along the side of the river at night to measure the incline and flow of the water. Eventually, an underground canal or *Anasaki* 800 m in length was dug from the connecting river. Without any modern tools, hand tools (chisel and hammer) were used to dig through hard rock. Advanced mining techniques were adopted later to speed up the progress, such as heating rock with fire, cooling it with water to crush it, and installing an inclined shaft in the tunnel at 60 – 80 m intervals to dispose of built-up gravel and dirt. Remains of these shafts can be found today in several sites. By the year 1775, 1,032 ha of land received water from the canal system.

Further improvements began in the year 1952, with the construction of stone-lined canals to protect the entire structure of the irrigation system. The canal became a vital lifeline, delivering water to the paddy fields in nearby villages and thus reducing poverty. The same canal continues to carry water to irrigate the area even after 800 years.

It was a cultural structure whose construction and even maintenance today reflect the Japanese traditions. In 1661, large-scale repairs were undertaken to channel water to the north. In ancient times long periods of drought created water scarcity. Therefore, the sovereign collaborated with the Buddhist priests of the temples to dig an underground tunnel 1,200 m in length through hard rock. Innovative methods of construction were used to complete the excavation as quickly as possible. An ancient Japanese device made of rope called *Mokko* was then used to carry the chiselled earth out of the tunnels by two labourers at a time. The combined efforts and endurance of over 3,000 labourers finally resulted in the excavation in 1663. After the excavation work was completed, a traditional cleaning tool called *Bori* brushed the remaining dirt and soil out of the tunnels. The same practice to clean tunnels was used for around 400 years. *Bori* is made by tying the vines of a long tree to the head of the Japanese cedar branch to resemble a mop. The tradition of using a *Bori* to sweep through the tunnel was unique and is not thought to be practised anywhere else in the world.

For hundreds of years, the protection and the structure of the canals have independently been overlooked by the area's residents. The Terui Land Improvement District currently maintains the Teruizeki irrigation canal system. The administrators of the canal system consist of members from the various associations, unions, and partners who use the canals. The channel guards are responsible for maintaining the facilities and the water condition, particularly in natural disasters and heavy rain. In emergencies, a communication system is implemented to avoid disasters. Similarly, the sluice guards watch over the regulating gates and spillways during heavy rain or typhoons.

Every spring, farmers and non-farmers from every household in the area gather, dredge and clean together to the bottom of the canals. The villagers show gratitude and, in turn, participate in the community maintenance of the Terui irrigation canals. Other maintenance activities are organized by a committee twice a year in spring and fall to ensure smooth water distribution to the community.

Furthermore, the silk industry was just one of the few industries that prospered from utilizing the Teruizeki canals, with one of the first completed silk mills in 1911. The silk mill operated from one of the Teruizeki canals, which used the falling water to generate 100 kW of hydroelectric power. Francis turbines were also imported from Germany to reach the full potential of the industry. As a result, the Teruizeki irrigation canal was innovative in supplying energy to the local factories and mills.

The Teruizeki irrigation canals contribute to local agriculture and regional development, which contributes to the nature, scenery, and culture of the area. Due to its significance, in 2006, it was inducted into the best 100 irrigation canals in Japan. The canals are also introduced as a case study in the Japanese curriculum. The multifunctional agricultural canals have an outstanding universal significance even today. The Teruizeki irrigation system shall be preserved in the future, with its community-based solid management and maintenance mechanisms.

8.40 TOKIWAKO RESERVOIR

Name	**Tokiwako Reservoir**
Location	**Ube City, Yamaguchi Prefecture, Japan**
Latitude	**33.950**
Longitude	**131.283**
Category of Structure	**Water Storage Structure**
Year of commissioning	**1698**
River Basin	**Tsuka-ana-Gawa River**
Irrigated/Drained Area	**17ha**

History

Lake Tokiwa is an artificial water structure made by an embankment in a desolate plain. Water has been stored not from the river but by rainfall. While this region didn't have any soil problems and the lake was shallow, its water quality was controlled. For more than 245 years, rainwater was pooled to form a pure freshwater lake for irrigation purposes.

In the face of severe droughts and uncultivable lands, feudal lords implemented new farm policies and constructed an embankment for a lake at Tokiwa in 1698. In addition, related basin complexes, irrigation channels and cadastral surveys were completed in 1701, enabling approximately 440 ha of paddy irrigation.

Later on, in the 20th century, the development of modern industry in the Ube area brought electric power, railways and harbour facilities mostly centred on coal mining that required securing a water source. Coal mining and industrial companies along the eastern coastline also struggled to have water. Therefore, in 1938, Yamaguchi Prefecture was planned, executed, and in 1943 completed the diversion of a river running through the city to Lake Tokiwa, an approximately 800,000 m^2 lake, as a project to improve its water conditions. The objective was to convey water to the industrial belt on the eastern side of Ube City, making Lake Tokiwa a median retarding basin. At that time, water utilization rights for Lake Tokiwa consisted of the distribution of 7 m^3/s for agriculture and 13 m^3/s for the industry.

Subsequently, Lake Tokiwa changed from agricultural applications to a retarding basin for industrial waterworks. While water accumulation depended solely on rainfall in olden times, it became possible to prevent the lake from drying up due to drought, which cut off irrigation.

The increase in population around the lake in recent years and the raising of swans, pelicans, and other fowl affected the lake water quality. Recently, the water quality has improved due to the dredging of the lake's bottom and installing a public sewage system for the area by Ube City, among other public works. The lake is known for its beautiful landscape, even mentioned in manuscripts from 300 years ago. The embankment of Lake Tokiwa never collapsed, as had occurred at basins elsewhere, and even now automobiles ride on top of it. Also, two originally built water canals are still in use today, albeit upgraded.

Description

Lake Tokiwa is the largest lake in Yamaguchi Prefecture, located in the southeast portion of Ube City (9.4 m embankment height, 65 m embankment length, 3800 m^3 embankment area, 3,767,700-ton reservoir capacity, 809,000 m^2 reservoir surface area, 3,450,000 m^2 catchment area). The lake spans approximately 1.8 km north-south and 1.3 km east-west, with the main basin running roughly north-south narrowing to a point northward. The shadow created by the long cape formed by this inlet and the forest around it changes the character of the expansive lake surface, giving it profound beauty. Lake Tokiwa even today irrigates 94 beneficial rice farm households over an area of 17 ha.

In 1943, efforts to improve irrigation from Lake Tokiwa led to the diversion of the Koto-Gawa River to the lake, turning it into a retarding basin and making its water available for industrial use. Originally an artificially embanked reservoir with rainfall as its principal water source, it was a pure freshwater lake. However, the water quality changed due to the introduction of KotoGawa River water, pelican husbandry and its use as a habitat for waterfowl. Even now, there are over one hundred species of wild birds near the lake, which has become a mecca for birdwatchers. Ube City, badly polluted with soot and dust from the post-war recovery, implemented flowering drives to overcome adversity. Sculptures were also built, and, in 1961, the Open-air Sculpture Exhibition was held in Tokiwa Park, the first of its kind in Japan. Even now, an abundance of greenery and flowers line the lake's edge, and the area is the venue for *UBE Biennale* (modern Japanese sculpture exhibition) and other sculpture shows. Lake

Tokiwa also has a 5.7 km track around it for walkers and joggers, adding to the variegated functionality of a beloved municipal park.

Lake Tokiwa, the heart of Tokiwa Park with an area of 1,894,000 m^2, aims to become an advanced, model park combining the environment with art, sports and welfare. It is a centre for sports where flowers abound, a showcase for sculptures and its zoo, recently renewed to provide a natural habitat for monkeys from around the world, and walking courses as a place of relaxation.

Water Heritage

Originally a pond for artificial irrigation built by feudal lords to develop new rice paddies and devastated farming communities in the surrounding area, Lake Tokiwa is presently the centrepiece of Tokiwa Park, which abounds with greenery flowers and sculptures. It is often referred to as the *Reservoir that turned barren lands into a food basket feeding four times as many people as the population.* The construction of the embankment, 1695 to 1698, was accompanied by an irrigation channel serving as the water source of the lake, and new farmland was created on its southern flank. The embankment's length and width are 18 m and 14.4 m, each while its height is 18 m on the interior and 26 m on its exterior. Only this embankment keeps the lake's water in.

The improvement in the food situation due to this lake was remarkable. *Koku* is the Japanese unit for measuring volume and is equivalent to the rice a grown-up consumes in a year (1 koku is approximately 150 kg of rice). The development increased the production of rice in this area from 2,638 *kokus* to 8,369 *kokus*. Considering that the local population was 1,200 people at the time of the development, the impact of an additional 5,000 *koku* yields was phenomenal. Moreover, the lake was not connected to any sizable rivers and has irrigated the land for 245 years using rainfall as the primary water source, which was only possible because of the geological condition. At the same time, planning and a scientific approach followed while executing the lake formation- the lake was designed to be shallow and wide.

Lake Tokiwa is a vital water facility that saved Ube city from deprivation and poverty and now has become an emblem of natural landscape and beauty. The volume of rice produced in Ube Village before the construction of Lake Tokiwa was 400,000 kg and reached 1,250,000 kg by the end of the Edo Period because of the lake. At that time, rice was the primary meal in Japan as the main source of nourishment; therefore, the annual consumption volume per capita was 150 kg. Lake Tokiwa raised the yearly production by 5,000 portions.

The largest lake in the prefecture was built, enabling the irrigation of rice paddies covering approximately 4,400,000 m^2. The water was distributed using a mesh-pattern irrigation system that boosted annual food production to feed about 5,000 more people. Considering that the population of Ube at the time of the embankment's construction was only about 1,200, it was a provident, innovative achievement.

The lake formed by the embankment has withstood over 300 years as the foundation of agriculture and industry in Ube City without any major accident or collapse. The aesthetic value of the lake is beyond comprehension. Several pieces of literature have been written about the lake's beauty and charm. Today, water utilization is mainly managed by the Lake Tokiwa Water User's Association and local affiliated companies. However, because it has been used as a scenic public park for over a century, its natural environment has been preserved relatively well as a lake near an urban area. The whole system is financed by water utilization fees paid by Association members.

Ube's population exploded from a village to a city due to coal excavation, mined near Lake Tokiwa. The Coal Memorial Hall was built in Tokiwa Park, where the entire lake can be seen from the top of the tower made from a converted coal derrick of the Edo Period.

Even though the structures' current utilization as an irrigation facility is continuously declining due to increased population and industrialization, roughly 440 ha of old rice paddy area on the southwestern side of Lake Tokiwa became a residential area. However, an area of about 17 ha consisting of 94 beneficiaries is still using the lake and benefiting from the traditional knowledge of their predecessors.

8.41 TSUJUNYOUSUI IRRIGATION SYSTEM

Name	**Tsujunyousui Irrigation System**
Location	**Yamato Town,Kumamoto Prefecture , Japan**
Latitude	**32.682**
Longitude	**130.994**
Category of Structure	**Irrigation System**
Year of commissioning	**1855**
River Basin	**Sasahara River**
Irrigated/Drained Area	**106.9 ha**

History

The Tsujunyousui Irrigation System, a group of irrigation facilities, including the Tsujun Bridge, the largest stone-built arch aqueduct bridge in Japan, was constructed between 1852-1855 to develop new rice fields in seven villages (4.2 ha) situated on the Shiraishi Plateau and Hata Village which was then called Minamide, an area surrounded by rivers. Local people depended entirely on spring water and suffered from the Great Tenpo Famine (1836 to 1841). Completed before pre-modern times, the Tsujunyousui Irrigation System can be considered a *culmination of agricultural engineering for rice farming developed in Japan*. Therefore, Tsujunyousui Irrigation System was conceived to mitigate their distress.

Description

In response to local communities' distress, the Tsujunyousui Irrigation System was constructed. The irrigation facilities take in water from a river, composed of the main canal (some 15 km in extension), branch canals (29 lines of 35 km in extension), and the Tsujun Bridge, an aqueduct bridge equipped with siphons, as well as a check gate (Honide-Dori Check Gate), a wasteway (Mizu-Otoshi Waterway), and other structures. The facilities are best characterized by engineering techniques adopted to sublimate one of the largest stone-built arch bridges in Japan into an aqueduct bridge for overcoming geographical challenges of rivers and small dissections tangling together in a complicated manner, and by the central canal composed of two canals laid one above the other for efficient distribution and repeated use of water.

Recent research shows that the project was carried out by the *Tenaga* (a unit of broad area administration consisting of farmers, similar to the present municipality) and formulated between the county and the village as a leading entity. According to the research, Yasunosuke Futa, *Tenage's* chairperson and Senior Village Headman played a leading role in estimating construction expenses, formulating a repayment plan, examining the technical

Tsujunyousui Irrigation System

Japan's Largest Stone Arch Bridge Irrigating a Plateau Plain

The Tsujunyousui Irrigation System was constructed in 1855 to irrigate the Shiraito Plateau plain, where people had suffered from chronic water shortages and even famine. Thanks to this irrigation system, the paddy field area in a plateau plain of that time increased by more than three times.

The Tsujunyousui Irrigation System has one of Japan's largest stone arch bridges called the "Tsujunkyo Bridge". Initially, Japanese engineers learned technologies for building a stone arch bridge from Dutch engineers during the period of national isolation, and, many stone arch bridges were built in Japan afterwards. The technology of building stone arch bridge was originally from the West, but this irrigation system used excellent technologies, including high-quality plaster, diversion work to prevent excessive intake, and two-tiered conduits allowing repetitive uses of water. It can be said that these techniques were a fusion of Japan's original cutting-edge technologies before modernization. Due to their rareness and importance, Tsujunkyo Bridge has been designated as a nationally important cultural property.

From a perspective of water use, the system ensures equality in water distribution. At a time of an extraordinary drought, water is delivered by day and night shifts between the upstream area and the downstream area in accordance with the "day-night alternation intake" rule. It is worth noting that a management organization was set up by the regional people right after the system was built, and the facilities have been maintained for about 160 years in their original form.

In addition, conservation and maintenance of the facilities have been promoted from the environmental and landscape aspects, not just from the irrigation aspect. The beautiful view of water flowing from the sediment outlet of Tsujunkyo Bridge attracts many tourists, and a special museum for this bridge has also been built. Moreover, environmental conservation activities have been promoted, and a new-breed of fish discovered in the area was named after Tsujunkyo Bridge. An integrated management system by beneficiary farmers and neighboring residents is now being established for future maintenance and preservation.


Beautiful tailwater


Shiraito Plateau

viability of construction of the Tsujun Bridge, estimating new rice fields areas for development. The entire project management- from planning, filing of applications, and preparation of terms of use, was conducted independently by the *Tenaga*. The Tsujunyousui Irrigation System embodies a form of society Japan reached before modern times as irrigation facilities.

Tsujunyousui System, while maintaining the basic form, has undergone several repairs and improvements to maintain efficiency and irrigation facilities even after 160 years of its construction. The Tsujun Bridge has so far gone through three significant maintenance works to keep its siphons working. Recently, the Project for Environment Development of Prefecture-run Local Canals (Preservation of Historical Facilities), from 2000 to 2002, restored the formula of *Shikkui*, a traditional plaster, for repair work of the siphons which was used for replacement work. The Tsujunyousui Irrigation System is operated by the Tsujun Land Improvement District, with district members looking after maintenance work. Additionally, beneficiaries and communities from the Shiraito Plateau and the other three main districts contribute to maintenance work, and the membership duty is equally shared among all the members. In spring and autumn, festivals are held at Futa Shrine to pay tribute to Yasunosuke Futa, the system leader and express their gratitude to each other. Since its completion, the Tsujunyousui Irrigation System has become an essential part of people's livelihood. Its uninterrupted water supply laid the foundation of the communities and their identity. After the system, the farming villages in hilly and mountainous areas developed unique livelihoods along the Tsujunyousui and engaged in improving the sustainability of their communities.

Water Heritage

Tsujunyousui Irrigation System is a two-stage main canal structure composed of channels laid one above the other: Uwaide (upper canal) and Shitaide (lower canal). The main canal operates so that the lower canal collects water once carried by the upper canal to beneficiaries for irrigating paddy fields downstream. This two-stage structure is quite rare for irrigation facilities and thus is an engineering marvel of its time. There are no similar examples other than the Kamiide Canal System, Kikuyo Town, Kikuchi County, and Kumamoto Prefecture.

Another unique point is its water use techniques of the canal system is division boxes mounted at connections between the main and branch canals. A division box has a cross-section in proportion to the area of beneficiary paddies the branch canal leads to prevent the branch from taking in excessive water. These techniques embody two water use principles: efficient use of water and fair distribution of water along with the irrigation canal system, a philosophy of water use planning still relevant today.

The Tsujun Bridge, one of Japan's largest stone-built arch bridges, sublimed into an aqueduct bridge is an aggregation of Japanese engineering techniques. The bridge has an arch span close to the Reitai Bridge, 28.25 m, also one of the largest stone-built arch bridges and national cultural property. The size was a technical limitation of those days. As a result, the bridge needed siphons with an intake and an outlet 7.8 m and 6.49 m above the bridge, respectively. Engineers solved the technical challenge by building a stone bridge as large, robust, and durable as possible, with siphons of an unprecedentedly large size. They made a stone wall almost vertical around the top. A bridge body is vulnerable to horizontal oscillations at a right angle to the axis. They adopted the Tsuriishi technique of hanging stones to enhance the stone wall, connecting stones above and below with steel dowels in an oval shape inside the body. To support the weight of the siphons and stone wall, their bases are equipped with *Sayaishigaki*, an early-modern stonework technique for castle construction and integrating the bridge's sidewalls. A traditional Japanese siphon technique called *Fusegoshi* was used to lay the underground pipes below the river bed. The bridge displays many other technical ingenuities, including the proper selection of materials and shapes of stone conduits adopted to improve water-tightness and durability, the angles at which they were set up along the bridge, and the traditional plaster formula used to close gaps. Techniques adopted for the Tsujun Bridge were not initially developed for its construction. However, they were an aggregation of Japanese engineering techniques, sublimated into the Tsujun Bridge.

Irrigation facilities and rice production studies showcase this development. In 1826, the Siraito Plateau had 46 Cho (45.5 ha) of paddy fields which grew from 92 Cho to 138 Cho (136.6 ha) by 1882. Documents revealed that the original plan was developing 41 Cho (40.6 ha) of paddy. Still, ultimately, more than double the designated areas of new paddies were created, and some villages trebled their paddy areas. As of 2012, the Tsujunyousui System irrigated some 106.9 ha of paddies as its beneficiary area.

Since the Taisho Period (1912 - 1926), the Tsujunyousui Irrigation System has undergone several repairs and improvements while maintaining its basic form. Improvement project for *Shitaide* (lower canal) of the main canal, carried out in 2009 and 2010, is of environmental significance, which maintained some earth canals, an environment of gentle slopes and slow water flow which preserved a rare aquatic biota, including aburabote, a freshwater fish in Tanakia, Cyprinidae, Cypriniformes, which could not exist before. Recently, *Sinonychus, Tsujyunensis,* a new species in Sinonychus, named after Tsujunyousui, has been found. The project was designed and carried out as a neo-natural river reconstruction method- a technique developed in Switzerland and modified in Japan for its river reconstruction projects. The system has successfully repaired channels and built pathways while keeping an excellent environmental balance. This is a rare example of an irrigation canal improvement project adopting the neo-natural river reconstruction method at a large scale.

The structure maintains a sustainable operation and management model. The Tsujunyousui Irrigation System formed a management organization that has held its original setup for almost 160 years. Participatory practices like sharing expenses by farmers and beneficiaries are still in use today. Rights are also distributed equally between those living upstream and downstream. They maintain a method called *Chuya-Biki* or around-the-clock irrigation, where, in droughts, beneficiaries upstream and downstream take in the water a whole day and night by rotation. The general framework of water sharing and action plan for repairs and damages, short supply, and dredging remains almost unchanged even today.

Tsujunyousui Irrigation System imprinted an indelible mark on the history of Japan's irrigation journey and the cultural fabric of the society. The Tsujun Bridge, a symbol of the Tsujunyousui Irrigation System, was designated as important cultural property in 1955 and listed on the Selection of 100 Fine Canals in 2006. In 2008, the Tsujun Bridge, the Tsujunyousui Irrigation System, terraced paddy fields, and associated livelihood avenues in an integrated fashion were selected as an essential national cultural landscape under the title of The Tsujunyousui Irrigation System and Terraced Paddy Fields on the Shiraito Plateau. Tsujunyousui Irrigation System contributed to the development of farm villages in the Shiraito Plateau.

The system has a special place in people's hearts and history. Episodes from the construction of the irrigation system, including water shortage and farmers' sufferings, and Yasunosuke Futa, the founder's teachings, are taught in school books. Futa Shrine was raised in 1936 to worship him, with family portraits of the Sheraton District's residents inside. Harvest festivals are held with consumers and tourists annually. Almost 160 years after its completion, the Tsujunyousui Irrigation System stays in the centre of the community as a keystone for the management of the community and the solidarity of people.

8.42 TSUKIDOME IRRIGATION SYSTEM

Name	**Tsukidome Irrigation Canal**
Location	**Kashiwara City, Osaka , Japan**
Latitude	**34.581**
Longitude	**135.627**
Category of Structure	**Irrigation System**
Year of commissioning	**1705**
River Basin	**Yamato-Gawa River basin**
Irrigated/Drained Area	**266 ha**

History

The Tsukidome Irrigation Canal, with a history of more than 300 years, consists of two canals, the Nagase-Gawa Canal and the Tamakushi-Gawa Canal, which contributed significantly to the development of Osaka. Due to the rerouting of the old Yamato-Gawa River for flood control, neighbouring villagers planned the construction of the irrigation canal on the former riverbed of the Old Yamato-Gawa River. Construction was completed in just six months, and irrigation water became available in the region. The canals were operated and maintained by an unprecedentedly large water users' association comprising 75 villages called Tsukidome-Higumi. In addition to these canals, new farmlands were developed on the reclaimed land with a spread-out width of 400 m. Old Yamato-Gawa River, located in the east of Osaka Prefecture, flowing from south to north, was prone to sedimentation from nearby mountains, with heavy rain often causing flooding and severe damage to local farmlands and disrupting lives. However, despite repeated petitions, it was rerouted only after 50 years in 1703. A levee was constructed on the right bank, where the old Yamato-Gawa River and Ishi-kawa River merged, to direct the river to the west. Despite being a historically tricky project, it was finished in 8 months by mobilizing a total of 3 million people.

Constructed initially using earthen and stone masonry, the Tsukidome Irrigation Canal has undergone repairs for more than 300 years. In the 1880s, wooden water gates taking water from the Yamato-Gawa River were reconstructed using brick, stone or concrete and continue to be in service. In the 1950s, water quality issues, increased pollution from adjacent factories and houses, and rapid urbanization of the Nagase-Gawa River area led to a significant renovation project. The cross-section of the canal was divided into three sections by concrete walls. The centre section was for irrigation water and the other two sides were for dirty water. This sewerage method is historically significant. Presently, the sewerage parts are enclosed and covered by a walkway on both sides, also serving as a water-friendly walking area for citizens.

Description

The Tsukidome irrigation canal consists of Nishi-Yousuiiji (western irrigation canal and present-day Nagase-Gawa canal) and Higashi-Yousuiiji (eastern irrigation canal and present-day Tamakushi-Gawa canal). Nagase-Gawa and

SUKIDOME IRRIGATION CANAL

Nagase-Gawa and Tamakushi-Gawa: Two Canals that Contributed to Osaka's Development

The Tsukidome Irrigation Canal consists of two canals, Nagase-gawa canal and Tamakushi-gawa canal. Their history dates back to more than 300 years ago. Due to the rerouting of Old Yamato-gawa River for flood control, neighboring villagers planned the construction of the irrigation canal on the former riverbed of the Old Yamato-gawa River. Construction was successfully completed in just six months and the irrigation water became available in the region. The canals were operated and maintained by an unprecedentedly large water users' association comprising of 75 villages, called *Tsukidome-higumi*.

Since the water volume of Yamato-gawa River was limited, innovative methods were applied to ensure stable and equal water distribution. Many *Sunazekis*, unique straw bags filled with sand, were placed in lines in front of distribution pipes so that a stable supply of water could be provided to downstream users. *Sadameishi,* a large stone, was placed in the canal and has been used as a benchmark to control the water level.

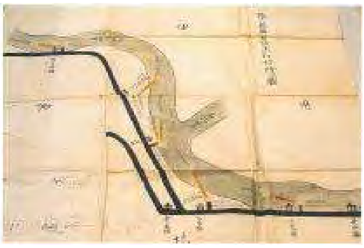
This irrigation system drastically improved agricultural productivity. New 4,000 hectares of farmland were newly developed, and as a result, the region transformed into a leading nationwide cotton producer. A radical method for efficient farmland use, *Shimabata* (see figure below), enabled the fields to be used as both paddy and cotton fields.

In 1888, imported bricks - the latest building materials of the day - were used in the renovation of the Tsukidome Second Water Tunnel. Now a National Tangible Cultural Property, the tunnel exhibits the construction landscape of historical importance.

The region has undergone urbanization due to recent changes in social conditions brought about by economic growth. However, the canal is still adored by local citizens as not only an irrigation infrastructure but also as a waterfront space, having also been selected by the Ministry of Agriculture, Forestry and Fisheries listed as one of the Top 100 Irrigation Canals. The area is well-maintained by the water users' association with local citizens and children taking part in cleaning and other activities.

Tamakushi-gawa canal (Past)

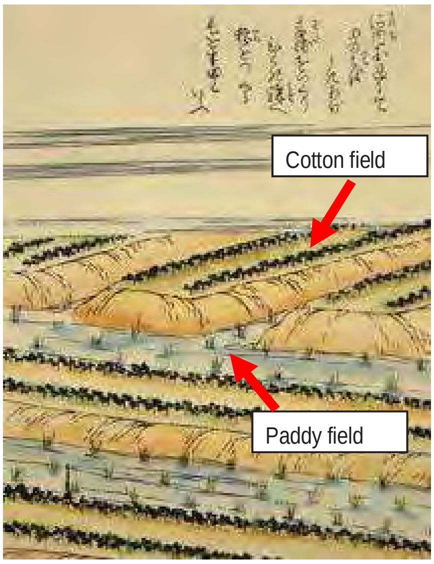
Tamakushi-gawa canal (Present)



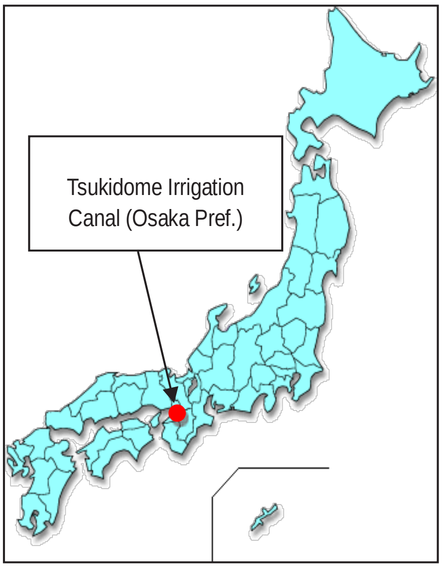
Sunazeki layout in 1760

Sadameishi stone benchmark
(In red circle)

The Tsukidome Second Water Tunnel
(National Tangible Cultural Property)



Shimabata technology



Tamakushi-Gawa. Nagase-Gawa canal's length is 14.175 km while the water intake is 0.8 - 1.0 m^3/s. Tamakushi-Gawa canal is 13.435 km long and has a water intake of 1.0 - 1.5 m^3/s. The overall width of both canals is around 20 m upper stream, 10 m midstream, and 5 m downstream.

This irrigation system drastically improved agricultural productivity. New 4,000 ha of farmland were developed, and the region transformed into a leading nationwide cotton producer. A revolutionary method for efficient farmland use, *Shimabata*, enabled the fields to be used as paddy and cotton fields.

For more than 300 years, these canals have played critical roles in irrigation in the eastern region of Osaka Prefecture and contributed to the development of agriculture in the area. These canals possess the following significant characteristics.

1. The canals and farmlands transformed the region into a major cotton producer. Since the quality of *Kawachi* Cotton harvested in the area was excellent, it was distributed nationwide and contributed to the agricultural sector and trade development.
2. The general management of the canals was carried out by a large water users association called Tsukidome-Higumi, the former name of Tsukidome Land Improvement District. The association involved as many as 75 villages while each village carried out day-to-day maintenance of canals.
3. Tsukidome's Second Water Tunnel was renovated in 1888. The horseshoe-shaped profound brick structure was registered as a National Tangible Cultural Property in 2001.
4. The aesthetic beauty of the canals is a true wonder. In spring, cherry blossom trees planted on both sides of the Tamakushi-Gawa canal can be enjoyed in full bloom, arching over the canal. These were planted under the, *making our town greener, and making the Tamakushi-Gawa canal a beautiful* movement against pollution and urbanization.
5. This scenery has been chosen as one of the Top 100 Townscapes and Top 100 Natural Landscapes by Osaka Prefecture, serving as a much-loved waterfront to local citizens.

Water Heritage

Tsukidome Irrigation Canal was a turning point in irrigated agriculture and regional development witnessed an increase in food production and expansion of trade and commerce. Watergates were constructed at the New Yamato-Gawa River levee to irrigate the Old Yamato-Gawa River dry river basin, allowing the formation of these two canals. Soon after its construction, the newly dried area was transformed into 1,000-ha farmlands in 1708.

Farms made from the dry river basin were quickly drained and harvested good quality cotton making the region a major cotton producer in Japan. A radical farmland utilization method known as *Shimabata* (island farm) was introduced, enabling the farmland to be used as both a rice paddy and cotton field. Using the Shimabata technique, the soil was piled up to 60 cm on the paddy surface in a rectangular shape. Cotton was planted on the piled soil to drain very well, whereas the low areas surrounding the piles were used as paddy fields. According to a national cotton farming manual, Menpoyoumu, water distribution to these farmlands through the new irrigation network resulted in increased paddy and cotton yields. Highly advanced farming technologies prospered due to the construction of canals and farmlands on the former river bed of the old Yamato-Gawa River, and the region became the third-largest cotton-producing area in Japan by 1870. According to records, the locally processed *Kawachi Cotton* was unsurpassable in quality, strength, and ability to be coloured.

The beneficiary area was considerably wide, accounting for 4,000 ha and 75 villages. Since the Old Yamato-Gawa River basin was flat, the two canals needed small accurate slopes of only 0.1% (1m/km) for gravity irrigation in the vast farms. This civil engineering technology was ground-breaking at the time. The sizes of distribution pipes for each village were strictly determined according to each yield to avoid conflicts over water administration. Forty distribution pipes of varying widths (0.09 - 0.85 m) still exist as remnants of that period. In 1888, imported bricks - the latest building materials of the day - were used to renovate the Tsukidome Second Water Tunnel. Now a National Tangible Cultural Property, the tunnel exhibits a historically crucial landscape.

The water management and maintenance of the beneficiary area were conducted by the water users' association, *Tsukidome-Higumi*, involving all the villages with guiding principles of fair water distribution rule with people monitoring discharge in the upstream and downstream areas during water shortages. The practice is still in effect in the present-day Tsukidome Land Improvement District, which is a testimony to the canal authorities' sustainable operations and management protocols. It was unprecedented to see the formation of such a significant association since water systems in other regions were more commonly managed by single or several villages.

The government realized that the potential farming area on the old Yamato-Gawa River bed would be larger than the farming area lost to create the New Yamato-Gawa River. So, they utilized the significant private capital of merchants to develop canals and farmlands. The cost of rerouting the river was 71,500 Ryo (approximately 130 million USD as of today. The budget was shared between the government, and the local governments with the majority share of the private sector based on property rights in the newborn area; 42 new farming lots were developed then. A kind of headquarters called *Kaisho* was set up for tax collection, fertilizer billing and managing expenses. *Kohnoike-shinden* Kaisho was registered as a National Historic Site in 1976, and *Yasunaka-shinden*

Kaisho was registered as a National Tangible Cultural Property in 2006. These *Kaishos* are historical evidence of past developments.

