[STUB: EMERGING]

ATLAS OF DRYLANDS DESIGN

USC ARCH698B 2020

CONTENTS

TERM

short description of the term, when and where.

Hardware -what is the physical nature of the system?

What natural physical conditions is the system designed to serve? Regional climate, historical climate circumstances, biophysical context: Terrain, slope, hydrology, vegetation?

What physical water function is the system designed to fulfill? Is its purpose control, irrigation, drinking water, santiation/hygiene? Does the system capture? contain? Lift? filter? distribute? recirculate? Drain?

What are the component parts of the manmade system? How is it physically constructed? Using what materials? Using what labor? What are the energy inputs—human, animal, hydraulic, gravity, other—to construct it? To operate it? Ie, how Is the system powered?

What are the physical design features—architectural/landscape architectural properties— of the system? Enclosed, open, hybrid? Dug, constructed, buried, elevated, hybrid? Central, distributed, peripheral? Singular or Networked? Visible, invisible? Informal, temporary, ephemeral? Permanent, fixed, stationary, monumental?

Software -what is the social nature of the system?

What human/manmade/social conditions does the system serve? urban? Rural? Both? Hybrid? Permanent? Nomadic? Hybrid? High density, low? Low, moderate or high income?

How is construction, operation, and maintenance organized or controlled? Privately constructed, operated? Or publically? Centralized authority or Shared/Collective? Vertical/hierarchical social context? Flat/communal?

What are the rules governing the system's operation? How is supply, demand, and cost/operation/maintenance regulated? Are those rules tied to time cycles: Daily, weekly, seasonal? Are they tied to social units: family, neighborhood, tribe, dynasties? At what scale?

What other intangible or indirect purposes are associated with the system? Religious or mythological meaning?
Ceremonial or political function? Public space, ecosystem services, or 'multibenefits'?

Who is it designed to serve? Power? Elites? Empire? Colonies? Colonizer, colonized? Families, tribes? Nomadic, sedentary? Men? women? children?

Who benefits? How? What do you see as costs or consequences, intended or unintended? How have historians—or how would you—characterize the ideological purpose of the system?

Functions

HOW TO USE THIS BOOK

TERM

ESSENCE OF THIS TERM: WHY WE CARE

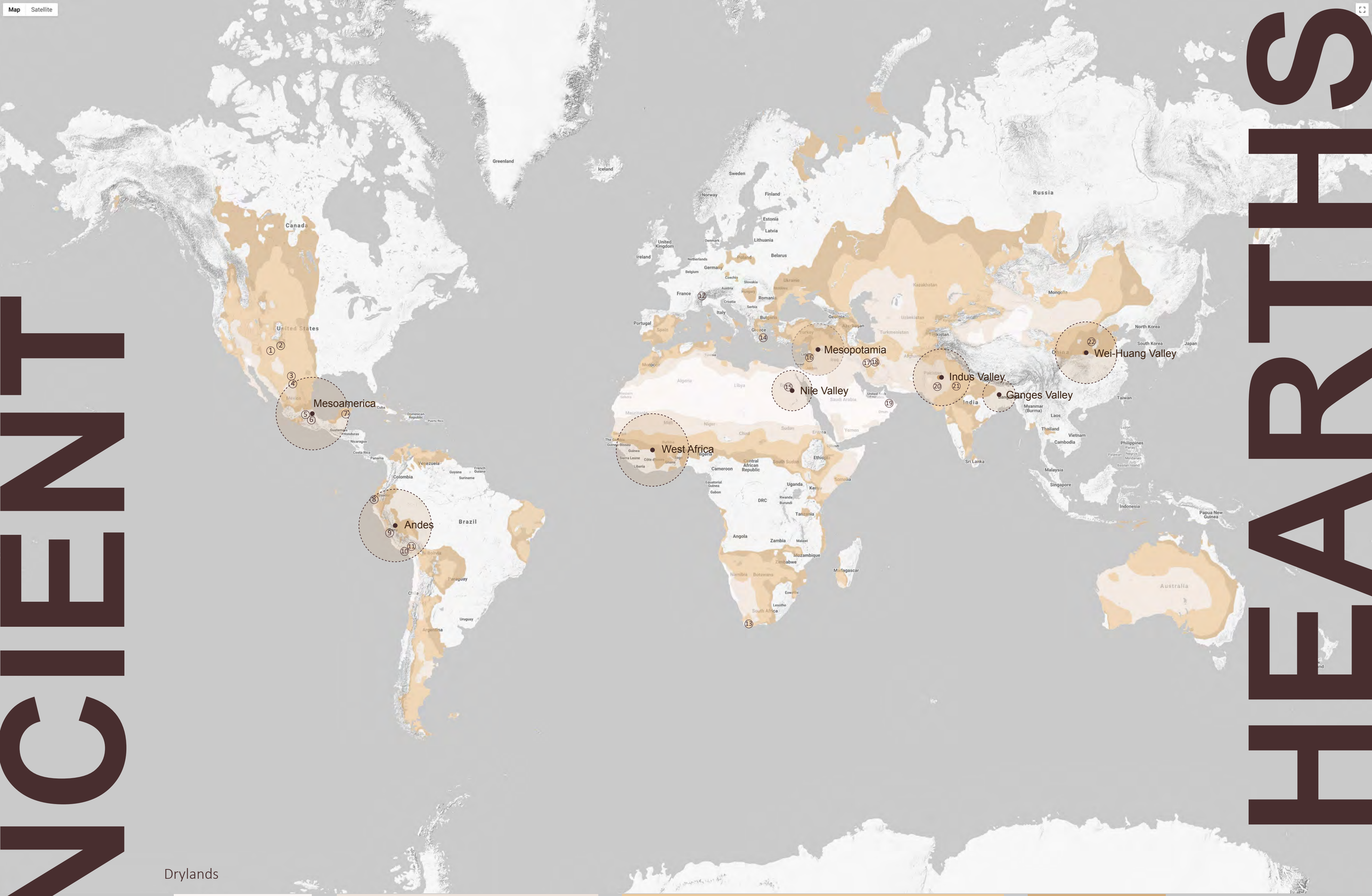
HYPER-ARID

ARID

SEMI-ARID

SUB-HUMID

ANCIENT HEARTHS



Drylands

Hyper-arid areas

- ⑲ aflaj
- ⑮ malqaf
- ⑯ maqsam

Arid areas

- ⑳ khadin
- ⑨ mamanteo
- ④ olla
- ⑰ paradise garden
- ⑩ puquios
- ⑱ yakhchal

Semi-arid areas

- ② acequia
- ⑧ albarrada
- ⑪ benching
- ⑫ bisses
- ⑭ clepsydra
- ⑬ leiwater
- ㉑ stepwell
- ⑥ temazcal
- ③ tinaja
- ① waffle garden

Sub-humid areas

- ⑤ chinampa
- ⑦ chultun
- ㉒ tianjing

HYPER-ARID

Drylands

Hyper-arid areas

- ⑲ aflaj
- ⑮ malqaf
- ⑯ maqsam

HYPER-ARID

AFLAJ

An Aqueduct that Makes Groundwater Available Year Round

Aflaj is a gravity-fed system designed to deliver remote groundwater to arid settlements via a combination of surface and subsurface channels.

Photo: Al Sharieh Falaj in Birkat Al Mouz, Oman, YouvicTours.

AFLAJ

An aflaj, or falaj, is a gravity-fed system designed to deliver remote groundwater to arid settlements via a combination of surface and subsurface channels. The system has existed in Al Dakhliya, Al Sharqiyah and Al Batinah regions in Oman since 500 AD.[3] Most aflaj are located on the north of inland Oman, where annual
precipitation ranges between 1/2” to 4”. According to the arid index, the aflaj are located in hyperarid to arid regions.[4] Borrowed from Arabic جَلَّجْ (aflāj), plural of جَلَف (falaj). "Aflaj" means "split into parts" in classical Arabic.[5] The system was originally developed in Persia circa 3,000 years ago, and spread to the east, west, south and north.[6] Comparable systems include: Kariz (Afghanistan), Foggara (Algeria), Kan’erjing (China), Ingruttato (singular, Italy), Ingruttati (plural, Italy), Qanat (Iran), Mambo (Japan), Ma-nan-po (Korea), Khattara (Morocco).[7]

Nizwa, Ad Dakhiliyah, Oman

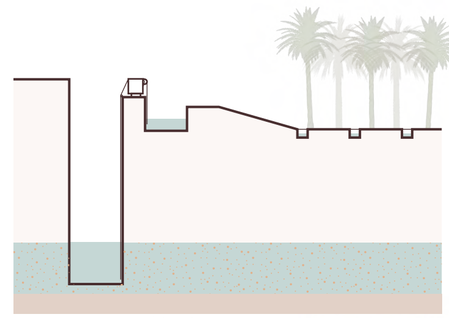
Hardware

Three Types of Water Source

Falaj Ayni

Well/Spring
Ephemeral

• Ayni Falaj directly extracts water from a spring or a well. The water temperature varies, some are hot, some are cold. The well is often made out of masonry or concrete. Historically water is lifted out of a well by men. Electric-powered water pumps are now more common.[8]

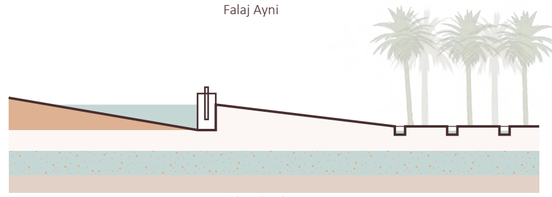


Falaj Ayni

Falaj Chayli

Stream/Wadi Base
Ephemeral

• Ghayli Falaj originates near ponds or running water (normally no more than 4 meters deep). Ghali Falaj uses a dam or a wall to divert water into a channel. The water supply is often sufficient after rainfall, followed by extended dry periods.[9]

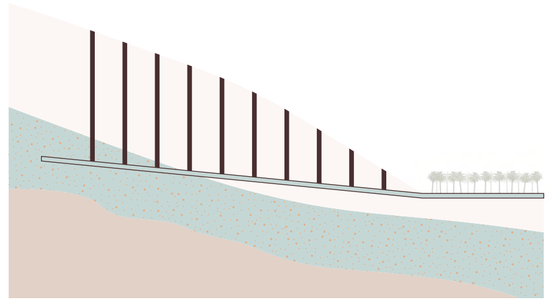


Falaj Chayli

Falaj Daoudi

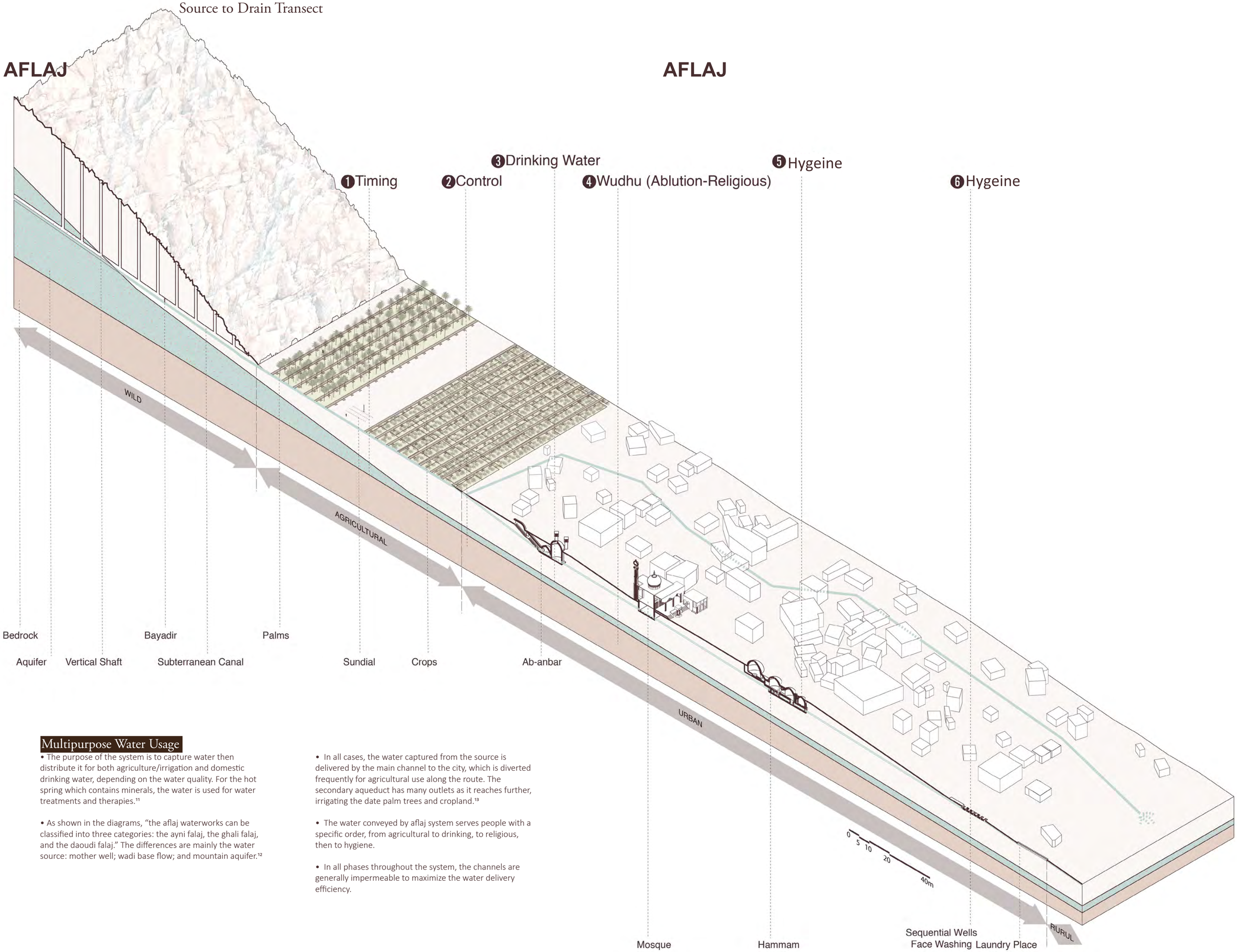
Stream/Wadi Base
Ephemeral

• Daoudi Falaj uses a series of vertical shafts to access groundwater. Once vertical shafts reach the water table, an underground channel is constructed to direct water from the aquifer to surface uses. Long channels dug underground extend for several kilometers with a gentle slope, and the depth reaches for tens of meters. The aquifer is one of the key elements in this system, allowing for year-round water supply on crops and in settlements.[10]



Falaj Daoudi

Source to Drain Transect



Multipurpose Water Usage

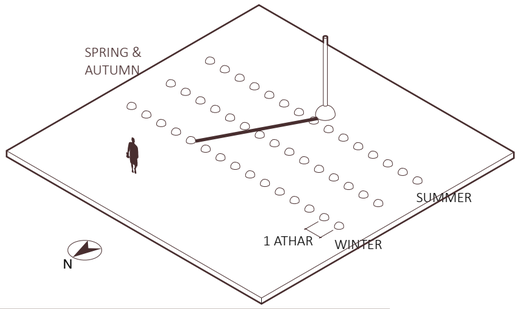
• The purpose of the system is to capture water then distribute it for both agriculture/irrigation and domestic drinking water, depending on the water quality. For the hot spring which contains minerals, the water is used for water treatments and therapies.[11]

• As shown in the diagrams, "the aflaj waterworks can be classified into three categories: the ayni falaj, the ghali falaj, and the daoudi falaj." The differences are mainly the water source: mother well; wadi base flow; and mountain aquifer.[12]

• In all cases, the water captured from the source is delivered by the main channel to the city, which is diverted frequently for agricultural use along the route. The secondary aqueduct has many outlets as it reaches further, irrigating the date palm trees and cropland.[13]

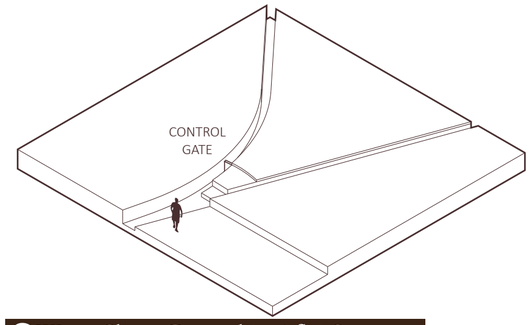
• The water conveyed by aflaj system serves people with a specific order, from agricultural to drinking, to religious, then to hygiene.

• In all phases throughout the system, the channels are generally impermeable to maximize the water delivery efficiency.



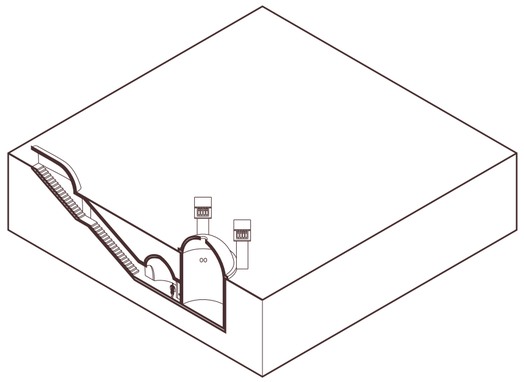
1 Sundial to Determine Water Rotation

The shadow moves between each rock indicating shifting the turn of running water in channels.



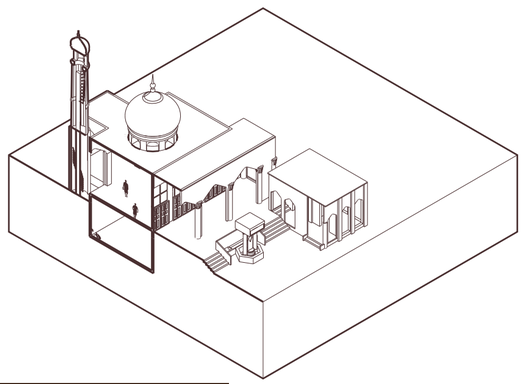
2 Water Share Control in Aflaj System

The water is diverted manually by a simple piece of wood.



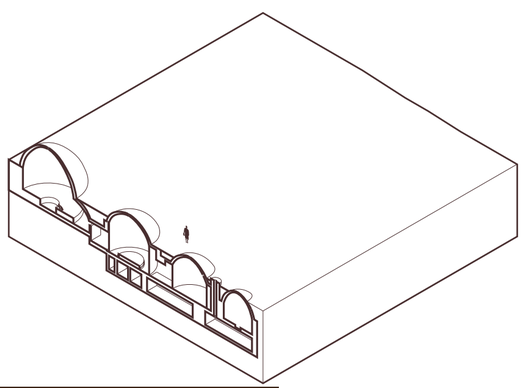
3 Drinking Water Storage: Ab-anbar

The water gets conveyed into ab anbar through two holes on the wall.



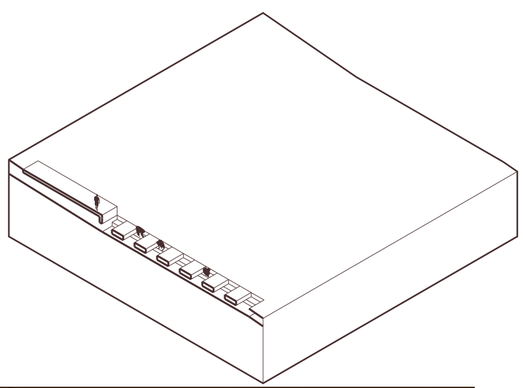
4 Wudhu (Ablution)

People can access the water for wudhu by faucets. Wudhu is a religious cleaning activity before salah (facing Mecca).



5 Hygiene-Hammam (Bath)

In the Islamic hammams, the bathers splash themselves with cold water. Though before this they come through several rooms with heated air to perspire freely.

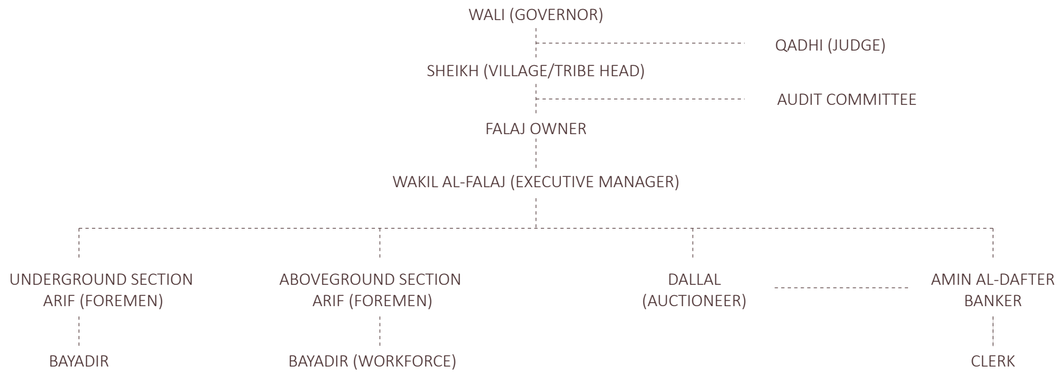


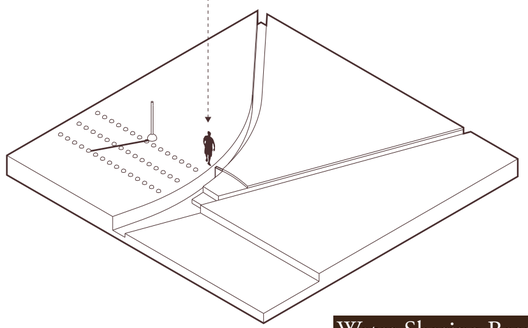
6 Hygiene-Sequential Wells for Face Washing

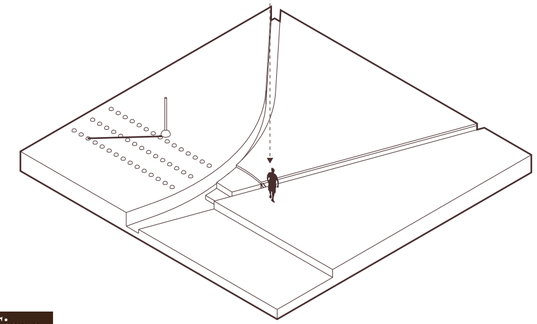
Each well/opening supports one person to wash his/her face.

Software

Governance Hierarchy







Water Sharing Based on Time

As time indicated by sundial goes on, the turn of water running in channel got shifted manually by a wood plank.

Administration Rooted in Persian Society

• When aflaj were first constructed, Oman was in the Persian period. “The northern part of Oman was part of the Maka satrapy of the Persian Achaemenid Empire.” [14]

• Aflaj should be considered as “hydrological, social, ecological and economical systems”.[15]

• “Typical large Omani falaj administration consists of a director, wakil, (ليآو) two assistants, arifs, (ٍفيرع) one for underground-section services and the other for above ground-section services, banker, qabidh (ضباق) , or amrin aldaftar, (رتفدلا نيمأ) and labor, bayadir. (ريدابي)”[16] Falaj have all or some of the above-mentioned administrators depending on the scale. At a minimum, wakil is needed. The owners of the falaj (land and water owners) chose the wakil (male agent[17]) from the village citizens.[18]

• Arif (ٍفيرع) can be in charge of timing irrigation in the field. The qabidh’s job is controlling the falaj income, which comes from waqf [19] (special water shares, land, and/or crops located for the falaj). He is also in charge of updating the falaj transaction book, giving an annual report to the falaj owners.

• Auctioneer-Dallal is in charge of falaj water rental. There are mainly two water rental periods: 7-14 days called Maqouda (ةدوعقم), one-year called Mazyodah (ةدويزم). Bayadirs rent the land and falaj to farm and harvest. Production is often used to pay the rent[20].

• When conflicts occur, wakil and falaj owners can report to the sheikh. If sheikh cannot resolve the problem, then wali should be involved. Wali, as the government representative, will transfer the matter to the court to be judged by the qadhi. The decision on the mater will be made according to Islamic law.[21]

Timing System and Irrigation Rotation

• In aflaj system, water is shared on a time basis. In Oman, irrigation rotation[22] (dawran) is divided to 7-14 days. Each day is then often divided to 48 Athars.[23](In this case, 1 athar = 30 mins.) Each farmer will irrigate his farm(s) with the same number of athars at each dawran. The sequence of water shares in the rotation of irrigation does not change if a farmer misses irrigating his land during the rotation.[24] Most of aflaj have a special number of athars to be rented for falaj service and maintenance. Traditionally, a sundial is used to calculate time intervals.

AFLAJ

Notes:

1 Al-Ghafri, Abdullah & Inoue, Takashi & Nagasawa, Tetuaki. (2003). “Daudi Aflaj: the Qanats of Oman”. Conference Paper of Proceedings of the Third Symposium on Xinjing, Uyghor, China, November 2003, pp. 29.

2 Aburawa, Arwa. “Aflaj: Ancient Channels Keep Water Flowing In The Desert - Green Prophet: Impact News for the Middle East.” Green Prophet | Impact News for the Middle East, 19 May 2011, https://www.greenprophet.com/2011/05/aflaj-ancient-channels-keep- water-flowing-in-the-desert/.

3 Medhat, Gehad. “The Gravitational Wonder of the Aflaj Systems of Oman.” Culture Trip, The Culture Trip, 16 Mar. 2018, theculturetrip.com/middle-east/oman/articles/the-gravitational-wonder-of-the-aflaj-systems-of-oman/.

4 Vaughn, Danny M. “Arid Climates.” Encyclopedia of World Climatology Encyclopedia of Earth Sciences Series, pp. 85–89., doi:10.1007/1-4020-3266-8_16.

5 “Aflaj.” Wiktionary, en.wiktionary.org/wiki/aflaj.

6 Macpherson, G. L., et al. “Viability of Karezes (Ancient Water Supply Systems in Afghanistan) in a Changing World.” Applied Water Science, vol. 7, no. 4, 2015, pp. 1689–1710., doi:10.1007/s13201-015-0336-5.

7 Al-Ghafri, Abdullah & Inoue, Takashi & Nagasawa, Tetuaki & Norman, W.“Aflaj Irrigation Systems of Oman, The Way of Water Distribution”. Conference Paper of The XIV Memorial CIGR World Congress, December 2000, pp. 1129.

8 Raynolds, William. “The Aflaj Waterworks of Ras Al Khaimah: Current Conditions and Prospects for Conservation.” Al Qasimi Foundation, 2019, doi:10.18502/aqf.0095, pp. 2.

9 Raynolds, William. “The Aflaj Waterworks of Ras Al Khaimah: Current Conditions and Prospects for Conservation.” Al Qasimi Foundation, 2019, doi:10.18502/aqf.0095, pp. 3.

10 Raynolds, William. “The Aflaj Waterworks of Ras Al Khaimah: Current Conditions and Prospects for Conservation.” Al Qasimi Foundation, 2019, doi:10.18502/aqf.0095, pp. 4.

11 “Aflaj in Oman.” Ancient Water Technologies, 10 Mar. 2019, ancientwatertechnologies.com/2019/02/19/aflaj-in-oman/.

12 Al-Ghafri, Abdullah & Inoue, Takashi & Nagasawa, Tetuaki & Norman, W.“Aflaj Irrigation Systems of Oman, The Way of Water Distribution”. Conference Paper of The XIV Memorial CIGR World Congress, December 2000, pp. 3.

13 Frías, Sara Martínez. “Aflaj Irrigation System, OMAN - Med-O.” Med, medomed.org/featured_item/the-cultural-landscape-of-aflaj-irrigation-system-oman/.

14 Miles, S. B. “The Countries and Tribes of the Persian Gulf”. Kalpaz, 2017, pp. 26-27.

15 Al-Ghafri, Abdullah & Inoue, Takashi & Nagasawa, Tetuaki. (2003). “Daudi Aflaj: the Qanats of Oman”. Conference Paper of Proceedings of the Third Symposium on Xinjing, Uyghor, China, November 2003, pp. 34.

16 Sutton, Sally, 1984, The Falaj a Traditional Co-Operative System of Water Management, Waterlines Vol.2 No.3, pp. 2-12.

17 Worden, Minky. “Boxed In: Women and Saudi Arabia's Male Guardianship System.” Human Rights Watch, 6 June 2017, www.hrw.org/report/2016/07/16/boxed/women-and-saudi-arabias-male-guardianship-system.

18 Wilkinson, J.C., 1977, Water and Tribal Settlement in Southeast Arabia: a Study of the Aflaj of Oman, Oxford, Clarendon Press, pp. 38.

19 Note: A waqf (Arabic: وَقْف‎), also known as mortmain property, is an inalienable charitable endowment under Islamic law, which typically involves donating a building, plot of land or other assets for Muslim religious or charitable purposes with no intention of reclaiming the assets. “Waqf.” Wikipedia, Wikimedia Foundation, 3 Jan. 2020, en.wikipedia.org/wiki/Waqf#Terminology.

20 Al-Ghafri, Abdullah & Inoue, Takashi & Nagasawa, Tetuaki. (2003). “Daudi Aflaj: the Qanats of Oman”. Conference Paper of Proceedings of the Third Symposium on Xinjing, Uyghor, China, November 2003, pp. 30.

21 Al-Ghafri, Abdullah & Inoue, Takashi & Nagasawa, Tetuaki. (2003). “Daudi Aflaj: the Qanats of Oman”. Conference Paper of Proceedings of the Third Symposium on Xinjing, Uyghor, China, November 2003, pp. 31.

22 Note: Water rotation is the method of rotation of the order of crop watering based on the timetable designed for equitable distribution of irrigation water. Water rotation implies the order of water delivery in accordance with the schedule where water delivery day, time, and duration are specified. Worden, Minky. “Boxed In: Women and Saudi Arabia's Male Guardianship System.” Human Rights Watch, 6 June 2017, www.hrw.org/report/2016/07/16/boxed/women-and-saudi-arabias-male-guardianship-system.

23 Al-Ghafri, Abdullah & Inoue, Takashi & Nagasawa, Tetuaki. (2002). Irrigation Scheduling of Aflaj of Oman: Methods and Modernization, pp. 3.

24 Norman, W. R., Shayya, W. H., Al-Ghafri, Abdullah, and McCann, I.R., 1998b, Aflaj Irrigation and On-farm Water Management in Northern Oman, Irrigation and Drainage Systems 12, pp. 35- 38.

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Jiang, Yuliang

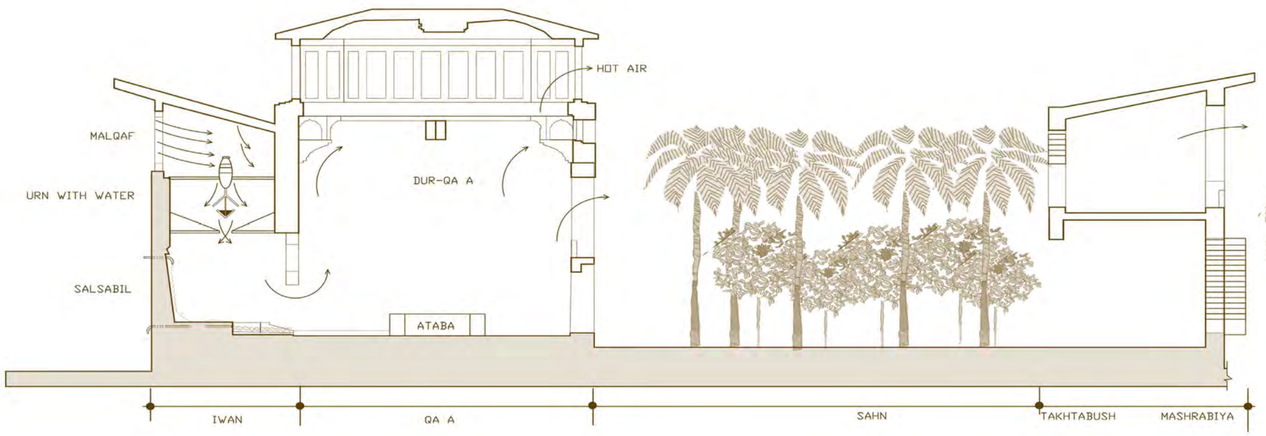
MALQAF

Natural Cooling System for Your Home Low Cost, Efficient

Malqaf is an Egyptyan invention of passive cooling system that uses natural ventilation. It dates back to 1300 B.C. Large courtyards connected to the malqaf serve as reservoirs of cool, fresh air in large urban network.[1]

Antique old historic images of Cairo Egypt by John Weston

MALQAF



A passive climatization system using water and wind. It is composed of a shaft rising high above the building with openings facing prevaling winds. Wind enters the building and travels past a water filled urn, down into the interior of the building where the salsabil (a wet marble plate) forms an angle against a wall, dispensing air movement, humidity, ventilation and promoting thermal comfort in the spaces around the adjacent rooms and gardens. Egyptians have employed the Malqaf in their residential and religious buildings since the Nineteenth Dynasty (1300 BCE).

The Iwan

A hall or arched space, covered and usually walled on three sides with one end entirely open to the Qa-a, Durqa'a or Sahn. [2]

The Malqaf

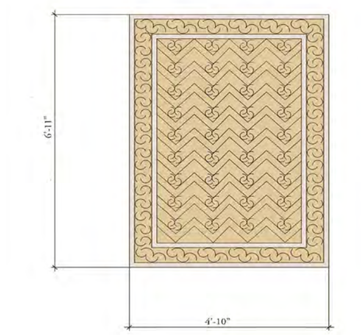
Ventilation opening in hot arid zones, oriented to capture prevaling winds. [3]

Water Urn

located in the center of the malqaf to provide humidity.

The Salsabil

Handmade marble plate, decorated with wavy patterns suggesting water and wind. It is placed at an angle against a wall at the bottom of the malqaf. It receives the current of wind and moisture coming from the Malqaf and distributes cool air with humidity to the adjacent spaces. The salsabil is the head of the fountain. [4]



Salsabil

Qa-a

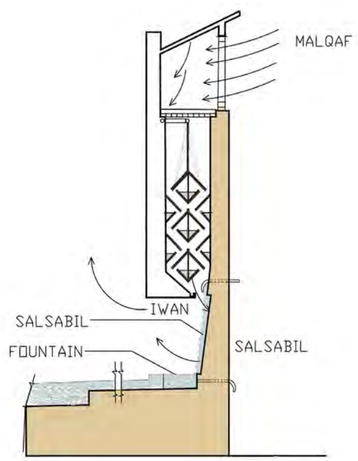
The central space in the structure; a roofed courtyard.

Dur qa-a

The space above the Qa-a where hot air rises and exits. [5]

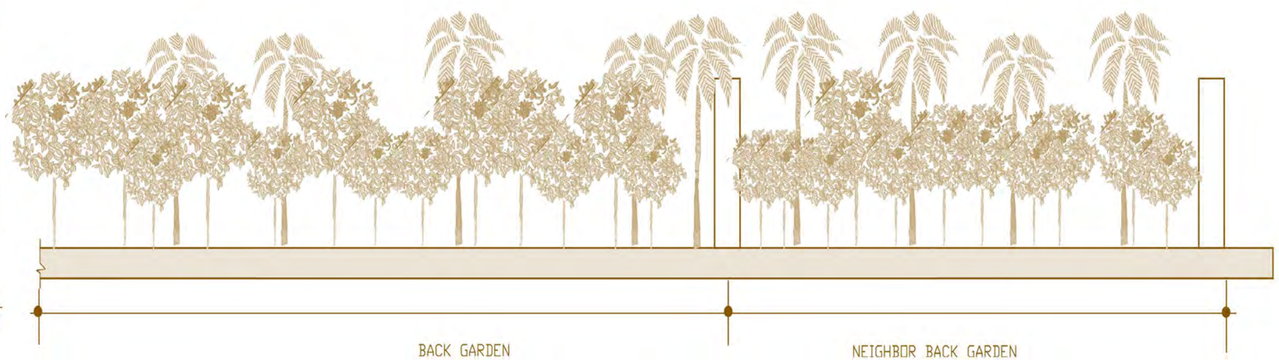
The Sahn

An internal courtyard open to the sky.



Malqaf

MALQAF

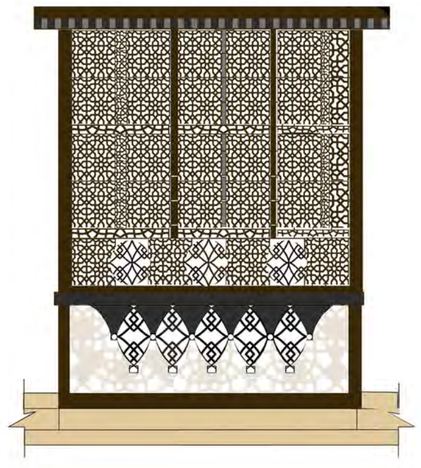


Takhtabush

A type of loggia, or outdoor covered seating place between the courtyard and the back garden, opening entirely onto the courtyard and through a Mashrabiya on to the back garden.

Mashrabiya

A type of window with carved wood lattice that allows the circulation of air from the courtyard to the back garden.



Mashrabiya

Back Garden

The back garden is larger than the courtyard and less shaded, air heats up more readily than the courtyard. The heated air rising in the back garden draws cool air from the courtyard through the Takhtabush and its Mashrabiya, creating a cool and continous draft (convection current).

The Neighbor Garden

The cool air from the courtyards refreshes the heated air in the gardens creating a cooling effect in the urban landscape.

Mashrabiya

MALQAF

AIR

Warm air is less dense than cool air and will rise in an enviro-ment of cool air creating convection currents the phenome-non called the stack effect.The Malqaf system uses this principle, providing cool air to replace warm air from the surroundins. The Takhtabush with its Mashrabiya generates a continuous and steady flow of air. The back garden is larger and with less shade than the courtyard. The heated air rising in the back garden draws cool air from the Malqaf, salsabil and the courtyard through the takhtabush, creating a cool draft.

WATER

In islamic architecture, the fountain is located in a privileged place in the middle of the courtyard with the Qa-a or living spaces opening onto it. Square in shape, the inner basin forms an octagon or a hexadecadon.
In places without enough pressure to permit the water to spout out of the fountainhead, the fountain is frequently replaced with the salsabil.

FAMILY

In Islamic architecture houses are shaped upon principles, values, and traditions derived from the Islam. Clustered spatial organization was used in urban fabric of residential zones. This system would protect family life and preserve the stability of the society. Courtyards were the best strategy to maintain privacy, family then can perform their social activities without any visual intrusion.

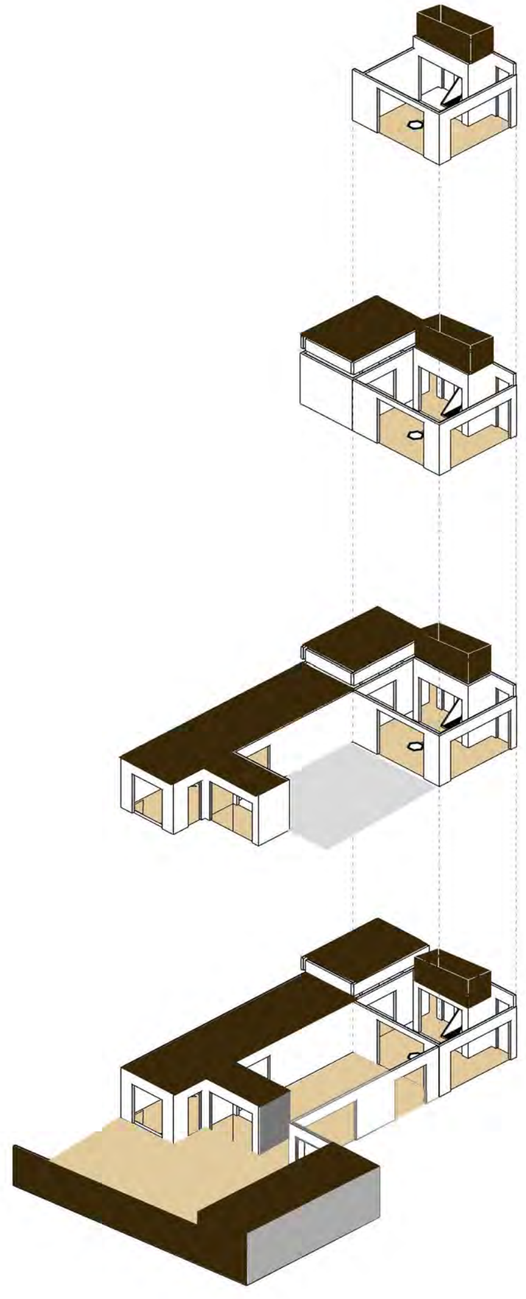
CITY

Although each unit of the malqaf system is part of a private household or religious building communal urban space benefit by locating the takhtabush with its mashrabiya between two squares, one larger than the other, the larger square on the leeward side creates draws by pressure differ-ential, cooling urban squares, parks and gardens. Large courtyards spread evenly within the urban grid serving as reservoirs of cool , fresh air helping to redistribute the heat within the city.

NEIGHBORHOOD

Neighborhood planning and design was the product of social relationships and cultural progress. Islam strongly encourages social life on a wide scale. The city urban fabric was set in a way that contributes to the enhancement of the social interaction and strong relationships. The clustering of the houses reflects the strength of the social fabric, courtyards, streets and stairs functioned as pubkic spaces providing convenient space for families and people to walk, gather, and to interact. [6]

MALQAF

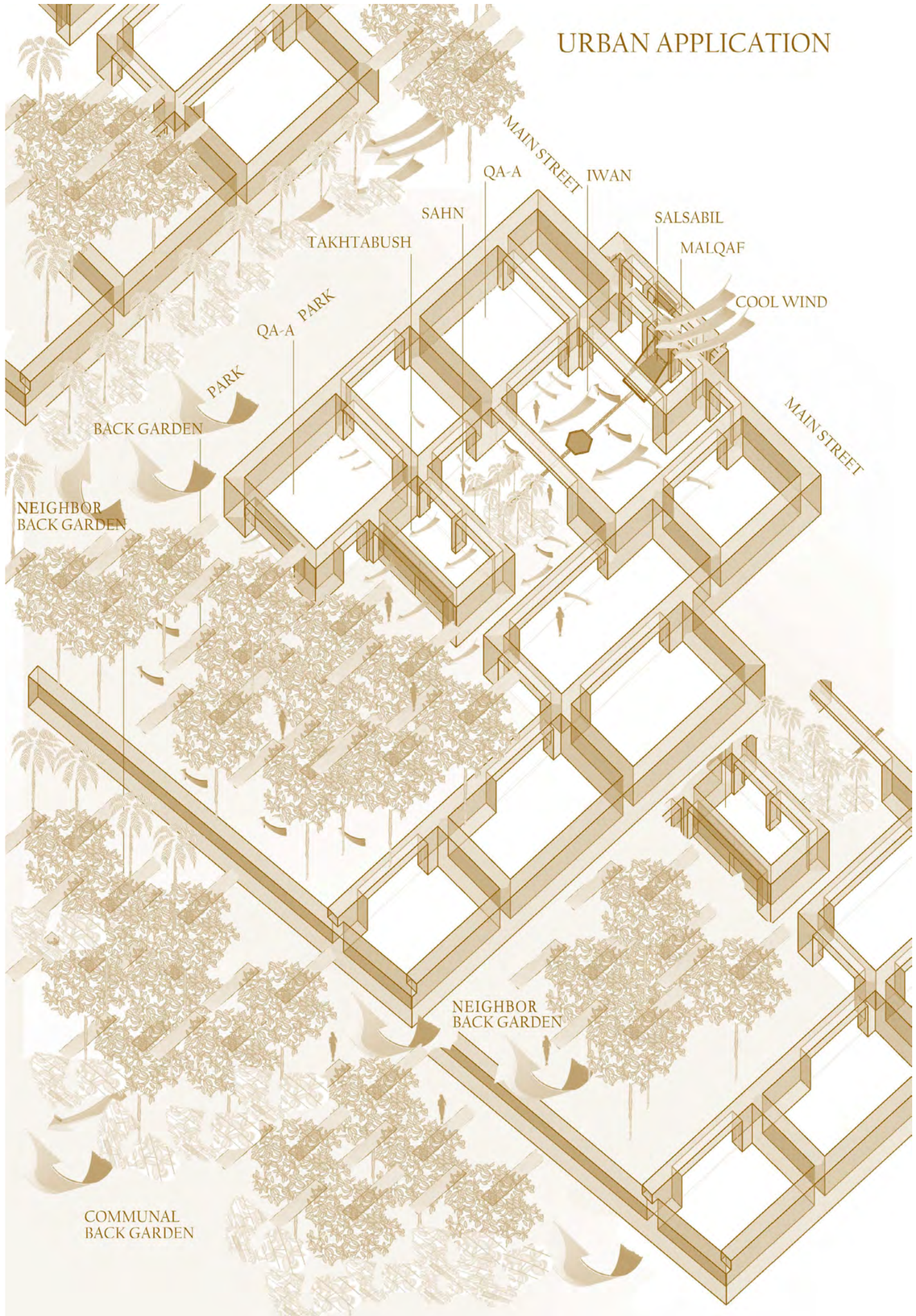


Malqaf + Salsabil + Iwan

Malqaf + Salsabil + Iwan + Qa a

Malqaf + Salsabil + Iwan + Qa a + Sahn + Qa a + Takhtabush + Mashrabiya

Malqaf + Salsabil + Iwan + Qa a + Sahn + Qa a + Takhtabush + Mashrabiya + Back Garden



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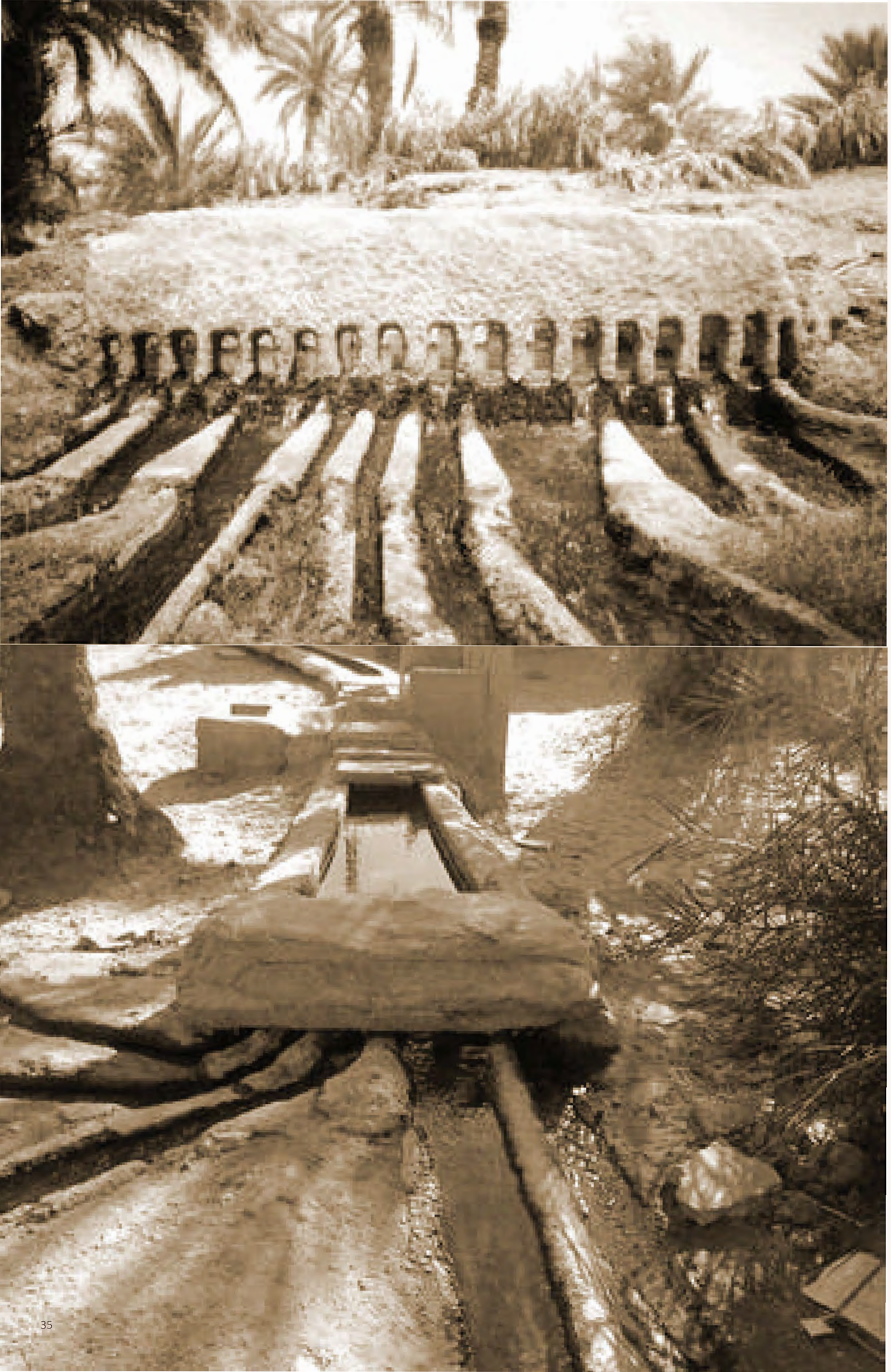
Student Contributor:

Clara, Yoshihara



Maqsam is a Divider for Water Justice

Maqsam is a water distributor which consists of some outlets of different sizes on which the shareholders have agreed.

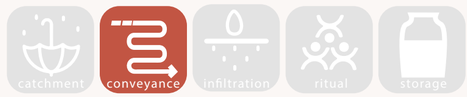


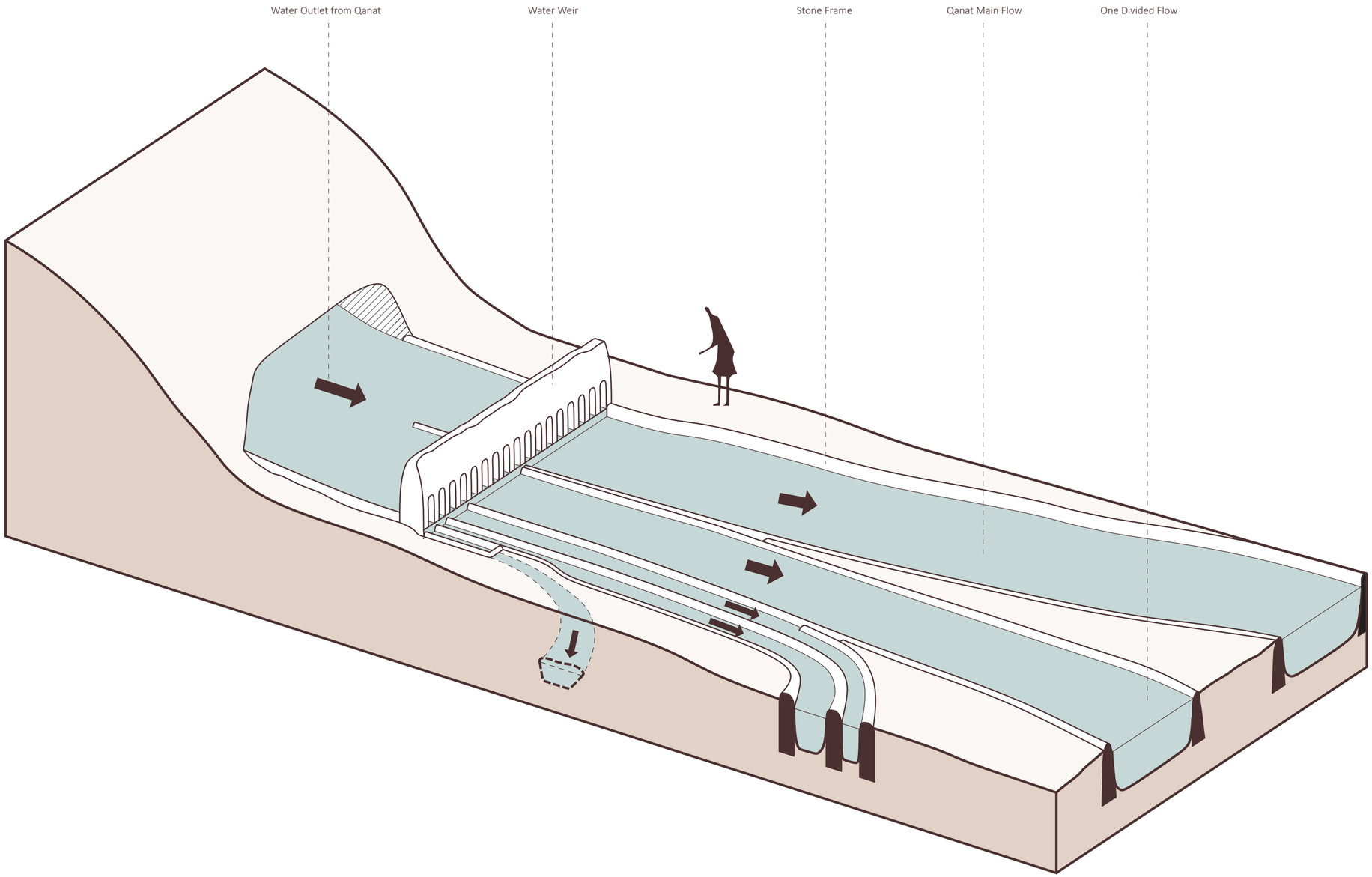
Photo: Semsar Yazdi, Ali Asghar., and Labbaf Khaneiki, Majid. Qanat Knowledge Construction and Maintenance . (2017)

MAQSAM

MAQSAM

Maqsam is ‘a water distributor which consists of some outlets of different sizes on which the shareholders have agreed.’[1] Maqsam comes from the Arabic wor’)misqum(مسقم‘ d, which means ‘divider’[2]. It has been used as part of qanat systems in Iran and Syria since 500CE.