The canals were an engineering marvel at the time of their construction. Since the Yamato-Gawa River's water volume was limited, innovative methods ensured stable and equal water distribution. Many *Sunazekis-,* unique straw bags filled with sand were placed in lines in front of distribution pipes for a steady water supply for downstream users. *Sadameishi*, a large stone, was placed in the canal and used as a benchmark to control the water level. In addition to the various distribution pipe sizes and the *Tsukidome-Higumi* agreement, a fair and efficient water management system was in place. To this day, these techniques are handed down from generation to generation in the Land Improvement District.

Tsukidome's Second Water Tunnel was constructed in 1705 to withdraw water from the Yamato-Gawa River. But after being destroyed by the 1887 floods, it was reconstructed using brick in the following year. As per local people's opinions, state-of-the-art brick from Europe was adopted as a durable material that was required to withstand disasters. Bricks at the downstream-side entrance were piled using the strong British-style brick building technique. The tunnel's cross-section is not rectangular but horseshoe-shaped, which is unique for a water tunnel of its type.

Tsukidome Irrigation Canal is an irrigation canal constructed on the former riverbed of the old Yamato-Gawa River. In 2006, it was selected as one of the top 100 irrigation canals by Japan's Ministry of Agriculture, Forestry and Fisheries due to its contribution to Osaka agriculture, including cotton, leafy vegetables and chrysanthemum production. In addition, the Tsukidome Second Water Tunnel has been a National Tangible Cultural Property since 2001 and is Japan's oldest irrigation brick tunnel. Such a long brick tunnel with a length of 55m is very rare and valuable. As part of their local history and environmental education program, Tsukidome Land Improvement District collaborates with the Kashiwara Municipal History Museum to provide primary school lectures regarding the history of the irrigation canal.

The region has undergone urbanization due to recent changes in social conditions brought about by economic growth. While the beneficiary farmlands have significantly decreased, the canal is still irrigating 266 ha and is managed by Tsukidome Land Improvement District. Water is supplied to Kashiwara, Yao, and Higashiosaka cities with consumer-friendly, reliable and safe agriculture producing leaf vegetables and flowers. Local citizens still adore the canal as not only an irrigation infrastructure but also as a waterfront space. It has also been listed in Japan's Top 100 Irrigation Canals by the Ministry of Agriculture, Forestry and Fisheries. The area is well-maintained by the water users' association with local citizens and children's participation in cleaning and other activities.

In 2003, the Nagase-Gawa Water Environment Promotion Council comprised Tsukidome Land Improvement District, Osaka Prefecture, Kashiwara City, Yao City, Higashiosaka City, local environmental groups, and neighbouring and primary schools. The Council's activities include environmental conservation such as canal cleaning and aquatic plant cultivation and public events such as a local waterside festival.

8.43 UCHIKAWA IRRIGATION SYSTEM

Name	**Uchikawa Irrigation System**
Location	**Osaki City, Miyagi Prefecture, Japan**
Latitude	**38.658**
Longitude	**140.864**
Category of Structure	**Irrigation System**
Year of commissioning	**1591 AD**
River Basin	**Kitakami-Gawa river system**
Irrigated/Drained Area	**3,312.90 ha**

History

Built amid Japan's civil war, Uchikawa Irrigation System was constructed in the 16th century. The renowned samurai Masamune Date ordered the castle's development, urban planning, and the construction of an agricultural irrigation canal to protect the castle. For military purposes, water continuously flowed through the canal, which surrounded the castle town. The local farmers benefited from the canal's presence and produced a large quantity of rice. Therefore, the canal played a dual role in protecting people's lives and their prosperity. In Japan, Uchikawa Irrigation System supports a vast beneficiary area, which refers to land that benefits from its water and the canal system.

Over the years, several repair works have been conducted to improve its efficiency. Today, the Uchikawa Irrigation

UCHIKAWA IRRIGATION SYSTEM

Constructed during the Warring Period and continuing to contribute to the development of the local agricultural industry

Uchikawa Irrigation System was built in the sixteenth century in the midst of Japan's civil war. The nationally renowned samurai Masamune Date, ordered the development of the castle town's urban planning as well as the construction of this agricultural irrigation canal with the purpose of protecting his own castle.

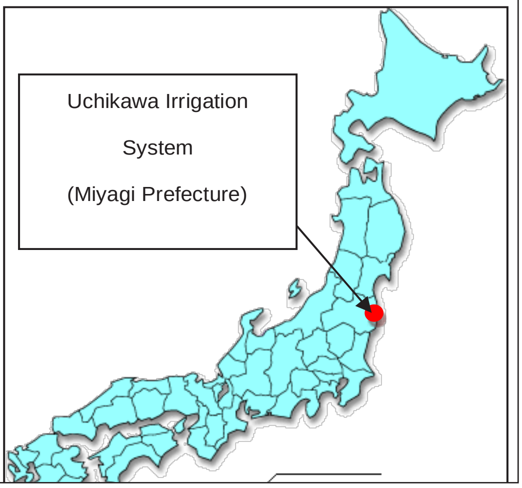
For military protection purposes, water continuously flowed through the canal, which surrounded the castle town. The local farmers also took advantage of the canal's presence and affluent availability of water to produce a large quantity of rice. Therefore, it was said that this canal played a dual role in protecting the lives of the residents. In Japan, Uchikawa Irrigation System supports a vast beneficiary area, which refers to the area of land that benefits from its presence.

Over the years, repair work has been done to improve its efficiency. Today, the Uchikawa Irrigation System continues to develop as the fundamental infrastructure for local food production and serves as the main irrigation system for this region.

At present, a group has been formed to actively carry out environment conservation activities, retain a clear stream, and educate people on the significance of the canal system. Uchikawa Irrigation System also serves an important role as a regional historic resource.

A bridge exemplifying beauty and tradition

Modern additions that take into consideration the surrounding natural scenery



System continues to develop as the fundamental infrastructure for local food production and serves as the primary irrigation system for this region. These days, environmental conservation is promoted, and an organization was also explicitly established for maintaining the fresh stream.

Description

Uchikawa Irrigation System is 2.7 m high, with an average width of 6.8 m, a depth ranging from 1.5 to 2.4 m, a length of 9.405 m, and an average gradient of 1 in 260. After being constructed as an earth canal (partly fenced in with fascine), the Uchikawa Irrigation System was filled with water and kept full. Since the canal was inside the castle's town, it was named *Uchikawa*, which means Inner River. Water for the canal was taken in through the Ozeki Diversion Dam, which had a height of approximately 14.4 m and a wooden head gate about 9 m in width. The dam was called *Ozeki* (which means Great Diversion Dam) because of its unprecedented size. The canal provides irrigation for 3,312.9 ha of farmland, draws water all year round, and contributes to the local environment and scenery.

The current Uchikawa Irrigation System was renovated in 1991 for the first time in 400 years, through a joint project conducted by the national government Osaki Western Area Irrigation and Drainage Project and the prefectural government Water Environment Renovation Project. After the recent construction was completed, several groups came together to prune the trees and plants in the area. After the renovations, the canal was named Number One Irrigation Canal, but locals still have an affinity for the old name. On February 22, 2006, Uchikawa Irrigation System was listed on 100 fine canals in Japan called Sosui Hyakusen.

Water Heritage

In 1987, the government's Irrigation and Drainage Project repaired and established facilities to eliminate water shortages for cultivated lands and drainage defects for 660 ha of land. At the same time, the prefectural government planned drainage and land consolidation projects in 19 districts, 12 districts of which have been completed, and 3,600 ha of land consolidation project will be finished, equivalent to 77% of the 4,700 ha targeted for improvement by 2022.

Uchikawa Irrigation System functioned as an irrigation canal for agriculture, as a hydrophilic space, and helped in the town's long-term planning. The canal type was based on a masonry wall structure considering the scenery, and the canal width was kept at about the same degree to secure the current shoreline. The facility, with its functionality, represents the prefecture's water environment while also providing a pleasing scenic effect. For renovations of the Uchikawa Irrigation System, a plan was developed after contributions from the community-which included a masonry embankment to highlight the scenery, a promenade and a water plaza along the shoreline, and the maximum number of trees to heighten hydrophilicity. For the waterfall work, the depth was adjusted to create areas for fish to rest, take shelter, and feed. Ayu (sweetfish) was used as a target to establish a fish nursery block and limited the maximum current to 1.5 m/s, a speed at which the fish can swim upstream.

Uchikawa Irrigation System was earlier managed by the improvement district, which has traditionally carried out maintenance, such as the canal's dredging and weeding of the surrounding area. However, after the renovations in 1992, the height of the canal was higher than before, so the dredging operations were consigned to local businesses. Since 1994, a district community group has carried out the dredging operations and cleaning activities for an approximately 800 m stretch.

In 1996, the Uchikawa Environment Beautification Liaison Committee was formed and carried out weeding work and cleaning for an approximately 600 m stretch along the canal. The Uchikawa Hometown Maintenance Corps was formed in 2002 to preserve Uchikawa's clean water and carry out educational activities for protecting the canal's beauty. Up until the present, they are preserving an approximately 800 m stretch. Residents from young children to the elderly participate in these clean-up activities to protect Uchikawa Irrigation System's clean water. Schoolchildren are also taught about the canal's history and the importance of conversation.

The canal carries a rich history of its people, with its water tracing its history from lordships and warships. Uchikawa Irrigation System is known for being the location of Yubikan, a nationally designated historical building site. Various activities like study groups about the system's history, preserving its environment, and beautification activities are conducted at Yubikan. Other activities include the Children's School, Lantern Festival and the Fishing School. In February 2006, in recognition of these activities and the role of irrigation water in supporting the next generation of Japanese agriculture, the Minister of Agriculture, Forestry, and Fisheries included Uchikawa in the list of 100 fine canals in Japan.

8.44 USA IRRIGATION SYSTEM

Name	**Usa Irrigation System (1. "Hirata" Irrigation System; 2. "Hirose" Irrigation System)**
Location	**Usa City, Oita Prefecture, Japan**
Latitude	**N33.51200 (Hirata irrigation system) N33.46270 (Hirose irrigation system)**
Longitude	**E131.33680 (Hirata irrigation system) E131.34400 (Hirose irrigation system)**
Category of Structure	**Irrigation System**
Year of commissioning	**1156–1870; 1156 – "Hirata" Irrigation System; 1870 – "Hirose" Irrigation System**
River Basin	**Yakkangawa River system**
Irrigated/Drained Area	**3,187 ha; (1546 ha – "Hirata" Irrigation System; 1641 ha – "Hirose" Irrigation System)**

History

The Usa Irrigation System was constructed to develop rice paddy fields in the Yakkangawa River basin. It consists of two irrigation systems: Hirata and Hirose. Since there are contrastive flat areas on either side of the river downstream, progress in developing agricultural engineering and irrigation in Japan is visible through the two irrigation systems. In addition, both irrigation systems were designed by the Usa Shrine, one of the most powerful shrines at the time. Historical material relating to the irrigation systems describes the situation of then-Japanese society.

Description

The Usa Irrigation System (UIS) was constructed to develop rice paddy fields in the Yakkangawa River basin. The river basin (390 km^2) is located in the northeast of Kyushu Island, one of Japan's four main islands. The Usa Irrigation System was designed by the Usa Shrine, one of the most powerful shrines at that time.

The Usa Irrigation System consists of two irrigation systems; Hirata and Hirose. The total irrigated area of the UIS has increased from its original 240 ha to 3,187 ha at present.

(1) Hirata Irrigation System (constructed in the 12th century): The Hirata Irrigation System was constructed in the low-lying area on the left side of the river in 1156. Its irrigated area has increased from the original approximate 140 ha to 1,546 ha at present. The irrigation system was smartly designed based on empirical knowledge of the river basin and represents the state of land development in ancient times.

(2) Hirose Irrigation System (constructed in the 19th century): The Hirose Irrigation System was

constructed in 1870 to develop the slightly elevated plateau of the right side of the river. The irrigated area has increased from the original approximate 100 ha. to 1,641 ha. at present. Its system design was based on highly specialized knowledge. For example, a 900-m irrigation canal was excavated through a mountainous area. Such construction techniques contributed to the modernization of Japan.

The Usa Irrigation System (Hirata and Hirose Irrigation Systems) is still an important irrigation structure for rice production. The original functions of the irrigation system have been maintained for several hundred years. The locations of the irrigation systems are almost the same as when they were originally constructed, although the irrigation structure has been partially repaired with either concrete or steel to improve irrigation efficiency.

Water Heritage

The Hirata Irrigation System was constructed in the low-lying area on the left side of the river in 1156. It covered an irrigated area of about 140 ha. when constructed. The main irrigation canal was about 12 km long. The irrigation system represented the state of land development in ancient times. In particular, the 12th century is an important transitional period from ancient times to the Middle Ages: the political power shifted from emperors and nobles to samurai during this period. The irrigation system was smartly designed based on empirical knowledge of the river basin: the former riverbed was partially transformed into irrigation canals to distribute water efficiently to the low-lying paddy fields, and the weir and inlet (headwork) were constructed to intake water efficiently at the starting point of the alluvial fan. Water distribution was the most important issue in the irrigation system. The distribution was managed by the Hirata family, descendants of the Usa Shrine, through the generations. In addition, small shrines have been constructed at the water division points to watch over the water division process. The irrigated area has gradually increased with the development of agricultural engineering. The irrigated area was 463 ha in 1603, 653 ha in 1765 and about 1,100 ha in 1924. Today it is 1,546 ha and the main irrigation canal is about 25.6 km long.

The Hirose Irrigation System was constructed in 1870 to develop the slightly elevated plateau of the right side of the river. Construction of the irrigation system began in 1751. Owing to the application of advanced construction techniques, such as tunnels and aqueducts required to deliver water from the upper point of the river to the plateau, it took about 120 years to complete. As such, various construction techniques can be seen in this irrigation system, which was designed based on highly specialized knowledge: a 900-m irrigation canal was excavated through the mountainous area; stone arch bridges and inverted siphons were built across valleys; and a 17-km long main irrigation canal was constructed, with a precise slope of 1/1000. Professional engineers with advanced techniques were brought in from other parts of the country to construct the irrigation system. The experience gained during this project enabled them to build many other important structures related to the modernization of Japan, including three major canals: the Asaka, Nasu and Lake Biwa canals. The irrigated area has increased from the original 100 ha to 1,641 ha at present. The main irrigation canal is 37.1 km long.

The river basin's water-retaining capacity is insufficient to control the river flow because the soil layer in the upstream region is shallow. In addition, the slope of the river is steep. Therefore, droughts and floods occurred frequently in the river basin. Water resource management, as well as flood mitigation, are important issues in a river basin. The best agricultural technologies, such as an oblique weir in the headwork and irrigation canals along the geographical contours were used to construct the irrigation system. An oblique weir has the following characteristics: 1) the angle of the weir is arranged to intake river water efficiently, and 2) the height of the weir is set so as not to receive flood flow directly. This structure was widely adopted by other irrigation systems in Japan.

Several water division works have been constructed in both irrigation systems during the expansion of the irrigated areas. Water use in each paddy field is controlled, in minutes, by a local rule known as Toki Mizu (Time Water).

The Usa Irrigation System (Hirata and Hirose Irrigation Systems) has been maintained and used by the local community for many years, even though the irrigation structures have been damaged many times by natural disasters such as floods and landslides. As mentioned above, the total irrigated area has increased from the original 240 ha. to 3,187 ha. at present. Although three large dams have been constructed to store irrigation water, they are insufficient, and strict water management is necessary. Currently, the UIS is mainly maintained by the Usa Land Improvement District, which employs professional staff for its maintenance and water management.

The Usa Irrigation System area was designated a Globally Important Agricultural Heritage Site (GIAHS) in 2013 and is one of the important parts of the GIAHS, Kunisaki Peninsula Usa Integrated Forestry and Agriculture and Fisheries System. In addition, the UIS was designed by Usa Shrine. Usa Shrine is the head of about 40,000 shrines in Japan and still has a large influence on Japanese culture. Therefore, there are many historical materials relating to the irrigation system. Such historical materials are conserved by the Oita Prefectural Museum of History and the local community.

Knowledge about the role and history of the irrigation system is passed on to younger generations through education programs in the local elementary schools. Seminars on the irrigation system are frequently held for the local community. In addition, thanksgiving festivals are held by the local community every year.

Usa City and Oita Prefecture work diligently on the public relations (PR) for the irrigation system. The promotion of agritourism in the Usa area is such an example. The local community also contributes to the PR on the irrigation system, especially by planning a TV drama series on one of the people who had a great impact on the success of the Hirose Irrigation System, Minami Ichirobe. It is hoped that after COVID-19, many tourists will visit the Usa area and see the irrigation system to learn about its structures and its role in agriculture.

8.45 UWAE IRRIGATION CANAL

Name	**Uwae Irrigation Canal**
Location	**Joetsu City And Myoko City, NiigataPrefecture , Japan**
Latitude	**37.000**
Longitude	**138.267**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**1664**
River Basin	**Sekikawa River**
Irrigated/Drained Area	**2,646.50 ha**

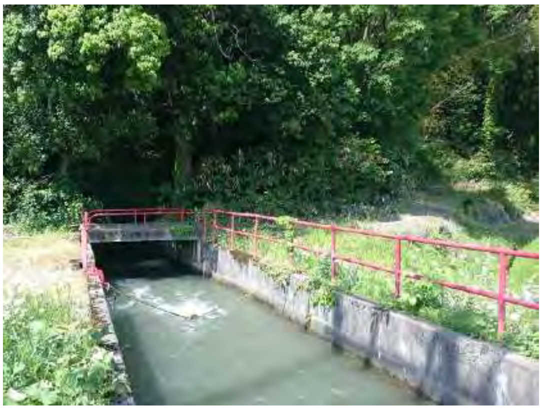
The Uwae Irrigation Canal

～A 130 Year Project to Create a Perfect Area for Delicious Rice～

The area around the Uwae Irrigation Canal is known all over Japan for growing very high quality Japanese rice, and that is all thanks to the canal, built through the hard work of villagers and farmers over 130 years. Before the Uwae Irrigation Canal was built, irrigation was done by damming up small rivers to store water. Owing to the heavy snowfall there was water during the spring planting season, but it was often not enough, and it was very difficult to save water until the September harvest season.　It's said that construction on the canals began in 1573, and continued for 130 years over three projects.　Villagers created the plans and use their own funds to make gradual progress, and the leader of each project would have a village named for them and statue carved in their image. These men are still revered today.

Construction included incredibly difficult stretches of tunnels, and owing to the always present danger of collapses, legend says that all the workers were paid daily. But even with these challenges the construction was flawless. During recent renovations to add iron pipes, the workers noticed that there were almost no problems or mistakes in these tunnels, a true testament to the impressive skill and techniques of the time.　When the canal was completed, over 60 villages had gained access to water, and some12,000 people in the region were able to feed themselves, leading to explosive development for the villages.

The rules for water charges were set down during the three projects and included some unique aspects, such as having farmers downstream pay the charges for farmers upstream. As this method is still somewhat effective, it is still respected and given priority over the modern river act. These days there are also new initiatives to promote hydroelectric power.



The tunnel today

Statue of an overseer

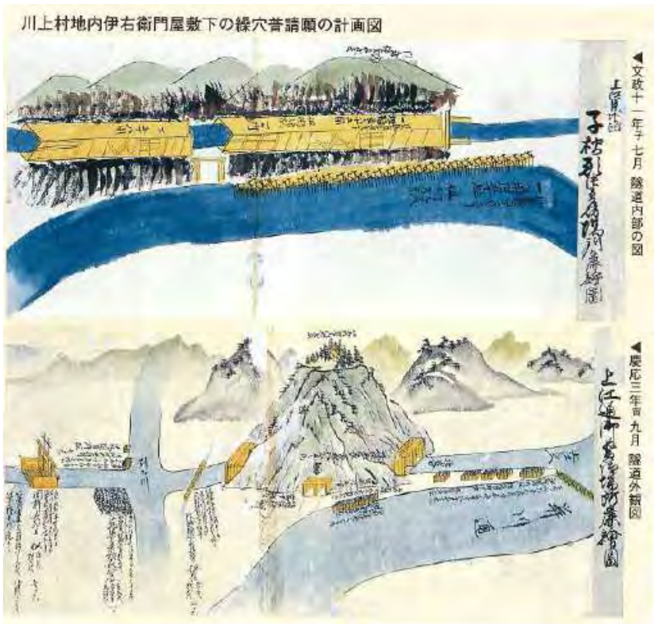
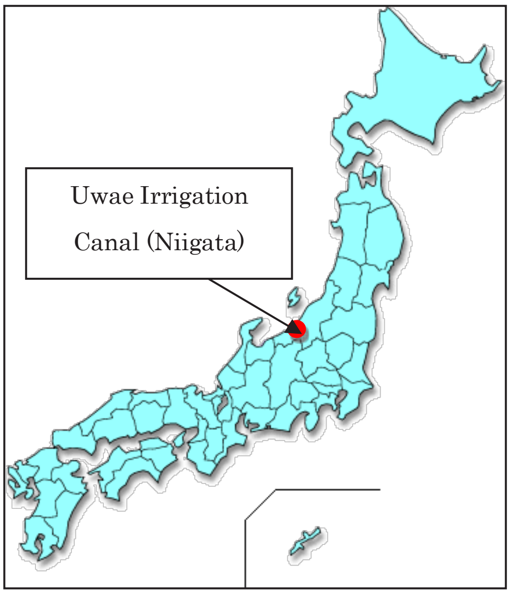


Diagram of tunnel used during construction



Location in Japan

History

Constructed during the Sengoku period in 1573, the Uwae Irrigation Canal and its water developed the best quality rice fields in Japan renowned even today built over 130 years. Before the canal's construction in 1573, small rivers were dammed to store water, but the stored water didn't last for harvest, which was the main reason behind the canal's foundation. Villagers created the plans and used their funds with gradual progress. A newly developed village was named after the leader of each project, and statues were carved in their image.

Description

The Uwae Irrigation Canal is 26 km long and irrigates some 2,646 ha of rice fields without any functional issues and supplies water, as designed centuries ago. Located in Myoko and Joetsu in the Southwest of Niigata Prefecture, the Uwae Irrigation Canal functioned along with the Nakae Irrigation Canal in the Takada Plain. The Nakae Irrigation Canal was completed in a short amount of time with financial assistance from the Takada Han prefecture. In contrast, the Uwae Irrigation Canal was built in three phases over 130 years with financial support and active participation from farmers and villagers. Even the management rules like the water charges for downstream and upstream users are still in effect today, with initiatives like hydroelectric power taking shape.

The first phase of construction (1573-1648) was managed by Kyuhachiro Tomisato, Yoshiki's village head; he oversaw excavation from Myoko's Kawakami area to the Yoshiki Shinden area. In the second phase (1650-1694), the in-charge was Matazaemon Shimizu, from an influential officials' family. He extended the canal from Joetsu Yonemasu to KamifukaSawa. After 1695, the demand for the canal's extension from the downstream's villages was dismissed several times by upstream villages. Finally, after 80 years, the third phase (1772-1781) began, and the influential landowner Tomijiro Shimotori extended the canal from KamifukaSawa to Okagi. Important developments at the construction stages are highlighted below:

1. The Kawakami Tunnel: The Uwae Irrigation Canal, first built alongside the Sekikawa River, suffered frequent damages from floods, making it challenging to move water downstream. In 1810, tunnels were excavated below the home of the head of the village, Lemon Matsuoka, which remained intact for more than 100 years and were repaired in 1931 after being collapsed.

2. Sanjobori: In 1775, during the third phase overseen by Tomijiro Shimotori, the Sanjobori, a 9 m tall tunnel coming down from the highest part of Okamine Hill, was built. Excavation work was difficult and dangerous due to mudslides while excavating the area under the Kushiike-Gawa River, but with Shimotori's will and the farmers' dedication, it was finished in 1780.

As the Uwae Irrigation Canal runs through rugged mountain terrain, mudslides and flooding have caused damage, so, to control the impact, protected forests are set up in dangerous areas.

Water Heritage

The Uwae Irrigation Canal contributed to agricultural development, social and economic expansion, and holistic development of the region. After the canal, over 60 villages gained a stable water supply, and rice production exploded, allowing rice harvest for roughly 12,000 people, a massive achievement for the time. This production became a cornerstone of farming in the area, and the region has become a rice production base. It is home to many of Niigata's granaries and now ships delicious, high-quality Joetsu rice all over Japan. After the canal's construction, the Takada domain was able to support 150,000 people in 670 villages. Of those 670 villages, over 60 used the water supplied by the Uwae Irrigation Canal, which helped provide food for 12,000 people, about 8% of the total population. The canal contributed to smoother operations of the Takada Domain Government.

The 26 km canal runs through rough topography and the mountain bases in the Takada Plain and many rivers. Excavation and construction were difficult and dangerous. With no mechanical equipment, native customised engineering techniques and human power were the only drivers ahead. In particular, for the Sanjobori tunnel excavation from downstream to upstream, tunnel lanterns were hung to mark the distance, pitch, direction, and other measurements. According to records, over 1,700 farmers were involved in the construction of the Sanjobori. Even though the canal building included incredibly difficult tunnel spans with the constant risk of collapses, the construction was carried out flawlessly. In the 1970s, steel pipes were inserted into the stonework of the tunnels as part of a national project. During this, the mortar was poured into the chinks in the stone. The workers noticed that there were almost no errors or mistakes in these tunnels. It proves the impressive skill and techniques of the time.

When the canal was first excavated, it ran along the Sekikawa River while at the same time damming it, but frequent floods washed it every time, causing problems for downstream farmers. So, in 1810, tunnels were built under the head of the Kawakami village, Matsuoka's house in the Kawakami village. The idea of having a canal below a person's house was innovative and demonstrated the people's passion for building the Uwae Irrigation Canal. The tunnel was made in a horseshoe- 3.3 m wide, 1.7 m tall, and 220 m long. Around 4,280 people worked on the project, and it cost approximately 15,860,000 JPY valued at present. The tunnel collapsed during torrential rain in 1931, and so reconstruction was carried out. During national construction in recent years, the tunnel was closely inspected. In a testament to the engineering skills of the past, it was found to have no warping or distortions in need of any further reinforcement were found.

The Uwae Irrigation Canal boasts of maintaining a sustainable operations and management model for equitable water distribution and a fair cost distribution mechanism. Over the years, many villages both from upstream and downstream used the canal facilities. They played a role in its formation by giving away their land, providing personal assets and working on the construction sites. The canal's unique water management method wherein downstream villages agreed to fully cover the water management costs of the upstream areas allowed smooth operations. *Kyakusui* (an area without cost allocation) provided irrigation water to 200 ha of paddy field without any cost allocation. The Uwae Land Improvement District, and the management body of the Uwae Irrigation Canal, merged and became the Sekikawa Irrigation Land Improvement District in 2006 and made a memorandum with the farmers in the Kyakusui area reaffirming the effect of the Kyakusui system, and agreed to cover 50% of the cost.

Besides agricultural development, the canal also became the foundation for electricity generation in the region. In 1907 a hydraulic power plant was built on the Sekikawa River. When the Uwae Irrigation Canal was excavated, water was let into the canal directly from the Sekikawa River. There are currently 12 power generators along the river from upstream to midstream. Water flows into the Canal after running through these generators, ensuring the water is useful for agriculture and hydraulic power. Due to hydraulic power generation, the drainage water losses from the Sasagamine Dam have been reduced and are now sent to the Canal. Furthermore, there is no need to intake water from the river, so the costs of running an intake facility have been reduced, which reduces the financial burden on farmers. Additionally, hydraulic power generation aided domestic production and is a stable source of renewable CO_2-free clean energy, positively impacting the environment.

The Uwae Canal is a culturally, historically, socially and economically important monument and irrigation infrastructure. It is an important marker in Japan's culture and history, which helped establish new villages in the region. Memorial stones and statues are in place, and festivals are held every year to honour the foremen and their leaders who had led the construction. From a heritage perspective, the Uwae Irrigation Canal's story and its contribution to the region's development are taught in elementary schools in Joetsu. The Sekikawa Irrigation System Land Improvement District has created pamphlets and picture books for younger children. Annually over 500 students visit the canal and learn from the achievements of their ancestors.

8.46 YAMADAZEKI BARRAGE

Name	**Yamadazeki Barrage**
Location	**Asakura City, Fukuoka Prefecture, Japan**
Latitude	**33.350**
Longitude	**130.750**
Category of Structure	**Barrage**
Year of commissioning	**1790**
River Basin	**Chikugo River Basin**
Irrigated/Drained Area	**652 ha**

History

Located in Chikugo River Basin, the longest river of the Kyushu Region, Yamadazeki Barrage was constructed in 1790, Horikawayousui Irrigation Canal in 1663, and Horikawayousui Waterwheels (the completion of the Tripler wheels) in 1789. The Barrage was the first of its kind in Japan. It was built as a sloping floor-type stone barrage and characterized by its elaborate and robust structure that endured enormous water pressure and rushing torrents of the Chikugo River.

In the Asakura Region, the farming industry is supported by the irrigation facilities composed of Yamadazeki Barrage, which takes in water from the Chikugo River, Horikawayousui Irrigation Canal, which lead the water to farmland, and seven waterwheels in three units, including the Hishino Triple Waterwheels, which carry water to rice paddies located above the Canal. They take some 553,000 m^3/day of water from the Chikugo River to irrigate farmland of 652 ha. Some of the historical accounts surrounding the development of the barrage are given below:

Yamadazeki Barrage (1790- present)

- The weir was constructed in 1790 with an estimated 6,20,000 to 6,40,000 workers, primarily farmers. The weir was entirely covered with stone, as seen today. The aim was to dam the Chikugo River, which caused havoc and was unmanageable and was also known as *Tsukushi-Jiro*, or the second most violent man in Japan.
- During heavy rains, the Chikugo River turns into a raging torrent, causing a flood. Large stones were laid

YAMADAZEKI DIVERSION WEIR HORIKAWAYOUSUI IRRIGATION CANAL, AND THE HISHINO THREE CONSECUTIVE WATERWHEELS

Ancient wisdom inherited across time and place

The Horikawayousui Irrigation Canal was constructed in 1663 in the Asakura district along the Chikugo River as a drought mitigation measure, and 150 hectares of paddy fields were developed. In 1790, the Yamadazeki diversion weir was built to secure more stable water supply for the Horikawayousui Irrigation System, and the total irrigation area increased to 370 hectares. In 1789, to deliver irrigation water for areas at higher elevations than the Horikawayousui Irrigation Canal, waterwheels, including the Hishino Three Consecutive Waterwheels, were installed to irrigate additional 35 hectares of agricultural land. At present, the system irrigates 625 hectares of farm land, and has contributed to the development of agriculture in the region.

The Yamadazeki diver weir is Japan's only "stone-facing weir with slanted floor surface" whose structure is sophisticated and robust enough to endure the water pressure and torrents of the Chikugo River, known as one of the three great wild rivers of Japan. The weir is 320 meters in length and 3 meters in height and has a stone-facing area of 25,370 square meters. It is also equipped with a south lock gate with a 190.4-meter-long lock chamber, a central lock gate with a 146.7-meter-long lock chamber to allow easy boat traffic. In addition, a 23.4-meter-long sand trap was installed so that sand can be discharged from the sand trap before it flows into the head gate. In addition, the weir had an eco-friendly design of allowing fish to move up and down the weir. Over 630,000 workers in total were deployed in constructing the weir at that time.