Functional Exploration of a Maqsam System



Hardware

• Physical Water Function

The purpose of a maqsam is divide then distribute. “In the case of high discharge qanats shared between several villages or farmlands, the water flow may be divided into separate streams before being utilized. If two or more villages or agricultural areas are entitled to a particular qanat, a maqsam is built across the canal immediately after the qanat water reaches the surface. By means of a maqsam, it is possible to distribute water among the areas.” [3]

• The Manmade Properties

A Maqsam is usually constructed with wooden frames or stone and a mortar of lime and clay in the past, but substituted by concrete today. In some regions, maqsam is built “inside a chamber whose door is always locked and only mirab who is in charge of water division has the right to enter the chamber, because of fear that someone illegally manipulates the outlets and changes the water shares.” [4]

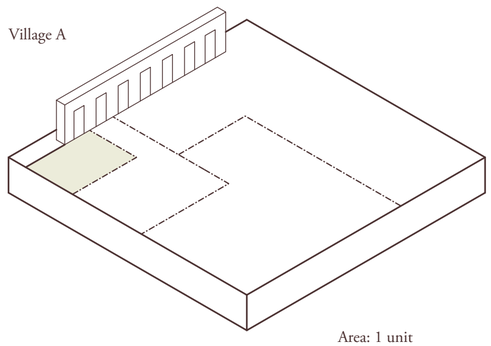
Hardware

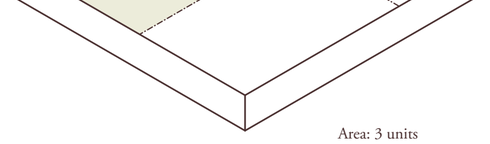
• physical design features

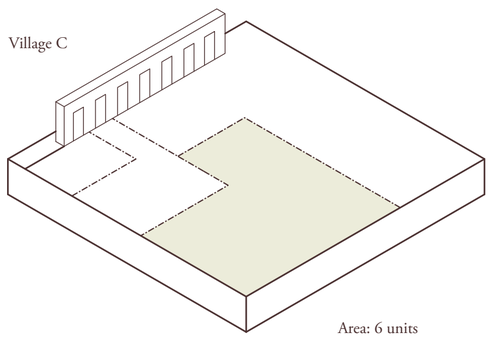
A Maqsam’s most essential designed part is the outlets’ framework, as described by King, “a long board fixed in the bed of the stream and having its upper edge the same number of notches as there are owners of the well.”[5]

MAQSAM working system exploration

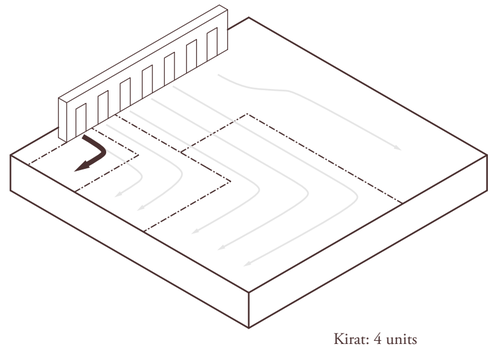
The Rule of "Fiddan" (Pre-determined Water Quantity)

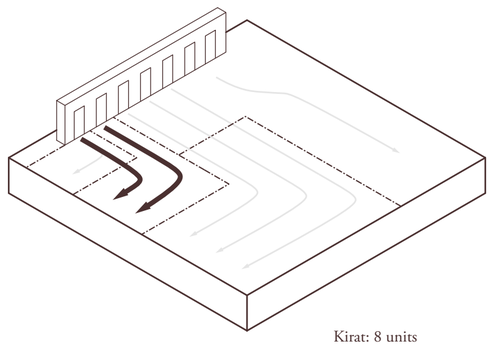


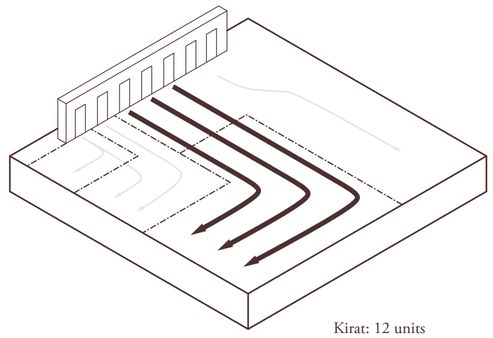




The Rule of "Qirat" (Determined by Width at Distribution Point)





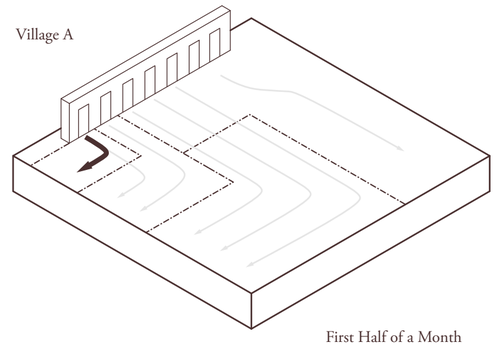


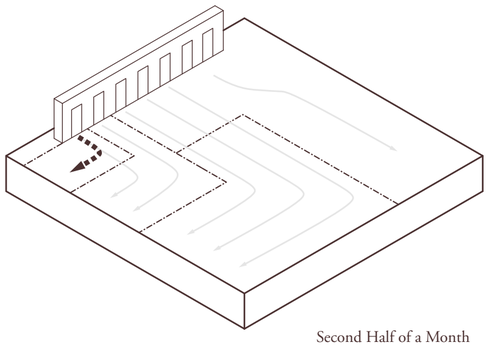
Software

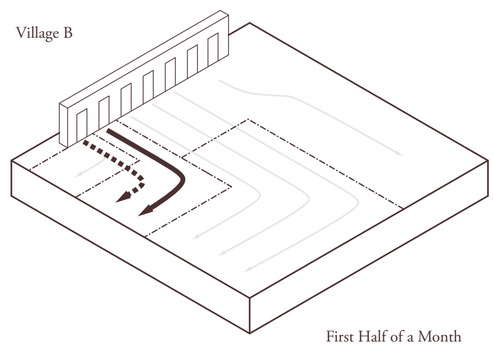
• The Working System

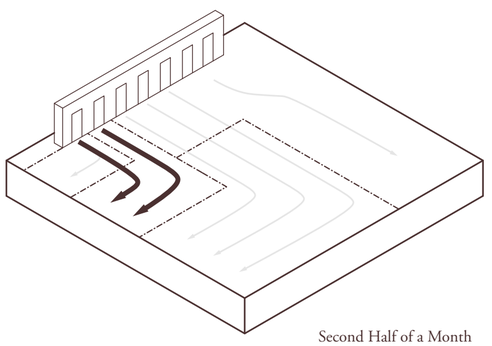
For example, at the first distribution point (maqsam), Qanat Tora divides into two main canals, one is the Tora main flow and the other is canal for adjacent villages. Both canals have twelve qirat evently, and each one shares 24 qirat again. The Tora main flow is distributed among five villages. The other canal is subdivided into three flows at the first maqsam, and is distributed among five villages. [6]

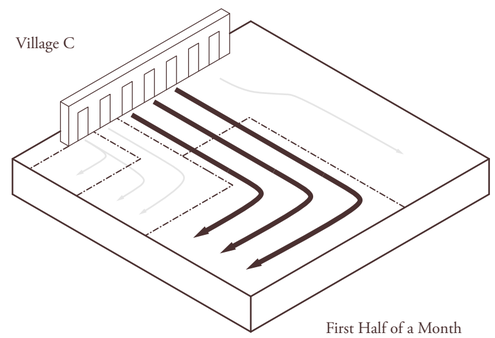
The Rule of "Addan" (Water Period)

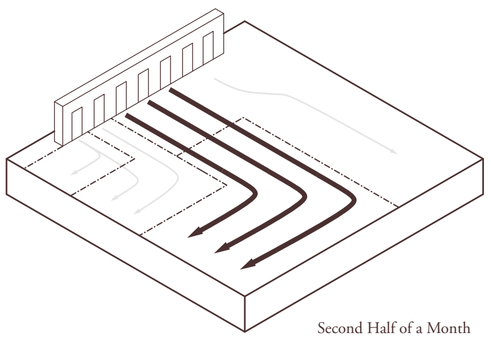












Software

• Condition

The Maqsam exist at the first point when the water from the qanat reach the ground.
The Maqam is an unchangeable structure, because it controls all the shareholders' water amounts and is predetermined before it was constructed.
The Maqsam is a public infrastructure, but the function makes it not a public place for citizens.

• Benefits

1. Water Justice
The Maqsam is the basic structure that ensures justice in shared water rights because the amount of water each shareholder gets is based on earlier agreements.
2. Water Distribution
As a part of the qanat system, the maqsam makes sure the water is efficiently distributed and used later, making desert land into an oasis.

Notes:

1,3,4 Semsar Yazdi, Ali Asghar, and Majid Labbaf Khaneiki. Qanat Knowledge Construction and Maintenance, 2017. P155

2 https://www.wordhippo.com/

5 Katō, Hiroshi, and Erina Iwasaki Rashda. the Birth and Growth of an Egyptian Oasis Village, 2016. P189

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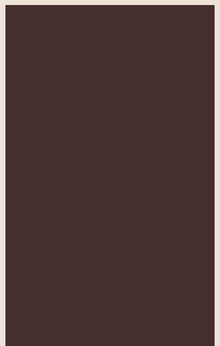
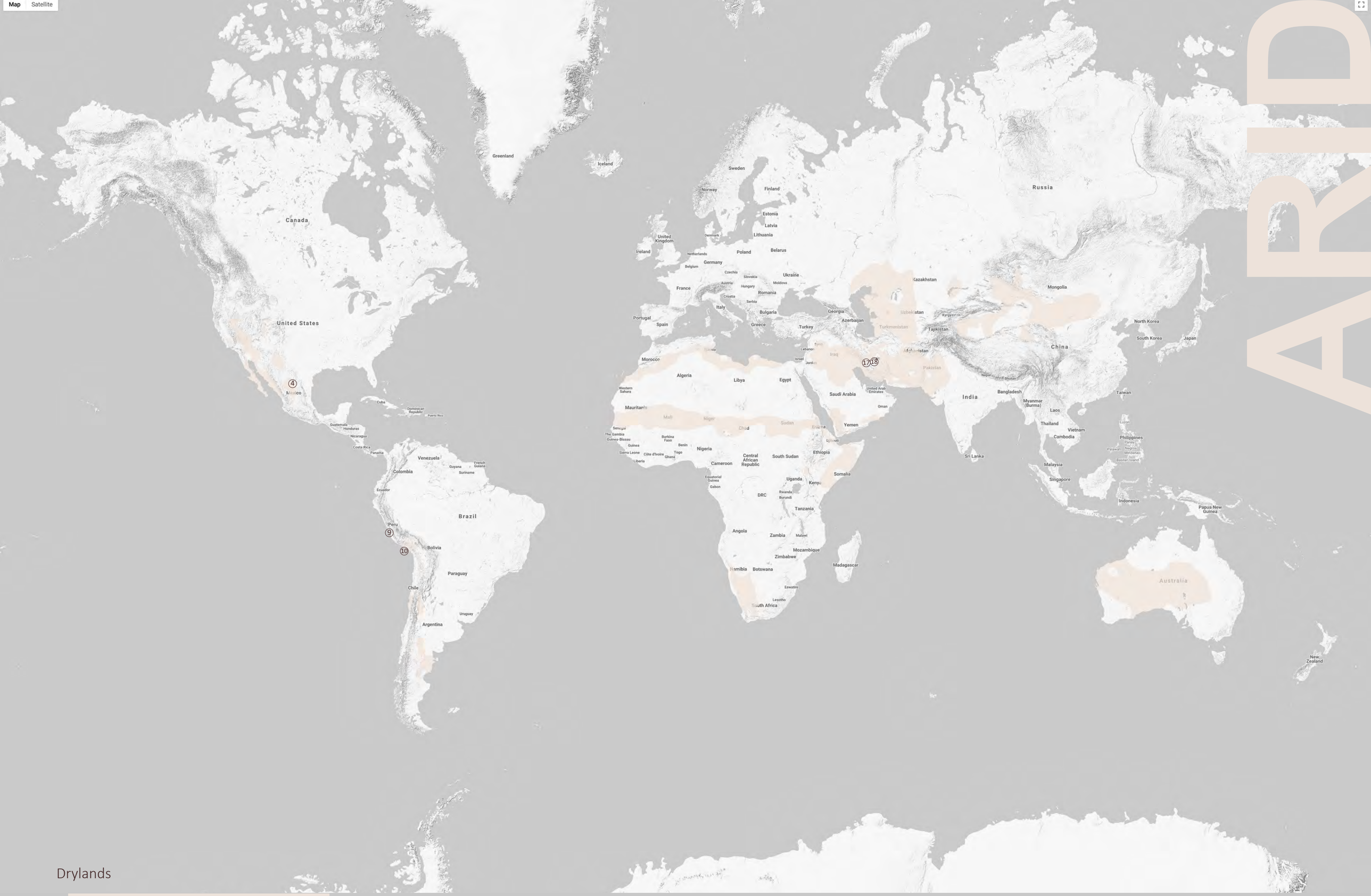
ARID





Drylands

Arid areas

- ⑳ khadin
- ⑨ mamanteo
- ④ olla
- ⑰ paradise garden
- ⑩ puquios
- ⑱ yakhchal

KHADIN

Low-cost Multifuncational Irrigation System for Food Production

Khadins are irrigation systems in the Jaisalmer district of Western Rajasthan. They collect run-off water from surrounding areas to increase soil humidity and recharge groundwater, which can increase food production

Photo: https://blaineharrington.photoshelter.com/gallery-image/G0000A4mFfS6EcRQ/I0000PIYy7aX7skM/35.

KHADIN

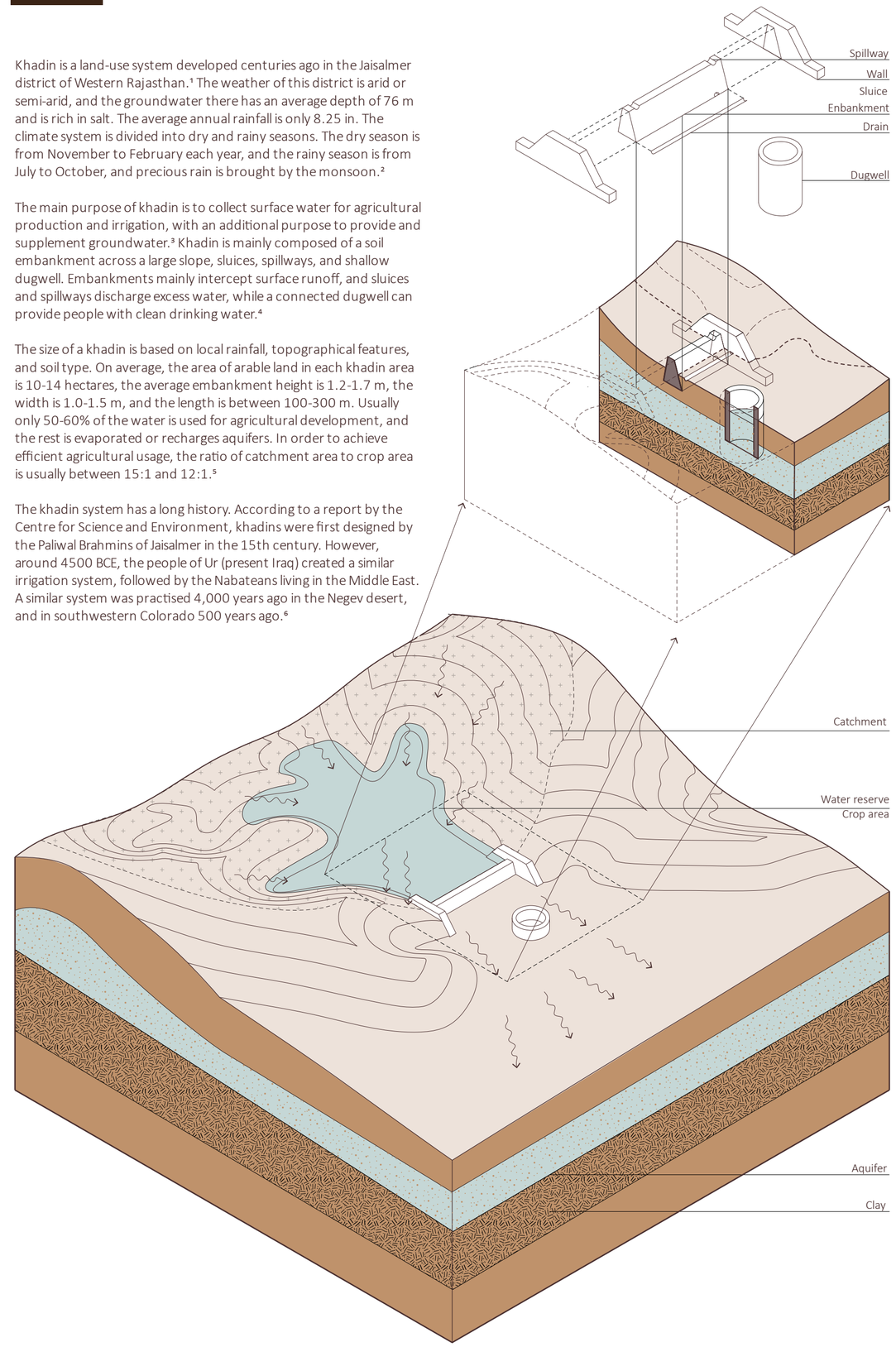
Hardware

Khadin is a land-use system developed centuries ago in the Jaisalmer district of Western Rajasthan.[1] The weather of this district is arid or semi-arid, and the groundwater there has an average depth of 76 m and is rich in salt. The average annual rainfall is only 8.25 in. The climate system is divided into dry and rainy seasons. The dry season is from November to February each year, and the rainy season is from July to October, and precious rain is brought by the monsoon.[2]

The main purpose of khadin is to collect surface water for agricultural production and irrigation, with an additional purpose to provide and supplement groundwater.[3] Khadin is mainly composed of a soil embankment across a large slope, sluices, spillways, and shallow dugwell. Embankments mainly intercept surface runoff, and sluices and spillways discharge excess water, while a connected dugwell can provide people with clean drinking water.[4]

The size of a khadin is based on local rainfall, topographical features, and soil type. On average, the area of arable land in each khadin area is 10-14 hectares, the average embankment height is 1.2-1.7 m, the width is 1.0-1.5 m, and the length is between 100-300 m. Usually only 50-60% of the water is used for agricultural development, and the rest is evaporated or recharges aquifers. In order to achieve efficient agricultural usage, the ratio of catchment area to crop area is usually between 15:1 and 12:1.[5]

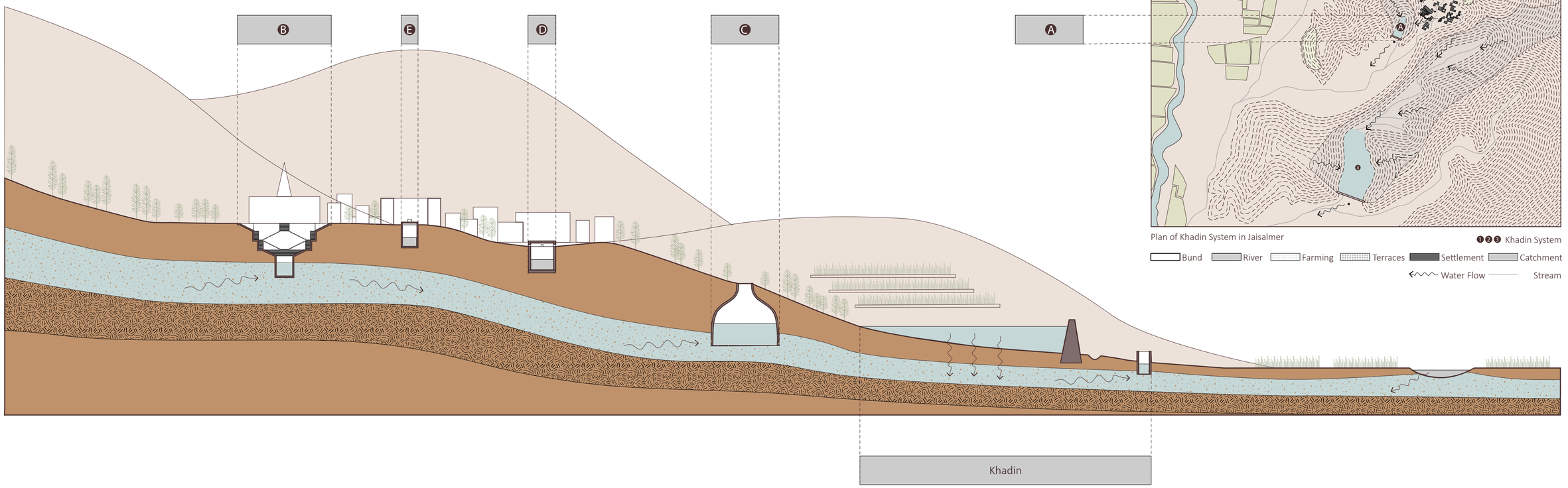
The khadin system has a long history. According to a report by the Centre for Science and Environment, khadins were first designed by the Paliwal Brahmins of Jaisalmer in the 15th century. However, around 4500 BCE, the people of Ur (present Iraq) created a similar irrigation system, followed by the Nabateans living in the Middle East. A similar system was practised 4,000 years ago in the Negev desert, and in southwestern Colorado 500 years ago.[6]



KHADIN

Urban System

A khadin is generally located below the city, surrounded by large terrain fluctuations. It also is linked to many other water systems, such as johad, stepwell, kuis, kund and tanka.



KHADIN

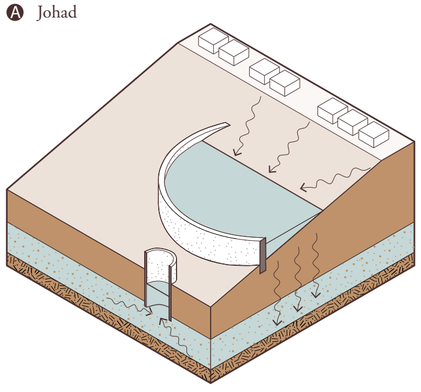
Plan of Khadin System in Jaisalmer

❶❷❸ Khadin System

Bund River Farming Terraces Settlement Catchment

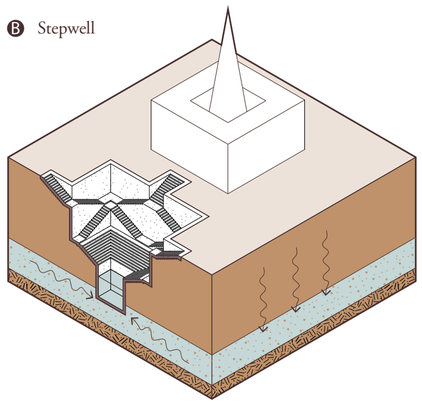
Water Flow Stream

Ⓐ Johad



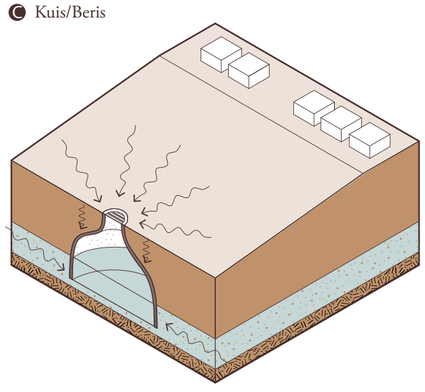
A Johad is a water tank for collecting and storing rainwater for drinking. The structure of Johad is similar as Khadin.[7]

Ⓑ Stepwell



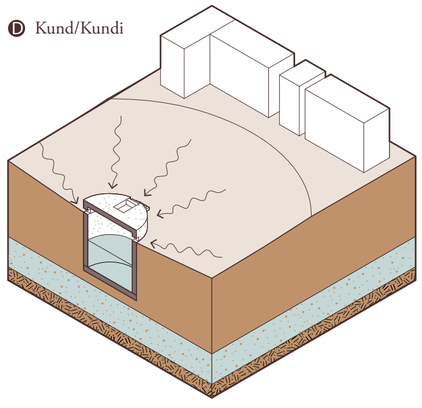
A Stepwell collects water from the water table to provide drinking and washing water. Khadins support this system.[8]

Ⓒ Kuis/Beris



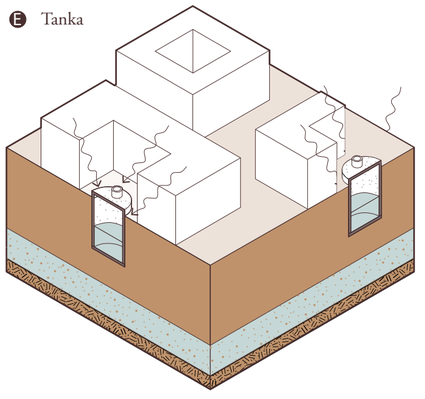
A Kuis is a10-12 m deep pit dug near tanks to collect seepage. The water in kuis is mostly used as the last water resources in crisis situations. Khadings support this system.[9]

Ⓓ Kund/Kundi



A Kund or Kundi looks like an upturned cup nestling in a saucer. These structures harvest rainwater for drinking and washing.[10]

Ⓔ Tanka



Tanka (small tank) is usually an underground tank found in Bikaner houses. They are built in the main house or yard to collect rainwater for drinking.[11]

Software

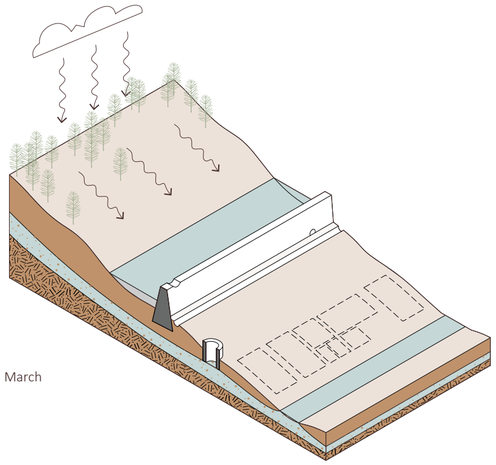
The khadin system can solve complex land problems with multiple benefits. During monsoon rains, a large amount of runoff from hills and gravel highlands will be blocked by the embankment, causing water to pool in the Khadin area. This water will penetrate into the soil and increase its water content. It also takes advantage of fertile sediment to increase soil fertility. The sluice or spillway then releases excess water, which can be collected into the downstream catchment system or used for irrigation. The crops can then grow in moist soil. The soil in this area contains salinity, which is usually a problem in dryland irrigation, but seasonal flushing of water in the khadin area can effectively reduce soil salinity. Khadins are also an effective supplement to groundwater, as they can raise the groundwater level. So below the embankment, the establishment of a dugwell can effectively use groundwater to provide people with drinking water.[12]

The khadin system has high economic and ecological value, and also provides a social place for people.