In order to irrigate the high elevation area, treadle waterwheels were initially introduced, but it was difficult to secure enough water using such human-powered pumping system. Consequently, a group of waterwheels, consisting of a set of three consecutive waterwheels and two sets of two consecutive waterwheels, were constructed in 1789, which succeeded in pumping 20,000 cubic meters of water per day to irrigate 35 hectares of paddy fields. Buckets attached to a rim of a waterwheel at an optimum angle, determined through trial and error, made it possible for the waterwheel to rotate with the help of water currents in the Horikawayousui Irrigation Canal. The waterwheels have continued to pump water for 224 years thanks to good maintenance and repairs. Therefore, these irrigation facilities, which manifest ancient wisdom and technical maintenance, have been designated as a national historical site, and selected as a national heritage.

Moreover, the technologies used for the Yamadazeki diversion weir and waterwheels which are the collection of the wisdom and great efforts made by our ancestors in the Asakura district were transferred to the Knaar River Irrigation System (stone dam) in eastern Afghanistan through a Japanese NGO. The irrigation system rescued Afghani people suffering from drought by changing about 3,000 hectares of wilderness into farmland. As such, the technologies of this system are widely known domestically and internationally for their achievements, and ancient wisdom and technology inherited across time and place.

at regular intervals to have more volume underground than one left above the riverbed, like an iceberg floating in the sea. This stable rockwork and robust structure endured the rapid flows and the force of a current. This arduous task was completed with only human intervention and no mechanical processes.

- Engineers also adopted a design to take in a more considerable amount of water. They laid stones higher around the Southern Ship Way, a part of the weir that receives the intense water pressure, in a way the surface would go down to the central part. In contrast, the stone pavement would gradually go up to around the sluice gate so that there would be a gentle slope around the central part of the stone floor. The hollow works as a flood sluiceway, carrying a good amount of water to the sluice gate without intense water pressure applied on the weir body.

Horikawayousui Irrigation Canal (1663- Present)

- Severe droughts in 1662-1663 and consequent poor harvests in the region led to the construction of the Horikawayousui Irrigation Canal 20 m downstream from the present Yamadazeki Barrage. At the same time, dikes were constructed with gutters laid along them to carry water from the weir to irrigate rice paddies. The completion of the Horikawayousui Irrigation Canal in 1663 enabled farmers to take water from the Chikugo River and develop 150 ha of new rice fields.
- Areas outside the purview of the Horikawayousui Irrigation Canal suffered from unstable dry field farming and severe droughts, along with the issues of sediment formation on the sluice gates. Therefore, after 60 years, a new sluice gate (1663 - 1722) was installed, and as a result, the paddy areas flourished in the region. Starting upstream and downstream, a tunnel of dimensions 20 m in length and 1.5 m in inside diameter was built. With limited technical facilities, essential tools like chisel and masonry work were used to dig a tunnel and remove a massive rock for the sluice gate, which was challenging and equally dangerous. The new tunnel was dug in a manner that the bottom of water around its outlet would be below the riverbed so that water flowing in from the gate would rush out from the outlet as wildly as that spring up from a siphon, a mechanism designed to prevent sediment from piling up in the gate.
- The sluice gate was enlarged in 1759 to have a width of 3 m to increase the beneficiary areas of the Horikawayousui Irrigation Canal and manage droughts. After five years of construction, from 1760 to 1764, the new Horikawayousui Irrigation Canal, 3.9 km in length, was completed to irrigate an area of 370 ha.

Horikawayousui Waterwheels (1751-present)

- To cater to the drought-prone dry farmlands that didn't have access to the Horikawayousui canal's water upstream, farmers introduced pedal-powered waterwheels. However, turning dozens of ha of dry farmland into rice paddies was far beyond the capacity of human-powered wheels. After years of effort, farmers in the district completed a unit of triple waterwheels and two units of double wheels in 1789. The same waterwheels are in use to this day to irrigate 35 ha of rice paddies.
- The waterwheels are at a fine-tuned angle at which buckets were mounted on a wheel. A bucket installed at a gentler angle throws out water drawn up from the canal far away across a receiving gutter, while a steeper angle allows water to fall before it. Farmers found the right angle based on several years of experience and wisdom to consume a large amount of water with the highest efficiency.

Description

Yamadazeki Barrage

Yamadazeki Barrage, 320 m in length, 3 m in height, and 25,370 m^3 in total area, is the only sloping floor-type stone weir in Japan. It has a structure elaborate and robust enough to endure immense water pressure and rushing torrents of the Chikugo River, the longest river in the Kyushu Region. Equipped with three channels, Southern Ship Way (Minami-Funatoshi), Central Ship Way (Naka-Funatoshi), and Sand Sluiceway (Doshahaki), the weir discharges from the sluiceway sand carried to it by the river before coming in from the intake gate, as well as avoids interfering transportation by ship, a prosperous industry of the days when it was constructed and allowed fish to move freely, and environment-friendly design.

Yamadazeki Barrage is made of large stones laid over and piled up on the riverbed. When it was constructed in 1790, the weir adopted "Karaishi-zumi," a stonemasonry technique of piling up fieldstones in an elaborate manner. During the repair work after a flood in 1980, the stonework was replaced by "Neriishi-zumi," which uses cement to fix stones together. Nonetheless, the weir maintains the original form of the days it was constructed.

Horikawayousui Irrigation Canal

Horikawayousui Irrigation Canal was excavated as an agricultural canal to carry farmland water taken in at Yamadazeki Barrage from the Chikugo River. When dug in 1663, the Canal was about 8 km in total length and was further extended to cater to distant farmlands. Its present total length has reached 88.1 km, 4.6 km of the mainline, 6.2 km of the trunk line, and 77.3 km of the branch line. At present, the Canal, 4 m in width at the maximum and 2 m in depth is in principle covered with concrete on three of its four sides. Around waterwheels, the sidewalls are covered with cobblestones, and accordingly, the design was chosen in consideration of the landscape. In 2006, Horikawayousui Irrigation Canal was listed on the Selection of 100 Fine Canals in Japan as one of the representative canals that supported the country's agriculture.

Horikawayousui Waterwheels

Horikawayousui Waterwheels, a unit of triple wheels and two units of double wheels, are all set up on Horikawayousui Irrigation Canal. The wheels draw up a total of 20,400 m^3/day to irrigate farmland of 35 ha located above the Horikawayousui Irrigation Canal.

A waterwheel is composed of a wooden wheel 4-5 m in diameter and several buckets. The wheels are driven by the water flow of the Horikawayousui Irrigation Canal automatically. In other words, they rotate along with the stream, while buckets set on them draw up water fuelled by the energy of nature. More recently, as pumps were replacing the waterwheels, the Asakura District faced maintenance challenges such as fewer artisans with special skills needed to build waterwheels. In 1990, Horikawayousui Waterwheels were designated as a national historical monument, together with Horikawayousui Irrigation Canal.

Over the centuries, the irrigation system has been restored, repaired, renovated and rehauled several times. The weirs were extended, the water wheels were replaced by electric pumps and the barrage was restructured. The irrigation system stood firm and is functional even today in the face of the flood causing the Chikugo River a raging torrent during rainfall. After its completion, the Yamadazeki Barrage was damaged by floods in 1874. Later in 1885, one-third of the barrage's broken stonework was restored using government funds.

Water Heritage

An engineering genius of its time, the Yamadazeki Barrage was built as a sloping floor-type stone barrage, with no other weir of this type constructed before in Japan. A variety of innovative mechanisms seen in the design demonstrates the weir was built with engineering techniques equally promising as the ones we have today. The barrage is visited by many people from the farming sector, researchers and students for inspection and research, and pupils of elementary schools in the neighbourhood as a destination for field trips.

The irrigation system was progressive in engineering design, structure dimensions, strategic planning, and overall impact. The facilities were constructed with native techniques when modern surveying methodologies were unavailable. Engineers and workers had nothing but human power, such as filling tubs with water and lanterns tied to the top of a pole for measuring elevations.

The weir was constructed adopting the *Karaishi-zumi*, a stone masonry technique of piling up field stones in an elaborate manner. After the 1980 floods, under repairs, the stonework was replaced by *Neriishi-zumi,* which uses cement to fix stones together. Nonetheless, the weir still maintains its original form. The weir has an environment-friendly design ensuring sand-free inflows to the canal and the waterwheels allowing aquatic life to flourish and move around freely.

In 2013, roughly 200 years after its construction, Asakura Waterwheels were used as a model for constructing a stone barrage and water-lifting wheels in Marwarid Canal in Afghanistan. Yamadazeki Barrage was also used as a model when the Peace (Japan) Medical Services (PMS), or *Peshawar-kai*, a civic organization based in Fukuoka City and working in Afghanistan and Pakistan, constructed a stone weir on the Kunar River, a tributary of the Indus River running through Kunar Province, the eastern part of Afghanistan. The PMS completed the Marwarid Canal in 2010, turning a wasteland of 3,000 ha into arable.

Known for its advanced engineering techniques at the time, the Yamadazeki Barrage is a masterpiece that revolutionized irrigation infrastructure forever around the world. It is an important historical monument passed over many generations and led to cultural and social exchange even among foreign countries. As described above, Yamadazeki Barrage, Horikawayousui Irrigation Canal, and Waterwheels, despite several improvements, still supply a more considerable amount of irrigation water, with no significant changes in their engineering utility as facilities for farmland irrigation between the phase of original design and operation. As a cultural heritage and symbol of Asakura City passed on for many generations, Yamadazeki Barrage, Horikawayousui Irrigation Canal, and Waterwheels are preserved and constitute tourism resources today.

8.47 YUKAWA IRRIGATION CANAL

Name	**Yukawa Irrigation Canal**
Location	**Asakura City, Fukuoka Prefecture, Japan**
Latitude	**34°22'26.5"N**
Longitude	**135°20'36.9"E**
Category of Structure	**Water Conveyance Structure**
Year of commissioning	**1446**
River Basin	**Kashii-gawa River system**
Irrigated/Drained Area	**60.65 ha**

History

The Yukawa Irrigation Canal has supported the water supply of the Hineno district of Izumisano City since it began the canal 800 years ago.

The Yukawa Irrigation Canal was constructed by the highest-ranking noble of the court to develop and irrigate the "Hinenosho", a private estate in Izumisano City, or a manor of the highest-ranking nobles of the court, and tax revenues from the local farmers in the manor were the income of the aristocrat. Therefore, the irrigation of the manor through the Yukawa Irrigation Canal was crucial to obtain stable tax revenues. This can be regarded as a living site that shows the history of this area.

Description

The current territory of Izumisano City, in the southwest of Osaka Prefecture, used to be a manor, the highest-ranking noble of the court in the 14-15th century. The Yukawa Irrigation Canal played an important role in the development of the manor. The irrigation system is estimated to be built at least about 800 years ago, as evidenced by two paintings from the early 14th century depicting Izumisano City. The attached archives passed down by a headman in Izumisano City show that the irrigation canal was connected to Junitani-ike Pond in 1446, and a map drawn in 1761 depicts the irrigation canal as it is today. The Yukawa Irrigation Canal is approximately 2.9 km long, and the elevation difference is only 3 to 5 m.

The Yukawa Irrigation Canal terminates at Junitani-ike Pond, and a spillway is located in the canal in front of the final entrance to prevent water over the amount used from flowing into Junitani-ike Pond. The Yukawa Irrigation Canal used to have a natural boulder as its intake and is constructed along the cliff face from the fan to the low plane. The structure of the irrigation canal has been modified to a three-sided concrete revetment, but part of it was a masonry revetment, and academic excavations have confirmed that the masonry revetment was the

THE YUKAWA IRRIGATION CANAL

"Medieval Irrigation System Inherited to the Present Day, which has Played an essential Role in the development of the Manor of the Kujo Family, an aristocratic Manorial Family in the Court"

The Yukawa Irrigation Canal is an irrigation canal that has existed for approximately 800 years. There are various theories as to when the canal was established, but a painting of a village drawn in 1316 shows that the canal was already partially utilized. The Hineno area, which was a manor of a noble family in Kyoto, the old capital of Japan, was then a wilderness, and the expansion of rice fields was an important issue.

The Yukawa Irrigation Canal, about 2.9 km long, draws water from a river that flows upstream of the estate and finally flows into a reservoir, the Junitani-ike Pond. The development of the Yukawa Irrigational Canal has dramatically expanded the area of rice paddies in this region. The difference in elevation from the water intake to the reservoir is approximately 3 meters. The development of irrigation facilities that take advantage of the slight difference in elevation demonstrates the advanced civil engineering technology of the time. The Yukawa Irrigation Canal continues to flow almost unchanged to this day, and continues to supply water to the rice paddies.

It is the only agricultural irrigation canal still in use in Japan that has been designated as a national historic site, and is a valuable heritage site that provides visitors with a glimpse into the history of cultivation since the medieval era.

original form of the irrigation canal. The excavations have also confirmed that the original structure of the irrigation canal was partially filled and levelled around the base of the terrace, and both sides were piled with locally available natural stone without processing. There is no evidence of a wooden canal. As the modern era approached, the method of piling stones around the canal changed to that of stone walls that used standardized stones and piled the stones through horizontal joints.

The Yukawa Irrigation Canal and the Junitani-ike Pond irrigated about half of the manor by the first half of the 15th century and played an important role in the development of rice paddies. Local people were grateful for the bounty of water brought by the Yukawa Irrigation Canal and dedicated a dance to the local shrine that managed the irrigation canal in spring and summer to pray for a bountiful harvest. This tradition is still carried on today. The Yukawa Irrigation Canal still supports local water conservancy and life today.

In this context, the Yukawa Irrigation Canal and Junitani-ike Pond are highly appraised by the national government as important elements of the construction of the manor, and the manor and its hydraulic heritage are introduced at the Izumisano City Museum. Currently, elementary and junior high schools in Izumisano City conduct fieldwork around the Yukawa Irrigation Canal as part of their extracurricular classes, and tourism volunteers lead guided walks around the area. Local volunteers also hold study groups and strolls. And Izumisano City and local breweries cooperated to produce Sake using rice grown in the water of the Yukawa Irrigation Canal, which helped revitalize the region.

Water Heritage

The development of the Yukawa Irrigation Canal irrigation system has promoted irrigation of the manor, and the water is still used for agricultural purposes in the area today. The route of the Yukawa Irrigation Canal to the Junitani-ike Pond has been the same since the Middle Ages, and although much of the canal has been modified with three-sided concrete revetments, some of the revetments still retain the original stone masonry from the time of construction. The irrigation area is still being enriched by the branch line from the waterway.

The Yukawa Irrigation Canal is about 2.9 km long, with a difference in elevation of only about 3 to 5 m, and is designed so that no more water is taken from the Yukawa Irrigation Canal than is used before it flows into the Junitani-ike Pond. These features show the deployment of the high technology of the time. The Yukawa Irrigation Canal used to have a natural boulder as its intake and is constructed along the cliff face from the fan to the low plane. The structure of the irrigation canal has been modified to a three-sided concrete revetment, but part of it was a masonry revetment, and academic excavations have confirmed that the masonry revetment was the original form of the irrigation canal. The excavations have also confirmed that the original structure of the irrigation canal was partially filled and levelled around the base of the terrace, and both sides were piled with locally available natural stone without processing. There is no evidence of a wooden canal. As the modern era approached, the method of piling stones around the canal changed to that of stone walls that used standardized stones and piled the stones through horizontal joints.

Currently, the Hineno Land Improvement District of Izumisano City, organized by farmers in the Hineno area, is responsible for the daily management of the waterway and reservoir, and since it is also a designated historic site, the city, prefectural and national government departments in charge of cultural properties are also involved in its preservation and utilization. The riverbanks have been repaired with concrete, but in some areas, the natural stone masonry revetment that was used at the time of construction is still in place. The irrigation canal is still in use today, and the restoration and maintenance of the waterway landscape and the specifications for the restoration of the water supply system of the Yukawa Branch Canal are being carried out with financial assistance from the national and municipal governments while efforts are being made for cooperative management with the land improvement district and residents. In addition, the enhancement of a tour route along the waterway is hoped.

9 KOREA, REPUBLIC OF

9.1 BYEOKGOL-JE

Name	Byeokgol-Je
Location	Gimje City, Republic of Korea
Latitude	35.750
Longitude	126.850
Category of Structure	Water Storage Structure/ Reservoir
Year of commissioning	330 A.D.
River Basin	Wonpyeong-Cheon (Sub Basin: Duwol-Cheon in Gimje)
Irrigated/Drained Area	10000 ha

History

Byeokgol-Je was the first and the most significant reservoir in Korea. In Samguksagi, the historical book of the ancient three kingdoms, it is written that the reservoir was built in the 21st year of Shilla King Heulhae's reign (AD 330). King Wonseong of the Unified Shilla Kingdom rebuilt it in the 6th year of his ruling period (AD 790). Later, King Hyeonjong and King Injong of the Goryeo Dynasty reconstructed it. And then, it was remodelled by King Taejong of the Joseon Dynasty (AD 1415). But it was flooded away due to heavy rains in (AD 1420) the 2nd year of King Sejong. Afterwards, Dongjin Farmland Reform Association converted the bank into a waterway for irrigation in 1925. The reservoir lost most of its original form but is still functional today.

Some of the noteworthy historical changes of the Byeokgol-Je are given below

- **790:** Restored by mobilizing the people from seven districts, including Jeonju.
- **1010 - 1031:** Restored to the original shape.
- **1143:** King ordered to destroy the restored structure because of cursed words by a shaman.
- **1415:** Mobilized 10,000 people and 300 government officials from each surrounding county to repair the structure and installed a monument of restoration (the epitaph of the memorial is recorded in a history book, Dongguk-Yeojiseungnam).
- **1416:** Established a farm cultivated by soldiers for military uses near the downstream of the dam.
- **1420:** A flood broke the embankment and inundated 2,000 ha of paddy fields.
- **1428:** The Byeokgol-Je was abandoned because of several reasons, such as potential flood damages, etc. Since then, no restoration of the embankment was performed due to various disasters, i.e., Sahwa (political massacres), Dangjaeng (political feud), Imjin-Waeran war (Japanese invasion), Horan war (Manchurian invasion), and other artificial disasters.
- **1684:** Moved the restoration monument to the top of the embankment and later moved to the south peak of Sinteol-me (hill).
- **1925:** The original shape of the embankment was severely damaged during the construction of irrigation canals as a part of the project. The original dam stretches 3.3 km along the north-south with two stone columns in Pogyo-Ri and Wolseung-Ri of Buryang-Myeon, Gimje-Si. When Dongjin Land Improvement Association used the embankment as the site for the central irrigation canal, the original embankment was severely damaged, and the reservoir area was cultivated.
- **1975:** Partial excavation started to restore the gates. Through the excavation of two gate sites, it was found that the embankment construction was substantial for the period, and advanced technology was used.
- **1980:** During the rearrangement of the Byeokgol-Je site, the monument of restoration was moved to the current location.
- **1998 A.D.:** Opened the Museum of Byeokgol-Je Irrigation Relics.

Description

Byeokgol-Je has five water intake gates. Those in the north and south (left and right) respectively functioned as spillways called Suyeo-geo and Yutong-geo. The three gates in the middle were used to take the stored water and are called Jangsaeng-geo, Jungsim-Geo, and Gyeong Jang-Geo, respectively. The water was conveyed to the southwest of Mangyeong and northeast of Buan, and west of Tae-in. Each intake gate was composed of two granite stone columns (5.5 m above ground surface and 1.5 m underground) spaced at 4.2 m. Each column has a groove 20 cm wide and 12 cm deep where a gate made of plank moves up and down for the operation. The bottom of the gate area is covered with large stones to prevent scouring. Byeokgol-Je has a second watergate called Jangsaenggeo, and the fourth watergate called Gyeongjanggeo 2 km south along the bank.

In the agricultural age, flood control was a matter of survival. This large-scale irrigation facility was a key industry of its time, employing at least 3,20,000 people per year to build the bank. The construction, maintenance, and repair of Byeokgolje was a significant national archaeological project. Built during the Three Countries era in Honam plain, the reservoir laid the foundation of one of the most immense rice cultivation plains irrigating the Gimje and Man-young area.

Water Heritage

Byeokgol-Je is the oldest and the largest reservoir recorded in Korea. According to Samguksagi, it was constructed by the King Biryu of the Baekje Kingdom (330 A.D.). The structure was the reason that a city called Byeokgol (a village of rice) came into existence. Byeokgol-Je was abandoned, and faced flood damages, political massacres, Japanese invasion, Manchurian invasion, and other artificial disasters but is still functional today. Apart from agriculture, the dam also promoted other livelihood avenues like the construction industry.

The technique to build Byeokgol-Je was described in the restoration monument installed in 1415 AD. The epitaph of the Byeokgol-Je recorded in the Dongguk-Yeojiseungnam (a history book of the Joseon Kingdom) shows that the embankment cross-section was a trapezoidal shape with 21 m of bottom width, 10 m of top width and a height of 5.7 m. Based on the total length of 3,250 m, the total volume of the embankment is 248,625 m^3. The total area of the reservoir water surface was 37 km^2. These numbers coincide with the data shown in the Samguksagi. Byeokgolje marks an epoch in the history of Korea, showcasing the ancient kingdom's advanced engineering skills to build the great reservoir. Byeokgolje reflects the rich cultural heritage which has been inherited from generation to generation. It is an important icon marking the history of irrigation in Korea. Byeokgolje and its repairing monument in the Joseon Dynasty have been designated as the 111th Historical Relics of Korea. Gimje city government has been operating the Byeokgol-Je Museum of Agricultural Culture to recognize the historical value of Byeokgol-Je as an ancient and the first large-scale irrigation dam in Korea. Gimje City founded and operates the museum to disseminate historical information about Byeokgol-Je in the region, one of Korea's most extensive rice paddy plains.

Since 2012, the Byeokgol-Je rehabilitation project has been excavating sites and irrigation canals destroyed during Japanese colonial times and is reallocated and restored with its embankment. Byeokgol-Je will be restored as a national relic, and the area will be rehabilitated as a symbolic place of agricultural culture and education. Furthermore, Girnje City presents Byeokgol-Je as the physical symbol of rice cultivation culture.

9.2 CHUKMANJE DAM

Name	**Chukmanje Dam**
Location	**Suwon City Government, Republic of Korea**
Latitude	**37.262**
Longitude	**127.029**
Category of Structure	**Dam**
Year of commissioning	**1799**
River Basin	**Seohocheon Stream**
Irrigated/Drained Area	**140 ha**

History

Located in Suwon City, the Chukmanje Dam (1799) was one of the three dams constructed together with the Manseokgeo Dam (1995) and Mannyeonje Dam (1998) during the King Jeongjo era. The construction of the Chukmanje dam is directly related to the construction of the Hwaseong Fortress, a listed UNESCO World Heritage site. The dams provided annexe facilities to the Fortress. The Fortress, which has 5.7 km in length, was built from January 1794 to September 1796. King Jeongjo of the Joseon Kingdom built a new capital city in Suwon with palaces, offices, and villages to honour his father. The Chukmanje dam was constructed after the Hwaseong Fortress to supply irrigation water to the paddy fields in the flat western area. Water was also required for the new town, its people, palaces, and villagers. For the town's self-sufficiency, the dam and the garrison farm were established. After its construction, the rice production was enough for the soldiers and townspeople even in dry years.

Description

The Chukmanje dam has a water surface area of about 20 ha and supplies irrigation water to 140 ha of farmlands. The length and height of the earth dam are 378 m and 2.4 m, respectively. The crest width is 2.3 m, and the water depth is 2.3 m. In the 1970s, the dam's height was raised by about 1 m, and the spillway was rebuilt from an overflow-type spillway to a gated spillway (one siphon barrel and four gates).

The construction of the Chukmanje dam was planned and implemented to establish the West Garrison Farm 4 years after Manseokgeo-dam and the North Garrison Farm. After the Chukmanje dam, in a period of 5 years from 1794 to 1799, there was a dramatic development in the history of Suown and Korea. Through irrigation development, food production was increased, drought damages were prevented, and poverty alleviation was accomplished.

Mannyeonje (萬年堤) dam site

Manseokgeo (萬石渠) reservoir

Records show that the first dam, Manseokgeo Dam's intake facility is similar to today's stop logs. The facility was made of pinewood and controlled the reservoir's water level and the downstream discharge. The same style facility was installed in the Chukmanje dam.

Among the three dams, i.e., Chukmanje, Manseokgeo and Mannyeonje dam, the Chukmanje dam is the largest and used as an irrigation water source for a more extended period. In contrast, the Manseokgeo Dam was turned into an urban park, and the Mannyeonje Dam became a historic stone monument.

Water Heritage

The Chukmanje Dam was a milestone development in the irrigation infrastructure of Korea. A unique innovation, it is the largest dam, directly related to the construction of Hwaseong Fortress, and provides water for irrigation and domestic uses. The Chukmanje Dam has a well-designed intake facility without any leakage at full storage water level and was the foundation behind Suwon's development.

The dam also made an outstanding contribution to enhancing food production. It was used as an irrigation water source for the downstream rice paddy area for two centuries and later supplied water to the agricultural experimental stations for more than a century. Even in dry years, rice production was abundant. Moreover, the dam aided the railway development in the region and led to new rice varieties.

Early in the 20th century, the Seoul-Busan railway was constructed, passing the eastern boundary of the Seoho reservoir. Due to the dam's stable water supply, industries flourished in the region, providing employment and increasing people's incomes. In 1906, the Government Agricultural Experimental Station was established in the south of the dam. The experimental station significantly contributed to agricultural development, poverty alleviation, and the green revolution through new high-yielding rice varieties in Korea as the central research and extension agency for 108 years from 1906 to 2014. Furthermore, Agriculture and Forestry School, founded in September 1906 in Seoul, moved to the dam site in 1907. During the 20th century and until recent years, Agricultural Experimental Station and Agricultural College supported Seho Reservoir to fulfil its central research and education organization in Korea.

The dam bears the stamp of cultural traditions of Korean culture- a 43.64 m long wooden pavilion named *Hangmijeong* was constructed near the west end of the dam in 1831. As a tourist attraction now, the pavilion continues one of the Joseon Kingdom's traditions of meeting and relishing nature today.

The dam's components are well maintained and preserved until today, proving that it was ahead of its time in terms of engineering skills and techniques. Seoho Reservoir is rehabilitated as a waterfront park area and is a tourist attraction. The dam is used as an irrigation water source for paddy production. Still, the irrigation area is now decreasing drastically due to the urbanization of the outskirt area of Suwon City. It is also affecting the reservoir's water quality.

9.3 DANGJIN HAPDEOKJE

Name	**Dangjin Hapdeokje**
Location	**Chungcheongnam-do Province (Dangjin City), Republic of Korea**
Latitude	**36.790**
Longitude	**126.789**
Category of Structure	**Dam**
Year of commissioning	**900-935 AD**
River Basin	**Seokucheon stream**
Irrigated/Drained Area	**720 ha**

History

Dangjin Hapdeokje was built before the Joseon Dynasty (1392-1910). The year of original construction is not known, but it was rehabilitated in the Joseon Dynasty. According to the history books, it was damaged by floods in 1473 (during the 3rd year reign of King Seongjong) and was rehabilitated in 1474. In 1506, the dam lost its function but was rehabilitated and excavated in 1768 (the 44th year of King Youngjo) to mobilise a workforce of 12,000 personnel from the Hongju area. In 1778 (2nd year of King Jeongjo), 8,053 people (4,553 from Hongju County and 3,500 from neighbouring counties) worked on two broken dam sections. In 1792 (the 16th year of King Jeongjo), 6,500 people (3,000 from Hongju county and 3,500 from neighbouring counties) rehabilitated the structure, followed by a big rehauling done in 1800 (the 24th year of King Jeongjo). More recently, the inside slope of the dam was reformed with a vertical concrete wall in 1913, and the spillway was repaired with concrete structures.

Description

The Hapdeokje is located about 90 km south of Seoul, Korea's capital city and in Dagjin City in the northern part of Chungnam Province. After rehabilitation, the dam was 1,771 m in length, 4 m in height, 6.5 m of crest width, 11.0~18.0 m bottom width, 8~9 km of circumference, and 102 ha of water surface area, which provided 720 ha of irrigated area. The dam increased grain production as well as increased farmers' incomes in the region.

In the 1960s, the Yedang reservoir was built 16 km south of the Hapdeokje. It provided irrigation water for fields in Hapdeokje, which was also included in the reservoir's benefitted area. Hapdeokje was famous for blooming lotus flowers in the reservoir during the Joseon Dynasty. Lotus covered most of the water surface due to shallow water depth and good soil. Although Yedang Reservoir, newly built in the early 1960s, has substituted the Hapdeokje, the prototype of the 1.771 m-long embankments is well preserved, which is of historical importance to the irrigated area and usage at that time.

Hapdeok (Hapsimdeokjeok) is named after a village of the same name suggestive of the people's cooperation in building and maintaining the reservoir till today. Seven villages formed one organization for operations and maintenance to forestall water disputes and derive local collective benefit. As a cooperative model case, it promoted community spirit and effective operation, which fuelled holistic development within the community.

According to 1915 maps, the reservoir's perimeter was 4.5 km, and the flooded area was 1.19 million m^2. This record confirmed that the benefited range was 4.6 km from east to west and the irrigated area was 9.5 million m^2 at most. This outstanding capability of the irrigation structure created sufficient water supply for agricultural water and domestic use even for seven neighbouring villages. The area's rice production per unit area was ranked second within the Republic of Korea.

As the Yedang reservoir was newly built in the early 1960s to supply water for irrigation use, Hapdeokje lost its irrigation function and turned into farmland to boost production. Presently, Hapdeokje is well-maintained today due to the government and the community's efforts. Its 1,771-m embankment and parts of the sluices are preserved in their original shape.

Water Heritage

The historical records confirm that Hapdeokje dramatically boosted (the area's) food production in irrigated areas. Today, the area's rice production per unit area is ranked second within the Republic of Korea. Several pieces of literature written during the Joseon Dynasty indicated that Hapdeokje was one of three large irrigation structures of the Dynasty with Byeokgolje of Gimje and Namdaeji of Yeonan, Hwanghae-do. Various historical works like *The Annals of Sejong, a UNESCO Memory of the World*, and *Diaries of the Royal Secretariat* mentioned Hapdeokje's characteristics and benefits. For example, Yeonji, which is at Hapdeokje, has a length of around 1 km and can irrigate around 10,000 m² vast fields.

The structure was a remarkable engineering piece of work. Its techniques and traditional wisdom revolutionalized the irrigation infrastructure. Excavations revealed that the leaves paving technique, one of the traditional techniques for building civil structures, was used for improving the ground stability of a civil structure built on low-lying ground.

It created harmony and community spirit among the population. The structure developed collaborative management mechanisms. The word *Hapdeok* in Hapdeokje symbolizes that the villagers built the system with one accord. Seven villages formed one single organization to manage water disputes. This cooperative model case showed community spirit and effective operations creating a win-win development within the community. The villagers had various folk rituals and beliefs, for example, praying for the security of Hapdeokje and bountiful harvests and a rain and drought ritual for the Dragon God. There were two folk songs directly related to the lotus flowers in the Hapdeokje.

Hapdeokje is a historical irrigation structure. It has a rich cultural lineage passed over many generations. Along the same line, many excavations were held from 1994 to 2008 to understand its complexities and traditional knowledge. Further exploratory research is being conducted to reassess its historical values to restore and repair the embankment. Dangjin City is also raising awareness among residents and students through educational programs and publications for the Hapdeok irrigation folk museum, established on traditional farming using water in 2005. Despite its small size, the number of visitors has reached around 0.4 million in January 2017. Hapdeokje is a cultural space where people can understand and experience traditional agriculture through rural theme parks and nature.

Unlike the straight embankment of Byeokgolje in Gimje, the embankment of Hapdeokje was wisely designed as a partly curved one to endure water pressure effectively. Hapdeokje was designated as Chungcheongnam-do Monument No. 70, in 1989 and since then, it has been utilized as a tourism resource through the restoration of cultural relics projects from 2007 to 2013. The area of the Hapdeok pond is 25.23 ha. It is famous for its elegant lotus flowers and the Yeon Ho Bangjuk (lotus pond).

9.4 GANGJIN LOTUS SMALL RESERVOIRS IRRIGATION SYSTEM

Name	**Gangjin Lotus Small Reservoirs Irrigation System**
Location	**Gangjin County, Republic of Korea**
Latitude	**34° 43' 11.8" N**
Longitude	**126° 48' 01.3" E**
Category of Structure	**Reservoir**
Year of commissioning	**14th Century A.D.**
River Basin	**Byeongyeong-Cheon Stream and other small creeks**
Irrigated/Drained Area	**1,136 ha**

History

The Byeongyeong region of northern Gangjin County has been home to vast fields but was not a place with abundant water. In 1417, the military compound that had been located in present-day Gwangju Metropolitan City was removed to Gangjin County, water demand for rice farming intensified in the region as the population rapidly increased due to the influx of soldiers, their families, etc., as well as securing water for the Byeongyeong fortress moat.

Faced with limited water resources, the Byeongyeong region overcame the challenge of securing water resources for irrigation and the Byeongyeong fortress moat, as well as household use, through the connection of five small reservoirs in series. The lotus reservoirs are at the centre of this water storage system. The people of the Byeongyeong region built numerous lotus reservoirs in an all-out effort to store stream water and rainwater. Influenced by the Dutch sailor Hendrick Hamel, who stayed in the region near the fortress for seven years from 1656, developments in advanced canal building were made and a system for water transfer to the downstream reservoirs was established.

Description

Gangjin County is located in the southernmost region of Korea. It is known for its vast fields and four distinct seasons, which gives the region advantageous natural conditions for cultivating crops. The earliest records of rice farming in the Gangjin area go as far back as the 2nd century B.C., and agriculture utilizing Yeonbangjuk (lotus small reservoirs) was practised mainly in the northern Gangjin area, where the stream was not developed.

Bangjuk refers to a dammed pond. Bangjuk is a pure Korean word for a pond or reservoir, and the ones in Gangjin County are called Yeonbangjuk because lotus (Yeon) grows wild in the reservoir and five reservoirs are connected (Yeon, which also means "continuous") through canals. For five lotus reservoirs, a single lotus reservoir is responsible for the irrigation of 150 to 310 ha of farmland and provides water for irrigation purposes to a total area of 1,136 ha.

Water Heritage

Bangjuk (small reservoir), as an irrigation system, has been built and utilized in agriculture throughout Korea. However, many Bangjuk have disappeared due to the development of large reservoirs in modern times. These lotus reservoirs have survived because of their essential role in sustaining the cultivation of rice crops. The reservoirs in the Gangjin region have been an invaluable irrigation structure that has made rice cultivation and double cropping possible and has been the driving force behind achieving necessary food production as well as making a living. After each farming season, farmers in Gangjin celebrate the harvest through "Garae-Chigi" (traditional fishing with fish traps) held at local lotus reservoirs, and this contributes to the development of local community culture.

In an all-out effort by the local farmers to secure water, reservoirs have been built in large numbers and a network of canals was introduced to provide irrigation to the rice fields with the water stored in lotus reservoirs. This is evidence of authenticity in irrigated agriculture practised by our ancestors.

The regions of Gangjin County now applying for nomination to the World Heritage Irrigation Structures once faced challenges in sustaining rice cultivation due to the high mountains near the fields and an underdeveloped stream system. Farmers built small-scale irrigation systems called Yeonbangjuk (lotus reservoirs) to secure adequate water for rice cultivation. The use of lotus reservoirs in Gangjin agriculture has played a crucial role in the livelihood of local farmers and food production for the region. A cooperative, communal, irrigation organization called "Lotus Reservoir Association" have been established with the common interest to achieve efficient irrigation water management for the lotus reservoirs. Members of the organization paid a certain amount in proportion to their farmland size and shared irrigation water. The collected funds are used to repair reservoirs and ponds, event management, such as "Garae-Chigi", and staff and labour expenses.

The Gangjin lotus reservoirs are of a "low-water, high-rice paddy" type. In this design, roads surface slightly above the centre of the flat fields and function as embankments as well. The reservoirs are constructed at places where the water paths gather. The reservoirs are 0.5-3 m deep in water level and 3 to 6 ha in size. The entry point in contact with the farmland is made of a low slope of earth and soil, and there are embankments of consistent heights at the exit. In modern times, this eco-friendly construction method is contributing greatly to the diversity of species.

Most reservoirs in Korea only provide irrigation within their irrigation zone. However, in times of water shortage, the Ganjin lotus reservoirs are able to transfer water to nearby lotus reservoirs through canals to participate in irrigation outside of their normal irrigation zone. The reservoirs of the Gangjin region exhibit a strong sense of community. After the busy farming season, the local farmers participate in "Garae-Chigi" (traditional fishing with fish traps) held at the lotus reservoirs. They share the catch and pray for a good harvest as well as for the well-being of their families and the village.

Good state of conservation: The five reservoirs are connected in series to other reservoirs, and each reservoir has its irrigation area. Therefore, they are well conserved and managed as long as rice cultivation continues in the area by the farmers under the assistance of the Gangjin County Office. Also, the County Office has the plan to connect the lotus reservoirs with the local tourism and floriculture industries as well as promote the value of traditional agriculture and share with other heritage locations in and outside of Korea. And, a conservation committee, consisting primarily of local farmers has been organized to participate in conservation activities. The designation of the lotus reservoirs as ICID WHIS will also help the conservation of this area.

Korea's Important Agricultural Heritage System (KIAHS): Korea's Important Agricultural Heritage Systems (KIAHS) refers to the agricultural heritage acknowledged by the national government to be worthy of preservation. In this system, the government designates traditional agricultural activities, agricultural landscapes, biodiversity, and usage for conservation and passing on to future generations. The Gangjin County Office applied the Gangjin Yeonbangjuk (Five Small Lotus Reservoirs) to KIAHS in 2020. It was accepted and registered in May 2021, as No. 16 KIAHS by the Ministry of Agriculture, Food, and Rural Affairs of the Korean Government. The lotus reservoir system will be financed and maintained by the government budgets based on KIAHS.

9.5 GOSEONG DUMBEONG (GOSEONG COASTAL AREA POND IRRIGATION SYSTEM)

Name	**Goseong Dumbeong (Goseong Coastal Area Pond Irrigation System)**
Location	**Gyeongsangnam-do, Republic of Korea**
Latitude	**34.983**
Longitude	**128.432**
Category of Structure	**Water Storage Structure**
Year of commissioning	**A.D. 18C**
River Basin	**No stream related**
Irrigated/Drained Area	**90 ha**

History

The use of Dumbeong began in the 1700s until the mid-1900s when modernized irrigation facilities took over. With an increased population, the demand for rice production also grew. Therefore, an irrigation system called 'Dumbeong' was built throughout Korea for agriculture. Dumbeongs are especially useful in rice cultivation in droughts. Today, some Dumbeong are found in the paddy-growing Goseong-gun region. However, as agriculture was mechanized in modern times, several Dumbeongs started to disappear in the process.

Description

Dumbeong in Goseong-gun coastal area was primarily constructed in areas with no irrigation water except ponds that store spring water, groundwater, or rainwater. Dumbeong is usually built by 4-5 neighbours who work together and collect necessary materials (stone, gravel, clay, etc.) from nearby mountains, valleys, and beaches. Goseong Dumbeong is similar in form and material to a well for drinking water.

Dumbeong was built in the selected site within the paddy field, and stone walls were made at a slope of about 15° from the vertical line to prevent the collapse of the stone wall. Besides, different sizes of stones were used in a way to avoid big pores in the structure. Clay and gravel have been used to fill the spaces with stone. Presently, one Dumbeong is typically responsible for the irrigation of 2-3 adjacent plots of rice paddies. Water infiltrated to the ground from the plots is collected in the other Dumbeong located downstream because the groundwater table in the coastal area is maintained almost constant by the seawater level. Currently, 444 Dumbeongs irrigate an area of approximately 90 ha of paddy fields in 13 sub-counties (1 eup and 12 myeon) in Goseong-gun.

Farmers who are unable to make Dumbeong can be a member of the water users' group. These groups at the village level cooperate for the efficient use of limited water resources. When farming season approaches, farmers repair their public water source and acquire necessary irrigation water through waterways. Currently, there are 256 water user groups, and 4,966 members are registered in Goseong-gun, with 512 facilities and 3,391 ha of benefited area. Most Dumbeongs are found in coastal terraced paddy farming areas, not inland Goseong-gun areas because the traditional farming conditions in inland areas have not yet been readjusted and are maintained as the coastal farming area.

Since the end of 2019, more than 30 Dumbeongs have been repaired as they failed to function correctly because of the collapse of side stone walls or the siltation at the pond bottoms. In 2019, Dumbeong in Goseong-gun coastal area was designated as the No.14 Heritage of Korea's Nationally Important Agricultural Heritage System (NIAHS) organized by the Ministry of Agriculture, Food and Rural Affairs of Korea. Various projects are going on to preserve Dumbeong's agricultural functions (water storage for irrigation purposes) and tangible and cultural characteristics through central government support. In addition, a conservation council centred on local farmers was formed.

Goseong-gun is also pushing for a project to prepare an ecological trail under the theme of Dumbeong that allows visitors to observe how Dumbeong's freshwater is used for irrigation purposes and lets them experience the local traditional culture. With this, Goseong-gun aims to utilise the areas to boost farming, preserve the environment and promote the participation of local farmers, students, and urban residents through systematic education and exchange programs.

Water Heritage

These 300 years old structures were built in the 1700s, when villages expanded in the Goseong area, until the mid-1900s. It has withstood the challenges of time, urbanization, technological advancements, and population, and at the same time creating a sustainable ecosystem.

In the Goseong area, Dumbeong is a valuable irrigation system that supplies water to the paddy field and gives farmers food production and a driving force to make a living. The farmers in Goseong repair Dumbeong during the non-farming season and prepare for farming the following year, thus creating a sustainable and reliable system.

Most of the rivers in Goseong-gun were dry except for the rainy season, making it challenging to meet irrigation needs. Therefore, most farmers constructed Dumbeong in their rice paddy to secure their irrigation water. Farmers in the area adjacent to the coast, in particular, have built Dumbeong because the groundwater level in the coastal area is maintained even in the dry season due to the almost constant sea water level. Dumbeong has contributed significantly to the livelihood of residents and food security, which helped create a stable avenue of livelihood. During severe drought, instead of irrigating merely adjacent plots, Dumbeongs help irrigate rice paddies farther away from the structure.

Dumbeong has a personal and communal character in the Goseong area. The water users' groups are also a symbol of the cooperation of the rural community. In addition, since Dumbeong is such a gift for the farmers' community. Farmers offered food to the Dragon King and others who participated in the construction of Dumbeong. This traditional ceremony is called the Dumbeong Yongwangje, wishing for Dumbeong water to never dry, hoping for a good harvest and a family's well-being. And the farmers sing farm songs (Nongyo) while transplanting and harvesting time. Goseong Nongyo has been passed down over the last 300 years until today by the Goseong Nongyo Training Association, which the farmers appreciate through their songs.

9.6 GUDEULJANG IRRIGATED RICE TERRACES IN CHEONGSANDO

Name	**Gudeuljang Irrigated Rice Terraces in Cheongsando**
Location	**Wando County, Republic of Korea**
Latitude	**34°10’56.1”N (based on the core zone)**
Longitude	**126°53’35.8”E (based on the core zone)**
Category of Structure	**Terraces**
Year of commissioning	**A.D. 17C ~ mid-20 C**
River Basin	**Small streams in the eastern part of Cheongsan-Myeon**
Irrigated/Drained Area	**1370 ha**

History

The structure began to be built in the 1600s, when villages were expanded in Cheongsando Island, until the mid-1900s, over 400 years old. According to recent studies, upon researching the pottery sherd found in stacked stones of nearby Gudeuljang rice fields, Gudeuljang rice fields are about 700 years old.

Rice terrace was the only method to grow rice in such conditions as found in many other rice-growing countries in the hilly or mountainous areas. The people on the Island wished to have a rice field, and finally, they found the method of Gudeuljang irrigating rice terraces. Gudeljang rice terraces are using the principle of Ondol, which is a traditional room floor heating system of Korean houses. It makes several longitudinal short stone walls and covers them with Gudeuljang (large flat stone) in every room. The heat produced in the fire inlet goes through those culvert-shaped passages and heats the room floor, then to the chimney.

Description

Cheongsando Island has an area of 41.95 km^2, with a maximum east-west distance of about 7.5 km and a north-south distance of 7 km. It is a mountainous area with five mountains among which three mountains are higher than 300 m from the mean sea level, with a maximum of 387 m. There was no adequate area for rice cropping that needs flat farmland and irrigation. Also, no stream was developed due to the small watershed area and steep mountain slope, and most of the soil was mixed with sand and various size of the stone.

Gudeuljang rice terraces are composed of Gudeuljang rice fields. Each parcel of the rice field was made with a stone layer to get a horizontal surface and boundary wall. The surface was covered with a water leakage prevention layer and then a rice cultivation soil layer. For irrigation water supply, a stone culvert covered with Gudeuljang was installed in the stone layer.

Major features of Gudeuljang rice terraces were an underground irrigation water supply system using an underground stone layer and a stone culvert covered with Gudeuljang stone. This was a very unique method for rice terraces in the sloping area available with much stone.

Water Heritage

Gudeuljang rice fields have the purpose of obtaining larger terraced flat farm parcels in sloped areas for the cultivation of rice crops. To make a larger flat parcel area, a higher downstream boundary wall and filling inside were required. On this island, much stone was available, therefore, stones were used for the wall and filling inside horizontally. After that, the horizontal surface of the stone layer was covered with clay soil or fine soil to prevent downward water leakage and then covered again with ordinary soil for the cultivation of rice crops. A larger parcel area has many benefits such as better irrigation water management, efficiency in farm work, increase in cropping area, etc.

For irrigation, the stone layer was designed to include a stone culvert covered with large flat stone (Gudeuljang stone). Irrigation water arriving at the upper side of the parcel can be introduced to the parcel for irrigation or directly enters to stone layer through a vertical inlet. Water entered the stone layer flows along the slope, then meet the culvert and finally goes to the downstream paddy field at the end of the culvert. The amount of water in the parcel and the stone layer shall be controlled depending on the need for irrigation water in the parcel. Water entering the vertical inlet will be irrigation water to the downstream parcels.

The difference between ordinary rice terraces and Gudeuljang rice terraces is the irrigation water supply system. Ordinary rice terraces depend on the paddy-to-paddy surface flow system, while Gudeuljang rice terraces are on an underground stone culvert flow system.

Gudeuljang rice fields embody Cheongsando islanders' strong attachment to land usage and food production. Currently, 72% of Cheongsando Island's land usage is wooded and sloped lands, while rice fields only take up 21.1%. When settlers who came to Cheongsando Island began farming 400 years ago, there were significantly fewer farmlands compared to today. On the Island, Gudeuljang rice fields were the only places to cultivate rice crops which were why they invented Gudeuljang rice fields with an underground culvert irrigation system. Before and after rice crop cultivation or in the dry year, the Gudeuljang rice fields were used for other crop production such as vegetables, barley, garlic, beans, buckwheat, potato, etc. On the isolated island, crop production within the island was most important for the living of the people.

Before agricultural technology developed and rice production and consumption increased, rice was hard to come by in Cheongsando Island so the rice could only be eaten during ancestral rites or holidays. This shows how little the amount of rice produced from the harsh and small Gudeuljang rice fields was. Islanders' main foods were sweet potato or potato, with rice mixed with barley, millet, or mugwort. Also, they frequently consumed various seafood which was easily obtained from the sea.

Gudeuljang rice fields exhibit a similar structure to Ondol, Korea's traditional floor heating system. Similar to how Ondol transfers the heat from the fireplace via Gudeul (similar to the culvert) laid out under the floor, Gudeuljang rice fields stack stones of varying sizes at the bottom of the rice field and controls water flow through the culvert that sends water to downstream paddy field.

The culverts are typically 3-10 m long under the parcel. And leakage prevention layer above the stone layer is placed by hand with puddled clay or fine soil to prevent remaining of any holes or cracks in the layer. The upper soil layer shall be about 20-30 cm depth with good quality soil for good crop growth.

The dolmens from the Bronze Age found on Cheongsando Island can be called the foundation for the island's Stone Stacking Culture. Stones were foundational material in constructing houses, roads, towns, etc. needed for the everyday life of the people. Cheongsanjinseong Fortress was built for defence in the Joseon dynasty. Moreover, Gudeuljang rice fields were developed as a way to solve food problems by developing mountain slope areas as cultivable areas. We can see low and high stone walls between parcels that provide a unique landscape.

Cheongsando islanders including soldiers made Gudeuljang rice fields via cooperative labour mobilization. Making one parcel of Gudeuljang rice field took a few months to 1- 2 years. Cooperative labour was an essential factor in constructing Gudeuljang rice fields. Also, they wisely came up with the idea of sharing the oxen for ploughing and material transport.

With Gudeljang (large flat stone cover) and Gudel (similar culvert), a room heating system in the house was used for the warm floor in the winter season, and the same principle was adopted to make cultivable Gudeuljang rice fields having stone culverts, under the cultivation soil layer, through which irrigation water is supplied.

After the 1990s, as the ageing of the island society and population outflow to cities increase, Gudeuljang rice fields, which took care of islanders' life for a long time, are left neglected and forested. It is estimated that 37.83% of the entire surface area is left as fallow land, especially those nearby mountain ranges and forests far from villages.

In response to the increase in fallow land caused by ageing and the outflow of population, Gudeuljang rice terraces have been continuously restored since 2018. According to the Gudeuljang rice field distribution status research held in 2019, it was found that 1,370 ha and 12,629 parcels of Gudeuljang rice fields are located across Cheongsan-myeon. Many Gudeuljang rice fields are distributed across basins near Buheung-ri, Yangjung-ri, Sangdong-ri, and Cheonggye-ri. Because Gudeuljang rice fields are made along mountain slopes they resemble regular terraced rice fields.

Efforts to maintain and manage the traditional agricultural system through the composition and operation of a resident organization in charge of Gudeuljang rice terraces

To solve this problem, the 2018 Cheongsando Island Gudeuljang Preservation Council formed Gudeuljang rice field join-cultivators to promote restorative and maintain idle Gudeuljang rice fields twice every year. Through this, approximately 10 ha of idle farmland was restored by the year 2020. Gudeuljang rice field join-cultivators are turning idle farmlands into scenic agriculture areas that farm landscape crops such as rapeseed or buckwheat via restoration and maintenance of fallow land, and they are making an effort to transform such land into a tourist attraction.

Systematization of policy support for the conservation of Gudeuljang rice terraces by designating GIAHS following KIA

After Cheongsando Island's Gudeuljang rice fields were designated as No. 1 Korea's Important Agricultural Heritage Systems (KIAHS) by the Ministry of Agriculture, Food and Rural Affairs in 2013, it was designated as Globally Important Agricultural Heritage (GIAHS) by the Food and Agriculture Organization of the United Nations (FAO) in 2014. As Gudeuljang rice fields' agricultural and cultural value is being recognized globally, central government and local government's policies and financial support are continuously taking place to support farmers' voluntary resource preservation actions.

Archipelago Maritime National Park, and the first Slow City in Asia

Cheongsando was designated as an archipelago maritime national park in December 1981, and the first Slow City in Asia in December 2001. Many people visit the Island and enjoy the slow scenery of the blue sea, green mountains, flat Gudeulgang rice fields covered with crops, dolmens, stone walls, etc. Therefore, islanders and the County Office pay more attention to the conservation of the Gudeuljang rice terraces.

9.7 MANSEOKGEO-DAM (ILWANG RESERVOIR)

Name	**Manseokgeo-Dam (Ilwang Reservoir)**
Location	**Gyeonggi-do Province (Suwon City), Republic of Korea**
Latitude	**37.301**
Longitude	**127.001**
Category of Structure	**Dam**
Year of commissioning	**1795**
River Basin	**Yeonghwacheon Stream**
Irrigated/Drained Area	**82 ha**

History

The Manseokgeo-dam is located in Suwon City, the capital city of the Gyeonggi-do province that surrounds the national capital of the Seoul Metropolitan City. It is about 40 km south of the centre of Seoul. It is an irrigation reservoir constructed in 1795 by King Jeongjo in the Joseon Dynasty, who aimed to cultivate the northern wasteland of the Suwon Hwaseong Fortress in the Suwon Area.

During the construction of the Suwon Hwaseong Fortress, a severe drought occurred; therefore, King Jeongjo suspended the construction process and built the dam. The Manseokgeo-dam was constructed four years earlier than the construction of Chuckmanje-dam (1799), the first reservoir built by King Jeongjo.

The privy purse covered the cost of constructing the dam and establishing the garrison farm without expense to the people. King Jeongjo ran the farm efficiently by adapting scientific irrigation equipment and improving agricultural technique. As a result, the place got out of the continuous drought disaster and raised agricultural productivity by making barren soil fertile. Profit from the garrison farm achieved the highest productivity at the time. A year later, a nationwide drought killed many people, but the Suwon area stayed unaffected. Manseokgeo-dam did not only take its role as a reservoir; it was also one of the most dramatic agricultural reforms in the Joseon era, which established the groundwork for the people in town to be self-sufficient.

Description

The Manseokgeo dam was the first new construction of an irrigation purpose dam in the Joseon Dynasty that started in 1392. It belonged to the comprehensive development plan of the Suwon area with the Hwaseong Fortress, a palace, a new town, and a garrison farm. The initiation of King Jeongjo implemented the program. The dam's success led to the construction of Mannyeonje-dam in 1798 and Chukmanje-dam in 1799. Yields from the garrison farms that were supplied with irrigation water from the reservoirs were used for the garrison unit and the maintenance of the fortress.

The total storage of Manseokgeo-dam is 337,000 m^3, located north of Suwon Hwaseong Fortress. It has a water surface area of about 24.7 ha and supplies agricultural water to 82 ha. The length and height of the dam are 378 m and 4.8 m, respectively, and the water depth is 1.9 m on average.

The primary intake device of Manseokgeo-dam is Su-gap (an intake gate system), which has a similar structure to the stop log but is further developed. Hwaseong Seongyeok Uigwe, a UNESCO Memory of the World, contains the illustration and explanation of the Su-gap used in Manseokgeo-dam. Su-gap is composed of Gap-pan (a wood plate), Su-gap (a box frame supporting the wood plates in a standing position) and Wa-gap (rectangular frame for culvert). Su-gap is linked to the upstream end of the Wa-gap, which is connected to an irrigation canal downstream. Most of the Wa-gap is buried in a bank of a reservoir. The irrigation flow is regulated by the number of Gap-pan in position. The Su-gap of Manseokgeo-dam has a feature that is not for drainage but totally for irrigation. Without being irrigated, the reservoir is drained through a separate floodgate, so the safety of the Su-gap and the accuracy of irrigation are well-maintained. In addition, it is a three-dimensional structure composed of Su-gap and Wa-gap, and Wa-gap that is buried down the bank of a reservoir.

Manseokgeo-dam had a floodgate and separated Su-gap, which ensured increased safety from the flood and convenience in the irrigation water supply. As the Su-gap of Manseokgeo-dam is equipped with an advanced structure, it is considered the best irrigation technique of traditional society.

Based on the agriculture infrastructure built during the era of Jeongjo, a National Agriculture Experiment Station and Agriculture and Forestry School were founded in the 1910s in Suwon. After liberation from Japanese rule, Suwon became the centre of agriculture research and administration, following the establishment of the Rural Development Administration and Agriculture College of Seoul National University. Today, after the expansion of the Suwon urban area, the area of Manseokgeo-dam has been developed into a park where 1.25 million Suwon citizens can be accommodated.

Water Heritage

Manseokgeo-dam's construction and engineering design were progressive and is recognized globally and are still in use today. Built in 1795, the Manseokgeo-dam has the most extraordinary irrigation technique of the Joseon

Dynasty called Su-gap, shown by its shape and function. Hwaseong Seongyeok Uigwe (1801), a UNESCO Memory of the World, contains the illustration and explanation of the dam. Su-gap of Manseokgeo-dam has safety and accuracy measures since it's not for drainage but totally for irrigation. In addition, the Su-gap is equipped with an advanced scientific structure. It was built in Mannyonje-dam (1789) and Chukmanje-dam (1799) afterwards. The dam contributed to poverty alleviation and drought damage mitigation as rice crops grew well even during the extreme drought in 1797 and 1798.

The construction of Manseokgeo-dam was directly related to the construction of the Suwon Hwaseong Fortress. The Dam, together with two other dams, constitutes annexe facilities to the 5.7 km long Suwon Hwaseong Fortress, which was listed in the UNESCO World Cultural Heritage in 1997. The fortress, constructed as the first new town of the Joseon Dynasty, brought stability to people's lives with irrigation infrastructure and long-term viable agricultural policy to reform the country. The policy aimed to construct a reservoir and enlarge the state farm owned by the military. Manseokgeo-dam and Daeyudun (a garrison farm) were built in 1795 to protect against the drought, generating resources for the people and the army and the holistic development of the local economy of Hwaseong. Even in the face of nationwide droughts, the dam significantly contributed to provisions, living, and starvation alleviation.

Yeonghwajeong (Pavilion of welcome flowers) was built in 1795 in the southernmost lake to view the Manseokgeo-dam. It was a wooden building and was repaired several times in history. The pavilion and the lake make a good landscape and attract people. One of the Joseon Dynasty traditions was meeting in the pavilion, enjoying nature, and discussing literature. Even today, it is one of the tourist attractions. The landscape with the clean and transparent water of Manseokgeo-dam and the fertile field of Daeyudun-farm was considered a leading scenery. Especially, as a giant sea of golden waves around Manseokgeo-dam in autumn became one of the 8 Great Views in Suwon, it is a scenic spot for many poets and has a cultural and historical lineage.

9.8 UISEONG SMALL RESERVOIR IRRIGATION SYSTEM

Name	**Uiseong Small Reservoir Irrigation System**
Location	**Uiseong County**
Latitude	**36011'~31' N**
Longitude	**128018'~53' E**
Category of Structure	**Water Storage Structure**
Year of commissioning	**14th Century AD**
River Basin	**Many small streams**
Irrigated/Drained Area	**1494 ha**

History

According to the Goryeosa-Jeolyo, the historical record of the Goryeo Dynasty (918–1392), states, "In the second year of King-Gongmin, he asked to repair the old reservoirs in Uiseong-Hyeon (present-day Geumseong-myeon) in preparation for the drought". It can be assumed that the reservoirs were built during or before the Goryeo Dynasty. In addition, the fact that the reservoirs around Mt. Geumseong depicted on a regional map from 1872 still exist today implies that they have a history that spans more than a century. - Jomun-Guk, the ancient state, existed in the Uiseong region, and it may be assumed that paddy agriculture began in this location in about B.C. based on the fact that farming tools such as Salpo were unearthed. - (In Korea, "Salpo" is a unique piece of agricultural equipment that was used to open the sluice gate of rice paddies and was employed by the farming supervisor or village chief.)

Description

Uiseong County is the lowest rainfall region in Korea, with abundant sunshine and considerable evaporation. The southeast of Uiseong County, surrounding the dormant volcano Mt. Geumseong, is the earliest volcanic region on the Korean Peninsula. Due to the characteristics of the soil, water loss is substantial, and surface water does not flow in most locations. Thus, even a single drop of water had to be conserved for agriculture, necessitating

the construction of reservoirs or ponds wherever water was gathered.

For this reason, water storage facilities were constructed in the Uiseong region, and water was divided and kept in the shape of a pond or small reservoir at various locations for agricultural use. By the end of 2021, a total of 6,227 small reservoirs/ponds were developed over centuries. Particularly, around 1,000 small reservoirs/ponds provide water to agricultural areas in the Mt. Geumseong region.

The traditional water intake facilities that supply paddy fields with water from small reservoirs/ponds consist of inclined conduits with several intake holes and stoppers and bottom conduits. Residents create a "Water users' group", which is a rural community that constructs, operates, and manages irrigation systems in one village or multiple villages to distribute the scarce water intelligently.

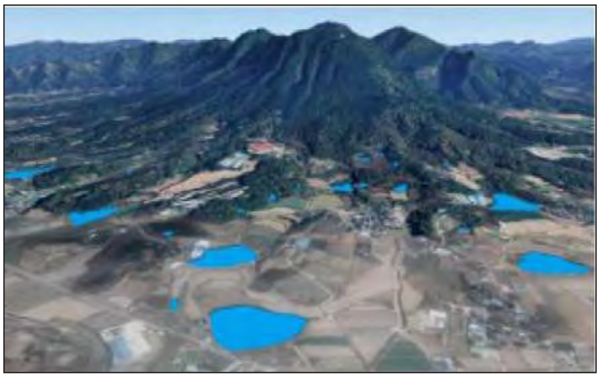
Water Heritage

Small reservoirs/ponds in the county of Uiseong make farming possible by storing and distributing water in the lowest rainfall zone. Until recently, 90% of food production was derived from rice farming. In paddy areas where rice cultivation has been completed, the second cropping of garlic cultivation generates agricultural income. In addition, farmers have developed a local community culture centred on irrigation systems and a distinct agricultural culture that announces the beginning of the rice growing by holding rites to ensure a fruitful crop during the "First Watering" event.

Using the water's flow and topography as a basis, the small reservoir irrigation system in Uiseong County possesses distinctive formation and utilization methods. The small reservoirs/ponds in Uiseong were formed or constructed in a variety of methods, depending on the water flow and the topography. The type includes a mountainous reservoir that stores water flowing down the mountain and a flat area reservoir constructed between rice paddies that rely on rainfall or reuse of water from the higher elevated paddy fields. The inclined conduit and bottom conduit, as well as the intake hole and stopper, were used to store and control water in small reservoirs

By wisely utilizing the water collected in small reservoirs/ponds, the income from rice and garlic crops increased considerably. Small reservoirs/ponds contributed to food production by enabling rice cultivation, which required a great deal of water over the required period. After irrigated rice farming, which uses water for more than six months, garlic cultivation follows as the second crop. Long-time watering of the soil before the cultivation of garlic contributes to the reduction of virus-caused garlic disease and the increase of farmer income.

The development of small reservoirs/ponds in the Uiseong area reflects the water flow and geography. In the case of mountainous water flow, the valley was blocked to store water, and in the case of farmland areas, small reservoirs/ponds were constructed to store rainfall and return flow from higher-elevated paddy fields. In the case of successive reservoirs connected by 'grandfather,' 'father,' and 'grandson' ponds, extra water from the upstream was sent downstream, and the return flow was also increased. In addition, it overcomes the inability to construct bigger reservoirs due to geological conditions by developing many small reservoirs system that stores all the water going down from the valley. This increased the rice farming area by increasing the overall capacity of the reservoir and made water recycling practicable. As a facility detail, an inclined conduit with several intake holes was built on the slopes of the embankment, and a bottom conduit going beneath the embankment was installed at the base of the embankment to facilitate safe water intake in response to fluctuations in the reservoir water level.



Surface water with higher temperature taken with the intake hole prevents cold damage to rice plant growth and increases production - Water from the reservoir enters the inclined conduit through the intake hole, and depending on the size of the reservoir, five to thirty intake holes are positioned from the bottom to the top of the conduit. Usually, the water intake hole is closed with a stopper, but this is removed to allow water to enter the conduit. This stopper is designed to regulate the limited use of water so that water from the upper portion of the reservoir drains from the top down. Allowing warm water from the upper portion of the reservoir to flow into the rice fields exhibits remarkable intelligence in minimizing cold water damage to crops.