Economic: The khadin system provides irrigation water for agriculture, fertile and moist soil, and reduces soil salinity. Therefore, it can generally increase agricultural output by 3-4 times, and increase the types of crops grown. This ensures that farmers grow at least one crop, even in very dry areas. The construction cost of a single khadin is generally between 125-175 USD, but the agricultural value it creates can pay for the construction cost within three to five years.[13]

Ecological: The khadin system can alleviate the problem of soil erosion and increase vegetation coverage by increasing soil moisture content. This can also provide a good habitat for wildlife.[14]

Social: Khadins provide opportunities to communicate and gather during water collecting and agricultural activies.



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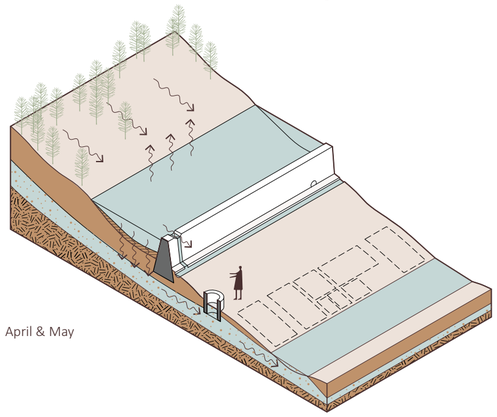
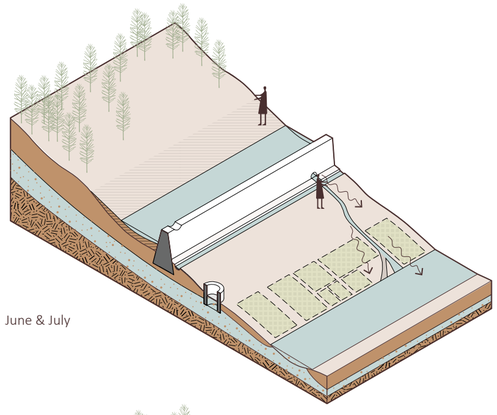
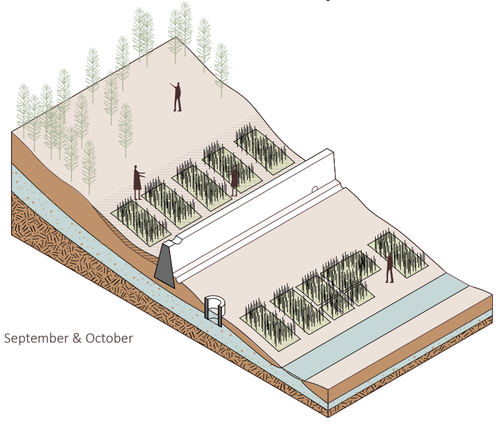


April & May



June & July



September & October

Notes

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MAMANTEO

Sustainable Land Art that Increases Natural Water Flow 500%+ In Dry Season

Mamanteo, or Amunas is a pre-columbian water runoff-delaying, harvesting and infiltration system that can transport water to different watershed and sustainably and effectively increases natural water water flow in dry season.

Photo: shows the part of the Mamanteo system called diversion canal. It led water away from the arroyo to the infiltration area.[1]

MAMANTEO

Mamanteo, or Amunas is a pre-columbian water runoff-delaying, harvesting and infiltration system used in Huamantanga in the Andean highlands near Lima, Peru.[2]

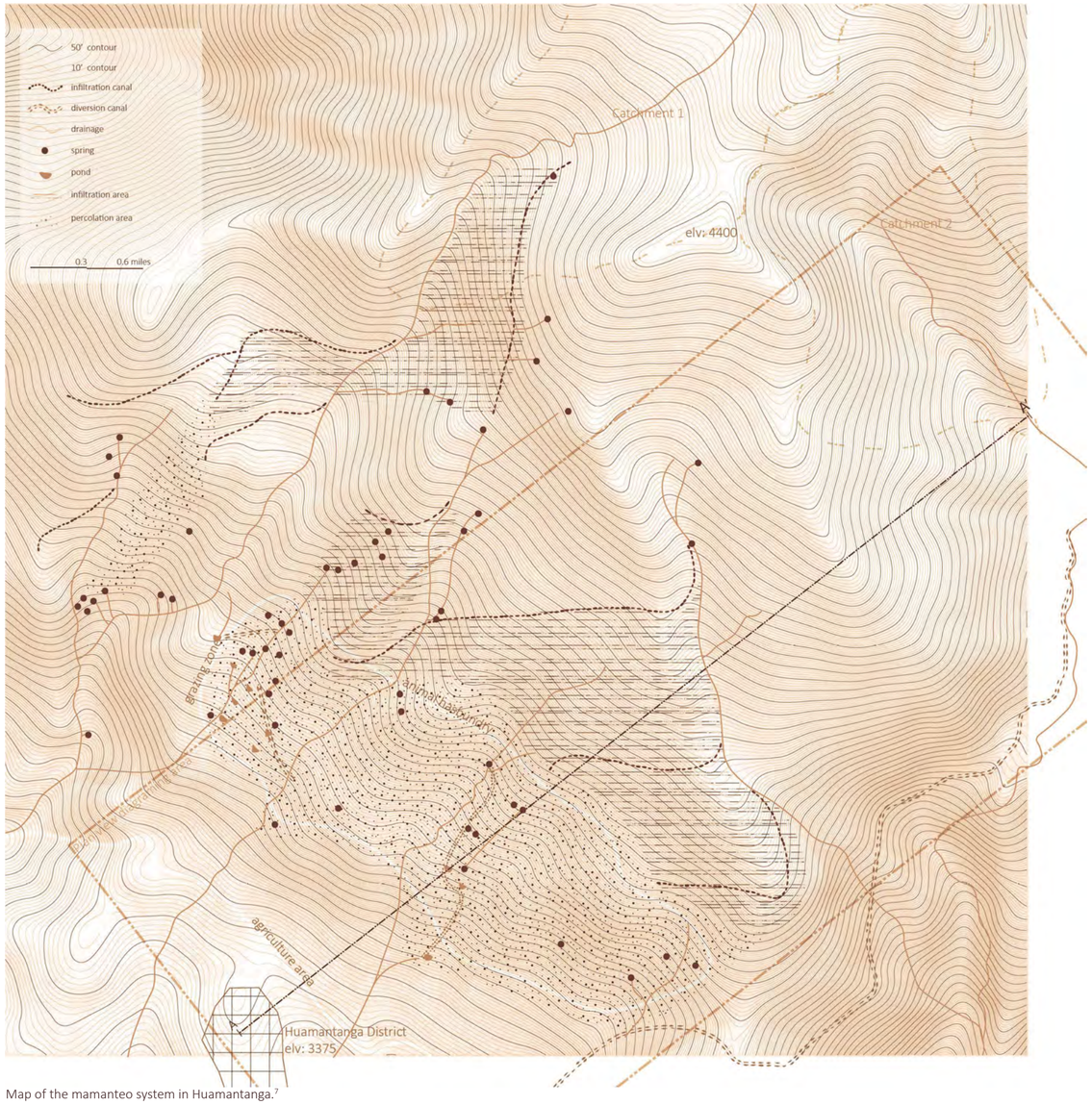
Mamanteo - Spanish for breastfeeding[3]
Amunas – Quechua for retaining[4]

Water Runoff-delaying, Detouring, Infiltration And Harvesting System In The Andes Mountains

“Complex Andean topography creates extreme spatial-temporal gradients in precipitation” [5]

Precipitation at the Andes mountains decreases from east to west. The towering Andes mountains block the warm and moist winds from the Amazon basin at the east during the monsoon season, and create a strong altitudinal precipitation gradient. In addition, at the west, along coastal region of Peru, the intertropical convergence zone and the presence of the cold Humboldt current and the subtropical anticyclone around the southeast Pacific Ocean produce arid condition.

In 600CE, a pre-Inca agropastoral community at Huamantanga, at elevation of 3,300m above sea level, invented a water runoff-delaying, infiltration and harvesting system to increase water security for irrigation during the dry season.[6]



Map of the mamanteo system in Huamantanga.[7]

MAMANTEO hardware

Percipitation

Landuse

agriculture / residential

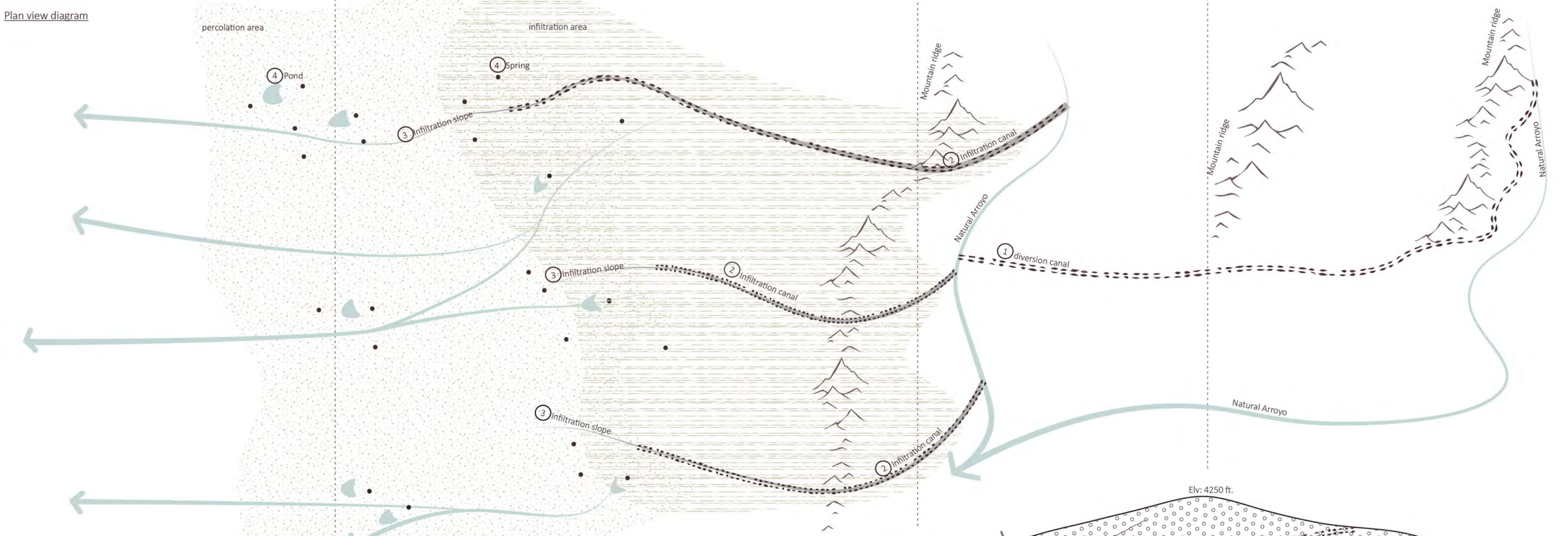
animal husbandry / grazing zone

summit dry side

summit rain side (cathment)

Water flow direction

Plan view diagram



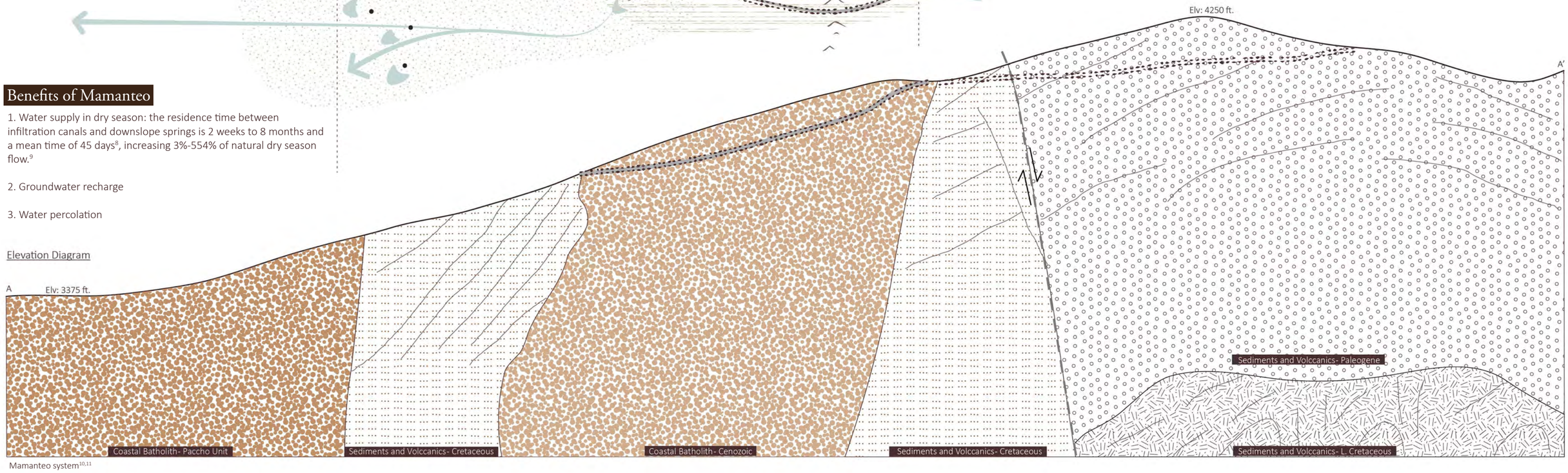
Benefits of Mamanteo

1. Water supply in dry season: the residence time between infiltration canals and downslope springs is 2 weeks to 8 months and a mean time of 45 days[8], increasing 3%-554% of natural dry season flow.[9]

2. Groundwater recharge

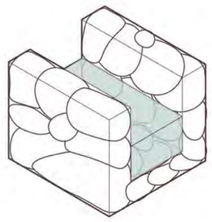
3. Water percolation

Elevation Diagram

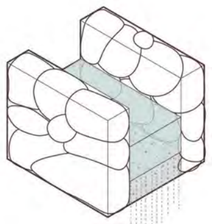


Mamanteo system[10,11]

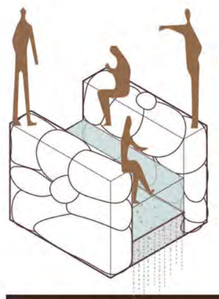
MAMANTEO hardware & software



① Diversion canals:
impermeable canals that divert arroyo to infiltration canals or transport excess water.[12]

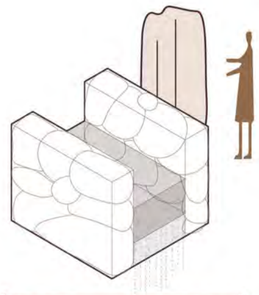


② Infiltration canals:
canals or ditches with an earthen bottom that can transport water to infiltration hillslopes while infiltrating water at the same time.[13]



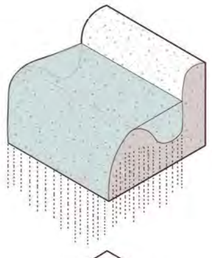
Religion Based Governance

In history, mamanteo was completely constructed, operated and maintained by the people of Huamantanga. It is a community scale water system. Every year, during water festival, people of Huamantanga will come to maintain the system. Over the years, fewer people celebrate the festival. In addition, overuse of the water for agriculture and industry has lead to the mamanteo to malfunction.[14]

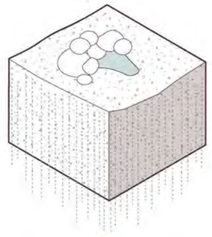


Religion and activities

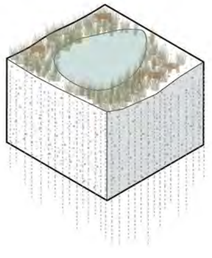
A huanca (in Quechua Ancashino : wanka) or chichic (tsitsiq) is an elongated vertical stone considered of symbolic value in the Andean worldview. Huancas are found in the Mamanteo system, for worshiping the god of farm.[15,16]



③ Infiltration hillslopes:
rocky or stony areas that receive water from canals and spread it in the hills.[17]



④ Springs:
natural springs that are enhanced by resurfacing of infiltrated water.[18]



⑤ Ponds:
small water bodies (around 300m^3 each) that are used to regulate the flow through the mamanteo system.
There are 2 purposes:
(1) to store water
(2) to allow further water infiltration[19]

MAMANTEO

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3 Ochoa-Tocachi, Boris F., et al. PP.585

4 Ochoa-Tocachi, Boris F., et al. PP.585

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6 Ochoa-Tocachi, Boris F., et al. PP.586

7 Ochoa-Tocachi, Boris F., et al. PP.588 Fig.3

8 OOchoa-Tocachi, Boris F., et al. PP.585

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17 Ochoa-Tocachi, Boris F., et al. PP.588

18 Ochoa-Tocachi, Boris F., et al. PP.588

19 Ochoa-Tocachi, Boris F., et al. PP.588

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Liu, Ai-Ju

OLLA

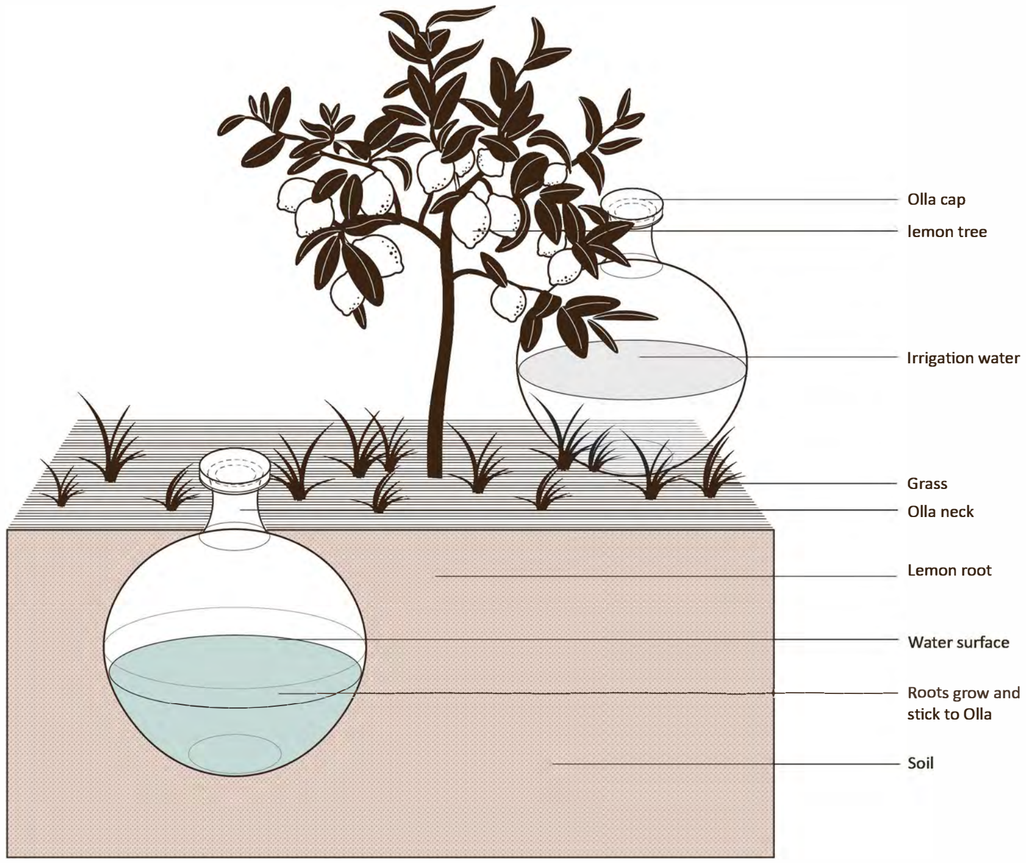
Better Plants than Your Neighbor.

Ollas are terracotta vessels planted in the ground and filled with water. Used to irrigate plants and save water. Ollas are very affordable and reduce plant stress improves quality.

Photo: https://www.pinterest.com/pin/AR3QcKJzitcDZLH9wtTXlGUA_x21Ox1qA8RmMnKCVjr00Qb4FVQonQ4/?lp=true

OLLA

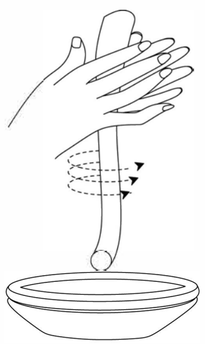
Olla/Ollae ol·la | OH-yas | \ ˈä-lə\
Etymology: Spanish, from Latin olla, aulla pot; akin to Sanskrit ukhā pot
Synonyms: Tupí (In certain areas of the Pyrenees in Catalonia a type of olla[1])
Ollas are handmade terracotta clay pot used as an ancient method of drip irrigation for container gardening or ground applications.



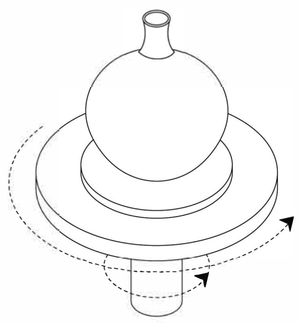
Manufacture

- Ollas are made of unglazed porous clay mixed with sand in a 4: 1 ratio, with an effective porosity of 10-15%.[2] Rice husks or hay are sometimes added to increase porosity.[3] (Barak, 2006)
- Ollas are made on pottery wheels (thrown), constructed by hand (built), or poured into gourd-shaped forms (cast).[4]
- Ollas are fired at a low temperature and left unglazed to maintain natural porosity.
- Ollas are produced by single individuals and family workshops.

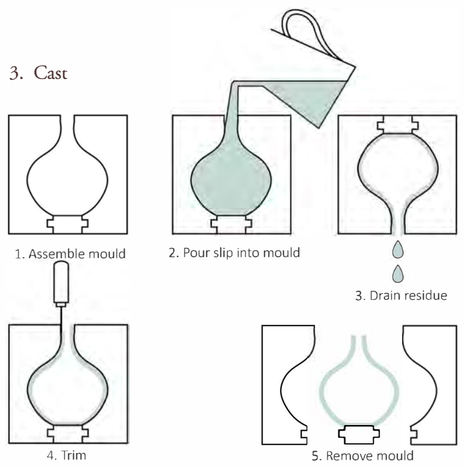
1. hand built



2. Pottery wheels

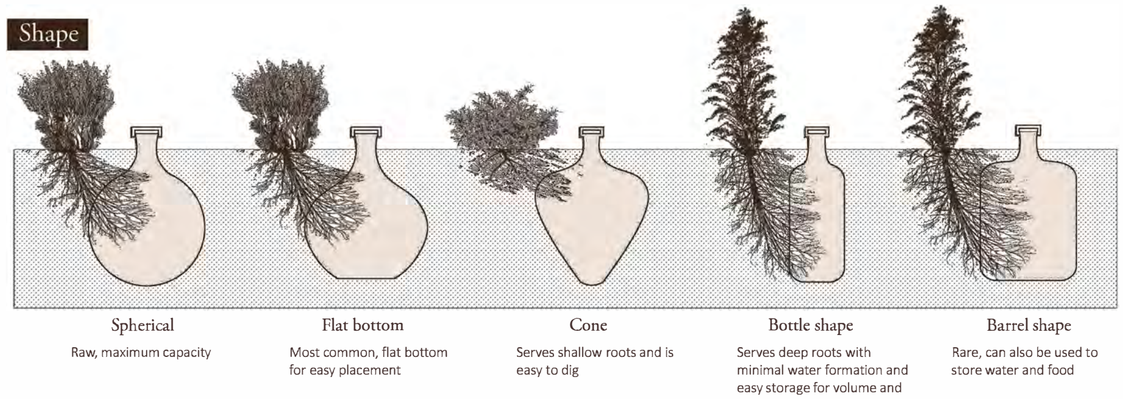


3. Cast



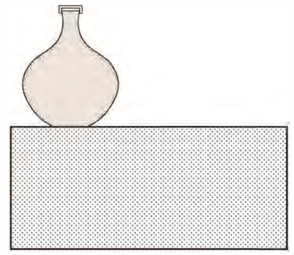
OLLA

Shape

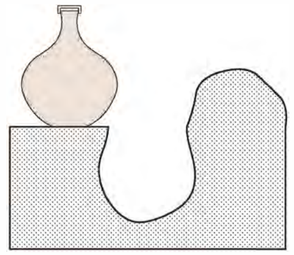


Hydrologic Function

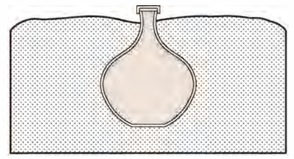
Burrow Olla underground and leave 2 inches above the soil surface. When Olla is filled with water, the olive oil's porous walls allow water to spread into the soil as needed by the plant. Water is drawn from the clay by infiltration. Suction is produced by soil water tension and plant roots. If the soil is dry, the water in Olla will be absorbed more quickly by the plant rhizomes. If the soil is saturated, water infiltration will stop until the soil moisture content is reduced to the extent that it cannot meet the needs of the plant. So using Ollas to irrigate the ground can be beneficial because it wets, but does not soak, the plant with water.[5]



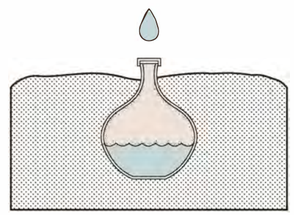
1. Prepare a 2 to 8 liter olla



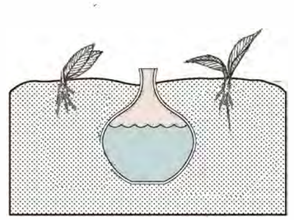
2. Dig a hole of the right size



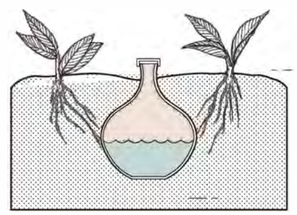
3. Bury in the soil and 2 inch exposed



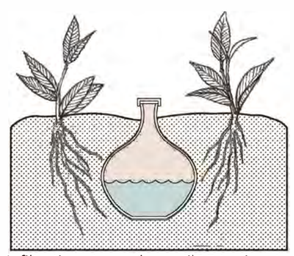
4.Fill with water then close the lid



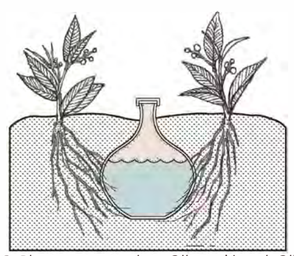
5. Plant the suitable plants



6. Plant roots start to absorb water



7. Infiltration stops when soil water is saturated



8. Plant roots attach to Olla and break Olla

9. Dig out Olla and store it for reuse

OLLA

History

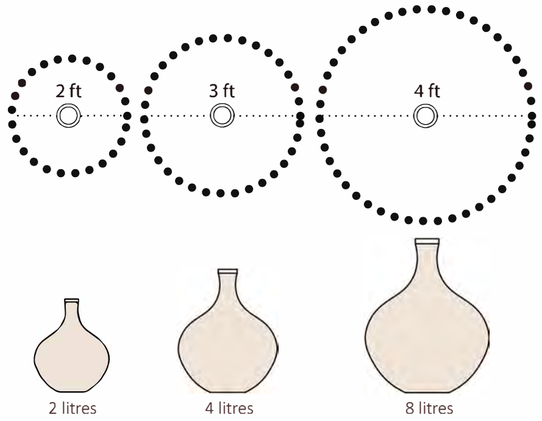
Ollas originated in North Africa and remain in use in South and West Asia (India and Iran),Africa (Burkina Faso and Nigeria)and, via Spain , the Americas (Brazil, Mexico and the Southwestern US). [6]

A comparable technology has been used in China for more than 4000 years.[7] This ancient irrigation canal was found 3500 years ago in Liaoning Province, China. The site was identified by the bottleneck pottery, and the unearthed cultural relics include brown small diameter pots, which are considered tools for irrigation.[7] To control water flow, farmers buried special unglazed pots near the trees and filled them regularly with water.[8]

Considering Olla's limitations in terms of irrigated area and water volume, the Olla irrigation system should be mainly used for small family farms or gardens in arid areas with rainfall of 500 mm / year. [9] Today, the Middle East, Central and South America are still using olla irrigation. Because the Olla irrigation system waters the roots rather than the leaves or soil surface of the plants,[10] this makes olla an ideal small area irrigation method for arid and semi-arid climates.

Description

A wide mouthed pottery container with a short wide neck and wide body, usually without looped handles and unglazed. It is a large container for water, cooking, and storage. Also, they are an ancient form of irrigation.



Irrigation radius

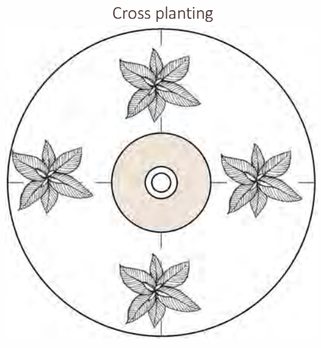
The small olla (2 ~ 3litres) can cover an expanding space of up to 2 feet in diameter.

the medium olla (3 ~ 6litres) can occupy 3 feet of space.

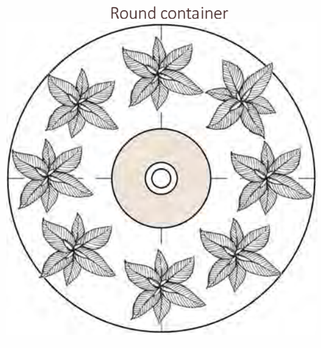
and the large olla (6 ~ 8litres) can cover 4 feet of space. Usually one olla does not exceed 10 liters. [11]

Ollas group use system

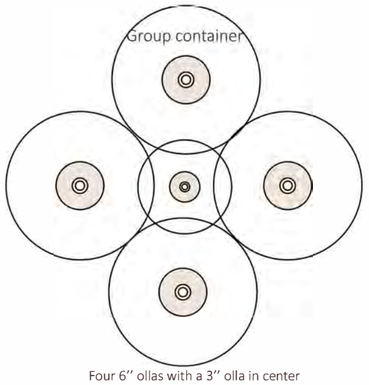
"Optimum plant spacing and distance will also be influenced by the root system and size of the plant.''[12]



For single olla applications, place plants around olla half of the water spread distance.
4.75'' water spread
8'' plant spacing 6'' olla width

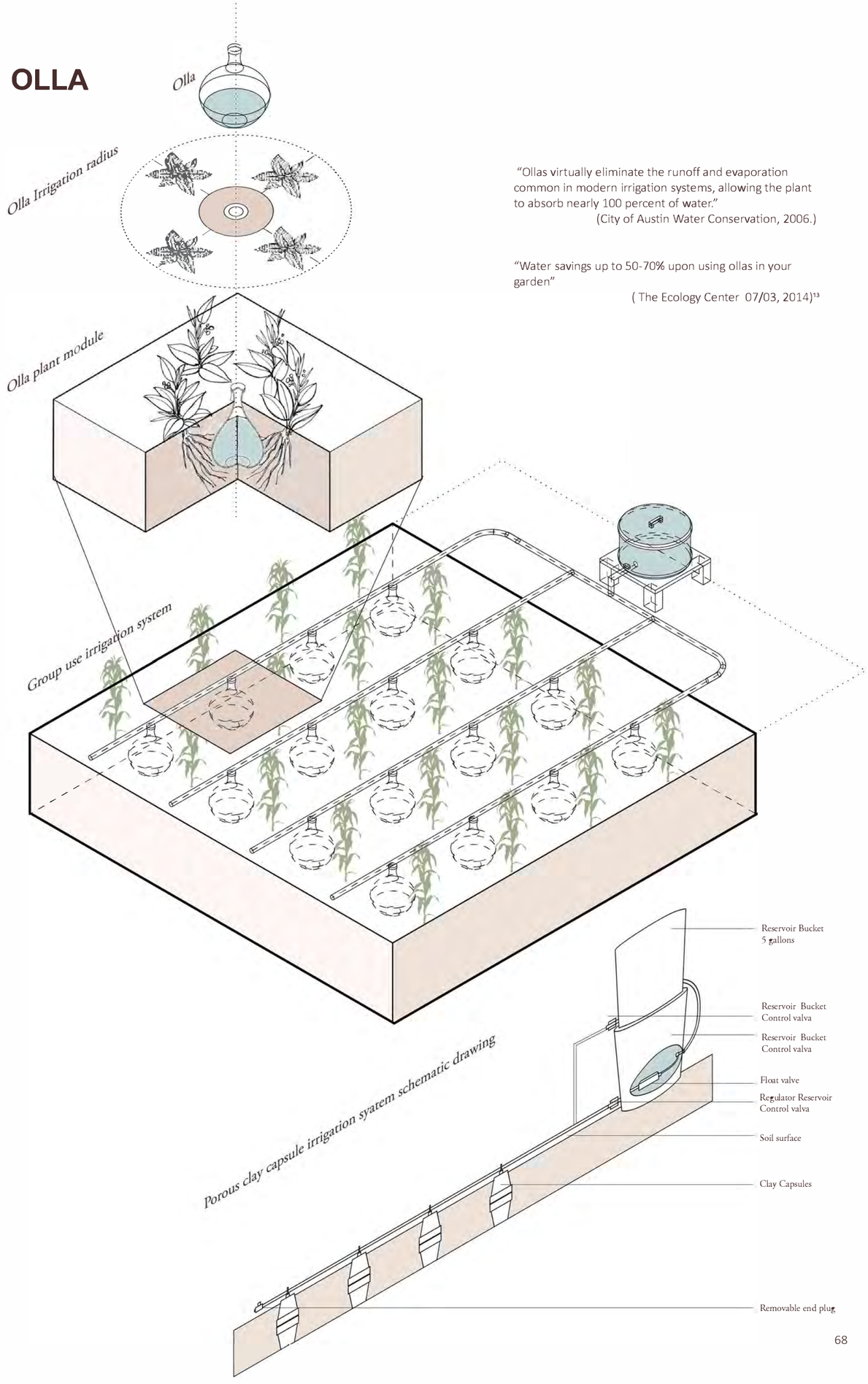


Round container
Olla width: 8''
Container size: 18''
Water spread: 18''



Four 6'' ollas with a 3'' olla in center irrigates a plan 40'' across

OLLA



"Ollas virtually eliminate the runoff and evaporation common in modern irrigation systems, allowing the plant to absorb nearly 100 percent of water."
(City of Austin Water Conservation, 2006.)

"Water savings up to 50-70% upon using ollas in your garden"
(The Ecology Center 07/03, 2014)[13]

Use-Cases: [Possible Applications]

Benefit

- Affordable: Suitable for small farms, personal and community gardens in arid areas. Uneven terrain and saline ground (surface irrigation is not possible)
- On-demand, self-regulating, carbon-free
- Improved water use efficiency: Ollas uses 50% to 70% less water than surface water irrigation.[13]
- Reduce plant stress: The soil and roots do not experience extreme drying and wetting cycles. [14]
- Reducing plant stress improves quality. Reducing plant water stress / appropriate pressure will prevent bitterness in fruits and vegetables.
- The Olla irrigation system promotes denser root growth and provides a more balanced water supply to the roots of the plant.
- Liquid fertilizer can be applied to clay pots, and the fertilizer is absorbed as a solute by the attraction of plant roots and water, which saves the amount of fertilizer. But be sure to only use liquid fertilizers and not water-soluble fertilizers (will stick to the olla wall and affect water penetration).

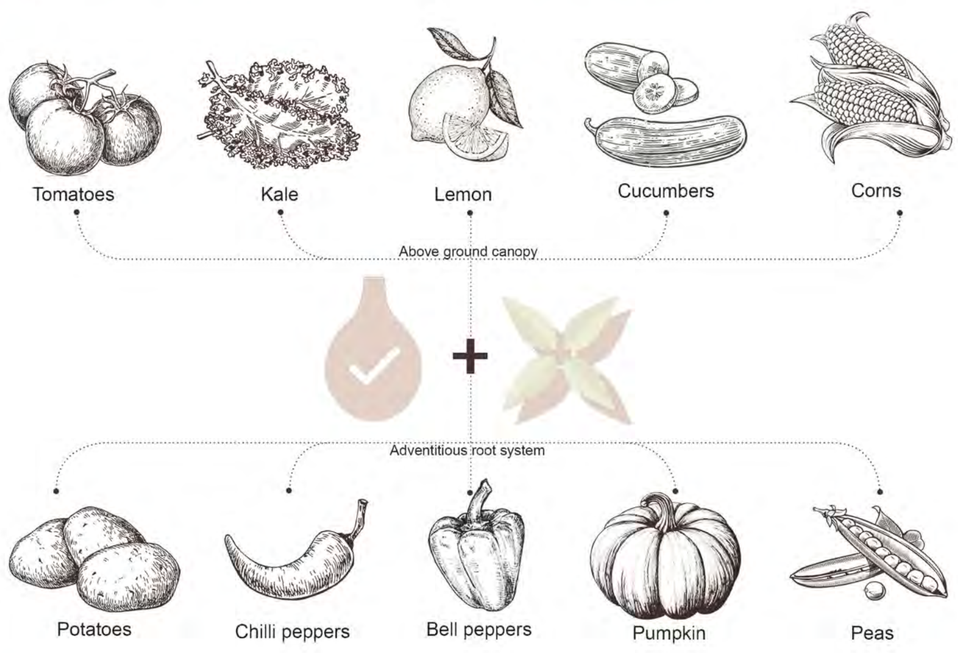
Limitations

- Olla's irrigation radius is limited to approximate size.
- Olla may rupture when winter temperatures are cold or frozen ground is present. [15]
- Plant rhizomes may entangle Olla, making Olla difficult to dig and reuse.
- Salt residue or debris may impair Olla permeability.
- Unsuited to grains and legumes due to area coverage (and number of ollas) necessary

Oya-friendly plants

" Broadly speaking, Ollas work best with plants that have fibrous root system (adventitious root system) and an above ground canopy. "[16]

Suitable for melon, pumpkin, tomatoes, pepper, chili, corn; perennial trees, potatoes (and most of the nightshades), cucumbers, salad greens, kale, herbs, edible flowers, gourds, melons, squashes, beans, peasvines and bushes in arid/semi-arid areas.



Software

- The social nature of the Olla system is not complicated. Olla is a very simple and effective small area irrigation tool and can be made individually. It can be used in urban gardens, rural farms or small areas in arid areas. It can be used alone or distributed across the network.
- The Olla system demonstrates a sustainable culture through improved water use efficiency and reuse, but there are still issues such as freezing, breakage, and salt deposits.
- Olla is easy to operate, but there are two points to note: the first is to prevent Olla from freezing and rupturing in winter (4 days before the last frost), ensuring that Ollas are empty and there is no water in it. Or dig out Olla and let it dry. The second is to add water when the water content of Olla is less than 50% to prevent the salt from sticking to the clay wall and reduce the water permeability.[17](Bulten,2006)

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Student Contributor:

Wang, Yihe

PARADISE GARDEN

The idea of perfection in this imperfect world

Paradise garden is a slice of heaven in the arid region, part of a larger infrastructure system that allows infiltration and stores water inside a walled garden. A modular design that is easy to replicate and soothing to the eye with symmetry. Garden in arid climate with cooler micro climate.

Photo: Naghsh-e-Jahan Sq. Isfahan, 1598.

PARADISE GARDEN

Definition – A paradise garden is a garden style started in Persia. The garden is generally walled or hedged, has a symmetrical design with water running in rills or canals to the center. [1]

Etymology – Paradise garden is a compound of “pairi” that is around and “daeza” or “diz” that is wall or a shape to enclose it. [2]
“The term "garden" originally meant a piece of land, share, heir, portion, and profit. It referred to a plantation of trees, bushes, or even sown plants.” "Borrowed from Median Paradaeza, meaning garden. The Persian term meaning Paliz, and the arabicized Ferdows are also derived from this term." [3]

Evolution- Paradise garden dates back to 529 BC with king Cyrus. The most traditional form of paradise garden is called Charbagh and the word is Indo-Persian and persian origin. Charbagh an Islamic quadrilateral garden based on how paradise is described in the Quran. [4]
In Islam, gardens became sacred places for contemplation and spiritual nourishment and there is a resemblance to the garden of Eden. Centuries later, gardens have become settings for romance and pleasure.[5]

Hardware

Water courses form along a principle axis and secondary axes of the main garden at Pasargadae.
Right angles and sharp edges were used to aid irrigation canals and channel periodic flooding. [6]

Natural physical conditions

The paradise garden is walled to provide refuge from the hot winds.
The arrangement of transverse walks, channels, pools and pavilion, nestled inside a courtyard for private use can be extended over a larger area by series of squares (6, 8, 10 or more) along the central axis.
There is a significant difference between the Persian and European Gardens which is based on two distinct and different ideologies: one looks at earth and the other observes the sky. [7]
The garden design consists of one great walk and runs in a straight line with rows of planters on the side with a basin of water in center.

Regional climate: Arid

Paradise gardens were generally built in areas with little rainfall of 5-25cm per year. [8]
As it is desert climate, water was supplied by qanat system(ancient water supply system that using aqueducts), the water is transported through underground tunnels running down from the mountains and arrives at the center of the garden in a formal pool or reservoir. [9]

Garden Elements

Gardens and palaces were deeply related and the garden dominated the architectural space.
The char bagh came in full form in India during the Mughal reign.The garden types were then named and divided based on their location, what they adorned or their features.[10]

The gardens were artificially created, with rills (jubs) and canals, a rectangular or octagonal center for water, and deep porticos for refuge (ayvans or ivans). Decorative gate with walls on all sides or hedges. Architecturally the design of the paradise garden is rigid with vertical walls that contrast with horizontal rills and canals. [11]

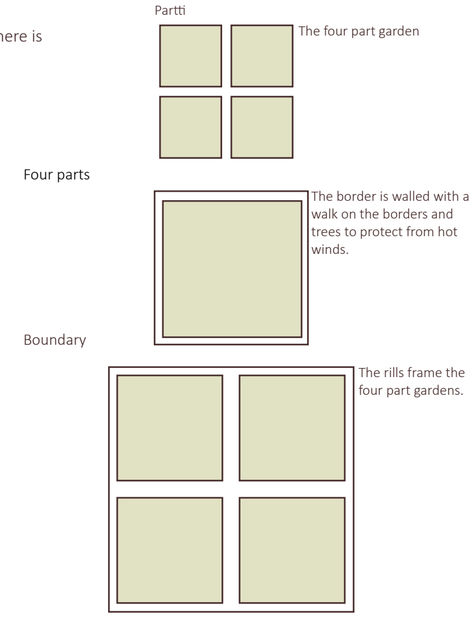
The dominating elements of the paradise gardens were walls, surroundings, water, fountains, pools, vegetation, shade and geometry. The garden consists of aromatic flowers and fruit bearing trees. Consists of figs, olives, dates and pomegranate for the passer bys to pluck. [12]

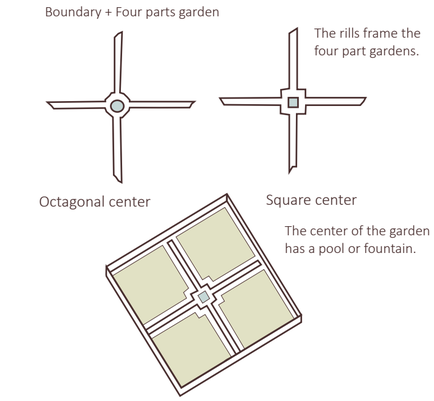
Water

The role of water was irrigation, cooling microclimate and soothing winds. [13]
The water was originally brought in by the qanat system, in the canals or rills in the garden, irrigation was done by overflowing the rills into the gardens. And finally captured in the reservoir or the pool in the garden. [14]

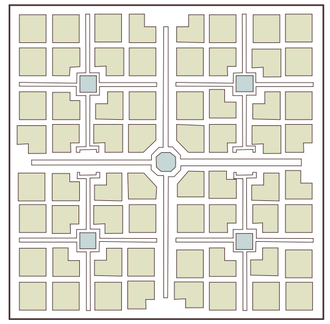
Plant and trees

Walls, surroundings, water, fountains, pools, vegetation, shade and geometry.
The garden consists of aromatic flowers and fruit bearing trees. Consists of figs, olives, dates and pomegranate for the passer bys to pluck. [16]





Form of paradise garden with square center



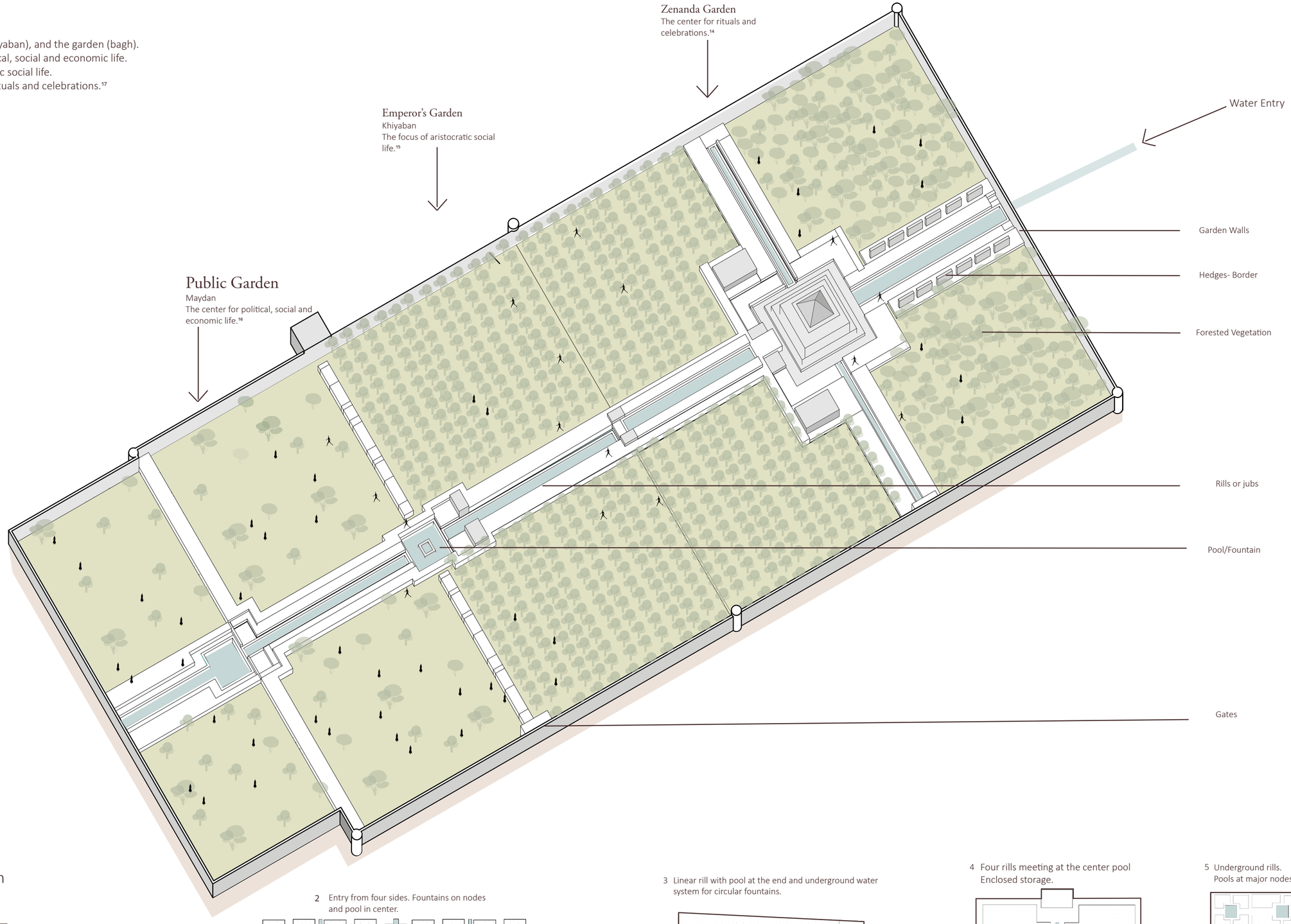
Complex Paradise garden with quadrilateral and square center

PARADISE GARDEN

The division of space

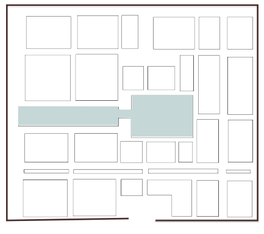
The plaza (maydan), the avenue (khiyaban), and the garden (bagh).
The maydan was the center of political, social and economic life.
Khiyaban was the focus of aristocratic social life.
The public garden were centers of rituals and celebrations.[17]

PARADISE GARDEN

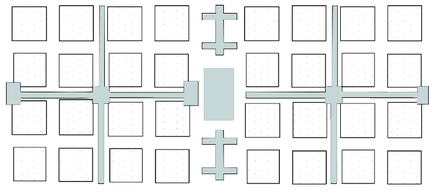


Types of paradise garden

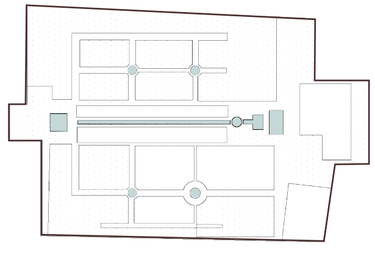
1 Singular Entry with a center pool



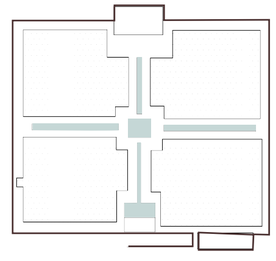
2 Entry from four sides. Fountains on nodes and pool in center.