Water users group and rural community development - The labour-intensive construction of small reservoirs and the maintenance and operation of the irrigation system developed a sense of community among the residents and farmers. It also fostered the growth of a community and a culture centred on the system. The "Water users group" is a local community organized by residents to share scarce water resources carefully. The individual in charge of water management in an organization is referred to as the "Chief manager," while the one in charge of water distribution is known as the "Water manager." The Chief manager and Water manager control the water in reservoirs systematically and prevent any dispute from using it. They have an annual responsibility to manage reservoirs and waterways, in particular, to have members of the water users group collaborate on the construction of reservoirs and waterways. In this regard, the traditional "First watering" ceremony, in which the stopper is removed to allow water to flow from the reservoir onto the rice fields for the first time, is still practised today.

Presently, in Uiseoung County, there are a total of 6,227 small reservoirs/ponds, of which around 1,000 are located around Mt. Geumseong. Eighty-three of them maintained traditional irrigation systems with conduits, intake holes, and stoppers. In addition, they continue to be utilized in agriculture, and a water users group centred on residents manages and operates the 375 small reservoirs and waterways.

In acknowledgement of the agricultural function and tangible cultural heritage of the small reservoir, the Ministry of Agriculture, Food, and Rural Affairs designated the system as "Korea National Important Agricultural Heritage (KIAHS) No. 10" in 2018. The maintenance and utilization of Uiseong Traditional Irrigation System Reservoirs were funded by the Korean government for three years with 1.5 billion won. Through this subsidy, it sponsored projects such as the preservation and utilization of agricultural heritage, the establishment of an agricultural heritage residents' council, education to increase residents' capacity building, the construction of a heritage road, and a public information centre. - Since its designation as a KIAHS site, Uiseong has made efforts to preserve and utilize the system sustainably, including "various utilization projects," "medium and long-term conservation and utilization plan," and "creation of display hall," and "plan for eco-museum."

10 MALAYSIA

10.1 WAN MAT SAMAN CANAL

Name	Wan Mat Saman Canal (Terusan Wan Mat Saman)
Location	Muda Plain, Malaysia
Latitude	5.83 - 6.083
Longitude	100.33 - 100.50
Category of Structure	Canal
Year of commissioning	1895
River Basin	Sungai Gurun/Sungai Limau/ Sungai Daun/Sungai Guar Chempedak/ Sungai Sala/ Sungai Choras
Irrigated/Drained Area	100,000 acres (40468.56 ha)

History

In 1885, under the order of Kedah's first Prime Minister, the Wan Mat Saman Canal was constructed southwards of Alor Setar towards the Kedah Peak (Gunung Jerai) mountain range. Wan Muhamad Saman led the construction of the canal with the assistance of villagers. The canal was dug at night with the use of traditional torches to ensure a straight alignment. It was built entirely by hand using traditional tools, and surveyors from Thailand also contributed to its construction as part of a collaboration between Kingdom of Thailand and Kedah.

Description Local Term

Upon its completion in 1895, the Wan Mat Saman Canal measured 35km (22 miles) in length, 7.3m (24 feet) in width, and 1.5m (5 feet) in depth. It remains the longest hand-constructed canal in Malaysia and continues to be in use today. The primary purpose of the canal was to improve drainage and provide a waterway for transporting paddy and other goods. It also serves as a flood mitigation route during heavy rain in the Gunung Jerai mountain range. The canal played a crucial role in transforming swamplands into fertile rice cultivation areas, attracting settlers who established small townships that became important economic centers.

Wan Mat San Canal promoted agriculture development in the Kedah State. The outcome contributed to the granary in Kedah, which is now known as the "Rice Bowl of Malaysia". This success continued with the development of the Muda Irrigation Scheme initiated by Malaysia's First Prime Minister, Tunku Abdul Rahman, which also benefited the southern part of Perlis. It created effective and systematic water management systems that allowed paddy double cropping and flood routing during the perennial monsoon flood. The Muda Area has since been able to produce nearly 40% of the nation's paddy production. It generates an industry worth more than 1 billion Malaysian Ringgit annually, elevating the standards of living of farmers in the Muda Area.

Before developing the Muda Irrigation Project, the Wan Mat Saman Canal was under the care of the State of Kedah Drainage and Irrigation Department (DID). When Muda Irrigation Project was developed in the First Malaysia Plan (1966-1970), the canal served as one of the significant trunk drains in the reticulation system. Since then, the canal has served as a primary drain to paddy cultivation and urban drainage final discharge point for the small town along the canal. The canal's management was then handed over to Muda Agricultural Development Authority (MADA). MADA cares for the canal cleanliness of Terusan Wan Mat Saman (Wan Mat Saman Canal) and the Public Works Department (JKR) currently maintained the roadside periodic clearing. Two Local authorities, Alor Setar City Council (MBAS) and Yan District Council (MDY) handle solid waste management.

In 2012, MADA initiated a conservation plan for Terusan Wan Mat Saman with funds from the Ministry of Agriculture and Agro-based Industry. The works carried out are i) the rehabilitation of the canal by desilting ii) the construction of a gallery depicting the history of Terusan Wan Mat Saman iii) the construction of the landscape at Kampong Padang Lumat, Yan, Kedah.

Water Heritage

The Wan Mat Saman Canal, constructed in the late 19th century, was a pioneering irrigation structure built by Wan Muhamad Saman, a distinguished leader who later became a Statesman. The canal's construction was a monumental achievement for its time and played a crucial role in the development of irrigated agriculture, reducing poverty among rural communities as Malaysia gained independence.

The canal transformed swamplands into fertile paddy cultivation areas, benefiting the entire region and the country as a whole. The present-day Muda Area, with its dense network of canals and drains, produces nearly 40% of Malaysia's rice production. The construction of the canal involved a transfer of technology between the Kingdom of Thailand and Kedah, with surveyors from Thailand assisting in its construction. The canal's alignment was used with the present-day road network Federal Route No. 1, which was built during the British Administration to connect Alor Setar and Kulim.

Local Term

- **Sungai :**River
- **Gunung Jerai:** Gunung Jerai refers to the Kedah Peak, which is a mountain range in the plain of Nortern Kedah, Malaysia.
- **Paddy:** Paddy is a local term used to refer to rice that is still in the husk, commonly used in Southeast Asia.
- **Muda Irrigation Scheme:** The Muda Irrigation Scheme is a local term that refers to a large-scale irrigation project implemented in the Muda area of Kedah, Malaysia. It involves water management systems for paddy double cropping cultivation and flood control.

Alor Setar City Council (MBAS) and Yan District Council (MDY): MBAS and MDY are local government authorities responsible for managing municipal affairs in the respective district of Kota Setar and Yan in Kedah, Malaysia.

Ministry of Agriculture and Agro-based Industry: The Ministry of Agriculture and Agro-based Industry is a government ministry in Malaysia responsible for overseeing agricultural and agro-based activities in the country.

11 MEXICO

11.1 CHINAMPA

Name	Chinampa
Location	Mexico City, Mexico
Latitude	19.269
Longitude	-99.069
Category of Structure	Agroecosystem
Year of commissioning	3000 years ago
River Basin	Mexico Valley Basin (Sub Basin: Xochimilco-Chalco)
Irrigated/Drained Area	25 km2 (2500.00 ha)

History

Sustainability, food security, climate change, overexploitation and degradation of natural resources are the main challenges of agriculture. One of the best alternative farming techniques for sustainable food production is Chinampa agriculture. This ancient agrosystem is still practised in some zones in the Mexico Valley, located mainly in the south of Mexico City. The chinampa, a sustainable high efficient agroecosystem associated with shallow lacustrine or wetland areas, was developed by pre-Hispanic cultures 3,000 years ago in several wetlands of Mexico. The chinampa at the Valley of Mexico has been recognized as a successful practice from the 15th century until now. This heritage system is cultivated by chinamperos (local farmers) at the Xochimilco–Chalco watershed southeast of the capital city of Mexico. It is evidence of why the lacustrine city was known as Tenochtitlan, the capital of the Aztec or Mexica empire, now Mexico City. One of the oldest maps of Mexico City by Alonso de Santa Cruz, a Spanish cartographer, dated 1550, indicates the cohabitation between man and water where the chinampas were essential for agricultural support of the ancient city of Tenochtitlan.

After the Spaniards' victory in the Tenochtitlan city, the original chinampa area was significantly reduced at the critical lacustrine zones of Mexico Valley because of Spaniard's draining techniques. However, the chinampa system has survived until now. Urbanization led to increased water demand and poor water quality in the lacustrine zone for supplying water to Mexico City. Consequently, aquifers and water springs were extensively exploited in the Xochimilco-Chalco sub-basin. In the 1950s, this demand rose as the local springs dried up, and the aquifer became dejected, so the government used waste-treated water to maintain the chinampas zone. Despite this situation, due to a reduced group of tenacious producing chinamperos with the help of the local government, the strong sustainability of the agro-hydrological system kept working with a high level of efficiency and productivity in equilibrium with the wetland ecosystems. Chinampas were almost extinct, but fortunately, rural communities preserved knowledge and cultivation practices. In 2016, it was estimated that there were nearly 20,922 chinampas in Xochimilco, out of which 3,586 were active and the others 17,336 were inactive.

Description

Chinampa´s name comes from the Nahuatl word *Chinamitl*, which means weaving a fence of canes. *Nahuatl* was the Aztec language spoken by Mexicas (dominant indigenous people inhabiting Mexico´s valleys). The chinampa is a farming practice that consists of a small permanent artificial island built on a freshwater lake for agricultural purposes. These rectangular islands, 60 cm above the water level, 5–10 m wide by 50, 100 or more meters long, surrounded by water, form a network with small channels between each chinampa and other broader channels that provide navigation routes and irrigation supply. The ancient chinampas were built by hand, constantly enriched using organic material from aquatic plants and sediments from the bottom of the lacustrine bodies and supplemented with a small amount of manure from animals in the vicinity. A typical chinampa is located on low-water zones of lakes and wetlands and reinforced the sides with local trees called *ahuejotes* -willows- (Salix bonplandiana) and post interwoven with branches (Chinamitl).

A typical Chinampa bed construction is described through the following steps.

1. Stick soundings locate shallow areas within a lake;
2. Rectangular bed areas are staked out;
3. Vegetation mats are piled in the staked area and possibly alternated with layers of lake mud;
4. The peat-like foundation is capped with a thick layer of mud from the lake bottom, alluvial sediments or from the tops of older chinampas;
5. The borders of the chinampas are planted with fast, straight-growing willows (ahuejotes) to reduce field edge erosion; and
6. The bed is capped with an organic-rich layer of muck before sowing crops. The result is a vibrant bed with high organic matter content, much higher than most agricultural soils.

However, crops were sub-irrigated, and water flowed through the Chinampa from adjacent channels. It then rises to the root zone by capillarity action due to the unique hydrodynamics properties of Chinampa´s soil, rich in organic matter. Chinampa´s soil surface is not sufficiently high from the canal water level to facilitate sub-irrigation.

The Chinampa system is very versatile and productive. Despite a permanent crop for the whole year, farmers used to produce several crops each year: main grains, mainly corn, beans and amaranth, vegetable, and fruits. This wetland ecosystem also supports aquatic flora and fauna in the water channels.

Currently, farmers are adapting their agro-systems to new conditions of a greenhouse, producing high-value flowers on a chinampa. However, modern chinampas are no longer self-sustaining systems. Plastic covers provide frost protection, gas-powered pumps deliver reclaimed urban water (transferred to the system) to the plants on the large fields, and external organic and chemical inputs introduce nutrients and contaminants to the soil. The average chinampa area also increased from 221 m^2 at Aztec times to more than 2,000 m^2 in the last century.

Water Heritage

Chinampas were a turning point in the history of irrigation and the development of irrigated agriculture. Despite the Spanish invasion, changing climatic conditions, and the urbanisation resulting in the disappearance of lakes and the natural habitat for chinampas which replaced the lacustrine marshes with concrete, tarmac and steel, the Chinampas agricultural system flourished and is even seen today in different parts of Mexico. The villages that maintain chinampas activity are located in the wetlands of Xochimilco and Tlahuac, counties in the south of Mexico City.

Chinampas helped the civilisations grow by enhancing food production, provision of livelihood opportunities, and rural prosperity. Along with an annual crop, farmers could produce a variety of crops throughout the year with Chinampa. Recent studies stated that a chinampa of Xochimilco is 5.5 times more productive per unit area than rainfed agriculture. In addition, the extensive and interconnected chinampa systems and their canals played several functions. Among the most important were: the transportation of goods and products, recreation, supply of water and irrigation sources. Watercourses constituted a system that contributed to the hydraulic control of the lakes. The lacustrine chinampas produced foods and enlarged the natural beauty of the landscape.

The Chinampa agricultural system was not just economically viable but also an environmentally friendly approach. The actual Chinampa area is around 25 km^2 which can be developed as a modern sustainable irrigated zone to promote the conservation of wetlands and protect and stimulate lake environments' biotic wealth. There are several benefits of chinampas, such as water culture preservation, a natural barrier against the advance of urban sprawl, preventing the deterioration of wetlands, recharging aquifers, and a diversified ecosystem. The chinampa is an integrated agricultural system that provides food, works and preservation of natural resources.

This system was developed and adopted more than 3,000 years ago by the Meso-American cultures that inhabited the central part of Mexico. Carrying the legacy and ancient wisdom, Chinampa is of great historical relevance. For its historical and cultural value, in December 1984, the chinampa zone was declared by UNESCO a Cultural Humanity Heritage. In 2004, Chinampa's area was declared a RAMSAR site by the convention on wetlands. Chinampa is one of the few ancient irrigation practices preserved practically unchanged until today.

The local knowledge of the sustainable agricultural system associated with the chinampa needs to be disseminated and conserved. Traditional peasant knowledge combined with scientific and technological research can lay the foundation for sustainable future projects, particularly those areas with similar ecosystems.

There is an urgent need for identifying potential alternative farming practices to achieve long-term sustainability and food security. Chinampa agrosystem is an excellent example of a farming technique for sustainable food production, practised for many centuries in the central part of Mexico.

11.2 LA BOQUILLA DAM

Name	**La Boquilla Dam**
Location	**Chihuahua State, Mexico**
Latitude	**27.545**
Longitude	**-105.414**
Category of Structure	**Dam**
Year of commissioning	**1915**
River Basin	**Rio Bravo, Rio Conchos**
Irrigated/Drained Area	**73,002 ha**

History

In Mexico, the construction of large dams began early in the last century. One of the first constructed was the La Boquilla dam, built on the Rio Conchos basin, a tributary of Rio Bravo, in 1910. Due to its geographical conditions and social movements, it constituted a technological challenge for its construction. Today, even after 100 years, it is operational and promotes the agro-economic development of the Delicias agricultural valley in the State of Chihuahua. The dam provides water to more than 75,000 ha area and about 9,000 users grouped in 12 irrigation modules of the region.

The dam was constructed during the government of General Porfirio Diaz. The planning and construction were carried out by Compañía Agrícola de Fuerza Eléctrica del Conchos (Agricultural Company of Electric Power of the Conchos River). Due to social uprisings and consequent delays, its completion was extended up to 1915, with its inauguration taking place a year later. The dam was constructed to meet the state's water storage needs and to generate electricity. Since its operation, it has been the trigger for agricultural, livestock, industrial, commercial, tourist, and educational development in the region. In addition, it has enabled the recharge of the Meoquí-Delicias aquifer, with an infiltration of about 430 MCM, and has regulated extraordinary floods and minimized the risks and damages in the towns downstream of the dam.

Description

The dam is located in the Mexican Plateau, in the country's north, predominated by volcanic rocks from the Tertiary period and foliated limestone from the Cretaceous period. The vessel is surrounded by limestone, shale, and sandstone formations. The dam wall is located, known as La Boquilla (the nozzle in Spanish), is asymmetrical; the left hillside has almost vertical walls, while the right flank has a smoother slope. The dam has masonry and concrete, curved, gravity-section wall. The crest length is 259 m, with a base width of 60 m and an elevation height of 80 m. The dam has seven steel pipes for water intake; four of them are equipped with electric power generators, two upper intakes for irrigation, and a lower intake built in 1950, all equipped with divergent valves. Seven pipelines were initially installed for the water intake, whose axes to the entrance are approximately 27 m below the crest. Only the four central pipes of 2.60 m in diameter were used for power generation. The maximum combined flow rate for the four pipes is 44 m^3/s. In the 1950s, a lower intake, approximately 10 m below the original intake, was built to extract the dead storage due to a severe drought. The maximum flow rate extracted from this intake is 35 m^3/s. Finally, in 1983, the two intakes at the extreme sides of the original intake were adapted to extract more flow for irrigation; both intakes have a maximum flow rate of 42.50 m^3/s each.

The overflow spillway is located independently to the right of the dam wall, in the port called *Babisas,* with a length of 720 m. A masonry dike called *el Tigre* (the tiger) was also constructed, with a length of 900 m and a maximum height of 32.5 m, with a vertical upstream slope and downstream slope of 1.5: 1, wrapped with gravel and variable slope sand. Seventeen small masonry dikes were also constructed, located between the main dike and the dam wall. Currently, the flow rate of the dam for irrigation delivery is approximately 80 m^3/s, of which about 44 m^3/s are taken from the water intakes used for electric power generation, combined with the upper intakes dedicated for irrigation. With the volume extracted from the dam, approximately 75,000 ha are serviced in the Irrigation District 005, Delicias, Chihuahua.

Since 1915, the conservation of the structure has been carried out by the Mexican government and Water Users Associations through the different departments and agencies throughout the country's history. Recent changes like pollution, invasion, tourism, and other issues have not affected or currently affect the dam's utility. To conserve this dam, the National Water Commission, through the Deputy Director General's Office for Hydro-Agricultural Infrastructure, provides the annual budget required to maintain and preserve this dam. With this budget complemented with irrigation fees, conservation work is carried out periodically to keep the dam in optimal operating conditions.

Previously, conservation work was carried out in the dam wall, the spillway, and the water intake. The conservation work carried out on this dam for 107 years has maintained it in excellent operating conditions, providing a constant water supply to meet irrigation demands in the region. Although throughout its history, the accumulation of sediments in the vessel has not been significant, this can be a factor that can affect the operation of the Dam in the long term, which could cause a reduction in its capacity for storing water for irrigation and, consequently a decrease in the service life of the reservoir.

Water Heritage

Constructed between 1906-1915, La Boquilla Dam was the largest dam in America until 30 years later, when another dam with a greater capacity was built in the country. According to its current storage capacity of 2,894 Hm^3, it is the 15th largest dam in Mexico.

The dam was a milestone for Mexico and the rest of America at its construction which shaped contemporary engineering practices and theories. Over the last century, the dam's construction has led to massive migrations to the northern part of the country. It allowed the agricultural development of this area, helped in electricity generation and created water storage, ultimately enhancing people's lives. The economic activity in the area revolves around the benefits provided by the dam and the volumes extracted for agriculture. The population has great respect for the dam. It acknowledges that the region's well-being depends on its optimal functioning, which is why people try not to alter the environment surrounding the dam.

This Dam project was an irrigation legacy that developed unique techniques and engineering skills. Costing around 22 million USD, a substantial amount for the time, it created history as the largest dam. Everything from planning, construction technique, structure, dimensions and surface area was studied in great detail. Before the construction, the technical staff did a great job in site planning. The dam is located at a strategic point on the Conchos River riverbed, where the rocky formation narrows down to form a nozzle named La Boquilla. Building this dam during the Mexican Revolution was quite an achievement because of the lack of labour and limited machinery and tools. Another critical factor was the lack of transportation, both for the workers and the materials required. A railroad track named Ferrocarril Camargo y Oeste (Camargo and West Railroad) was built to solve this problem. Comanche Indians were hired from a reservation in the state of Arizona, USA, to supply labour for laying the foundation since the most labour-intensive job was an activity known as *boleo*, which consisted of making 10-cm-thick clay balls, of which 1,50,000 per day were needed. These rocks of clay were baked as bricks, and then large mills were used to pulverize them. The resulting powder was mixed with the cement, which was imported from the United States of America. The Government of Mexico granted tax exceptions for all the elements required for the work.

The volume stored in the dam enabled the development of 75,000 ha in Delicias, one of the firsts in the country and currently one of the most productive nationwide, contributing to the improvement of food production. It has contributed to reducing poverty in the region since agricultural activities generated a constant labour source with high economic regional remuneration. Due to its hydrological and structural design, it is considered a unique engineering work of its kind, advanced for its time. The geological and soil mechanics studies were adequate. La Boquilla Dam is a structure that has contributed to the social and economic well-being of farmers and the general population located in the south-central region of the state of Chihuahua, particularly the municipalities of San Francisco de Conchos, Camargo, La Cruz, Saucillo, Delicias, Rosales, Meoqui, and Julimes. The construction of this dam marks the modern hydraulic history of Mexico.

12 MOROCCO

12.1 KHETTARAS

Name	Khettaras
Location	NA
Latitude	NA
Longitude	NA
Category of Structure	Water Conveyance Structures
Year of commissioning	1913
River Basin	NA
Irrigated/Drained Area	12750 ha

History

The presence of Khettaras span from the Middle East to Afghanistan, China and Japan in the East and West to the Maghreb, in Sicily (Palermo) to Andalusia (Spain). In Morocco, the first use of Khettaras dates several centuries back. In the 16th and 17th centuries, the Almohad dynasty ensured the diffusion of the technique of draining galleries in many regions of the Empire.

Examples of the structure in Morocco include the old Khettaras of Ighrem Akdim in Tinghir province, the sets of Khettaras of Jorf in Tafilalet, the amphitheatre of the Khettaras of Skoura in Ouarzazate province and near Marrakech, the Khettaras of Akrich in the south of the city.

The Haouz of Marrakech is a high place in Mediterranean hydraulic history. In a semi-arid plain with an extremely hot summer climate, generations of marrakchis have been able to capture groundwater resources for over nine centuries through the establishment of hundreds of Khettara. In Marrakech, the Khettara system is at the origin of the city's water supply, and irrigation of gardens and palm groves of the city. Previous investigations indicate that in the 1970s, (i) in Marrakech, there were 567 Khettaras of which 500 were in use (ii) in the South of TAFILALET region, 570 have been listed, and (iii) in the Province of TATA, 150 Khettaras have been identified, of which 70% were operational.

The oases of the Tafilalet Region occupy a central place in the Moroccan civilization of water, the Khettaras reflect centuries of human ingenuity to benefit from the floods of the Ziz and the Gheris rivers coming from the High Atlas and to extract the underground water by draining galleries, With the arrival of Islam in the seventh century in the Tafilalet in Sijilmassa zone, the knowledge of the hydraulic sciences was written in treatises in Arabic. It highlights how the social organization of the sharing of water was meticulous.

Description

Background and System Design

The Khettaras still constitute today, in the oases of southern Morocco, an ingenious system for collecting groundwater from the water table. They are also known in other countries under the name of Foggara or qanât.

This ingenious groundwater catchment system includes two types of Khettaras:

- Khettaras of the river (Oued) – Originate in a wadi and drain the groundwater from his courses. Length: varies from 500 m to 1 km.
- Khettaras of the water table – Located at the foot of a "Jebl" (Mountain) or on the terraces of a wadi; Length: can go up to 10 km (case of TAFILALET)

This hydraulic structure allows at its end the collection of water underground while minimizing losses through evaporation.

Today, the preservation of sustainable hydraulics is a major challenge for the future. The census undertaken during August 2000 shows that the number of Khettaras in operation in the Tafilalet area is 308 Khettaras with a length of 1,190 km serving 155 perimeters with a total area of 12,750 ha.

The Khettaras is a sort of water mine, an underground gallery that intercepts the water of a water table located upstream of the area to be irrigated. The water collected is transferred by simple gravity to the outlet (the slope of the gallery is lower than that of the slope of the ground). Many inspection wells are visible on the surface, they allow aeration during construction and maintenance of the structure. The pipes follow a slight slope (a few mm of height difference per m) and run about 5 or 10 m below the surface of the ground. The Khettaras themselves have a sufficient diameter (1 to 1.20 m) to allow the movement of a bent man, a worker advancing from downstream to upstream at the time of the drilling, and a worker circulating to carry out maintenance work. Regarding the duration of the construction of a Khettaras of a length of 1 km with wells (12 m depth), every 20 m would need 10 men for 1 year. The flow rate varies according to rainfall, annuals upstream, the length of the draining part and the qualities of the ground and basement from a few litres / second up to 30 l/s and sometimes more depending on the water table load. The irrigation of oases with underground water resources relies on the whole art of combining wells to extract rare waters and Khettaras which provide little water throughout the year.

Water Heritage

The ingenuity of the Khettaras lies in its design and its adaptation to the conditions of life and the Saharan climate: It eliminated the exhausting tasks of water supply chores, which took most of the time of the inhabitants, and ensured a limited but continued supply without risk of drying up the water table and limiting evaporation to a minimum.

- Khettaras are designed to serve as a catchment system of rainwater, seepage water
- It is an appropriate technology adapted for water supply
- -Low-cost structure, built using local labour and know-how
- -Can supply water for various uses drinking water for populations, irrigation of crops and trees and animal watering
- -No energy cost for its operation since it is based on gravity flow of water
- -Managed by the water users association or the community
- It requires periodic control and maintenance and rehabilitation operations as necessary

The analysis of this system, thousand years old, shows to what extent men who occupied this immense territory of desertic areas without water resources were able to challenge nature hostile to human life to make it so attractive and possible for the development of several civilizations.

Performances of Khettaras

The flow rate of Khettars is variable according to rainfall, annuals upstream, the length of the draining part and the qualities of the ground and basement.

Water rights and water towers: managing the water shortage – Water rights are in principle proportional to the work invested by families in past centuries for the construction of Khettaras. The turn of water is determined by the time between two irrigations of the plots of a beneficiary of the resource. With time and its corollary, the successive inheritances of land, and water rights have become fragmented. Nowadays the lowering of the water tables, recurring drought years, the construction of dams and urban demography, and the digging and drilling of individual wells have led to a decrease in water resources. The water turns went from a few days (10 to 20 days) to more than 2 months in certain cases. The ingenuity of this system, which has enabled it to resist throughout history, calls on us to deepen its analysis and study from all sides, particularly technical and organizational.

The Khettaras is an ingenious system cleverly developed within North Africa. The management system is characterized by democracy in decision-making and sharing. The election is democratic and is carried out unanimously, the office is elected for only one non-renewable term over one year. The maintenance is carried out in proportion to the parts of each beneficiary The Khettaras constitute a comprehensive system that integrates the human and the ecosystem which makes it a heritage to be safeguarded. They contribute to the maintenance of life in the oases, without the Khettaras as a source of drinking water and irrigation, all the oases will be deserted by the populations They help to fight desertification, the progress of sand in the region and therefore safeguard human life and the environment of the region. Khettaras' issues are now not reserved for the small world of scientists but enter the cultural world, at least. It is a heritage for future generations.

Management of the Khettaras - Traditional Management

A water right also translates into obligations to provide maintenance services. It is the community switchers who take charge of the organization of the provision of these services by reminding the beneficiaries whenever the need arises. The maintenance work carried out under the supervision of these dispatchers generally concerns cleaning, unblocking, sealing leaks, etc. For this type of work, the beneficiaries provide the dispatchers with the necessary labour. In the case of masonry, concrete or upstream extension work, the formula adopted consists of creating a fund whose contribution from each user is based on the shares they hold.

Modern management by NGOs

In recent years, several associations have been created in the Khettaras areas. These associations are set up by people living in the areas of action of the Khettaras under the law in force relating to the creation of associations, in this case, the Law on Associations of 1958 revised in 2002 and Law 2-84 on the Association of Agricultural Water Users. These associations are subject to the publicity and filing formalities imposed by the laws in force and their activities meet the objectives announced in their statutes. Currently, there are more than 141 such associations established in the ORMVA action area of Tafilalet. A part of these associations is called by ORMVA of Tafilalet as Association of Khettaras being that the objectives that they have set are focused on the rehabilitation and preservation of the Khettaras, although their statutes do not differ much from other associations having the main objective of rural development. An association of Khettaras may concern one or more Khettaras according to the choice of the owners of each Khettaras. In the region of Jorf, there are 9 associations for 59 Khettaras and in the region of Tinejdad, there is an association that brings together 24 Khettaras. These associations provide support to farmers and help to drain financial resources from national and international donors for the rehabilitation of Khettaras and other rural development projects in the Khettaras regions. The characteristic of these associations is that they are formed for the most part by the heads of Khettaras only and not specifically by the members. In the Jorf region, there is an association union that is supposed to promote information exchange and coordination among association members. It should be noted that in other areas, in particular in the village of Hassi Labiad, a rural development association has invested in the rehabilitation of the village of Khettaras via the mobilization of funding from an international donor.

13 PAKISTAN

13.1 BALLOKI BARRAGE

Name	Balloki Barrage
Location	Punjab Province, Pakistan
Latitude	31.233
Longitude	73.867
Category of Structure	Barrage
Year of commissioning	1913
River Basin	Beas and Ravi River Basins
Irrigated/Drained Area	1.064 million acres initially; 3.06 million acres

History

Constructed in 1913 on River Ravi, the Balloki Barrage is located about 60 km D/S of Lahore, Punjab. The Barrage feeds two canal systems viz. Lower Bari Doab Canal (LBDC) and Balloki Sulemanki Link Canals (BS Links). It was a revolutionary project which completely transformed the command area wastelands into prosperous food-producing agricultural land in a few years, boosting farmers' income and improving the area's economic condition.

In 1633 Ali Mardan Khan, a celebrated engineer, constructed the Hasli Canal from Madhopur on the Ravi River for irrigating a part of Bari Doab but chiefly for supplying water to the pleasure gardens of Shalimar at Lahore. In 1847 Lord Napier of Magdala, the first Irrigation Chief Engineer of Punjab under British rule constructed the Upper Bari Doab Canal. Due to inadequate water supply in the Ravi River, canals were cut short to less than a half down the tract. However, the lower portions of the Doab couldn't benefit from the canals. The gross area was about 18,22,217 acres with 14,60,650 acre culturable area. Popularly known as the Crown wasteland, the area had meagre cultivation, dwindling water tables and little rainfall (about 7" annual falls in the southwest to 11" in the North West). A large part was covered with scanty growth of *wan, jhand* and *karil* bushes. There was little well-based irrigation in about 8000 acres only in *Kharif* (monsoon) season. A large portion of the population of the Ravi Khadir migrated to the adjacent Chenab Colony. These unfulfilled demands led to several future renovations and restructuring of the canal system. The existing remodelled Barrage was constructed in 1970 as part of the gigantic project under the Indus Basin Development Fund Agreement under the Indus Water Treaty between India and Pakistan.

Description

The Headworks structure was constructed in a level crossing at the Upper Chenab right bank where water flows into the Ravi River, crosses it at the bed level, and passes on Balloki's right bank. The complex consists of an inlet, a barrage, a regulator, and training works. A silt excluder in the shape of tunnels at the barrage in front of the head regulator was constructed to control silt entry into the main canal. In the century-old original structure, the silt entry was controlled by a second temporary sill to exclude heavy silt from the canal channel.

The barrage consists of a weir of 1646.5 feet extreme length divided into 35 bays, 40 feet clear by piers 7.25 feet wide. Due to the river bed's fine soil, the floor is extensive to reduce the danger of blowing up. The flank walls and piers are 22.34 feet high and are surrounded by steel trestles, which carry the operating platform. The gates are counterbalanced on the Stony principle, and the machinery is geared to lift the gates at short notice and lower them according to the requirements of the regulation.

The Head regulator has 15 bays, each 20 feet clear divided by piers of 3.8 feet wide. A permanent sill is 6.41 feet high and a further temporary sill of 2.5 feet height is obtained by a rising gate 2.75 feet tall to exclude heavy silt from the canal channel. The gates are in two parts, the upper falling and lower rising to shut the vents. A roadway crosses the barrage, on the downstream and the upstream of the gates to operate machinery, geared to close the vents quickly and open them at leisure.