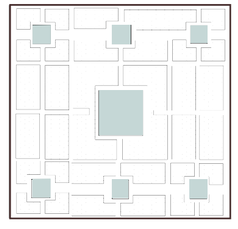
3 Linear rill with pool at the end and underground water system for circular fountains.



4 Four rills meeting at the center pool
Enclosed storage.

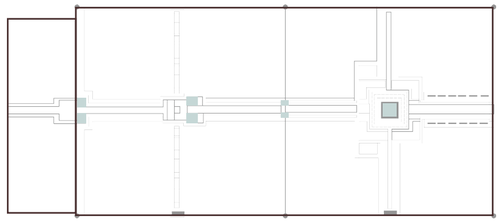


5 Underground rills.
Pools at major nodes and center.



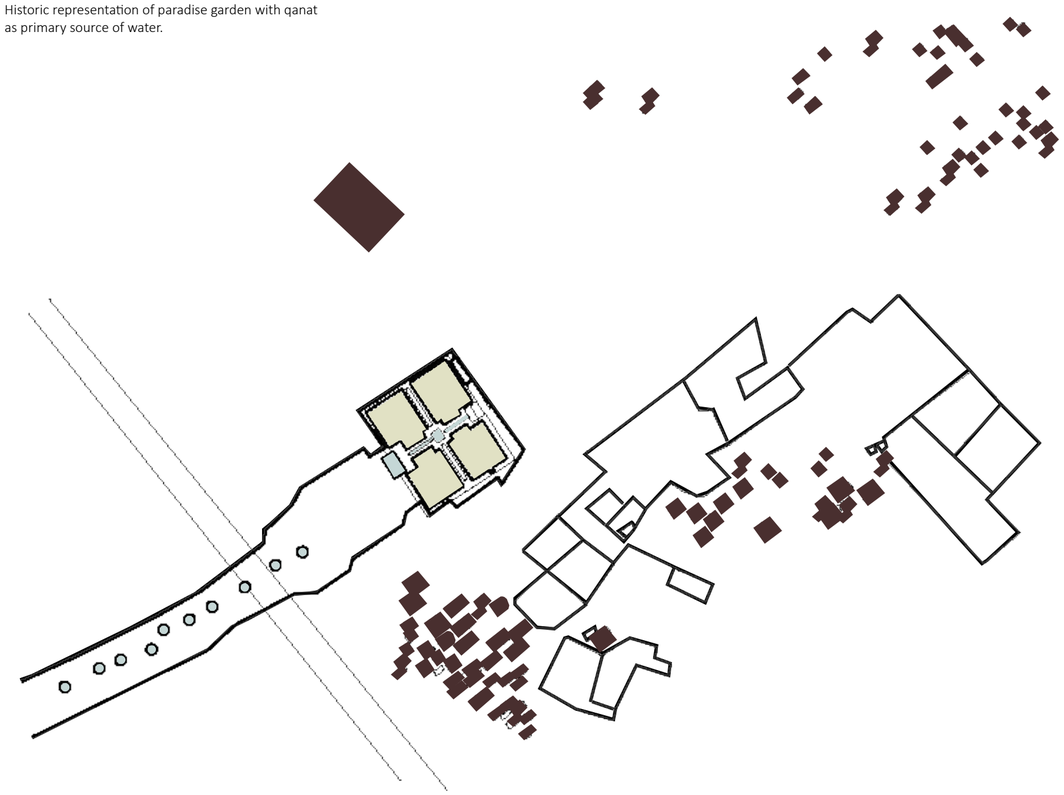
PARADISE GARDEN

Plan



Section

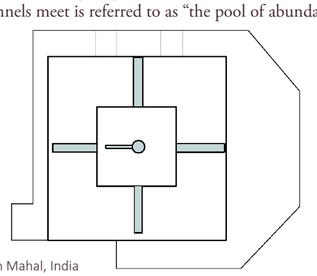
Historic representation of paradise garden with qanat as primary source of water.



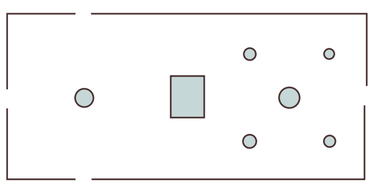
Software

Religious Influence and symbolism.

The design of the paradise garden is created considering the four holy elements in the highest regard by the architects in different forms and the central waterway with the irrigation system play the main role in design and utilization of the four principle elements.
Evidence suggests that original design of paradise garden has influence from Egyptian and Mesopotamian cultures.
There is a strong religious symbolism that relates to life after death. The four rivers signify the water, milk, wine and honey. The center where the four channels meet is referred to as “the pool of abundance” and as “Al-Kwather” in the Quran. The center is where the man meets God. [18]



Shish Mahal, India



Turkish Bagh

PARADISE GARDEN

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Ravani, Sneha

Monumental desert spirals that reliably deliver groundwater to villages.

PUQUIOS

Photo: Véronique Debord-Lazaro.

PUQUIOS

Definition - Puquios are horizontal wells: It consists of an open trenches and/or subterranean galleries that connect a point on the surface with subsurface water. The underground water filters into the puquio, flows through it, and empties into either a small reservoir (kocha) or directly into irrigation canals.
Puquios provide not only a reliable source of irrigation water but also a year-round supply of domestic water. [1]

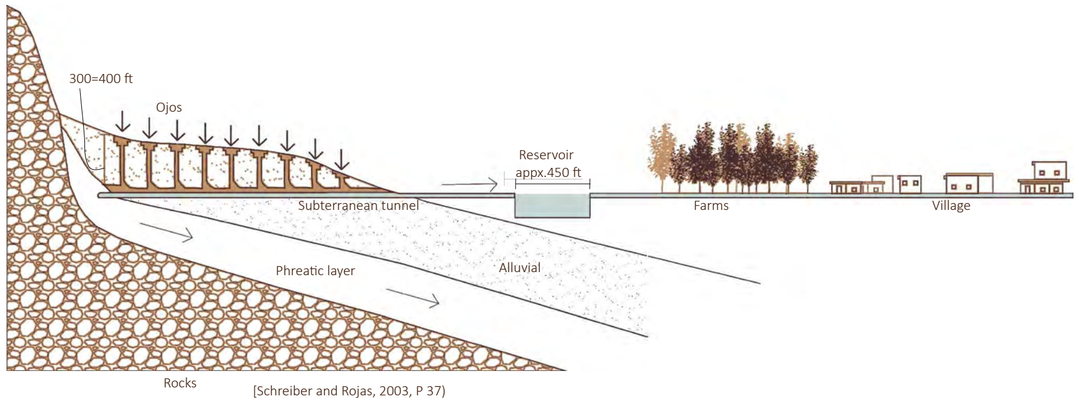
Etymology- Puquios is ultimately from Quechua, meaning "spring of water". [2]

Evolution- Pozo Kocha. A Pozo kocha is constructed in areas where acquifers are not too deep, a deep straight down trench is dug to excavate the water from aquifer and create more arrable land. This alteration is most commonly seen in Las Trancas Valley, where three puquios have been converted. [3]

Location- Puquios are found in Nasca, Taruga, and Las Trancas valleys of the Río Grande de Nasca drainage of the south coast of Peru.[4]

Time period- The initial construction of puquio dates to roughly 400-500 CE. [5]

Culture - "The term puquio has a variety of meanings in Quechua, all of which have in common the denoting of a source of water. Most commonly used to refer to a natural spring, puquio can also refer to manmade water sources, such as sunken fields, irrigation canals, and filtration galleries.
The aqueducts of Nasca are called puquios by the people who use them. It has become fashionable in some circles to use the word acueductos to refer to them." [6]



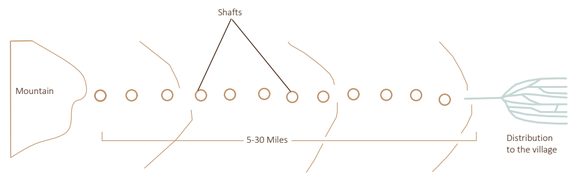
[Schreiber and Rojas, 2003, P 37)

Hardware

The dimension of galleries are less than 1 m in height and width.
(upper most portion). Some are more than 15 m at the surface and narrow down to 1 m.
Ojos, also called respiraderos or chimeneas, are the galleries on the surface (for maintenance and air flow).
The new ojos are typically built when a cave in has blocked the gallery. The length of the puquio is determined by the depth of water table and slope of land.[7]

Natural physical conditions

Puquios system was developed in the hot and arid Nasca region. The rivers were not very reliable for water availability.
Puquios aid in accessing the water from phreatic layer, using slope. [8] Water from phreatic layer flows via subterranean tunnel to the kochas(reservoir/ Storage) for use by people living in the middle
portions of the Nasca, Taruga, and Las Trancas valleys of the Río Grande de Nasca drainage of the south coast of Peru. [9]

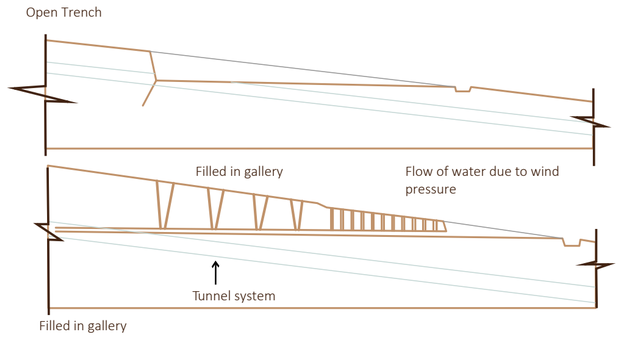


[Schreiber and Rojas, 2003, P 37)

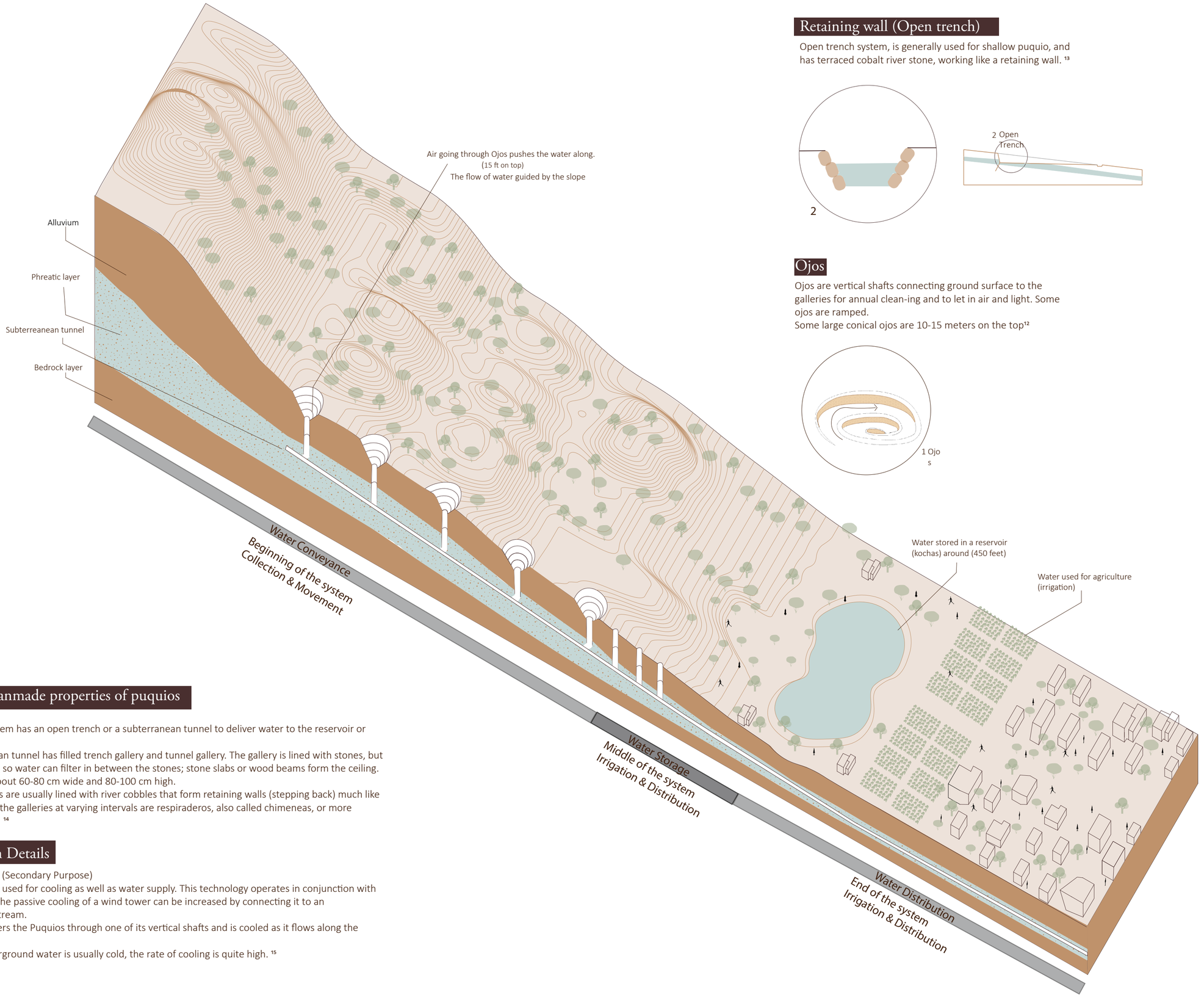
Types of Puquios

1. Puquios with open trenches tend to be shorter, shallower puquios. The base of the trench is usually a meter or so. The walls of the trench have river cobbles and are terraced like a retaining wall.
2. Puquios with filled trench galleries have a much deeper and longer puquios.[10]
3. Hybrid (Dug and Constructed): Puquios can have open trenches or subterranean tunnels depending on the depth of the phreatic layer. Wells, tunnels.

The puquios system is a singular distribution system that branches out in the villages. The system is partially visible. Puquios provide water ephemerally.[11]



[Schreiber and Rojas, 2003, P 37)



Physical manmade properties of puquios

The puquio system has an open trench or a subterranean tunnel to deliver water to the reservoir or kochas.
The subterranean tunnel has filled trench gallery and tunnel gallery. The gallery is lined with stones, but without mortar, so water can filter in between the stones; stone slabs or wood beams form the ceiling. The gallery is about 60-80 cm wide and 80-100 cm high.
The trench sides are usually lined with river cobbles that form retaining walls (stepping back) much like terraces. Along the galleries at varying intervals are respiraderos, also called chimeneas, or more commonly ojos. [14]

Fabrication Details

Cooling system (Secondary Purpose)
Puquios can be used for cooling as well as water supply. This technology operates in conjunction with a wind tower. The passive cooling of a wind tower can be increased by connecting it to an underground stream.
Hot dry air enters the Puquios through one of its vertical shafts and is cooled as it flows along the water.
Since the underground water is usually cold, the rate of cooling is quite high. [15]

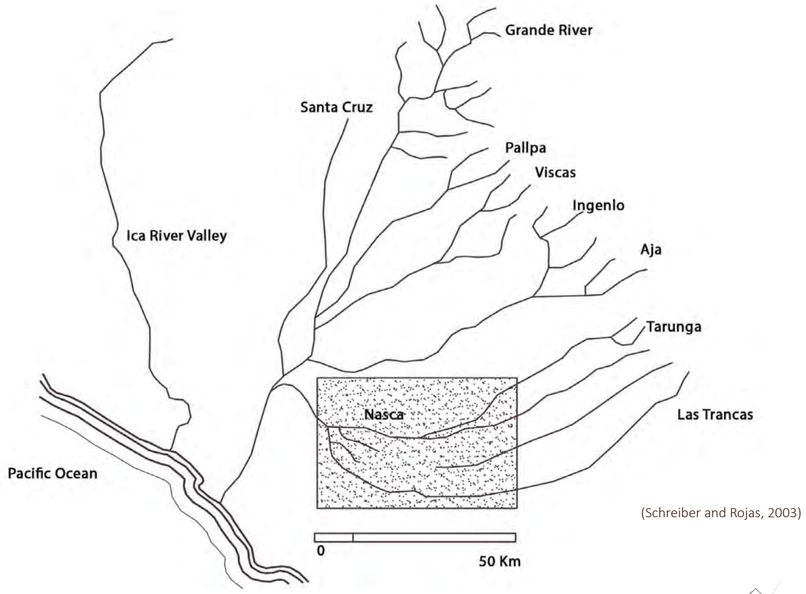
Retaining wall (Open trench)

Open trench system, is generally used for shallow puquio, and has terraced cobalt river stone, working like a retaining wall. [13]

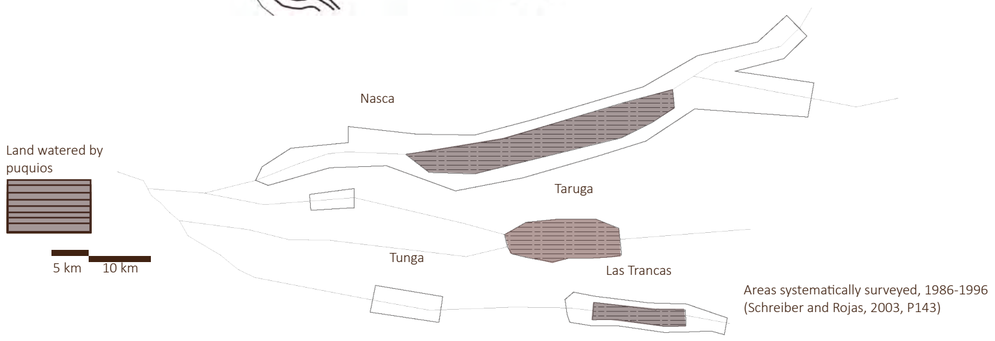
Ojos

Ojos are vertical shafts connecting ground surface to the galleries for annual clean-ing and to let in air and light. Some ojos are ramped.
Some large conical ojos are 10-15 meters on the top[12]

PUQUIOS



(Schreiber and Rojas, 2003)



Areas systematically surveyed, 1986-1996
(Schreiber and Rojas, 2003, P143)

Software

Control of water

"Puquios construction and maintenance would have required substantial planning, labor, and management, and over time as the irrigation system grew, it is likely that certain groups or individuals were able to control the system.

This was probably an important aspect in the growth of centralization and inequality in this period. "[16]

The Allyus were the people who managed the water.
In the Andes, land and water rights were traditionally centered on kin-based social groups called ayllus."

Ayllu are important people even today, they were known as "enduring group", described on the core as people who connection between people and land and collectively maintained the land by labor on communal agriculture and irrigation canals." [17]

Later, Wari changed the control of communities on irrigation and agricultural systems, Wari associated local elites to have greater control over the puquios and created discrepancy in water supply and social inequality.

Puquios were named based on their qualities, for example Agua Santa which means holy water was named so as it never dried up, even in the worst droughts.[18]

PUQUIOS

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17. Conlee, Christina A. "*Regeneration as Transformation Postcollapse Society in Nasca, Peru Christina A. Conlee*." After collapse: The regeneration of complex societies (2010): 99.
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Student Contributor:

Ravani, Sneha

YAKHCHAL

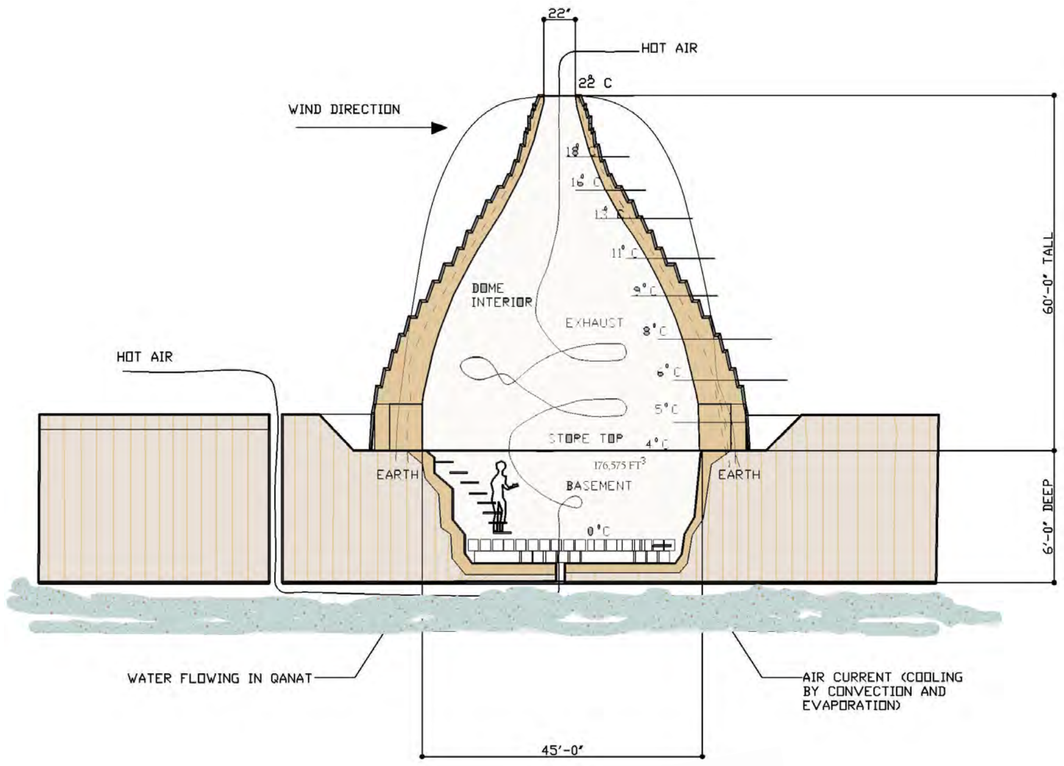
Natural Cooler, Low Cost, Efficient for a Community

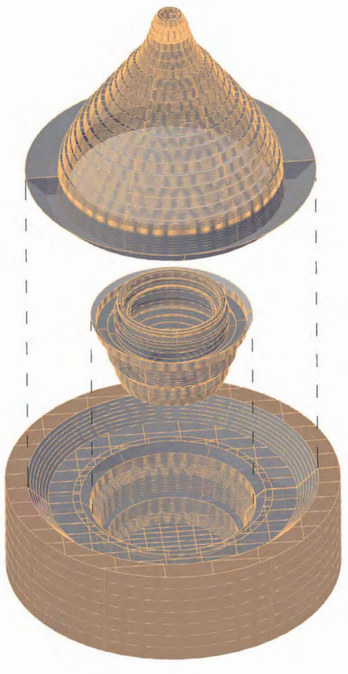
Yakhchal is a Persian invention for storing ice year round in arid climates. It isa passive cooling system that uses natural ventilation. It dates back to 330 BCE.[1]

Aerial vie from Google Earth of Abdolabad, Semnan Province.

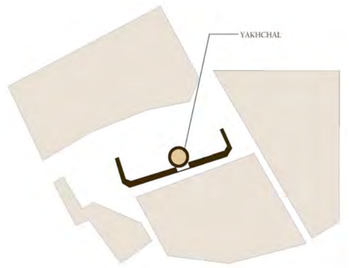
YAKHCHAL

Yakhchal is a Persian passive-evaporative cooler that stores ice in the summer.[2] It dates from 330 BCE. The Ice is made in the winter, by wind and water channeled from a qanat. It is composed of a dome-shaped structure made out of large mud bricks, often rising to 60 feet tall. Below are large open underground spaces, up to 176,575cubic ft, often used as storage. There are 4 regional typologies: Domed Yakhchal ice pit, Domed Yakhchal with walls, Domed Yakhchals with Ice Ponds, and Domed Yakhchals with Shade walls.[3]





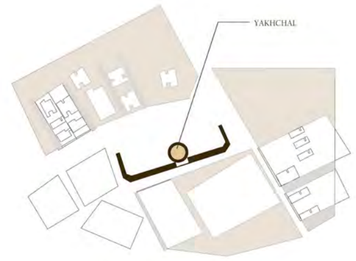
YAKHCHAL hardware & software



YAKHCHAL RURAL ORIGINS

Agriculture Area

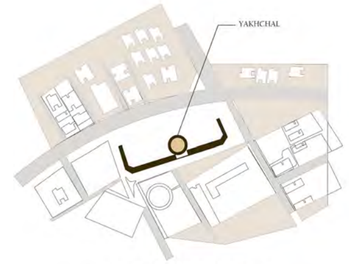
Yakhchals are located in the suburbs of the city along or near by lined Qanats.



YAKHCHAL URBAN INTEGRATION

Neighborhood

Communal and urban space benefits from the strategic location of the Yakhchal because it is a gathering space for inhabitants.

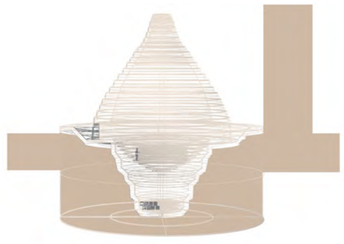


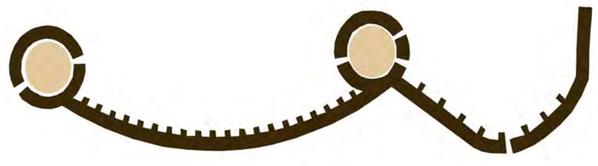
YAKHCHAL AS PUBLIC SPACE

City

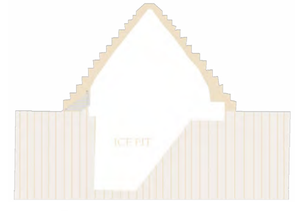
Urban planning and design integrated the evaporative coole in a strategic location adjacent to farming zones and in the center of the urban grid.

Regional Typology A





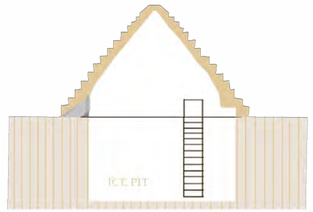
Yakhchal Locared in Sirjan, Kerman Province



Section

YAKHCHAL

Yakhchal located in Raver, Kerman Province Floor Plan



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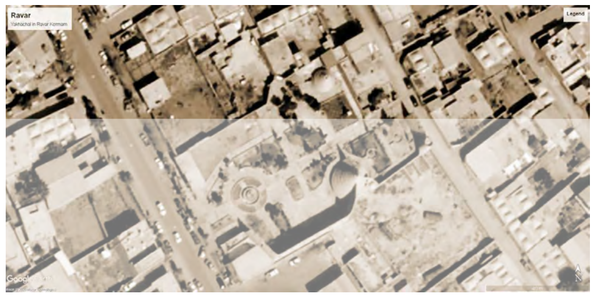
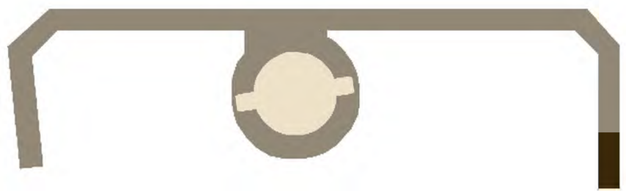
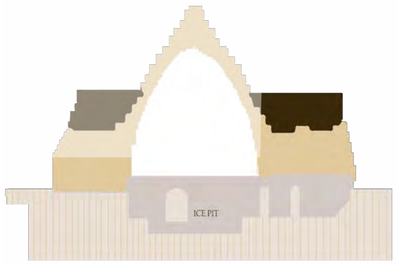




Yakhchal located in Moayeri, Kerman Province Floor Plan



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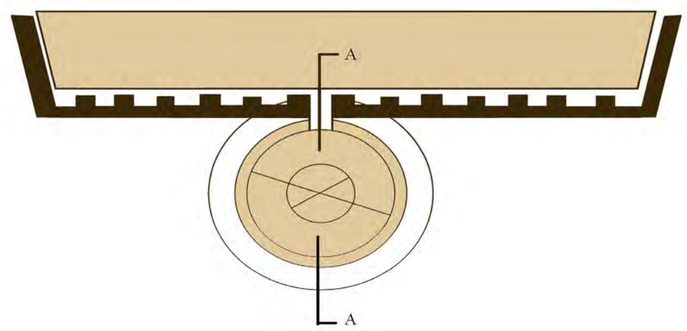
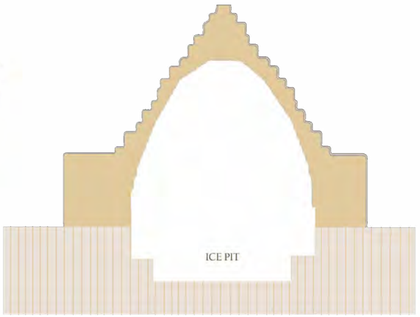
YAKHCHAL



Yakhchal located in Meybod, Yazd Province Floor Plan



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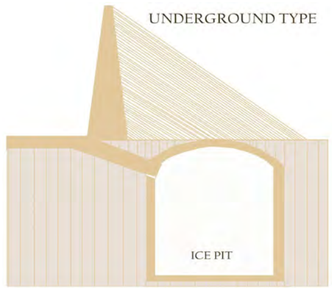
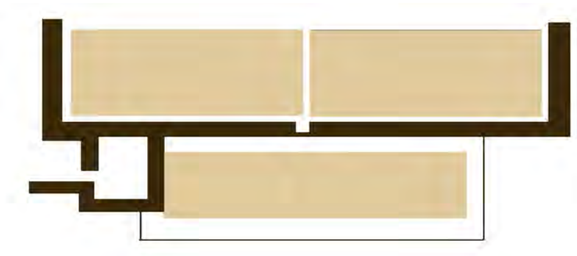
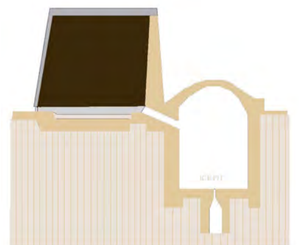
Regional Typology B





Yakhchal located in Yazd Province Floor Plan



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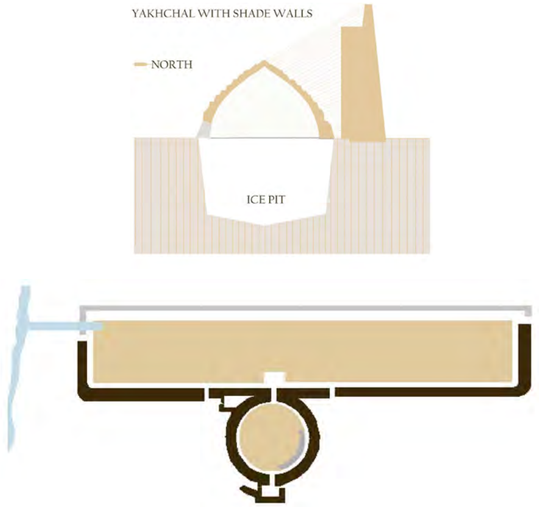
Regional Typology C



Yakhchal located in Abargu, Khorasan Province Floor Plan

Section

Regional Typology D

Yakhchal located in Raver, Kerman Province Floor Plan

Section

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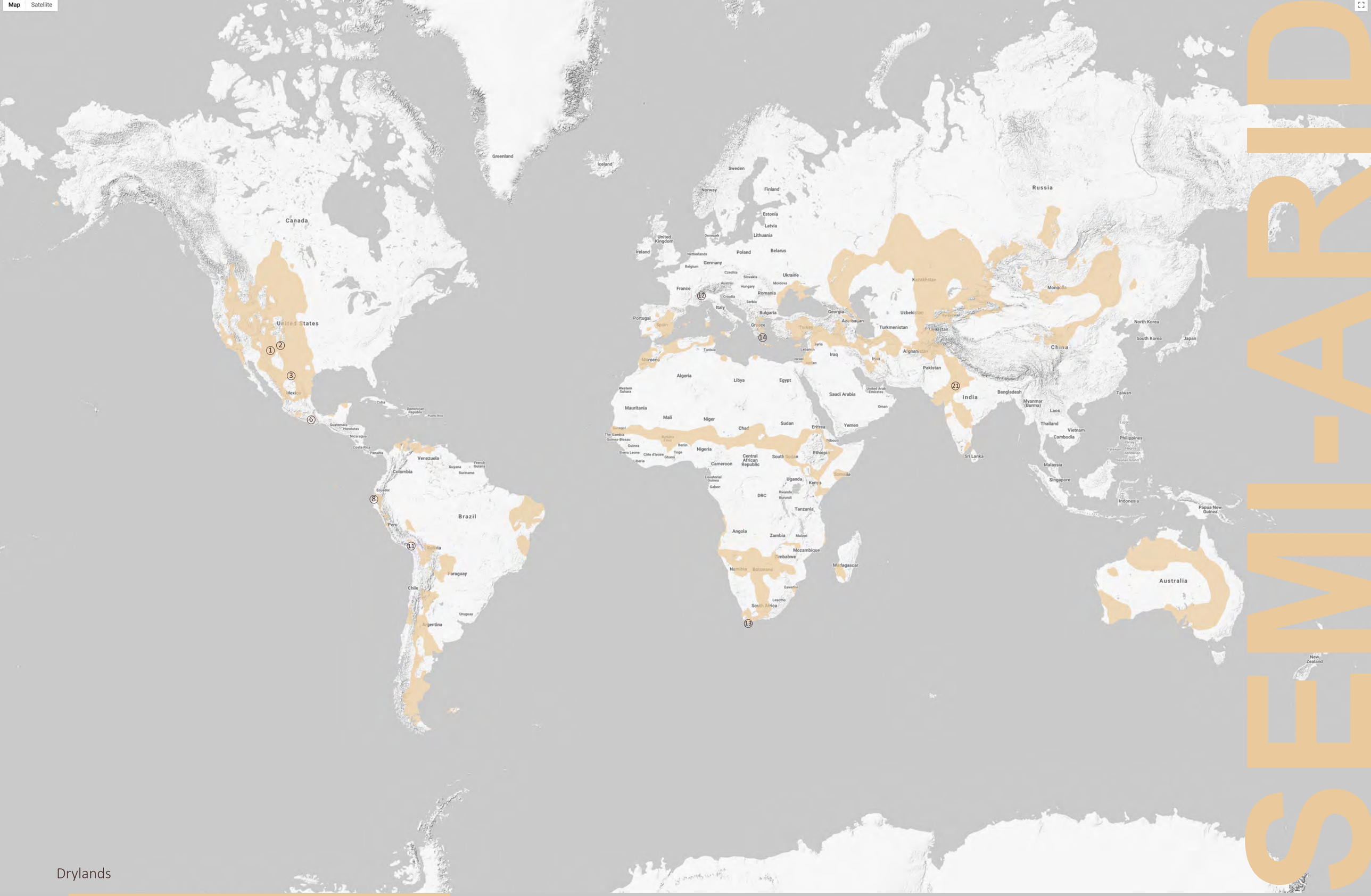
Student Contributor:

Clara Yoshihara

SEMI-ARID



Drylands

Semi-arid areas

- ② acequia
- ⑧ albarrada
- ⑪ benching
- ⑫ bisses
- ⑭ clepsydra
- ⑬ leiwater
- ㉑ stepwell
- ⑥ temazcal
- ③ tinaja
- ① waffle garden

Fair System
for Ecosharing
in the Neighborhood

ACEQUIA

Photo: https://www.abqjournal.com/685714/headline-438.html.

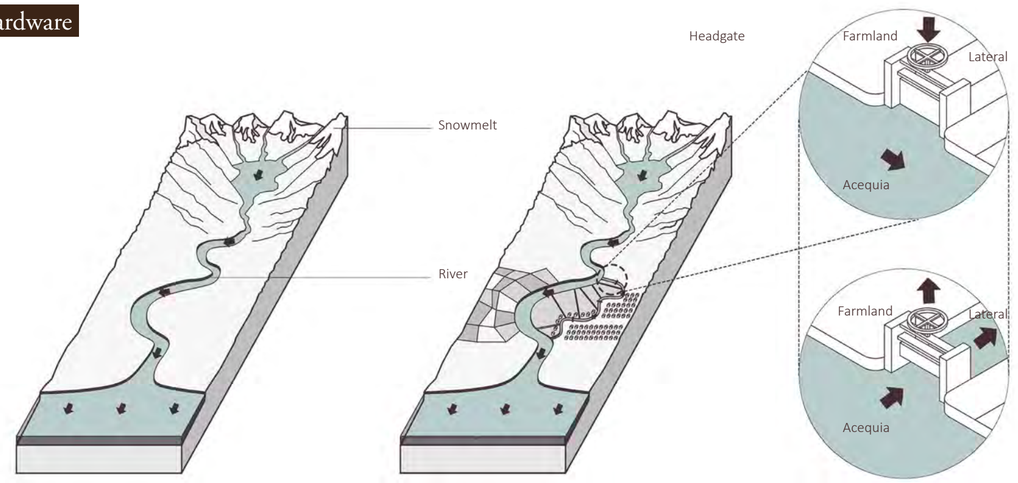
ACEQUIA

An irrigation ditch or canal.[2] it is located in Spain, the Andes, northern Mexico, and the American Southwest.[3]
Borrowed from arabic al-sāqiya, from al, definite article + sāqiya "irrigation ditch," from feminine active participle of saqā "to give to drink, irrigate"[4]
aqueduct, arroyo, ditch, watercourse, waterworks, weir, runner, canal, channel[5]

Plan: Functional Exploration

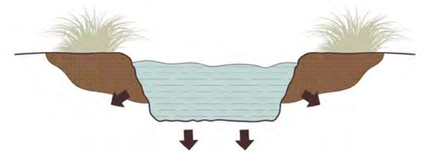
[Rio Grande-Alcalde Acequia Irrigated Corridor, New Mexico.]

Hardware

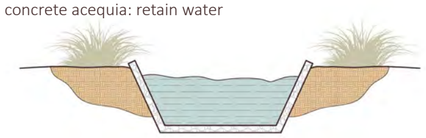


The acequia agroecosystem is a gravity-driven system and has several pieces that can help to run the whole system. The diversion dam serves as the primary diversion for the acequia system and helps to guide water from the source river.[6] Then, the acequia madre is the central irrigation canal and through this channel, water is supplied to communities and fields.[7] The Presa also named diversion/ headgate, is constructed by using brush-and-rock, earth, or logs, and diverts water from the supply source into the acequia system.[8] When it comes to the controling the start and stop the water flow in the watercourse, the Atarques(Checks) are structures that, when closed, stop the flow of water in the ditch, which creates water storage structures like reservoirs. When the space is full of water, it will be distributed to the neighboring laterals or the fields surrounded the channel.[9] The Puertes/ Compuerts is a temporary water diversion structure that will divert the water from the acequia madre into a nearby lateral or directly to the nearby field.[10] Canoas convey water over impediments and arroyos.[11] The Desagues is a ditch that transfers water back into the supply river and is located at the end of the acequia system.[12]

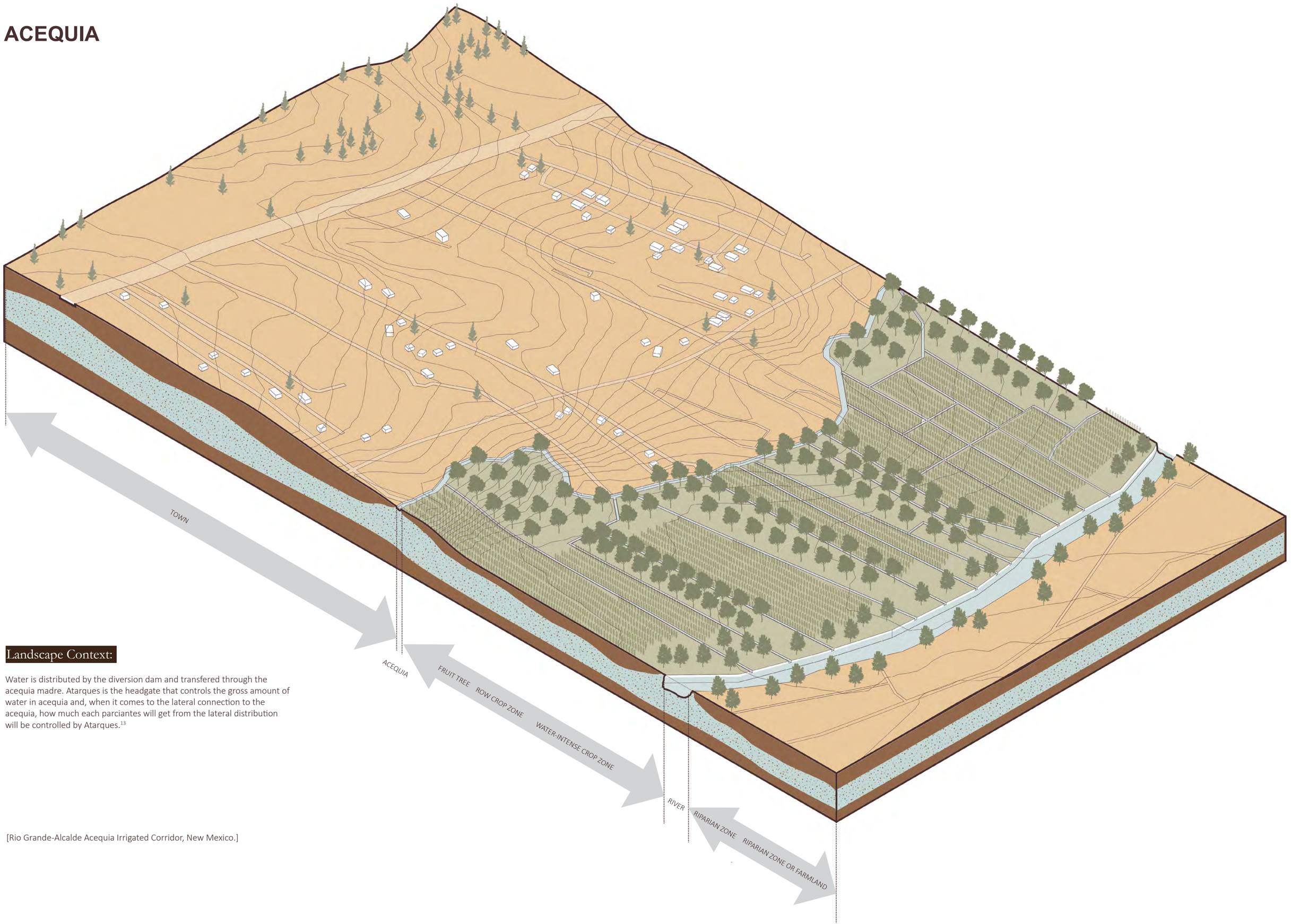
soil acequia: water seepage



concrete acequia: retain water



ACEQUIA

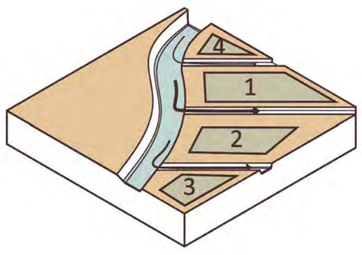


Landscape Context:

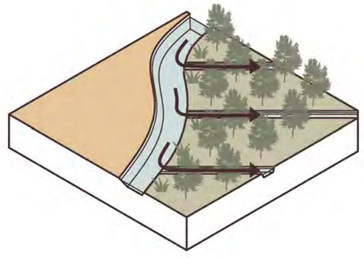
Water is distributed by the diversion dam and transfered through the acequia madre. Atarques is the headgate that controls the gross amount of water in acequia and, when it comes to the lateral connection to the acequia, how much each parciantes will get from the lateral distribution will be controlled by Atarques.[13]

[Rio Grande-Alcalde Acequia Irrigated Corridor, New Mexico.]

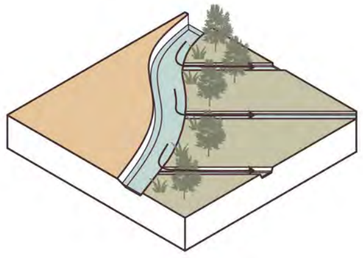
Equitable Water Distribution Principle



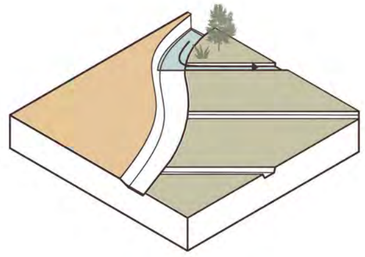
Plenty Water Situation



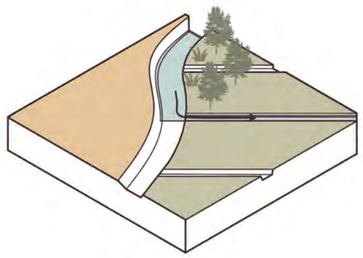
Less Water Situation



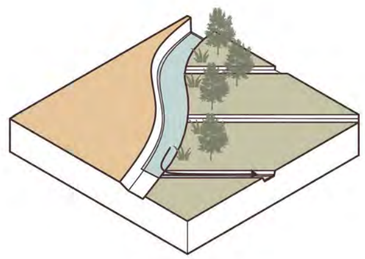
Drought Situation: Week 1 distribution



Drought Situation: Week 3 distribution



Drought Situation: Week 2 distribution



• The parciantes are the people who live based on the acequia. Parciantes can decide the amount of water they need and the irrigation water will flow through a headgate to a lateral ditch to irrigate their land. Because water distribution needs to be fair, the amount of water will be decided by the amount of available water from the watershed and the needs of neighboring parciantes.[14]

• The mayordomo is officially elected by parciantes and has responsibility for the day-to-day management of the acequia. [15] Mayordomo has other responsibilities, such as levy fees, gathering labor for emergency repairs and overseeing the water distribution between the parciantes in the community.[16]

• Equal to mayordomo, the commissioners are also selected by parciantes. The commissioners are a treasurer, a secretary, and a chair.[17] The commission arranges the rules, establishes annual fees, and often make the final decisions in disagreements in the union.[18] Because of this system, an acequia is a self-governing community in which parciantes, mayordomo, and commissioners rely on each other.[19]

Notes:

[1]T. S. Last | Journal North Editor. "Acequia Activism: Men and Women Help Protect a Vital Network of Irrigation throughout New Mexico." *Albuquerque Journal*, www.abqjournal.com/685714/headline-438.html. 2019

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[3]Rivera, José A.; Martínez, Luis Pablo. "Acequia Culture: Historic Irrigated Landscape of New Mexico", *Agricultura, Sociedad y Desarrollo*, vol. 6, núm. 3, septiembre-diciembre, 2009, pp. 311-330

[4]"Acequia." Merriam-Webster, Merriam-Webster, www.merriam-webster.com/dictionary/acequia.

[5]"Acequia Synonyms." Power Thesaurus, https://www.powerthesaurus.org/acequia/synonyms

[6]Draft Instructions for Acequia Detail Form. www.nmhistoricpreservation.org/assets/files/arms/Manual-for-Acequia-Detail-Form.pdf. page 6, 2019

[7]Acequia terminology, http://bloodhound.tripod.com/aceqglos.html

[8]Draft Instructions for Acequia Detail Form. www.nmhistoricpreservation.org/assets/files/arms/Manual-for-Acequia-Detail-Form.pdf. page 6, 2019; Acequia terminology, http://bloodhound.tripod.com/aceqglos.html, 2019

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Student Contributor:

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ALBARRADA

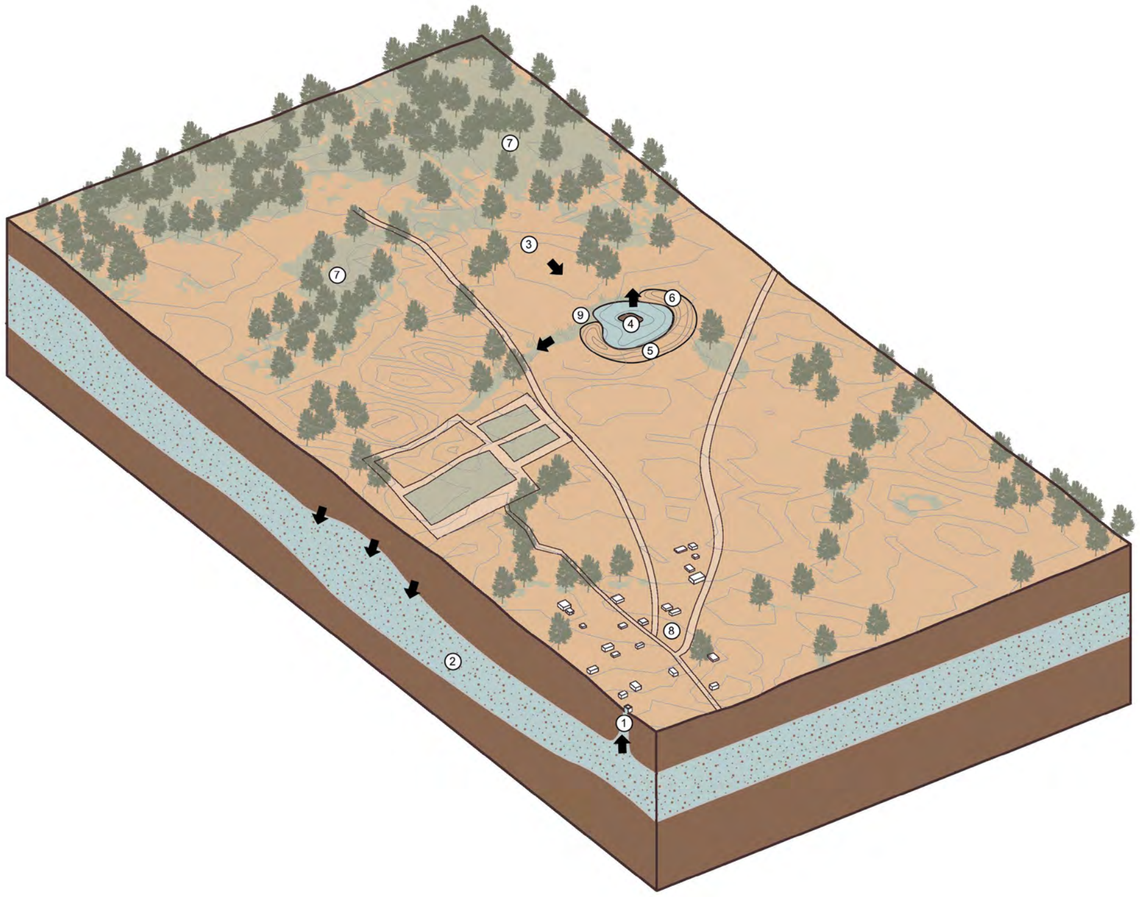
Embrace Hillsides to Capture the Runoff for People, Animals, and Food

Photo: https://www.eltiempo.com.ec/noticias/cultura/7/embalses-ancestrales-manabi.

ALBARRADA

date from 2000 BC. it is located in coastal Ecuador, recorded for much of the Santa Elena Península
These U-shaped lagoons (called albarradas), retain water behind small earth dams[2]
horma,hormaza, muro, pared, tabique, tapia [4]

Functional Exploration



Hardware

• Catchment: The albarrada system can be built with local available resources in a gentle slope area. It faces up hill to work as a dam to collect rainwater runoff during the short rainy period without the help of a feeder canal.