The training works consist of many bunds and groynes to bring the stream to the barrage and divert it to a safe distance downstream. The benefitted gross command area is 1,822,217 acres, and the culturable commanded area is 1,460,650 acres for the LBDC system only. The original design capacity was 139,500 cusecs. However, the barrage has discharged more than its design capacity many times. Fused plugs in the Left Marginal Bund pass the extra flood for its safety. Keeping in view frequent floods at the Balloki barrage, a gated flood spillway structure is also planned to pass the additional flood discharge over and above the design capacity guaranteeing an extra safety cushion against the floods.

The structure was initially constructed to feed a canal system to irrigate 1.064 million acres of the culturable commanded area infertile and productive lands in Kasur, Pakpattan, Sahiwal, Okara, Vehari, Khanewal, Bahawalpur, Bahawalnagar, and Multan districts. Presently the structure is feeding water to about 1.67 million acres of LBDC command area. Moreover, the construction of the B.S. Link in 1960 further supplies water to 3.06 million acres of land in the districts of Pakpattan, Vehari, Multan, Bhawalpur and Bahawalnagar.

Water Heritage

The irrigation structure was a bold engineering experiment of its time. It was executed in a short period and gave tremendous results. It enhanced agricultural production and the area's economic condition by providing sufficient irrigation water supply.

During the *Kharif* (monsoon) crop, irrigation water was supplied from the Ravi River from April to September. However, the *Rabi* (winter) crop from October to March was difficult, which was the prime focus of the irrigation system. The gross area of 8,82,528 acres (4,41,264 acres in *Kharif* and 4,41,264 acres in *Rabi*) was covered by Balloki Barrage and Lower Bari Doab Canal (LBDC). The annual sanctioned perennial volume for the LBDC command is 4.91 MAF made up of 2.78 MAF in *Kharif* (monsoon) and 2.13 MAF in *Rabi* (winter). The design discharge for LBDC is 9,841 cusecs and includes 1,100 cusecs of Sutlej canals commands supply via the seasonal link. LBDC was initially designed for a cropping intensity of just 67%, which gradually increased to about 170%, driven by population growth and enabled private wells to pump groundwater which was negligible before the project. In Okara and part of the Sahiwal division, spring-maize, rice, potato, spring potato, maize autumn, and potato farming system is practised at more than 200% intensity-an appreciable acreage. There is a potential effect on yield, and some farmers are obtaining as high as 5 tons/acre yield of spring maize with conjunctive use of canal and groundwater and high input technology.

Balloki barrage, along with its LBDC system and Balloki Sulemanki Link Canals (BS Links), supplies water to the Pakpattan Canal at Sulemanki Barrage, enhancing agriculture production. It is estimated that about 42.72 million tons of assorted agricultural commodities are annually produced in the LBDC command area; this includes 8.68 million tons of cereals, 5.08 million tons of vegetables and fruits, 20.28 million tons of fodders, 6.88 million tons of sugarcane, and 1,636,000 tons of cotton. Oilseeds and pulses amount to 160,000 tons.

In terms of engineering design, construction strategy, and the size of the command area, the irrigation system was ahead of its time. When the structure was constructed on alluvial soil 100 years ago, there was limited energy dissipation through a hydraulic jump. Still, the techniques used for the structure's parameters (i.e. crest level, and downstream floor level) catered to the energy dissipation through a hydraulic jump. The facility is still functional today, even after getting five upstream discharge diversions. It was constructed to divert only 6,500 cusecs, but today, it is capable of diverting 9,841 cusecs to LBDC and 24,500 cusecs to BS Links without any change in the main structure.

Balloki barrage has a pronounced effect on groundwater development in Lower Bari Doab. Due to increasing irrigation demands and the development of private tube wells, groundwater use increased from 0% to 60% at the start of the 21st century, becoming an essential contributor to agricultural growth for many years. More than 48,000 tube wells were installed throughout LBDC Command Area, supplying about 60% of the irrigation water. Groundwater pumping is carried out in both cropping seasons, with groundwater pumping distributed approximately 35% in *Rabi* and 65% in *Kharif*. This agricultural boost improved the living standard of inhabitants.

Balloki barrage was constructed to provide water to 8,82,528 acres of cultivated culturable area and is today providing for about 1,67 million acres of LBDC command area in the districts of Kasur, Okara, Sahiwal, Khanewal and Multan after 100 years. Currently, diverting 8650 cusecs to the LBDC system in the future will divert 9,841 cusecs in the LBDC system after the remodelling of the distribution system. About 3.06 million acres in Pakpattan, Vehari, Multan, Bahawalpur and Bahawalnagar districts receive irrigation supplies through this canal. The total area that benefited from this barrage is about 4.73 million acres, i.e., 23 % of the total command area of the province.

The barrage was a critical irrigation infrastructure for the region and the time it was built. Agricultural production enhanced, groundwater usage increased, and the economy prospered. From an engineering perspective, it was a masterpiece that withstood time damages, political turmoil, increasing demand, and natural disasters. Even today, it provides irrigation water supply and will continue to do for many years to come.

14 RUSSIA

14.1 DRAINAGE SYSTEM IN NOVGOROD REGION

Name	Drainage System in Novgorod Region
Location	Velikii Novgorod, Russia
Latitude	58.533
Longitude	32.717
Category of Structure	Drainage System
Year of commissioning	1854
River Basin	Nevsko-Ladojskii
Irrigated/Drained Area	100 ha

History

The academician Zheleznov Grove developed the first of its kind the closed mole-tile drainage method. It has no counterparts in the European part of Russia and is recognized as the only natural sanctuary of the federal level in the Novgorod region of Russia. The farmyard of Matveikovo, a forest wetland area, was presented as a gift to the academician by his wife. Based on his experience in forest management, he started experimenting with restoring neglected homestead lands and developed a scientific drainage system. Here he built a factory where he produced tubes, which he used to create the first pottery drainage in Russia. Unfortunately, in 1917 the Naronovo Estate and Matveikovo Estate were nationalized and later plundered and destroyed. Nevertheless, the drained fields continue to be used and are cultivated each spring, giving heavier yields.

Description

The first experimental area was a park in Matveikovo with terrain drainage. Pottery was used to manufacture drain tiles from burnt clay. First, pipes were laid at depths of 1.2 m to 2.1 m with drainage lines spaced 8.5 m to 11.3 m apart, predominantly in the recently redesigned Matveikovo homestead, 4 km away from Naronovo. After setting up the land improvement system, the forest and field plots were effectively drained, thus positively affecting the crops. Some of the drainage system water was collected in special wells and utilized on the farm using a pioneering water supply device. The water running out of drain tiles was pure and strained, and potable. The end of one drain tile led to a tank in the house's cellar from where water was pumped to the upper floors.

Пруд

A vast vegetable garden and orchard were developed using trees and shrubs relocated from the Naronovo nursery garden in the wetland areas. A unique landscape park on the Valdai upland of about 42 ha with a harsh climate was also designed with groves, glades, meadows, clumps, lanes, a pond, and a reservoir on the small Krivchaga River. The local flora species, Siberian and silver firs, Siberian stone pine, larch, and American arborvitae, were also grown. At present, the park comprising lanes of ancient oak trees, elms, limes, Siberian fir, arborvitae, Chinese quince, larch, Hungarian lilac, and other species is known as the Academician Zheleznov Grove. After 130 years, the best fir specimens are growing 40 m tall with a breast height diameter of about 1 m. The Siberian larch measures 38 m and 90 cm and the Siberian stone pine 26 m and 68 cm, respectively. American arborvitae in corridor plantings is 15 m tall. Amazingly, the trees' parameters being grown on Novgorod soil exceeded those growing in Siberia. Even the trees and shrubs planted in the middle of the 19th century demonstrated good condition.

Apart from the drainage system, relocating large-sized trees using a particular machine was also developed. The biological features of numerous plants were studied in detail. Drainage ditch weeds were used as hedges in homestead planning. The estate had a set of farm implements, including steam thrashing, winnowing, mowing and planting machines, a grain dryer, etc. Nowadays, such ideas are still topical and are often employed in modern landscape designs.

The successful implementation of wetlands drainage in the Novgorod region was soon noticed and replicated in other areas like the Aleksandrovsk village of Schlissenbach's Estate near St Petersburg. As a result, the yield of spring wheat was significantly higher on the drained lands than on the undrained ones.

Поляна перед домом
вид с балкона
фото 1911г.

Over the years, scientists and specialists from many countries have studied drainage systems and the Matveikovo region. In 1981, I.M. Burmatov and V.T. Nikolayonok, researchers from the Novgorod Experimental Reclamation Station within the Northern Research Institute for Water Engineering and Land Improvement, uncovered the drainage lines of the land improvement network. They established the drain's depth, and parameters of drain tiles, revealed that the joints between drain tiles were unprotected, and determined the angles at which drains joined the collector drain. In 1981, forestry specialists led by A. N. Avdeev relocated Siberian fir seedlings from dense stands to the seed plantations and planting areas in the Novgorod, Krestets and Okulov districts of the Novgorod region, where they were successfully established.

In 1983, researchers from the All-Union Research Institute for Nature and Wildlife Preservation, led by N.G. Vasiliev, a prominent biologist, surveyed the park with a plane-table mapping and counted the trees of introduced species. The survey showed good natural regeneration of the fir and the replacement of the wood sorrel spruce forest by fir and spruce stands. The findings served as a basis for delineating sanctuary areas.

In 1990, scientists from the Forest Experimental Station of the Leningrad Forestry Research Institute resurveyed the park. They identified the plus trees of Siberian fir and Siberian larch, which were later declared a natural sanctuary of the regional (oblast) level Zaruchevye and the stow Matveikovo (Marat) together with neighbouring forest and farmland.

In 1990, the territory of the former estate of Nikolay I. Zheleznov received the status of a regional nature reserve "Zaruchevye".

Water Heritage

The Academician Zheleznovs Grove was the first place in Russia drained using the closed mole-tile method, which is still partially functioning today, after 170 years It has no counterparts in the European part of Russia and is recognized as the only natural sanctuary at the federal level in the Novgorod region. After the land improvement system, the forest and field plots were effectively drained, thus positively affecting the crops.

The structure was an engineering marvel which laid the foundation for future engineering theories and practices. Meteorological observations were conducted to secure reliable experimental results and compare the drained and controlled land in terms of temperature, humidity and yielding capacity. A weather station was built 0.5 km away from the Naronovo homestead to collect data on the climate of the Novgorod province – at a time of limited technical capabilities. Remarkably, the meteorological studies of Zheleznov are still precious as they track changes in climatic conditions of the Novgorod region. Contemporary scientists have concluded that the Novgorod region climate has become warmer and more humid over the past 150 years.

During the experiments, it was found that the drained field took 12 days less for the oats to ripe versus the undrained one, with a 12 % higher. Even the unwanted weed growth was reduced by 50 %. In 1857 repeated experiments showed an even higher yield difference. The drained field gave a four times higher yield than the undrained one. N. I. Zheleznov carried out his drainage works with great enthusiasm, which even put aside his other scientific research. In 1860, a report about soil properties and methods of soil drainage based on the system revealed that land fertility depended on the water ratio and Northern Russia's excessively wet soil; draining soils was necessary for agriculture. The academician N. I. Zheleznov discovered that it was essential to introduce better drainage methods, such as tile drainage above all others. He laid down the main principles of tile drainage, specifying the depth of laying pipes and advanced detailed ways.

For his research and the drainage system introduced in the northern parts of Russia, in 1857, Zheleznov received a gold medal from the Free Economic Society. In his book titled 'Field Drainage', he expounded on the theory and practice of land improvement. After a century and a half, the drainage system is still in operation, draining forests and farmlands.

The unique drainage system was a pioneering scientific experiment in Russia and should be preserved and, if necessary, rehabilitated. It can serve as a sanctuary and an academic facility for agriculture and forestry specialists. Under Resolution No. 199 of the State Planning Committee, the stow Rovnushko, the homestead, received the status of a state natural sanctuary of the republican level The Academician Zheleznov Grove'. With the construction of M11 (Moscow to St Petersburg) next to the experimental drainage area, there is scope to develop it as a historical site of land improvement for tourists and scientists of the Novgorod region and other regions and countries.

15 SRI LANKA

15.1 ABHAYA WEWA RESERVOIR

Name	Abhaya Wewa Reservoir
Location	Anuradhapura District, Sri Lanka
Latitude	8.350 N
Longitude	80.383 E
Category of Structure	Water Storage Structure
Year of commissioning	4th Century BC (rehabilitated in 1874)
River Basin	Malwathu Oya Basin
Irrigated/Drained Area	156 ha

History

Abhaya Wewa Reservoir, located on Malwathu Oya River, Sri Lanka, with 932 ha of the catchment area, is the most ancient reservoir in the country that continues to serve even today, playing a pivotal role in fulfilling the water needs of millions of pilgrims besides providing irrigation facilities.

The reservoir is located west of the present city of Anuradhapura, the first ancient capital of Sri Lanka, which served as the country's capital for the most prolonged period. It is famous for its well-preserved ruins of the Great Sri Lankan Civilization. The Hydraulic Civilization, which was built in this city, was one of the greatest civilizations of Asia and the world and serves as one of the very significant preserves of world heritage. It is identified as "Bassawakkulama" and is associated with King Pandukabhaya, 4th century BC. In 1870, the British found the reservoir and renovated it in 1874.

Description

The length of the earth embankment is about 1425 m. The present full capacity is 2 MCM and the water spread at the full supply level is about 107 ha. Even after 2500 years, the reservoir continues to supply water to Anuradhapura. Presently, the reservoir is fed by the Tissa Wewa reservoir, which is augmented by Mahaweli diversions. This reservoir had only one sluice for agricultural purposes and served a cultivated area of about 141 ha. Though today, the priority use of the reservoir water is for domestic purposes and not irrigated agriculture.

The operation and maintenance of the Abhaya Wewa reservoir, and the central system including embankment, spills, sluices, main canals, branch canals and feeder canals are carried out by the Irrigation Department. Two farmer organizations established by the Irrigation Management Division manage the sub-system, including distributary canals and the field of the irrigation scheme with financial support from the Irrigation Department.

Water Heritage

Abhaya Wewa is one of the oldest reservoirs in Sri Lanka, which paved the way for many more irrigation projects. Constructed from ancient wisdom, the structure reflects Sri Lanka's rich history and knowledge in the irrigation space.

The construction of the structure in the 4th century BC represents remarkable development in agricultural production and irrigation infrastructure at the time. The reservoir initially provided irrigation to an area of 156 ha and now facilitates an additional 371 ha. For more than 2500 years now, the structure has helped in food production and improved the economic condition of the farmers. Given its historical relevance, the reservoir is important to locals and tourists for religious and cultural purposes.

One of the most ancient reservoirs in the historically reserved city of Anuradhapura, the reservoir remarks the civilization's past, culture and traditions. The structure has contributed positively to society and has been providing for millions of pilgrims besides providing irrigation facilities and domestic use for the local population. The drinking water facilities offered at the Buddhist festivals are still revered today.

The structure is a prominent example of sustainable operation and management mechanisms passed over many generations. The Irrigation Department operates and maintains the primary system, including embankment, spills, sluices, main canals, branch canals and feeders. Established by the Irrigation Department, two farmer organizations named Abhaya and Sarabhumi manage the subsystem, including distributary canals and the field of the irrigation scheme. Collectively, for the management of the reservoir, a unique participatory approach is adopted.

15.2 DAM & OLD SLUICES OF PARAKRAMA SAMUDRAYA

Name	**Dam & Old Sluices of Parakrama Samudraya**
Location	**Polonnaruwa District, Sri Lanka**
Latitude	**7.941590 N**
Longitude	**80.998330 E**
Category of Structure	**Dam**
Year of commissioning	**1153 – 1186 A.D.; Thopawewa reservoir: 386 A.D.**
River Basin	**Mahaweli Basin, Amban ganga**
Irrigated/Drained Area	**More than 10,100 ha**

History

Parakrama Samudraya is one of the largest and most famous reservoirs in Sri Lanka which is situated in Polonnaruwa District. According to the chronicles, the lake was constructed in the reign of King Parakramabahu, who is one of the most powerful and famous rulers in Sri Lankan history. As the stories fold on, the lake is mainly constructed by connecting five mini lakes with a proper canal, now named Theppan Ala. The northernmost lake is called Thopa wewa, which was built by King Upathissa back in the 6th century, the middle one is Eramudu wewa and the southernmost one is Dumbutulu wewa. There were two more lakes named Kalahagala wewa and Bhu wewa, but they have been taken off from the main reservoir in the reconstruction process back in the 1950s.

There are a large number of stories that are related to the Parakrama Samudraya. One story tells that there was a small harbour-like part in the lake where small ships sailed through the Mahaweli River and Kalinga Ala (Canal) as King Parakramabahu is a ruler that conquered many foreign countries. The main feeder canal of the lake is named Angamadilla Yoda Ala which was constructed at the time by diverting the Amban Ganga. The ancient anicut is called the “Raja Bamma”. It was reconstructed around 1939.

Description

There are a few ancient sluice gates found around the lake and they are known to be some of the best ones in ancient history. The technology, the construction methods and the locations are unbelievable. One can be seen near the Lake Rest House which is located at the beginning of the Thopawewa dam. Another one is located in the Bendiwewa area and it is the one that anyone can investigate the technology well, as it is now separated from the old lake dam. And there is another one located nearly 15 km away from the Thopawewa. It is named “Bhuwewa Sorowwa” and the old Bhuwewa Lake has been filled up and encroached by farmers, as that part of the Parakrama Samudraya had been neglected when the rehabilitating process started back in the 1950s.




The tank was rehabilitated under the instructions of former Prime Minister, The Rt. Hon. D.S. Senanayaka increased capacity of tank 135.68 MCM after further improvements. Then after the construction of modern spillway gates, the storage increased up to 143.207 MCM.

Parakrama Samudraya is located in Thamankaduwa divisional secretariat division in the Polonnaruwa district in North Central province. The catchment area of the lake is 72.52 km^2 and the capacity at F.S.L. is 143.207 MCM. The dead storage is 18.5 MCM, the full supply level of the lake is 59.43 m MSL and the High Flood Level is 59.74 m MSL. The dam is constructed as a Homogenous Earth fill embankment. The length of the dam is 12.4 km and the average height is 15 m. The maximum height of the dam is 15.85 m. The lake is mainly fed by the water from Angamadilla Yoda Ala diversion structure which is constructed by crossing the Amban Ganga at Angamadilla area.

Water Heritage

Parakrama Samudra has provided livelihood to a large number of inhabitants. Many people benefitted from various employments such as paddy cultivation, cultivation of other field crops, inland fish industry, ornamental fish production, home gardening, fertilizers production and animal husbandry. The Wasgamuwa National Park is considered a major feeding area of the lake. The tourism field is also highly benefited as the National Park is around the Parakrama Samudraya.

Another major thing is there are stone pillars located in the dam and they are known to be the measurement posts at the time. They are named “Gaw Kanu” and one Gawwa is nearly similar to 1 km. There are ancient ruins of a castle in the middle of an island located in Parakarama Samudraya. It is known to be “Seetha Maligaya” and folk tales say that there were many castles in the middle of the ancient Parakrama Samudraya. And the ancient spillway was located in Bendiwewa and some remains of the ancient spillway canal can still be seen there. When the lake was founded in the late 1800 s, there was just one breach which was about 18.28 m in depth and 182 .88 m in width. It was then named Eramudu Kapolla and there was a canal named Diwulapitiya Ala, which carried a lot of water in rainy seasons. At one point, it was proposed to construct a new reservoir barraging Amban Ganga, leaving Parakrama Samudraya without reconstructing.

Parakrama Samudra dam was rehabilitated under Dam Safety and Water Resources Planning Project (DSWRPP) funded by World Bank. Major rehabilitation items attended under DSWRPP are, renovation of rip rap, strengthening of the dam, address to water seepage issues in the downstream toe by constructing loading berms, rehabilitation of spill gates and sluice gates, the establishment of bathing steps, installation of piezometers on the dam, establishment of bathing steps, provision of toe filter & toe drain and construction of access road for inspection etc.

15.3 ELAHERA ANICUT

Name	**Elahera Anicut**
Location	**Polonnaruwa District (Colombo), Sri Lanka**
Latitude	**7.734 N**
Longitude	**80.793 E**
Category of Structure	**Barrage**
Year of commissioning	**65 - 109 AD**
River Basin	**Mahaweli Basin / Amban Ganga**
Irrigated/Drained Area	**6,700 ha**

History

Elahera Anicut (Barrage) was constructed by King Vasaba (65 - 109 AD). According to Mahawangsa the Elahera, King Vasaba built the Canal to supply water to Minneriya and Girithale tanks. King Aggabodhi II (608-618) renovated and improved it further. Later, King Vijeyabahu (1055 - 1110) further repaired and rehauled the structure. It has been recorded that renovation works between 1856 -1900 were failed attempts due to a lack of policies and reconnaissance surveys. A novel scheme was commenced in 1884, and by 1890, Rs. 54,000 was spent on restoration. However, due to engineering difficulties and rugged forest terrain, the project was soon discontinued. It was then recommissioned in 1945.

Description

Giritale and the Kantale were constructed by King Aggabodhi (604 AD), but it is evident that Parakrama Bahu I renovated the Giritale during the Polonnaruwa era. This irrigation system includes a diversion structure constructed at Elahera across Amban Ganga (a tributary of Mahaweli Ganga), which starts from the foothills of Matale. This massive canal conveys water from this point to Minnerlya, Giritale, and Kantale reservoirs. On this long way from Elahera to Kantale, the canal irrigates small tanks like Ihakulu Wewa, Rota Wewa, Matalu Wewa, and Konduru Wewa. The first stretch of this canal from Elahera to Diyabeduma (where it is bifurcated to Minnerlya and Giritale) is 33.75 km long. After 4.02 km up the Nehinne Ela, it enters the Giritale tank and the other branch, which falls into Talawatura Oya and enters Minneriya after 40.2 km from Elahera.

During December 2012 and 2014 floods, the barrage was flooded up to the Passerel level. The excavation research concluded that the spill gates of the structure were not enough to manage rainwater from the current climate changes. Therefore, new maintenance protocols were developed.

Annual routine operation works of the scheme included purchasing tools, payment for the farmer organizations,




employment of additional labour during the flood seasons, and so forth. Maintenance works included works such as clearing of weeds along the canal bund and reservation in the feeder canal, clearing of weeds along the central canal bund and reservation, desilting the main canal bed, repairs of structures, greasing, oiling of structures' parts, painting of steel parts of structures and so on.

Water Heritage

Elahera Anicut (Barrage) was a visionary irrigation structure that innovated unique native solutions, employed engineering mechanics, and stood firm over the generations. Evidence indicates that the preparation of cement-like solid plaster, used as a binding medium for building brick or stone walls in ancient edifices, has also been unearthed in the Elahera Anicut. Finely grounded clay, sand and lime with seashells or gravel mixed with herbal oils extracted from trees like dorana and mee was well-known in ancient Sri Lanka. One of the examples can be seen in the brick plaster used at Elahera anicut ('amuna'). The plaster used in the Elahera anicut, though immersed in water for several centuries, had withstood its strength. Research has indicated that this plaster has been prepared by ground limestone mixed with herbal juice subject to intense heating and finally allowing the plaster to dry out and wet again when in use.

On the other hand, the ancient engineers mastered the technique of using barrages to block the major rivers. They were successful in controlling the Amban Ganga at Elahera using the dam. Blocking the flow in a major river with a barrage across can be a disaster if proper technology is not used. But they overcame this problem. The barrage and the unique technology used in its construction were truly ahead of their time. Barrages (widely known as anicut) were used to head up the water of a perennial river and divert it directly for irrigation fields or to store and use later. Ancient engineers had mastered this subject and dam construction, and they successfully controlled the Amban Ganga at Elahera.

For centuries, Elahera Anicut (Barrage) has represented a rich history of the region, and the irrigation infrastructure and has become the marker of Sri Lanka's social and political developments. There are several references to the barrage in ancient literature. R.L. Brohier, an irrigation scholar, said, "*This remarkable relic of ancient irrigation is generally assumed to have diverted the waters of the Amban Ganga and to have conducted it ultimately to Thambalagam Bay, linking amongst others the major tanks of Minneriya, Giritale, Kaudulla and Kantalai.*" He further stated, "*It is today known that mingling its waters with those from other drainage lines tapped on the way, the Elahera canal provided a continuous lifeline to irrigation up to Tambalagam near Trincomalee, 85 miles from the intake.*"

15.4 ETHIMALE (RESERVOIR) TANK BUND

Name	**Ethimale (Reservoir) Tank Bund**
Location	**Moneragala District / Sri Lanka**
Latitude	**6.82578 N**
Longitude	**81.4511 E**
Category of Structure	**Water Storage Structure**
Year of commissioning	**161 – 137 A D; Rehabilitated in 1958-1964**
River Basin	**Wila Oya River Basin**
Irrigated/Drained Area	**406 ha**

History

Ethimale tank bund was built by Brother Saddhatissa of King Dutugamunu (161-137AD). According to folklore King Dutugemunu had entrusted his brother Saddhathissa with the development of the East and South-east areas of the country. Prince Saddhathissa had developed the water resources in the area and had created an environment where people did not have to face food shortages. King wanted to check the progress achieved and had sent a person with a bag full of paddy and wanted him to sell it. The person had walked in the entire area but could not find anyone who wanted to buy and had finally reported it to the King. King has realized all are self-sufficient and had called back his brother with the message “enough brother” which means Ethi Male in Sinhala. After that area has been known as Ethimale and the tank was last built as Ethimale. However, this area had been deserted over many centuries later, until the Irrigation Department commenced the development of the water resources at the beginning of the 1950s. In 1958 restoration work of Ethimale had commenced and 334 families selected from Badulla, Welimada and Moneragala were given land. By 1964 on completion of the canal systems water was released for cultivation.

Description

The Ethimale tank is situated in the Uva province of Sri Lanka across the upper part of the Wila Oya catchment. The technology used to build the Ethimale tank bund was advanced. The earthen bund made to retain water had been constructed in three sections joining four different mountain hills. The water from the reservoir is not released to the paddy fields directly but to the Wila Oya stream and at an anicut 4.5 km downstream, it is diverted through a canal system to the fields. The main canal runs 2 km parallel to Wila Oya stream and only after that the water is released to fields through distributary canals. The water thus distributed is retained by few small tanks along the canal and thereafter released to adjoining fields from these tanks.

Ethimale tank has its catchment area of 24.6 Km^2, gets an annual rainfall between 1400 to 1600 mm and stores 6.796 MCM of water at its full supply level with 0.6167 MCM as dead storage. This tank bund consists of 3 sections of homogeneous earth fill interconnecting four mountains. The length of the dam is 1.10 km and the bund top elevation is 113.087m above MSL.

Ethimale tank is issuing water for 406 ha of paddy fields in the Ethimale irrigation scheme. In addition, this tank is utilized for domestic purposes as well as fisheries and tourism industries.

Water Heritage

Ethimale tank belongs to the Monaragala irrigation region and it is located in Siyambalanduwa divisional secretariat division in the Monaragala district in Uva Province. The maximum capacity of the Ethimale reservoir is 6.796 MCM It serves 406 ha of paddy lands, and its catchment area is 2460 ha. The main spillway discharges to the Wila Oya stream. This tank is the main water source in this area and gets water during mainly Maha season falling from October to December every year. The full extent is cultivated in Maha season whereas a portion of farmland is selected in Yala season with calculating available water volume. About 60 % of the command area would benefit from the Yala season averagely according to the past records.

Ethimale tank is to be rehabilitated and augmented under the proposed Kumbukkan Oya reservoir project funded by GOSL. Identified Major rehabilitation are such as; Raising of spill level, Renovation of rip rap, Strengthening of the dam, Establishment of bathing steps, Establishment of tor filter & toe drain, Installation of piezometers on d/s slope of the dam, construction of access road for inspection, Installation of levelling monuments. Installation of boundary stones.

Steps to be followed during the rehabilitation process are mentioned below:

- Awareness programmes have to be conducted at the district level to aware stakeholders of the rehabilitation programme.
- Dam Construction Monitoring Committee is to be established to monitor the entire rehabilitation process.
- Final designs for the dam, spill and other features to be finalized.
- Inspection boat, Digital camera, Bush cutter, Tilford wincher, Chain saw, Desktop computer and software, printer, Generator, Inspection boat and safety jackets etc need to be provided to dam office to improve the Operation & Maintenance and capacity development of dam operators to ensure the safety of the dam.

Geological investigations done by the Irrigation Department revealed that as per the geological formations in the area, there is a likelihood of water seeping through the foundation or the mountain hills. In 1984, the tank was breached due to seepage at such a location between a hill and the bund. One who would have visited the area will remember the rock outcrops common in the area.

15.5 KALA WEWA

Name	**Kala Wewa**
Location	**Anuradhapura District /Sri Lanka**
Latitude	**7.993388 N**
Longitude	**80.539312 E**
Category of Structure	**Water Storage Structure**
Year of commissioning	**Balaluwewa: 44-22 BC and Kalawewa: 453-477 AD**
River Basin	**Kala Oya Basin**
Irrigated/Drained Area	**37,485 ha**

History

Sri Lanka has been a country with an agriculture-based economy since ancient times. Historical records indicate that three tribes called Rakshas, Yakkhas, and Nagas were living in Sri Lanka when Prince Wijaya, the founder of the Sinhala nation, landed in Sri Lanka in the 6th Century BC. When he disembarked from his ship, he saw the Yakkha Princess, Kuveni, at a Spinning Wheel beside a tank. It can be seen, however, that tanks existed in pre-Wijayan times.

According to the great chronicle Mahawansha, Anuradhapura is the first great kingdom that lasted more than a millennium in the middle of the dry zone of the country. Ancient engineers of Sri Lanka had constructed tanks to conserve the water received from monsoon rain and from the streams of the area to protect the kingdom from drought. And it was used for the cultivation and needs of the nation, forming one of the great irrigation civilizations in the world. The eco-friendly culture formed under the great leaders of the nation has protected the system for over two millenniums.

There are a lot of folklore about Kalawewa and its construction. One story says, Kadawara, who found the location and informed King Dhathusena, was in charge of the Kalawewa. One day he found piping in the dam and kept his head against the hole until aid from villages came, after which he died. The villages believe in the soul of Kadawra, as Kadawara Deviyo still protects Kalawewa and surrounding villages. The devotees of Kadawara still visit the Kadavara Devalaya at the Kalawewa dam. Both investigation and testimony hold that in the past, four major canals or Yodha Ela distributed the water stored in Kala-Balalu Wewa. One of them is known as Balalu Wewa Ela and the other is the Jaya Ganga of the Mahavansa. Jaya Ganga starts from a sluice at the Kala wewa end of the tank and trails northwards to Anuradhapura and beyond. The bund of this giant channel meanders over the country in easy curves and deflects the water over astonishingly easy gradients. Some idea of this can be measured by the fact that for the first seventeen miles, the fall is not much more than six inches per mile. The Jaya Ganga was not only an engineering marvel but also an ecological system that benefited the public and nature as well. The ancient spill of the twin tank Kala-Balalu Wewa is said to have existed for centuries before it was enlarged in 477 AD. It is a stupendous work of hammered granite, excellently dressed and at the crest morticed. This ancient spill has been retained untouched in the last scheme of restoration effected in 1877.

All the major old irrigation schemes of Nuwarakalawiya were closely linked with these three rivers called Malwathu Oya, Kala Oya and Modaragam Aru. We might, with good reason, say that although closely linked with these rivers, they take their origin in a magnificent artificial lake described on modern maps as Kala Wewa and Balalu Wewa. These twin tanks were formed by an immense dam thrown across a low valley which held up the waters of the Dambulla Oya, the Mirisgoni Oya and the Hawenella Oya, all of them originally feeders of the Kala Oya. Apart from supplying water to numerous valleys of Nuwarakalawiya for irrigation, there was a time when the very existence of Anuradhapura depended on the water held conserved in this valley.

Description

Kalawewa is one of the great irrigation heritage structures constructed during the Anuradhapura kingdom. It is situated 7 km southwest of Kekirawa in the Anuradhapura district. Present Kalawewa is known as a combination of two ancient tanks called Balaluwewa and Kalawewa. According to the Mahawansha, the older tank, Balaluwewa, was constructed during the period of King Kutakanna Thissa (44-22 BC) across Hawenella Oya, and Kalawewa was constructed during the period of King Dhathusena (453-477 AD) across Kala Oya.

Kalawewa is situated northwest of Dambulla, downstream of the Dambuluoya and Kandalama reservoirs. The catchment area of the lake is 552 km^2, and the Gross storage up to FSL IS 104 MCM. The full Supply Level of the lake is 129.235 m above MSL, and the Probable Maximum Flood is 133.28 m above MSL. The dam is constructed as a Homogenous Earth fill embankment. The Length along Crest is 6.5 km, and the Maximum Height above Bed Level is 14.5 m. The main river that flows into the Kalawewa reservoir is Kalaoya which collects water from an area of 525 m^2 of the local catchment of the reservoir. The Mahaweli water diverted from Bowathenna flows into the bifurcation at the Lenadora via the irrigation tunnel of Bowathenna dam and diverted into Dambuluoya and feeds Dambuluoya reservoir. From the Dambuluoya reservoir, water is diverted to Kalawewa through Kalaoya.

The historical records say that the Kala Wewa dam had been breached 3 or 4 times, and the reasons are still unknown. According to known history, Kala Wewa was restored in 1877 during the period of British Governor Sir William Gregory. Last time, Kalawewa had restored after the breach in 1958 due to the well-known heavy flood which breached more than 1300 tanks all over the country. At last, major rehabilitation works of Kalawewa were carried out by the Mahaweli Development program in 1976 when the spillway was raised to accommodate Mahaweli water diverted from Polgolla. The gross storage was then increased to 123 MCM.

According to Brohier, there was evidence of four ancient canals stared from the dam. The sluices of them are called Kalawewa Goda Ela, restored in 1887, Balaluwewa Goda Ela restored in 1887, Puliyankulama restored in 1973, and the most popular Yodha Ela sluice was restored in 1885, which are still in use. The Right Bank sluice and Left Bank sluice were constructed in 1976 under the Mahaweli Development program.

Twenty-one piezometers were installed by the Water Resources Board under the consultancy of the Central Engineering Consultancy Bureau (CECB) in the year 1989. Three additional piezometers were installed by the MRRP project. Another six piezometers were installed by Dam Safety and Water Resources Planning Project (DSWRPP), funded by World Bank in the year 2012. Major rehabilitation items attended under DSWRPP are supplying and installation of levelling monuments, supplying and installation of piezometers, furnishing and installation of V – notch and pipe culvert, renovation of rip rap, renovation of toe drain and access road, renovation of spillway gates, left bank sluice, Balaluwewa Goda Ela sluice, Kalawewa Yoda Ela sluice, Kala wewa Goda Ela sluice and Jayaganga sluice.

Water Heritage

Kalawewa and its waterway Yodha Ela (Jaya Ganga) is one of the most magnificent achievements of the ancient irrigation engineers of Sri Lanka. The reservoir has a total area of 2913.7 ha at the full supply level. Gross storage at the full supply level in 2018 is 104 MCM. The ancient spill is measured to be 183.5 m in length. The spill was built using hammered granite, a solid structure one could imagine. Each block of granite is shaped precisely to fit its neighbour. The whole structure eventually acts like one huge rock. The total length of the dam is 6.50 km, and the maximum Height above Bed Level is 14.5 m. Yodha Ela has built to bring water from Kala wewa to the city of Anuradhapura (Abhaya wewa, Tissa Wewa and Nuwara Wewa), and the Nachchaduwa reservoir was fed by the Yodha Ela. The length of the Yodha Ela is 87 km. The gradient of Yodha Ela was measured to be 6 inches per mile (1:10,000). Maintaining such a gradient is an extremely challenging task, even for modern engineers who have access to laser-guided survey equipment. Ancient Yoda Ela was later replaced with Nawa Jaya Ganga. The people of Nuwarakalawiya have benefited from Kalawewa since 477 AD or more according to the records. At Present, Kalawewa directly feeds 37,485 ha of paddy lands of Mahaweli system "H" and supplies water to Thisa Wewa and so beyond. Although the main purpose of the tank is agriculture, inland fisheries, domestic water supply, and the tourism industry also benefited from it. The Forest reservation upstream of the tank has been declared a national park considering the ecological and historical importance of the location. With the proof of all these historical data, Kalawewa has served the nation for over 1,500 years and has become a landmark heritage structure of the area all over the period. And it is among the great heritage irrigation structures of the world.

15.6 KANTALE WEWA

Name	**Kantale Wewa**
Location	**Trincomalee District (Colombo), Sri Lanka**
Latitude	**9.365 N**
Longitude	**80.998 E**
Category of Structure	**Water Storage Structure**
Year of commissioning	**608 -618**
River Basin	**Mahaweli Basin/ Kantale Oya**
Irrigated/Drained Area	**7,513 ha**

History

This ancient irrigation construction is situated in Trincomalee District. According to the chronicles, the Kantale tank is also named Gangathala Vapi. It was built by King Agbothe II (608-618), rehabilitated, and further developed by King Parakramabahu (1153 - 1186) the Great. It is believed that the Jayaraja Reservoir was initially built by King Wasabha (65-109 AD) and was donated to a Brahmin (priest) who was meditating in a nearby rock cave to heal his eyes.

The Kanthale Wewa was built by damming the Kantale Oya, which begins from Hurulu Forest Reserve and falls into the sea from Trincomalee. The reservoir is also fed by Yodha Ela, which brings water from the Elahera Amuna to Minneriya Wewa and Kaudulla Wewa.

From a construction perspective, it is believed that before 1876 there were two spillways to the Kantale tank, and during modification, they were converted to one spillway. This new spillway was constructed in a small rock outcrop near the Kusum Ela - a small stream. Subsequently, the spill tail canal was called Kusumakadawela. This tank was modernized in the year 1952, and farmers started settling in.

Description

Kantale reservoir, in the Trincomalee region, is located in Kantale divisional secretariat division in the eastern province. It covers an area of 23 km^2 and has a carrying capacity of 140.6 MCM at full capacity. The dam is 16.75 m high and 2.5 km long. Next to Kantale Wewa is a smaller reservoir called Vendarasan Wewa, more recently known as Jayaraja Wewa, but its history is unknown.

Kantale Wewa feeds the reservoir through 4 large tubes with a diameter of 3 m. The maximum capacity of the Kantale reservoir is 140 MCM. It serves 7,513 ha of paddy land, and its catchment area is 48,692 ha. The spill comprises ten radial gates of 4.6 m width and 2.43 m height, each. According to the records, the spill discharge during the flood seasons is found to be 61.2 m^3/s. The

Kantale reservoir is fed by Mahaweli water from Minneriya – Kantale – Yoda Ela, MKYE. The water is also fed to the other reservoir named Vendrasan Kulam, linked to Kantale reservoir, having a capacity of 25 MCM and an extent of 650 ha.

As of 2018, the renovation of Kanthale Reservoir was under the Dam Safety and Water Resources Planning Project (DSWRPP) funded by World Bank. Some planned rehabilitation activities include renovation of rip rap, strengthening of the dam, establishment of bathing steps, removal of unnecessary trees from the dam, placing of the gabion wall, establishment of tor filter and toe drain, the establishment of a drainage system on the dam, construction of access road for inspection, repairing of sluices, repairing of the office building for maintenance and repairing of gates.

Water Heritage

An engineering marvel, Kantale Dam, withstood many disasters, destruction, invasions, and infrastructure upgrades. A large embankment dam, Kantale Tank Bund, was breached in 1986, killing more than 120 people. Though the reasons are unclear, a plausible explanation could be wear and tear and heavy vehicle movement over the Bund road, which is now banned. It was a significant challenge for the Irrigation Department, which was managed successfully by restoring the bund within a short period. It was a disaster that emphasized the importance of Dam Safety.

The dam witnessed the emergence of cultures, a fusion of traditions that influenced society throughout different dynasties and invasions from the Britishers to the Dutch and the ancient kingdoms. There is rich folklore on Kantale Wewa, including tales in Tamil. There are records that the Dutch who controlled the coasts of Sri Lanka carried out rehabilitation work. The British Governor Sir William Gregory also commissioned reconstruction work at Kantale Wewa. It is noteworthy that the governor of Sri Lanka modified the Kantale tank in 1876. During this period, the tank's full supply depth increased to 8 m.

15.7 MADURU OYA ANCIENT DAM AND THE SLUICE

Name	**Maduru Oya Ancient Dam and the Sluice**
Location	**Polonnaruwa District**
Latitude	**7.647 N**
Longitude	**81.214 E**
Category of Structure	**Water Storage Structure**
Year of commissioning	**44-22 BC (King Kuutakannathissa); 273 AD (King Mahasen)**
River Basin	**Maduru Oya Basin**
Irrigated/Drained Area	**42,000 ha (from present sluices)**

History

This ancient irrigation structures prove that Sri Lanka is well known for its ancient hydraulic civilization and major irrigation works constructed since 3rd century AD. Maduru Oya Ancient Dam and the Sluice are believed to be constructed by King Kuutakannathissa (44 – 22 BC) but as per the grate chronicle, this reservoir was built by King Mahasen (273 AD). The Maduru Oya Sluice made up of stone slabs and bricks. Famous archaeological Professor in Sri Lankan Senarath Paranawithana believes that this sluice way was built by King Kutakanna Tissa (42-20 BC).

Description

The outlet conduits of the sluice are about 66 m in length and are encased in a brick structure which is about 9.5 m wide and 2.84 m in height. Bricks of an exceptionally strong type had been used in the reservoir. Specimens of bricks from this part of the structure measure about 0.45 m in length, 22.5 m in width and 0.065 cm in thickness.

An interesting and unusual element in the layout of the conduits is the incorporation of the so-called “wing wall”. This wall, built of a kiln–made brick, projects to the left of the path of the outlet conduits and extends along the line of the dam for about 10 m. It seems probable that the designers of the Maduru Oya sluice realized their construction, which had to withstand the effects of the passage of water at high pressure, needed, in addition to a good foundation, a means of securing its lateral stability.

The outer end of the sluice is formed of a stone block of massive proportions, which has been horizontally placed above three short stone pillars. The horizontal block is 2.5 m long and about 0.83 m in width. The central pillar is of a similar cross-section, but the pillars on either side are each about 0.35 m in width. Each of the two outlet orifices measures 0.7 by 0.95 m. Though in general layout and appearance, the outlets are quite similar to those of sluice in other ancient reservoirs, there is one feature which is specific to the Madur Oya sluice. The brickwork to the north of the outlet had been carefully

designed by a person who had a close acquaintance with the behavioural characteristics of fluids.

The builders of the Maduru Oya sluice laid a thin course of bricks over the stone roof of the rectangular outlet conduit. It is likely, they reasoned, that it was sufficient to prevent seepage under normal pressure. And if under exceptional circumstances, an unusual increase in pressure led to seepage, the thick brickwork forming the corbelled arch would have been meant to provide the second line of defence against seepage.

Water Heritage

Sri Lanka is well known for its ancient hydraulic civilization and major irrigation works constructed in the 3rd century AD. Some of these structures are often quoted as technically parallel to modern engineering designs and constructions. The ancient Maduru Oya sluiceway is one such structure as is coincidence with the same various site designed for the modem sluice under the recently executed Accelerated Mahaweli Development Project.

Compared with the remains of ancient sluices in Sri Lanka. The Maduru Oya ancient sluice possesses some salient features. One such feature is its twin inlet conduits, dressed in stone slabs enclosed in a massive, corbelled arch-shaped brickwork. Covering stone slabs with brickwork is a common construction pattern in ancient sluices, but this corbelled arch-shaped brick enclosure is only limited to the Maduru Oya sluice.

The central pit forms special interest as its right wall has a peculiar terracotta design of dancers. A similar feature has not been located in any other sluice in Sri Lanka.

The Maduru Oya Sluice made up of stone slabs and bricks is about is about 9.1 m high, 9.1 m wide and 67 m long. Famous Sri Lankan Professor Senarath Paranawithana believes that this sluiceway was built by King Kutakanna Tissa (42-20 BC). Carbon dating carried out in the USA has also placed the time to the 1st century B.C. But the popular local belief is that the original dam here was built before the arrival of Vijaya by the Yaksha Tribes around the 6th century BC.

Maduruoya main dam is located across the Maduruoya between two inselbergs known as Kandegama and Danagala, located at about 77 km from the river mouth. This was the first of the main river reservoir projects to be completed under the accelerated Mahaweli project to provide irrigation waters to the Mahaweli system B area to cultivate about 42,000 ha of paddy lands (28,000 ha from the Left Bank and 14,000 ha from Right Bank outlets). This reservoir has a hydropower generation capacity of 7.5 MW.

At Present, Maduruoya Reservoir has provided livelihood to a large number of inhabitants. Many people benefitted from various employments such as paddy cultivation, cultivation of other field crops, inland fish industry, ornamental fish production, home gardening and Hydropower generation. The Maduruoya National Park is considered a major feeding area of the reservoir. The tourism field is also highly beneficial as the National Park is around the Maduruoya Reservoir.

15.8 MINNERIYA RESERVOIR

Name	**Minneriya Reservoir**
Location	**Polonnaruwa District, Sri Lanka**
Latitude	**8.043 N**
Longitude	**80.898 E**
Category of Structure	**Water Storage Structure**
Year of commissioning	**275–301 AD**
River Basin	**Mahaweli River basin / Amban Ganga Basin**
Irrigated/Drained Area	**9,099 ha**

History

Minneriya reservoir is believed to build by King Mahasen during his reign from 275-301 AD. He improved the Elahera barrage built by King Wasaba to divert water to the Minneriya reservoir through Elahera-Minneriya-Yoda-Ela trans basin canal. Minneriya reservoir was historically known by many names like “Minihiri”, “Manihira”, “Minihiriya” and “Minihoru”.

Description

Minneriya tank is based in a flat area of agricultural plain and has a catchment area of 23,983 ha. It receives water from Polgolla via Bowathenna, Moragahakanda, and Elahera-Minneriya Yoda Ela (EMYE) in addition to the local inflows. Minneriya Dam is a homogeneous-earth-fill embankment with a length of approximately 2,320 m and a maximum height of 20m and comprises two embankments separated by a hill.

Minneriya Reservoir is situated between latitude 8.043 N and longitude 80.898 Annual rainfall is 1500 – 2000 mm, and the average temperature is around 30^0 C in the Minneriya area. The North-East monsoon begins from October to January, but for the rest of the year, this area experiences a dry situation. Minneriya Reservoir issues water for paddy fields in the Minneriya irrigation scheme and provides water to the National Water Supply and Drainage Board for potable water requirements.

Minneriya Dam was rehabilitated under the Dam Safety and Water Resources Planning Project (DSWRPP) funded by World Bank during 2010-2015. Some of the significant rehabilitation work carried out under DSWRPP was the renovation of rip rap, strengthening the dam, establishing bathing steps, toe filter and toe drain, installing piezometers on the slope of the dam, construction of access road for inspection, installation of levelling monuments and boundary stones.



Minneriya, being an old dam with unknown construction mechanisms, poses management risks during floods. Besides, the sudden release of water from the reservoir through spill gates also creates a disastrous situation for the downstream residents. Therefore, an Emergency Action Plan (EAP) was prepared with clearly defined responsibilities and provided specific procedures to identify unusual conditions that may endanger the Minneriya dam. It further stated mitigative action to be taken in the event of distress or potential failure of the dam and sudden high-water release from the reservoir emergency. This document also provides procedures and information for the Irrigation departments to notify emergency management officials, issuing early warning and notification messages for people living in critical areas downstream of the reservoir in case of an emergency. The procedures outlined in this EAP are used to protect the public from property damage or loss of life due to the uncontrolled release of water due to a dam breach.

Water Heritage

Minneriya Reservoir is a technological marvel which played an essential role in the region's history. With the construction of the reservoir, the economy flourished, agricultural production increased and improved the lives of the people. Minneriya Reservoir belongs to Polonnaruwa Irrigation Region, and it is located in Minneriya Divisional Secretariat Division in Polonnaruwa District in North Central Province. The maximum capacity of the Minneriya reservoir is 135 MCM. It serves 9,099 ha of paddy land, and its catchment area is 23,983 ha. The main spillway called Agalawan Oya discharges along a 6 km long canal into the Kaudulla reservoir. It compromises a gated section with seven radial gates together with an ungated ogee section. There are two spills called the Agalawan Oya spill and Minneriya-Kantale Yoda Ela (MKYE) spill that direct water to the Kantale reservoir. The MKYE spill tail canal act as the Kantale feeder canal. Thus, the reservoir, along with its canal network, ensured a stable water supply not just for irrigation but also for the domestic needs of the population.

The reservoir is built with a holistic understanding of its environmental surroundings. The reservoir capitalised on the mainstream Elahera-Minneriya-Yoda-Ela trans basin as well as local inflows. After its construction, the area flourished with greenery and wildlife. The immediate catchment of the Minneriya reservoir is a habitat area that harbours rich flora and fauna, large herds of elephants and many other wild animals that are easily found in the surrounding areas. The Minneriya Reservoir area was designated as a national park in 1997, having been initially declared a wildlife sanctuary in 1938. The reservoir is also being utilized for inland fisheries and tourism industries. The reservoir is a cultural relic and has been standing strong for many generations. It carries stories and traditions from King Wasaba's reign who built the dam, the British period, and the contemporary evolution in irrigation.

15.9 NACHCHADUWA WEWA RESERVOIR

Name	**Nachchaduwa Wewa Reservoir**
Location	**Anuradhapura District, Sri Lanka**
Latitude	**8.233 N**
Longitude	**80.467 E**
Category of Structure	**Water Storage Structure**
Year of commissioning	**535 -555 AD**
River Basin	**Malwathu Oya River Basin**
Irrigated/Drained Area	**2540 ha**

History

Known as the Anuradhapura city reservoir, the Nachchaduwa Dam is an ancient structure situated about 15 km southeast of the ancient city of Anuradhapura, which was the capital of Sri Lanka for an extended period. One of the problems faced by the ancient settlers was water scarcity during the year's dry spell. The area received fairly substantial rainfall, but most of this was concentrated during the North-East Monsoon period. Rest of the year, the rainfall was low, and the streams would run dry, leaving no water even for domestic use. Therefore, the ancient settlers constructed reservoirs, commonly known as tanks, near the ancient city. They are the trio of reservoirs, Abaya Wewa (BaSawakkulama), Tissa Wewa and Nuwara Wewa. They were built in the period from 430 BC to the 1st century BC.

Tissa Wewa and Abaya Wewa each had less than 10.36 km^2 of the catchment area. As time went on, it was realised that these reservoirs failed to fill regularly since they had very small catchments. This problem gave rise to some of the finest examples yet seen of ancient trans-basin diversions. Tissa Wewa and Abaya Wewa reservoirs were fed from the reservoir Kala Wewa by a canal 86.9 km long and were considered a marvel of hydraulic engineering. A canal was constructed from a diversion weir across the stream Malwathu Oya to feed the Nuwara Wewa reservoir. It was at this place that the reservoir Nachchaduwa was later built.

Description

Nachchaduwa Wewa is a reservoir in the North Central region of Sri Lanka with an average elevation of 96 m above sea level. The area is mildly populated, with 140 people/km^2. The total length of the distributary canal is 5.36 km, while the field canal covers 8 km.

The reservoir was cited by damming a narrow neck in the valley of Malwathu Oya. It comprised an earthen dam across the stream Malwathu Oya, a stone-paved spillway and a dressed stone masonry sluice of Bisokotuwa kind. In addition, to augment the Nuwara Wewa reservoir with a right-bank canal, the reservoir was used to irrigate its lands on the left bank. In 1917 the tank's capacity was also improved. In 1957 a massive flood caused severe damage to the tank; nevertheless, in 1958, the tank was rehabilitated. Today it receives diversion from the Mahaweli System Kal Wewa. Nearly 3,400 farm families are benefited from this scheme.

As of 2014, the renovations of the Nachchaduwa Wewa reservoir were in progress under the Dam Safety and Water Resources Planning Project (DSWRPP) currently. The government of Sri Lanka initiated the DSWRPP to ensure public safety and address the critical challenges faced by the water sector of Sri Lanka.

Water Heritage

Nachchaduwa Wewa Reservoir has witnessed many renovations, constructions, and additions, sometimes to increase its efficiency or to maintain its functionality. It is remarkable that the dam withstood natural disasters, and political blunders and was still able to provide a stable water supply. This dam is part of a rich cultural heritage that has been passed over to the current generation in the form of an irrigation structure.

In the past, due to unknown reasons, the possible flood of earthen dam was breached maybe because the spillway was inadequate. It is equally probable that the South Indian invaders breached the embankment in their numerous wars against the Anuradhapura Kingdom. Whatever the cause, ultimately, the dam was destroyed beyond repair and was left to oblivion in the forests, as was the kingdom. After nearly a millennium, the tank was re-discovered by the British rulers of Sri Lanka. The earthen dam was breached and overgrown, while the sluice and the spillway were damaged. The entire area was under the thick jungle.

The reservoir was restored in 1906 by the Irrigation Department. The breaches of the earthen dam were filled, and a sluice and a gated spillway were constructed. In 1957, a cyclone struck the island, and Nachchaduwa was among the tanks breached. These damages were repaired in 1958, and the tank has been in existence since then to provide irrigation facilities to its lands and augment Nuwara Wewa and Tissa Wewa reservoirs. The reservoir's original structure and excellent engineering design formed ensured its longevity of this reservoir.

Recognized as a heritage structure, the reservoir has become a tourist attraction. It has an Irrigation Museum that holds demonstration farms with traditional yams, paddy varieties, and medical plants. It also acts as an educational centre for students who learn about irrigation and history there.

15.10 PADAVIYA TANK

Name	**Padaviya tank**
Location	**Anuradhapura District, Sri Lanka**
Latitude	**8.800 N**
Longitude	**80.760 E**
Category of Structure	**Water Storage Structure**
Year of commissioning	**3 AD; rehabilitated 1955**
River Basin	**Mora Oya & Mukunu Oya River basin**
Irrigated/Drained Area	**5,584 ha**

History

Padaviya tank was built by King Mahasen (3 AD). There is evidence that two sluices were there before rehabilitation, and the tank bund had broken from two locations. This tank was done during the Mahasen King's era and rehabilitated during Maha Parakramabahu King's era.

Padaviya Wewa, one of the important historical irrigation sites, is a "must travel" place and should be on the itinerary of those who love archaeological wonders and nature. There are no records to indicate who built the tank, but historians have ascribed the original construction to King Saddhatissa (137-119 BC) and King Mahasena (276-303). Excavation carried out in the mid-1900s by Mr. D.T. Devendra, Assistant Archaeological Commissioner has supported the view that King Mahasena was the original constructor of the tank. But Pujavaliya's ancient text credits King Saddhatissa for building 'Padi' and several other tanks. There are strong indications that 'padi' refers to the current-day Padaviya Tank. An ancient pillar inscription on the bund of Padaviya Tank proudly proclaims, "By Sri Parakrama Bahu, the Sovereign Lord of Sri Lanka, who is concerned with doing good to the world, has this been constructed". Although this pillar proclaims that King Parakramabahu I (1153-1186) was the builder, it has been concluded that the tank is much older, and King Parakramabahu probably would have carried out extensive renovations or expansions to the existing tank.

Description

Padaviya tank is sited in a flat area of agricultural plain & sanctuary zone, and the tank has a catchment area of 53,871 ha. Padaviya Dam is homogeneous with a length of approximately 4.60 km and a maximum height of 9.7 m.

It has been identified as Ratmalkandawaapi during King Mahasen's reign, Dhanawaapi during King Moggalana's reign and Padeewaapi during King Parakramabahu I's reign. Historians have further recorded Padaviya Wewa as Ratmalkatiya, Mahakulunawa, Padvidora or Mah

Padaviya at different times. Since the exact history of this reservoir has not been recorded anywhere yet, it should be a research topic for those interested. However, there is evidence that agriculture was practised under the Padaviya reservoir during the previously mentioned reigns. An inscription by King Nissankamalla declared the Padaviya reservoir area as a sanctuary, and catching fish and hunting all living beings had been prohibited.

Henry Parker, an Irrigation Engineer who has done a thorough survey of the remnants, has stated the following in his sessional paper of XXIII of 1886; “Although the largest, Padaviya is probably the least known of all the great reservoirs of the island. The general ignorance regarding it is doubtless due to the difficulty of approaching it, for not only is it situated in the little-known North-eastern corner of the North-Central Province, but also surrounded by a wide tract of dense forest which, except in the south-eastern part, is inhabitable. “He further records that the bricks that were used for sluice construction were similar to those used during King Mahasen, and he cautions us that the bricks of that era might have also been used but at a later stage.

The reservoir was formed by damming the two tributaries of Ma Oya, namely Mora-Oya and Makuna_oya. Even though many surveys and investigations were done by Irrigation Department after Parker’s report, restoration of the reservoir and system was taken place only during the 1954-1960 period. It would have been made possible because of the colonization policy of D.S. Senanayake and the priority given by the then government to irrigation development under the second Six-Year Development Plan of 1954-1960.

While restoring the reservoir, repair of the breaching sections of the reservoir embankment, construction of a new sluice and a canal system, provision of radial gates, expansion of the natural spill and clearing of the forest for land development and settlement were attended. The current capacity of the reservoir is 104.84 MCM, which is more than the capacity of ancient works. That was achieved by raising the embankment and the spill. When the reservoir is at spill level, it inundates 2630 ha of land. The total length of the two main canals is 48 km, and those two main canals serve 43 distributary and field canals. The government spends a considerable amount of funds annually for the operation and maintenance of the system.

Restoration of Padaviya Irrigation settlement schemes was a gigantic project since it covered the provision of all infrastructure facilities for the settlers, including housing, the access road from Anuradhapura, internal roads, hospitals, schools and the urban facilities.

Annual rainfall is 1500 – 2500 mm, and the average temperature is around 30^0 C in the Padaviya area. The North-East monsoon is activated in the period of October - January, but for the rest of the year, this area is suffering from a dry situation. The catchment area of Padaviya tank is done a great service by providing food and habitats to the animals. This area has been declared a wildlife sanctuary. Padaviya tank is issuing water for paddy fields in the Padaviya irrigation scheme. In addition, this tank is utilized for domestic purposes as well as fishery industries.

Water Heritage

Padaviya tank is formed by an embankment across Ma Oya. The ancient bisokotuwa (Sluice) is situated 6.1 km east of the spill. It consists of a stone tower of 0.975 m^2 with two inlet openings 0.609 m long and 1.52 m high on the tank side, leading it to a twin conduit with tapering barrels 48.77 m long. At the end of the barrel is a five-hooded cobra rock carving which is usually found on most tanks. The upstream wall of the Bisokotuwa has several boundary stones with projecting parts sculptured to be in the form of Elephant Heads. A 304.8 m long solid rock outcrop on the western side has been used as the spillway. The tank has been designed in such a way that the rock bed lies approximately at the full supply height of the tank.

In the northeastern part of the North Central Province, there are two large ancient irrigation tanks – Padaviya Wewa and Vahalkada Wewa. Of these, Padaviya has commanded more attention, perhaps because of the traditional belief that it was the largest of the ancient tanks.

Many colonial administrators undertook the arduous journey to see this tank and were duly impressed by the ruins of the ancient work. Governor Sir Henry Ward (1797–1860) described it as the “most gigantic of all works” and estimated that “its construction must have occupied million people for 10-15 years”. Sir Emerson Tennent (1804–1869), who had written several books on then Ceylon was so impressed with the sluice, for he reported, “the existing sluice is a very remarkable work, not merely from its dimensions but from the ingenuity and excellence of the workmanship”. However, Henry Parker was attached to the Irrigation Department from 1873 to 1904, and carried out a detailed inspection of the work in 1886 and recorded his findings.

Padaviya reservoir belongs to the Anuradhapura irrigation region, and it is located in Padaviya divisional secretariat division in the Anuradhapura district in North Central Province. The maximum capacity of the Padaviya reservoir is 105 MCM. It serves 6000 ha of paddy land, and its catchment area is 53871 hectares. The spill tail canal called Ma Oya discharges along a 35 km long canal into the Kookilai lagoon. It compromises a gated section with two nos of radial gates together with an ungated CO-type section.

Padaviya was rehabilitated under Dam Safety and Water Resources Planning Project (DSWRPP), funded by World Bank. Identified Major rehabilitation by DSWRPP is such as the renovation of rip rap, strengthening of the dam, establishment of bathing steps, establishment of tor filter & toe drain, installation of piezometers on d/s slope of the dam, installation of levelling monuments. installation of boundary stones. The Environmental Assessment and Environmental Management Plans (EMP) were cleared by both World Bank and Central Environmental Authority (CEA), followed by the awareness programmes at the district level to make the stakeholders cognizant of the rehabilitation programmes. Dam Construction Monitoring Committee was established to monitor the entire rehabilitation process and the final conceptual designs for the dam were submitted by the Implementation Support Consultant. The inspection boat, digital camera, bush cutter, tirfort wincher, chain saw a desktop computer and software, printer, generator, inspection boat and safety jackets were provided to the dam office to improve the operation and maintenance and capacity to ensure the safety of the dam. The Dam Construction Monitoring (Oversight) Committee was established and held several meetings to monitor the entire rehabilitation process and the final construction was completed in the year 2017.

15.11 SORABORA WEWA

Name	**Sorabora Wewa**
Location	**Badulla District (Mahiyangana City), Sri Lanka**
Latitude	**7.367 N**
Longitude	**81.014E**
Category of Structure	**Water Storage Structure**
Year of commissioning	**2nd Century BC**
River Basin	**Mahaweli Basin**
Irrigated/Drained Area	**809.37 ha**

History

Sorabora Wewa, which was called the Sea of Binthanne in the ancient past, is unique to all other ancient reservoirs. It is considered the only existing reservoir that does not use a *Bisokotuwa* (explained below), the heart of all other large reservoirs. This ground-breaking invention enabled the ancient people to build massive reservoirs since the 4th century BC.

The tank is believed to have been built during the 2nd century BC when the warrior prince Dutu Gemunu was fighting with the Tamil invader Elara from the Yakka tribe, the indigenous people of Sri Lanka. When Gemunu's army and his ten generals marched towards Anuradhapura, the army camped at Kadali Pathra village (currently Keselpatha) near Mahiyangana. At this time, a strongman called Bulatha (Balathirala) from the village of Kiripattiya in

Ududumbara joined the army of the Gemunu and helped construct the tank.

Description

The Sorabora Tank was built by damming the Diyawanna Oya with a 1590 feet (485 m) embankment. It is located in the Mahiyanganaya Divisional Secretariat of Badulla district in Uva province, and the Mapakada Wewa Irrigation Division handles its dam operations. The tank is situated about 1.5 km from the city of Mahiyangana. It can be accessed on the Mahiyangana-Padiyathalawa (A26) road.

The primary catchment of Sorabora Wewa is fed by the Diyabana Oya, which is a stream connected with the Mahaweli trans-basin canals. The leading utility of this dam is providing irrigation water which cultivates over 809.37 ha of paddy lands owned by six farmer organizations. Fishing is another water use managed by a fishery organization. Over 450 farmer families are dependent on the Sorabora Wewa tank today.

The Bisokotuwa regulated the water pressure at the sluice gates inside the tank and protected the embankment from erosion. The builders of the Sorabora Wewa didn't place the sluice gates at the embankment but strategically located a natural rock away from it and cut a deep canal that acted as the sluice for the tank. Since the stone was not subject to erosion by water pressure, the ancient builders pursued the tried and tested Bisokotuwa for this creation. The tank covers 445.15 ha and holds 14.6 MCM of water at full capacity presently. The slice gates are professionally cut into the natural rock and are about 1.52 m wide.

Water Heritage

Sorabora Wewa was an engineering wonder. The invention of bisokotuwa during the construction of the reservoir, which proved to be a unique simple solution to manage erosion, changed the way reservoirs were built in Sri Lanka forever. The construction design was outstanding, and proved to be a game-changer for the irrigation infrastructure.

In the reservoir, one ancient sluice is situated at the lower or southern end of the bund. It is composed of substantial cut stones built into a wedge-like cutting in the rock. The smaller end of the wedge is outward so that the weight of the water against the structure tends to keep the stones in position. From the smaller end of the wedge, a channel of about 1.37 m wide flowing for a considerable distance out of the solid rock conducts the water to the fields. This ancient design provided for another sluice at the northern end of the bund but more towards its middle. This positioning of elements took the form of a bisokotuwa, built as a square shaft cased with cut stone, with a tunnel or arched channel leading under the bund, provided with a sluice gate. The outlet was at a lower level than the former and was probably intended as an under sluice to let the silt off and cleanse the tank of mud, as well as for irrigation. Even today, the southern channel discharges a stable water supply, and irrigates hundreds of acres below the bund. In contrast, the northern low-level channel trailed northwards, where fields of the finest soil lie along the right bank of the Mahaweli River.

The reservoir influenced many cultural traditions and became the inspiration for literature of the time. Several books and poems are written on the tank appreciating its value and the difference it brought in people's lives. A steady water supply transformed the local economy and brought prosperity to the region. One of the Sinhala folk songs dedicated to the reservoir states, "*Sorabora Wewa by mighty woods is bound, through cloven rock her waters feed the ground, in Aluthnuwara's faces her lotus blooms are found, behold this wonder and your anthem sound, the idyllic man-made Sorabora Weva*". In ancient times, Sorabora or Horabora was named the 'Sea of Bintenna'. Sorabora was once upon a time a Veddah settlement in the early 1920s. This reservoir showcases a large display of the engineering feats of ancient Lanka, which are still retained their picturesque charm today.

Sorabora Wewa was an ecologically sound project which improved the environmental situation around its region and protected the people from natural calamities. Both upstream and downstream of the tank have a rich biodiversity, and at the moment, deforestation activities are affecting the lower reaches. A concurrent issue that needs immediate action is the encroachment of the tank bed and the reservation area by Arawatta villagers for seasonal paddy cultivation, negatively affecting the tank's aquatic ecosystem due to fertilization.

15.12 THEKKAM ANICUT

Name	**Thekkam Anicut**
Location	**Mannar District, Sri Lanka**
Latitude	**8.37029 N**
Longitude	**80.027589 E**
Category of Structure	**Diversion Structure (Anicut)**
Year of commissioning	**455 – 473 AD**
River Basin	**Malwathu Oya River basin**
Irrigated/Drained Area	**12,400 ha**

History

Thekkam anicut is believed to have been built during the Anuradhapura Period (Asanga & Nishantha, 2018). The chronicle Mahavamsa states that a channel (present Yoda Ela) was made to bring the water to the Giant's tank by King Dhatusena (455-473 A.D.) by damming the river Malwathu Oya. The water was diverted at a location known as Thekkam anicut in Mawathu Oya.

Description

The Thekkam Anicut is constructed with giant granite blocks using a rocky foundation at an angle across the river. The Malwathu Oya has been dammed by this anicut about 67.59 Km from its mouth to divert the river water to Yoda Wewa and the Akathimurrippu Scheme (Arumugam, 1969). It is a massive structure about 4.3 m high, 200 m long and 4.8 m wide. On the northern side of the anicut, there are three large openings to release excess water.

This ancient dam was renovated during the Polonnaruwa Period and finally during the British Period (1815- 1948 A.D.). A canal was cut to carry the diverted waters just before the anicut. The canal snakes through the natural counters of the terrain parallel to the Malwathu Oya for over 10 km before turning north and finding its route to the final destination. The total length of this marvel is about 25 km.

Water Heritage

Malwathu Oya basin was among the regions that supported the original civilization in Sri Lanka at the time. Prince Vijaya landed near the river estuary. The landing was not by chance; the location was part of the ancient trade route, with pearls being found in the nearby sea. Giants Tank in Mannar is the lifeline for hundreds of paddy cultivators in the area known as the Paddy Bowl of Sri Lanka; this is the second largest reservoir made in ancient Sri Lanka, with a 7.4 km long

curving dam attributed to King Dhatusena (459-477) who diverted water from Malwathu Oya and a built a 25 km long canal along the flat land to build Yoda Wewa. This reservoir was an experiment of a gigantic scale since the conventional reservoirs were built across a river or stream encompassing a valley for several miles over a large area of a river basin, creating a reservoir. The land in the Mannar district was so flat that a new way to irrigate the land was required. The engineers under King Dhatusena then decided to build a 25 km long canal from Malwathu Oya to a natural depression in the area where the Giants tank stands today. Although the reservoir lies just over 5 km from Malwathu Oya as the crow flies, the engineers selected a location almost 20 km upstream to divert the water considering the level of the river and the reservoir to build the Thekkam anicut. An analysis done by British scholars of a concrete sample dating back six centuries (at that time) in 1889 obtained from an anicut associated with Giants Tank in Mannar (Thekkam Anicut) is described below. This article explains to us that the usage of the best quality raw materials for the construction of irrigation systems was one of the main reasons for the success of our ancient irrigation heritage.

16 THAILAND

16.1 RANGSIT CANAL & CHULALONGKORN REGULATOR

Name	Rangsit Canal & Chulalongkorn Regulator
Location	Eastern part of the Chao Phraya valley, Central Thailand
Latitude	13.981
Longitude	100.606
Category of Structure	Water Conveying Structure
Year of commissioning	1897
River Basin	Chao Phraya
Irrigated/Drained Area	188,500 ha

History

During the reign of King Chulalongkorn (Rama V) the Great 1868-1910), farmlands' expansions coupled with increased population created water scarcity. To manage the situation, the Canals and Irrigation Company was ordered to excavate canals and develop the vast wasteland on the east bank of the Chao Phraya River called *Tung Luang* in 1888. The company first excavated the main canal linking the Chao Phraya River on the West to Nakorn Nayok river on the East with a length of 56 km in 1890. Two regulators were also constructed at both ends of the canal. After seven years, construction of the canal and the regulators was completed in 1897. The canal was later named Rangsit Prayurasakdi Canal, and the regulator on the Chao Phraya riverside was named Chulalongkorn Regulator, and the one on Nakhon Nayok riverside was named Saovapa PongSri.

Branch canals were constructed on both sides, the Northside and the Southside of the Rangsit canal, each lateral about 2 km apart. This system of canals and structures was called the Rangsit Irrigation Scheme that received water from the Chao Phraya and Nakhon Nayok rivers during high flow periods in the rivers. The Rangsìt area became a central rice-producing area of the time. However, with increased demands and a growing number of farmlands, the water supply from high water levels in the rivers was insufficient. So the Irrigation Department constructed the Greater Chao Phraya project with a major diversion dam in Chaìnat Province and major canals and related structures. The Rangsit Irrigation Scheme was merged into the larger project and currently receives water supply from two main irrigation canals (the Rapeepat Canals). The total area of the Rangsit Scheme was divided into two new subprojects, the Northern Rangsit Operation and Maintenance Project and the Southern Rangsit Operation and Maintenance Project. The Rangsit Prayurasakdi Canal and the Chulalongkorn Regulator are under the custody of the Southern Rangsit Operation and Maintenance Project.

Description

The Rangsit Irrigation Scheme had a total irrigated area of 188,500 ha of rice paddy fields. It has one main canal, Rangsit Prayurasakdi Canal, (16 m width, 3 m depth, and 53.2 km long) and two large canals, the Upper Hok Wa canal (12 m width, 3 m depth and 39 km long) and the Lower Hokwa Canal, (12 m width, 3 m depth and 61 km long). There are two regulators at both ends of Rangsit Canal – the Chulalongkorn Regulator has four vertical gates, 3 m by 4.5 m for each gate, and can release water up to 60 m^3/sec and Saovapa Pongsri Regulator, which is smaller. Fifty lateral canals are branching out vertically from these three large canals with a total length of 915 km. Water supply for the scheme comes from Chao Phraya and Nakhon Nayok rivers during high water level periods in the rainy season. Due to drought, water from the main canals of the Greater Chao Phraya Project is used as the primary water supply source now, and river water is extracted only occasionally. At present, the Rangsit Canals and Regulators system functions both as an irrigation system and a flood mitigation model. High-capacity pumps are installed near the regulators for such additional duties.

Water Heritage

Both the Rangsit Prayurasakdi canal and the Chulalongkorn Regulator represented a milestone in the development of irrigated agriculture in Thai history. The scheme is the first large irrigation project to be developed in Thailand. Both structures have been operated continuously for more than 119 years now and will be operational for many years to come. Under the supervision of the Royal Irrigation Department, the required water controlling assignments are conducted successfully. Both structures are examples of a well-designed and well-maintained system that provides water and benefits society with periodic maintenance.

Since the 1990s, the irrigation system has contributed to water availability, enhanced agricultural production, economic development, and disaster management in the region. It raised people's income and improved the living standards of the community by providing different facilities. Both the Rangsit Prayurasakdi Canal and Chulalongkorn Regulator had been critical elements in promoting rice cultivation in the Rangsit area. It was transformed into a thriving settlement with hundreds of yearly immigrations from the sparse areas with meagre populations. After completion of the canals, a rice-growing area in Rangsit expanded, becoming one of the prominent rice-growing areas of the country. Rice yield reached 100,000 tons per year or about 10 % of the rice yield of the central region. These developments were augmented with technological advancements, the induction of ploughing machines, among others. Rangsit area was also known for its high-quality produce. Research and development grew in the region, and an experimental rice station was also established for seed for providing to the farmer.

The irrigation system is an excellent example of sustainable operations and maintenance practices carried forward from one generation to another. Both structures have been well maintained by the Southern Rangsit Operation and Maintenance Project, Royal Irrigation Department. They are operating as they used to historically with a few modifications due to issues like flooding. Additional pumping stations are being installed nearby to accelerate the draining of the heavily flooded area in Rangsit and the vicinity. Even now, after more than 119 years after construction, both the Rangsit Canal and the Chulalongkorn Regulators are operational both for irrigation and flood mitigation. Today the Chulalongkorn Regulator and attached pumping stations are vital structures to control floodwater in the large flood plain on the east bank of the Cho Phraya.

16.2 SARITPHONG DAM

Name	**Saritphong Dam**
Location	**Sukhothai Province, Thailand**
Latitude	**17.00299**
Longitude	**99.67808**
Category of Structure	**Dam**
Year of commissioning	**1314 AD**
River Basin	**Mae Yom Basin (Sub Basin: Mae Lam Pan)**
Irrigated/Drained Area	**197.5 Acre**

History

The name of Saritphong was found in the first inscription of the Sukothai Era, which in ancient Thai means dam or dyke. Originally, Saritphong was designed as an earthen dyke to distribute the water within ancient Sukothai City in the Sukothai Era (in the 14^{th} century). It was operated as the main structure that used to serve people in Sukothai city at that time. Furthermore, the Saritphong Dyke has been recognized as conclusive evidence proving that the irrigation system existed in Sukothai Era.

In 1968 (2511 B.E.), with the collaboration between the Fine Art Department and the Royal Irrigation Department, the Saritphong earthen dyke was repaired and renovated to the Saritphong Dam to serve the agricultural field in the Sukothai Province.

Description

After the renovation, the dyke is 10.50 m high and 487 m long. The spillway is 20 m long and can release more than 20 m^3/s of water. The reservoir can restore up to 4,00,000 m^3 of water. The drainage area of the Dam is 17.45 km^2.

Currently, the Saritphong Dam and its dyke serve about 500 rai agricultural fields in 3 villages, equivalent to nearly 80 ha. Moreover, in times of flood, it can also prevent and reduce the damage to the fields.

Water Heritage

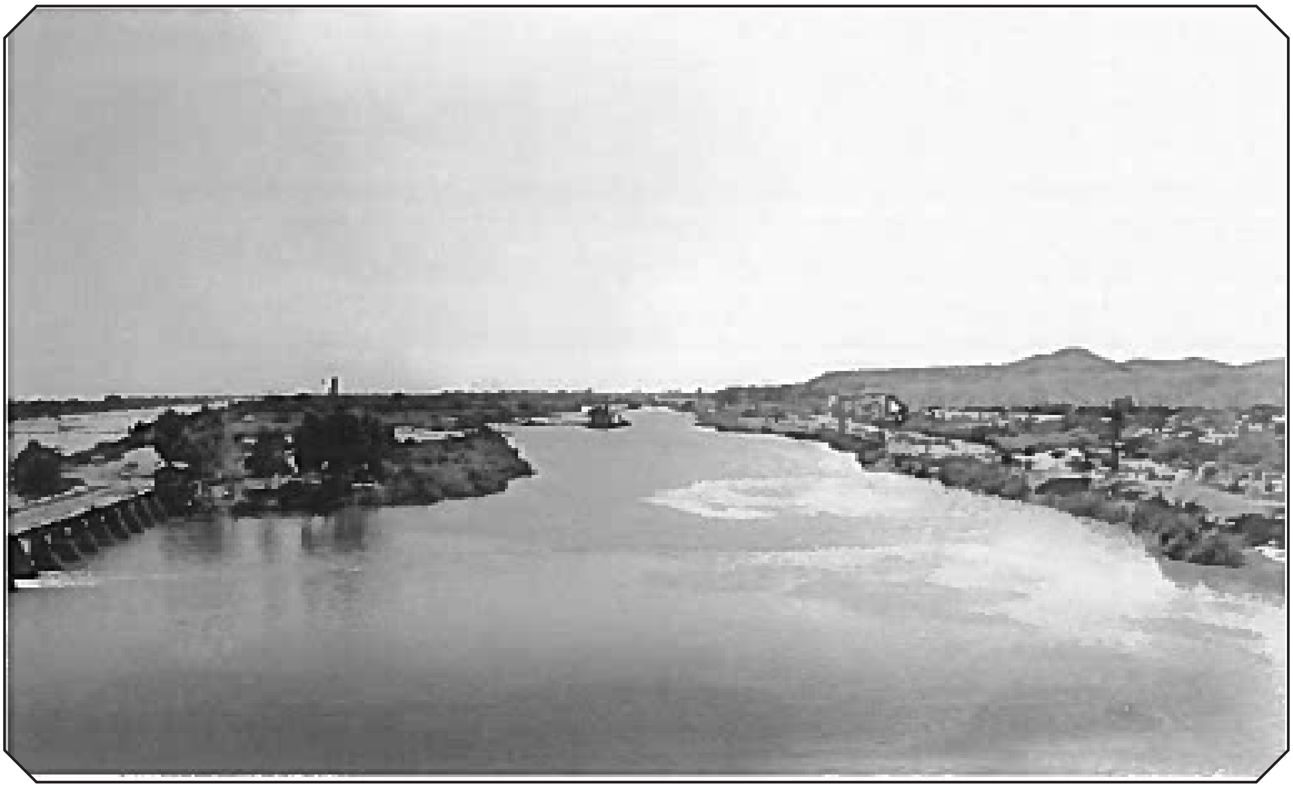
Saritphong Dam showcases an exceptional testament to the history of irrigation in Thailand. The dam and its dyke represent a milestone in developing irrigated agriculture and other water use in ancient Thai history. With its ample storage area when it was built, it could serve the water demand for the entire old city of Sukothai.

The Saritphong Dam and its dyke were used in conjunction with the motes and the city walls of Sukothai to protect the city from the enemy and also to direct the water which flows down from Khlong Sao Hor canal on the west side to the southwest side of the inner moat through water pipes. Along with its dyke, the dam is one of the most stable ancient structures that are still in operation today. The Saritphong Dam is also registered as an archaeological site of the Sukhothai period by the Fine Art Department of Thailand.

17 UNITED STATES OF AMERICA

17.1 ALAMO IRRIGATION SYSTEM

Name	Alamo Irrigation System
Location	South-western US and Northern Mexico, United States of America
Latitude	32.72 – 32.73
Longitude	-114.72 – -114.71
Category of Structure	Irrigation System
Year of commissioning	1900 AD
River Basin	Colorado River Basin
Irrigated/Drained Area	479000 acres



History

In the late 18th century, the Imperial Valley in southern California (USA), near the border with Mexico, was almost entirely unpopulated because of its harsh climate. It is one of the most arid sections of the United States, with annual rainfall averaging approximately 75 mm, and in some years amounting to less than 12.5 mm. The intense summer heat has maximum temperatures over 37.8 °C for more than 110 days out of the year. The Colorado River is the Imperial Valley's nearest water source, located approximately 60 km east. The Algodones Dunes, about 72 km long and 9.7 km wide, lie between the Imperial Valley and the Colorado River. This area is covered with wind-swept sand with sparse vegetation and constituted a challenge in channelling water from the river due to the broad erg between the two. Thus, an alternate route was pursued by the California Development Company (CDC) to build a canal from a point in the United States, travelling south, into Mexico, and connecting westerly to the dry Arroyo Alamo that drained at a northwest orientation (in the direction of the Imperial Valley/Salton Sink). Given the existing terrain, the strategy to route the channel into Mexico and back to the United States by using a current natural drain route was perceived as the fastest, least expensive, and most practical option.

In 1900, the CDC constructed the Alamo Canal from Pilot Knob in the US and connected it to the Arroyo Alamo in Mexico. The CDC was able to clear the Arroyo Alamo bed, enlarge it, and at a point about 67.5 km west of the Colorado River, they carried their canal northward, across the US/Mexico boundary line again, into California. The CDC utilized most of the Alamo River (US Territory) as a part of their initial irrigation system, and the first waters were brought into the Imperial Valley in 1901.

Description

The project consisted of constructing a controlled, gravity-fed irrigation system within the Colorado River basin, taking water from the Colorado River (2,330 km in length) of the Southwestern United States and northern Mexico. A new water channel and control structures: the Alamo Canal (1900), the Hanlon Heading (1906), and the Rockwood Gates (1918) were constructed. The CDC further built the canal project and temporary gates to divert water from the Colorado River to irrigate the Imperial Valley in a controlled and reliable manner. At the same time, the existing structures were erected by the Imperial Irrigation District.

Water was channelled via gravity flow, from a site in the US at Pilot Knob (a small mountain peak in Southern California near Yuma, Arizona) and through a newly constructed 23-km Alamo Canal that crossed south of the border into Mexico and ran parallel to the Colorado River for approximately 6 km before connecting westerly to the Mexican Arroyo Alamo (a dry river bed). The Arroyo Alamo bed was cleared out, and enlarged for connection by the new Alamo Canal. At a point about 67.5 km west of the Colorado River, the canal moved northward, across the US/Mexico boundary line again, and into California. The channel worked well for the first couple of years. Still, siltation issues required the construction of the Hanlon Heading and Rockwood Gates, which served as a long overpour weir, over 213 m in length and constructed parallel to the flow of the river with 75 openings each about 2 m wide, through which water entered the Alamo Canal.

The Pilot Knob site was selected for the headings and gates due to the availability of a solid rock foundation and to avoid the Algodones Dunes. Hanlon Heading is a massive steel and cement gate structure built on the solid rock foundation of reinforced concrete, having 11 culverts (3.05 m high and 3.66 m wide), separated by 45.7 cm thick walls. The floor is 29 m above sea level and 1.5 m below the bed of the river. The gates are of "Taintor" type (or radial gates), having radial arms of steel. Instead of sliding in vertical grooves, they revolved for a portion of a circle about a horizontal shaft placed behind them with a 4.3 m radius. The pressure of the water against the gate was transmitted to the turning point on the shaft; thus, the lifting apparatus was powerful and operated by hand. The structure has a height of 3.66 m above the culverts that held back high water and provided room for the gates when they were raised with a flow capacity of over 280 m^3/s. A railroad spur was also constructed across the heading structure by the Southern Pacific Railroad to haul rock into Mexico.

Rockwood Heading was constructed on the bank of the river, 2 km upstream from Hanlon Heading, to assist with diversion during shallow flows and the increased bed elevation from the excessive silt deposits of the river, which was considered the highest silt content of any river in the world. The structure was designed as a long overpour weir, over 213 m in length and constructed parallel to the flow of the river with 75 openings, each about 2 m wide, through which water entered the Alamo Canal. Water was controlled by flashboards placed in grooves in the gates. The sills of the upstream 27 gates were 2.4 m lower than the remainder to assist diversion during shallow flows by continuing to draw from surface flow, reducing the amount of silt entering the Alamo Canal. The project transmitted Alamo River water to the Imperial Valley connecting to over 128 km of main canals and over 1,127 km of distribution canals.

Due to the 1911/1912 Mexican Revolution, the Imperial Irrigation District initiated a re-route for an "All-American" canal, which had bought out the CDC. The Alamo Canal and its structures were sold in 1961 after the 1942

All-American Canal construction that ran parallel to the US/Mexico border on US property. An environmental cost is that south of the All-American Canal, the Colorado River no longer flows above ground for much of the year into Mexico. After several altercations in the structure and its administration, in 1961, the Alamo Canal and all of its systems on Mexico territory were sold. However, the Hanlon Heading and Rockwood gates remain in US control, albeit not operational.

The unsurpassed, progressive impact of the project on the agricultural economies of the two countries is noteworthy. The Imperial Valley prospered at unprecedented rates. Irrigated acreage in the Imperial Valley had increased from 600 hectares in 1901 to 32,000 hectares by 1905. Over 128 km of main canals had been constructed in the Imperial and Mexicali Valleys belonging to the CDC and the Mexican Company (a Mexican corporation formed by the CDC in 1898). An additional 1,127 km of distribution canals in Imperial Valley were placed by 1905. Irrigated acreage in the Imperial Valley had increased to 89,000 hectares by 1911. It is believed that this record constitutes the most rapid development of any reclamation project in the western United States.

According to the California Department of Food and Agriculture, Imperial County, which contains the Imperial Valley, was the sole producer of sugar beets; the number one producer in the United States of alfalfa hay, onions, wheat, sweet corn, alfalfa seed, and Sudan hay; and among the top five producers of cattle/calves, lettuce, broccoli, carrots, celery, cauliflower, spinach, potatoes, cantaloupes, watermelon, sheep/lambs, salad greens, grapefruit, dates and honeydew melons. Today, the Imperial Valley produces 80% of the country's winter vegetables, and agriculture is the largest industry in the Imperial Valley, accounting for 48% of all employment. The Mexicali Valley also prospered significantly, becoming one of the largest fertile valleys in Mexico with a current population reaching one million (over five times the size of the Imperial Valley). There are over fifty different crops produced in the Mexicali Valley. However, primarily growing wheat, cotton and vegetables, Mexicali is one of Mexico's most important exporters of asparagus, broccoli, carrots, green onions, lettuce, peas, peppers, radishes and tomatoes to the world.

Water Heritage

The Alamo Irrigation System was an engineering genius of its time. The project's planning, design, and dimensions were used as a reference for future irrigation projects. In the winter of 1905, there were five floods, prompting attempts by the CDC's engineers to close the cut and construct a control gate. Attempts to build dams were washed away, and the cut widened to 46 m. The Colorado River began to eat away at the banks of the cut to a point in which it had grown to 823 m wide and resulted in significant flooding. The Hanlon Heading was built at Pilot Knob to channel and control water from the Colorado River to combat these impacts. The heading also incorporated a built-on railway used to haul rock south into Mexico to seal the breach at the Lower Mexican intake that had failed. Although the Hanlon Heading alleviated some of the silt challenges, the ultimate design and incorporation of the Rockwood Gate completed in 1918 became inevitable. Rockwood Heading was designed as a long overpour weir, over 213 m in length, and constructed parallel to the river's flow to assist with diversion during shallow flows in the river by drawing from the surface flow and reducing the amount of silt entering the Alamo Canal.

The Alamo Irrigation System diverted water from the Colorado River into two barren valleys in the US and Mexico, respectively. The irrigation system enhanced food production, increased the beneficiaries' income and brought together two communities creating a rich culture of joint management and cooperation. The CDC constructed the project to channel water for irrigation to southern California, Imperial Valley, and the Mexicali Valley in Mexico. Both the Imperial and Mexicali Valleys were perceived as untameable, flood-prone desert deltas before the project. The project-initiated settlement increased food production to exceptional levels and created thriving agricultural economies in both valleys.

The Imperial Irrigation District manages over 2,575 km of canals and laterals, which deliver water to approximately 4,700 delivery gates serving the 194,000 hectares of farmland within the Imperial Valley as of 2019. The mild winter season and year-round water supply meant that the area was always in production, with most fields being double or triple-cropped. The total irrigated crop acreage as of 2017 was 184,318 hectares, and the area (including an additional 9,065 hectares just outside the Imperial Valley) had gross agricultural production of $2,065,600,000 (US) for the same calendar year. Imperial Valley produces over 100 different types of crops. Initially designed on geographic conditions, the dam was constructed with particular attention to the environmental aspects of the time.

17.2 THEODORE ROOSEVELT DAM

Name	**Theodore Roosevelt Dam**
Location	**Tempe, Arizona, United States of America**
Latitude	**33.671 N**
Longitude	**111.161 W**
Category of Structure	**Dam**
Year of commissioning	**1911 AD**
River Basin	**Salt River within the Tonto Basin**
Irrigated/Drained Area	**248,239 acres**

History

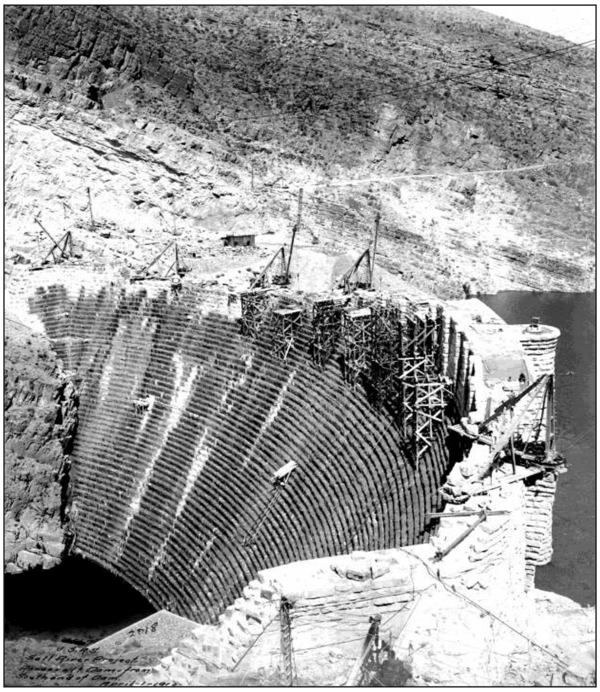
Theodore Roosevelt Dam, a rubble-masonry gravity arch dam, was constructed in 1910 along the Salt River within the Tonto Basin region, roughly 80 miles northeast of Arizona's capital, Phoenix (USA). Due to its remote location in the Arizona Territory (Arizona became a state in 1912), a road was built before the dam construction to move materials between Mesa and the dam site. Originally called the Mesa-Roosevelt Road or Tonto Wagon Road, it was later named the Apache Trail after 1915 and promoted scenic tourism in the area.

The dam received funding after the US Reclamation Act of 1902 was passed and signed by President Theodore Roosevelt, which allowed federal financing and construction of irrigation infrastructure to be later repaid by the local water users. Following this, local water users formed the Salt River Valley Water Users' Association (SRVWUA) in 1903, which managed the water in the dam and the repayment of the federal construction loans.

The construction of the Theodore Roosevelt Dam contributed significantly to the development of the Salt River Valley in Central Arizona. Farming and irrigation had taken place in the Salt River Valley area since 600 A.D., beginning with the indigenous Hohokam (Ancestral Sonoran Desert peoples). However, around 1450 AD, evidence of their irrigation usage and population declined. The first Anglo settlers arrived in the Salt River Valley in the 1860s and began revitalizing the ancient Hohokam canals and building new irrigation structures.

Description

Upon completion, the dam was 85 meters tall and 305 meters long, making it the world's largest stone masonry structure at the time. The reservoir covered over 6,900 hectares, creating what was also the world's largest artificial lake. The dam was modified due to increased safety standards in the late 1980s and 90s. The modifications raised the dam to a height of 109 meters and increased the reservoir's storage capacity by 20%. Presently, the lake covers 8,697 hectares. The rubble-masonry surface of the dam was also altered and is now encased in concrete. However, the original light fixtures remain prominently along the dam's crest as a homage to the original structure.



The completed dam included two large spillways on each end of the structure, allowing excess floodwaters to pass by the dam without it overtopping. Also of structural importance was a sluicing tunnel for flushing silt out of the reservoir, which doubled as a diversion tunnel during the construction phase. Particularly innovative was the inclusion of water pipes built into the dam's downstream face, designed to cool the surface through evaporation. These cooling pipes were added to the design following concerns that the fluctuation of temperatures in the region (mainly the extreme heat) could compromise the dam's structural integrity.

The dam continues to serve as it was designed to, operating in conjunction with the vast system of dams and canals which deliver water to the Phoenix metropolitan area. Following the modifications, the utility of the dam was improved to continue serving the area for generations to come. These modifications not only made the structure safer; they also increased the storage capacity of the dam by raising its height by 77 feet, providing even greater water assurance for the Salt River Project's customers in times of drought. The spillways were also deepened to allow more water to be released during flooding incidents. A new lake tap was added, further increasing the amount of water that can be released from the reservoir.

Water Heritage

Theodore Roosevelt Dam marked a turning point in the prosperity of the Salt River Valley. Despite the presence of a vast network of canals in the area before the dam's completion, the Salt River was an unstable, unreliable source of water for the farmers in the area, prone to both drought and flooding. The reservoir and dam provided a more secure water supply in times of drought and protection from flooding. Roughly ten years after the dam's construction, the acreage under cultivation in the Salt River Valley nearly doubled, as did the number of farmers in the region. Today, Phoenix is one of the top five most populated metropolitan areas in the United States. The dam's construction and its ongoing contribution result from substantial community-based operations and management approach that is relevant today and has transformed the area. The Association, a coalition of commercial farmers and small ranchers; wealthy businessmen balanced by corner grocers, boosters, and real farmers, was formed in 1903. The valley residents invested in building the necessary water infrastructure for growth through collaboration and pooling of interests. In the process, Arizona and SRP grew together into a state of several million residents and an organization that today supplies nearly 986,000,000 cubic meters of water annually and delivers power to more than a million customers. In 1917 the federal government transferred the dam's operation, the Salt River Project (SRP), to the SRVWUA in Arizona. As the first project operated by a local entity, SRP became the model of what reclamation could accomplish in developing Western lands.

As its home community changed, marked by a shift from agriculture to an increasingly urban service area, SRP responded to the needs of its customers by strengthening its role as a power provider. With the completion of additional hydroelectric dams on the Salt River, SRP worked on electrifying the Salt River Valley's farms, houses, and businesses. Over time, SRP's water and power services have helped ensure the economic development of the Valley and the region. Even today, SRP continues to build upon the achievements of the past in pursuit of a better future.

The dam enhanced food production and changed the residents' lives for good. Following the completion of the Theodore Roosevelt Dam, the Salt River Valley's water supply became much more reliable and manageable. The effect on Valley farming was not only positive but swift. The area under cultivation nearly doubled with the dam's construction from approximately 53,000 hectares in 1902 to 82,300 hectares in 1923. The number of farmers in the area also doubled, from 2,130 in 1910 to 4,359 in 1921.

In addition to its contribution to the growth and livelihood of the Salt River Valley and the Phoenix area through stable water supply and the subsequent development of agricultural industry, Theodore Roosevelt Dam also represented engineering distinction at the time it was constructed. Before dam construction could even commence, a road between Mesa and the dam site was built for which engineers sourced locally available materials from the nearby Sierra Ancha Mountains.

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