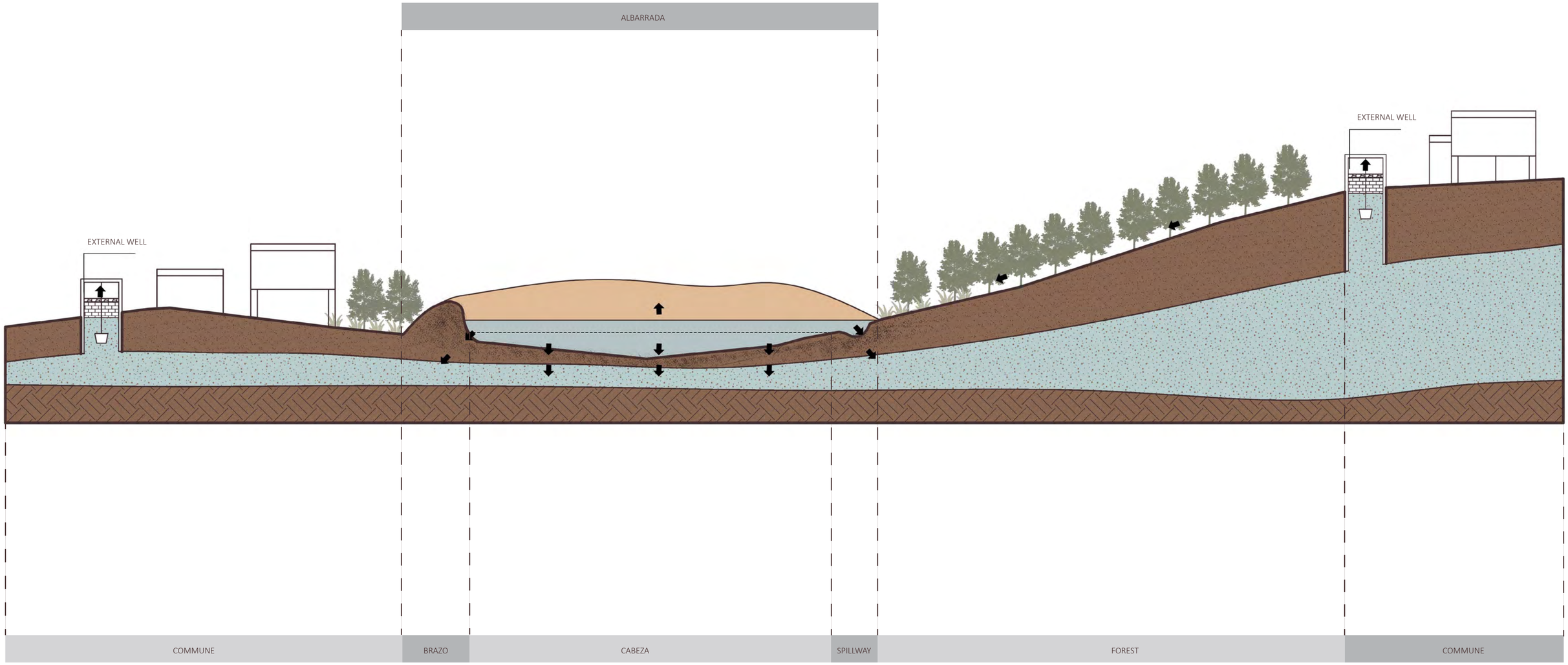
• Arms: The excavated surface soil from the lagoon is stacked along the downstream area. Villagers will compact it physically. When it comes to the dry season, the albarrada will dry out and the crops can be planted in the lagoon area. When the crops grow, the clay and silt from the albarrada area will be cleaned out and collected to be accumulated on the outer dam hills to make them thicker and higher. [5] It has two functions: one is to reserve water, the other is to plant crops along the edges.

• Wells: Infiltrated water can be used by the same village through the “external wells” which help to get water from the aquifer or by the spring a short distance downstream to benefit the livestock and agriculture. [6]

• physical parts:
Muro: wall(made by the soil, clay, silt from the lagoon) [7]
Vaso: lagoon area to collect and capture water from rainwater runoff. [8]
External wells: the deep wells which can store water and extract water for pot irrigation. [9]
Springs downstream: released water from albarrada will help irrigation and to raise livestock in the village. [10]

1. pozo externo asociado a la albarrada
external well associated with the albarrada
2. acuidero alimentado por la albarrada
albarrada-fed aquifer
3. area de aportacion
contribution area
4. “lechuguin”(pistia stratiotes)
specific aquatic plant
5. muro de albarrada
cadeza head
6. muro de albarrada
brazo arm
7. bosque
forest
8. comuna
commune
9. area de desfogue
release area

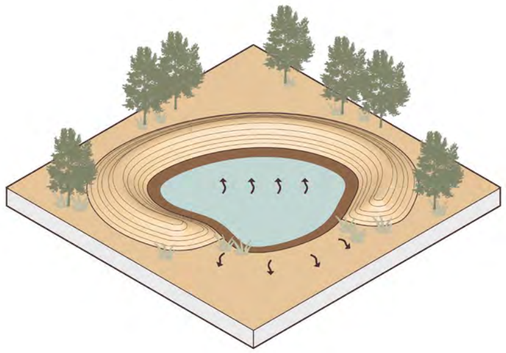
ALBARRADA section



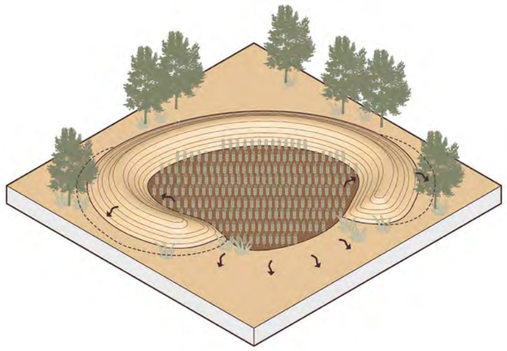
Landscape Context:

The albarrada system also known as jagüeyes, marsh dams or simply lagoons, date from pre-Columbian times. Today it continues to reproduce and generate and in some places it is the only source of water which the population to access.[11]

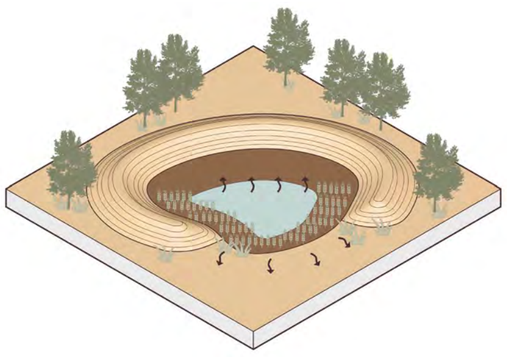
more water: water storage system and water infiltration



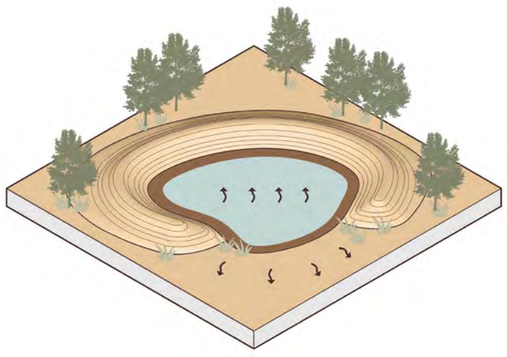
drought: crop planting and build muro



less water: water evaporation and crop planting



next year rainy season: more water capture and water



Software

• Management organization: The completed system will be managed by the Communes Sacachún, Pechiche, and El Real. The Regime Law and Organization of Communes 1937 is the formalized the ancestral right of the settled native communities since colonial times. These regulations prove the communes are units sociopolitical of a stable nature, linked by relations of kinship, and identified by their association to a territory. [12]

• Ritual : Based on the evidence of three large mullo shells(Spondylus princeps) found in the channel of the albarrada Achallan in Santa Elena, it proved the common ritual practice in the Andes: people used this creature to pray for more rain. Also, using this ritual meaning while village chief would avoid the accuse from the communal activities if the albarrada system failed to bring water to the village. [13]

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BENCHING

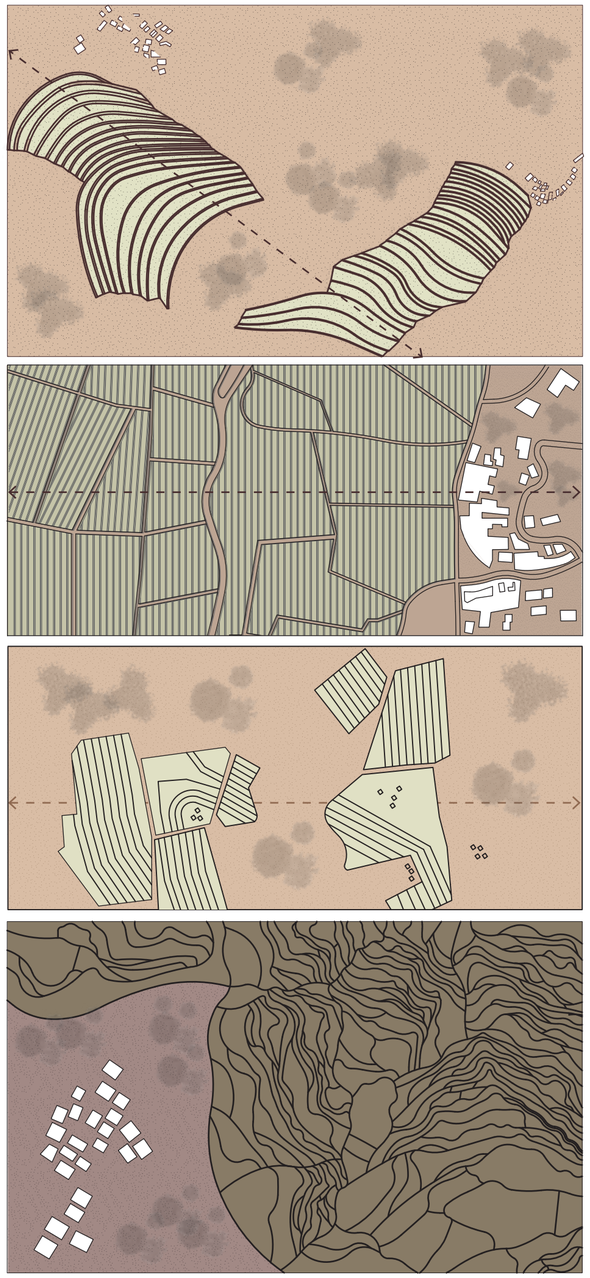
Prevent Landslides, Grow More Food, Save Water and Create Land Art in One Action!

"Bench terraces are a series of level or virtually level strips running across the slope at vertical intervals, supported by steep banks or risers."[1]

Photo: https://www.entouriste.com/adventures-in-peru/stone-terraces-at-machu-picchu/.

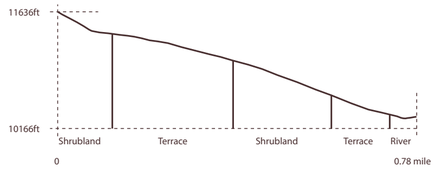
BENCHING

Pronunciation: [ben·chuhng]
Etymology: Old English benc "long seat," especially one without a back, from Proto-Germanic bankon(source also of Old Frisian bank "bench," Old Norse bekkr, Danish bænk, Middle Dutch banc, Old High German banch). [2]
Synonyms: terraced field, paddy terrace
Location: east, south, and southeast Asia, as well as the Mediterranean, Africa, and South America.
Time period: Concept of benching terrace were found as long as the agricultural civilization first developed. “The earliest practices of terracing were recorded in Palestine and Yemen about 5000 years ago.” [3]



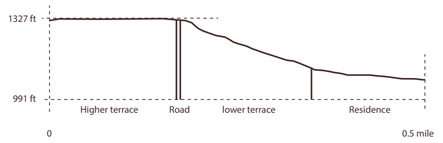
Andean, South America

- Arid and semi-arid climate
- Plant corn or patato in South America
- Stone bund wall terrace



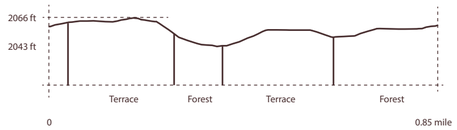
Marchesi di Barolo, Italy

- Mediterranean climate
- Vineyard or olive garden in Mediterranean area
- Water channel along trail



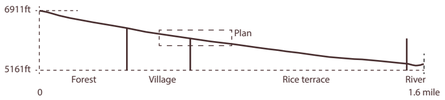
Fanya juu, Kenya

- Arid and semi-arid climate
- Plant corn or bean in Africa
- Water channel along embankment



Honghe Hani Rice Terraces, China

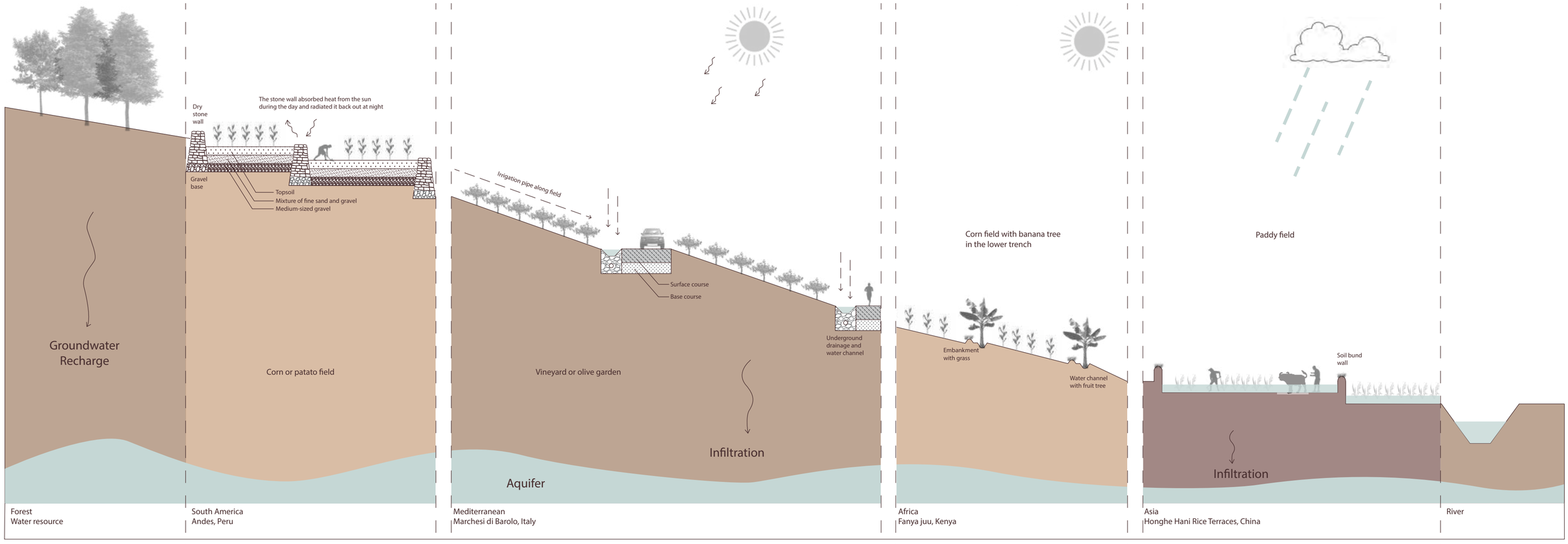
- Humid continental or humid subtropical climate
- Crops need dip in water
- Soil bund wall terrace

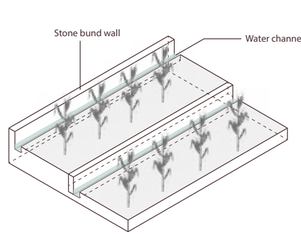


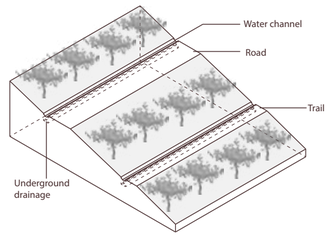
Hydrologic Purpose

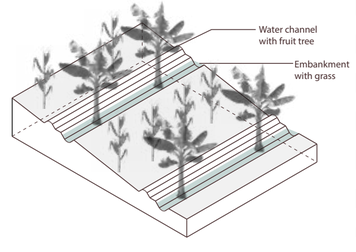
- Reduce run-off or its velocity and minimize soil erosion;
- Conserve soil moisture and fertility, facilitate modem cropping operations i.e. mechanization, irrigation and transportation on sloping land;
- Promote intensive land use and permanent agriculture on slopes and reduce shifting cultivation.

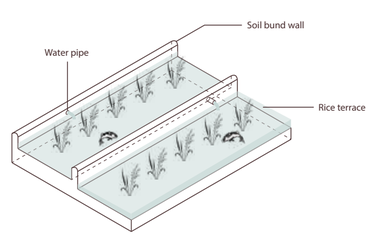
BENCHING











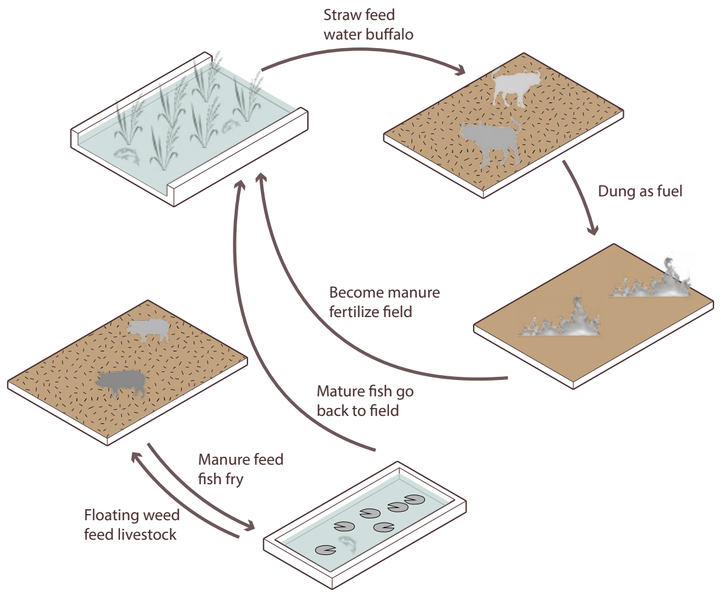
Construction Method

- Bench terraces can be found in tropical and subtropical rainforests, deserts, and arid and semiarid mountains across the globe. [4]
- Bench terraces are particularly suitable for several conditions, such as areas with severe erosion hazards, areas where crops require flood irrigation, and areas with steep and fairly steep slope land having deep and moderately deep soil. [5]

- Bench terraces are used to irrigate crops, capture and infiltrate water on site.

- Local farmers measure the slope of the hill and calculate the benching space than cut and fill the mountain side, makes stair-stepping field to grow crops.
- The edge of the terrace is higher than the plantation part of the field, and it calls bund or bund wall. Bund will hold water in the crop field.
- Based on the different climate and geographic conditions, the benching terrace system would also include a network of canals, sluices, and pipes.

Ecological Circulation System



General Operation

• Benching terraces are mostly found in the areas with small holdings and a dense population, and areas where there are food shortages or high unemployment rates. [6]

• Benching terraces operate differently in different countries of the world. In southeast Asia the terrace system was determined by their religious believes, such as the Subak in Bali island, Indonesia. In Europe, such as Italy, the terraced field were constructed by communities.

Honghe Hani Rice Terraces

• In Southern Yunnan, China.

• The Hani people have developed a complex system of channels to bring water from the forested mountaintops to the terraces. They have also created an integrated farming system that involves buffalos, cattle, ducks, fish and eel and supports the production of red rice. [7]

• Hani terrace forming a original agricultural ecological circulation system of rivers, terraces, villages and forests. The forest is in the upper part, the village is in the middle, the terrace is in the lower part, and the water system runs through it.

BENCHING

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Student Contributor:

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BISSES

Let Water Flow Lead You to the Food and Wine

Bisses are “Historic irrigation channels” transport the stream water from mountain to the “arid pastures and fields, vineyards and orchards.”[1]

Photo: https://www.houseofswitzerland.org/swissstories/history/bisses-valais-irrigation-channels-tourist-hit.

BISSES

Pronunciation: [‘bise]
Etymology: Bisse in old French means “wild animal” [2], from Vulgar Latin bīstia means “snake” [3]
Synonyms: “rayes”, “suonen” and “wasserleiter” [4]
Location: Canton of Valais, Switzerland
Time period: From 13th century to 20th century [5]

Melting Glacier Streams
Principal Conveyance Channel
Secondary and Tertiary Channels
Building
Agriculture Land

Hardware - General System

1. A Sand Trap with prise d’eau (means water intake) and an overflow outlet diverts water from melting glacier streams. [6]

The sand trap is a box shape structure that can hold the precipitated sediments from water. It originally was wooden, but modern forms usually made from concrete. [7]

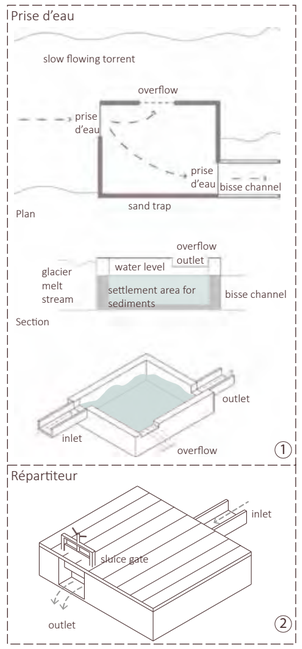
The prise d’eau has two openings on the sand trap that let water into the sand trap and outflow to the bisse channel. The overflow outlet will let excess water flow back to the steam.

2. The répartiteur is a structure that divides water between different sectors. The form of répartiteur is similar as the prise d’eau but with a sluice gate. [8]

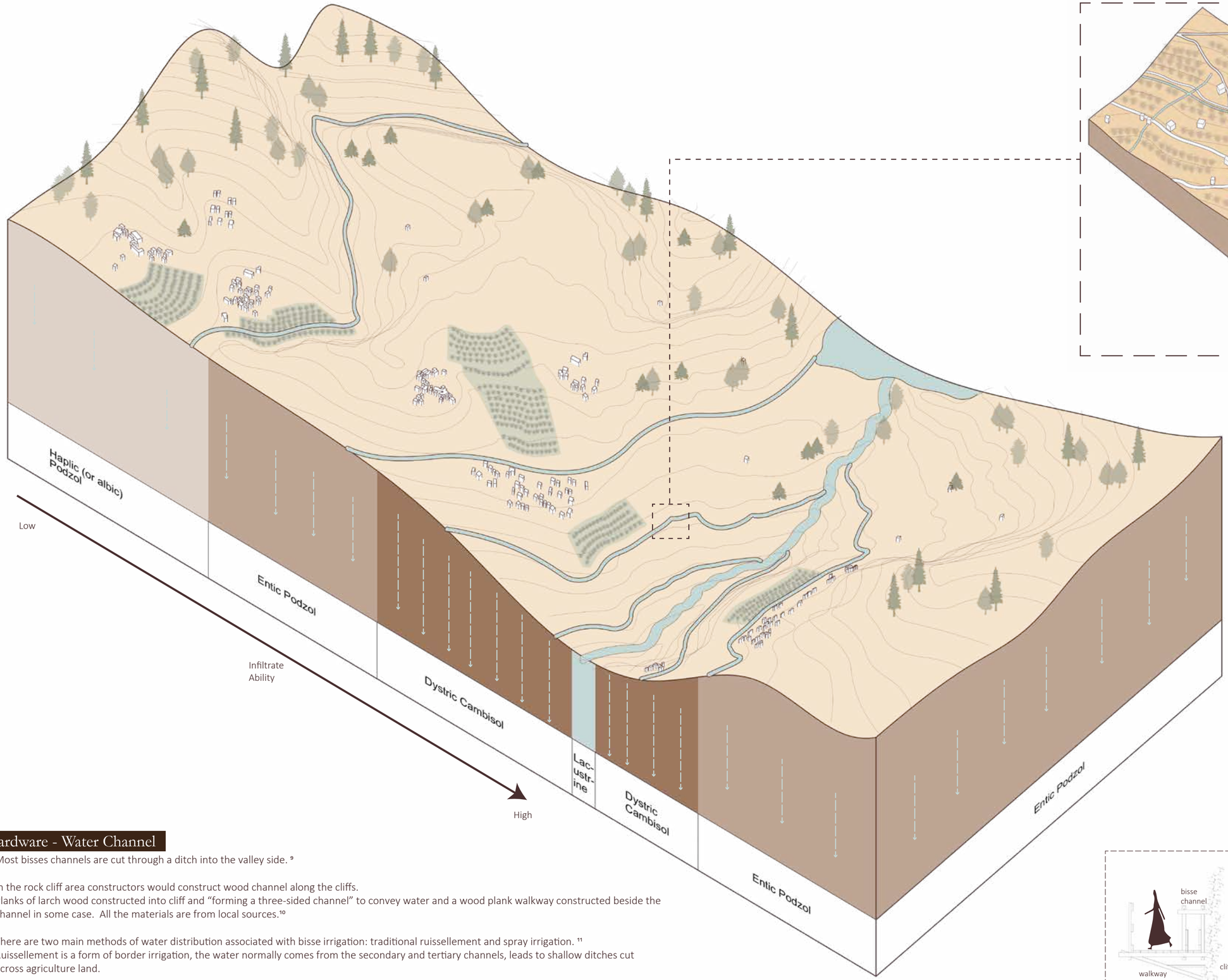
3. This structure then directs water to the principal conveyance channel. The principal conveyance channel transports water close to the agriculture land.

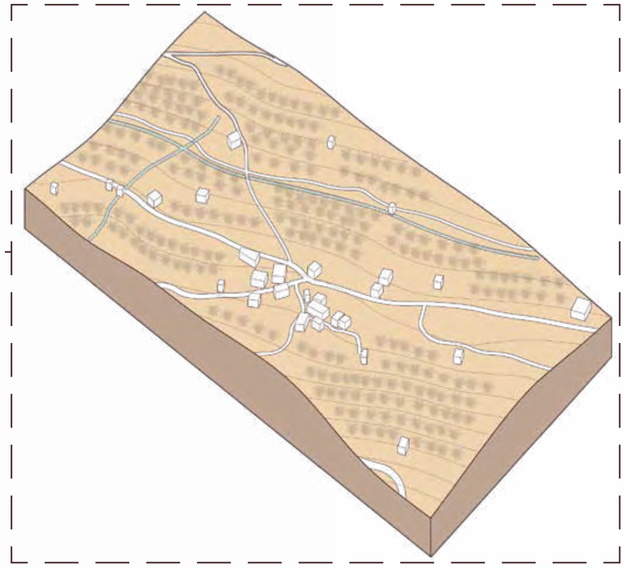
4. The secondary and tertiary channels will then distribute water to landowners point of use.

5. The bisse channel will eventually lead water back to the glacier melting river at the bottom of the valley.



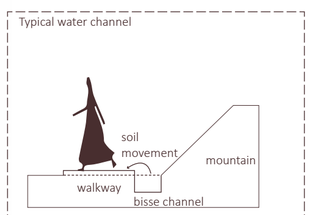
BISSES

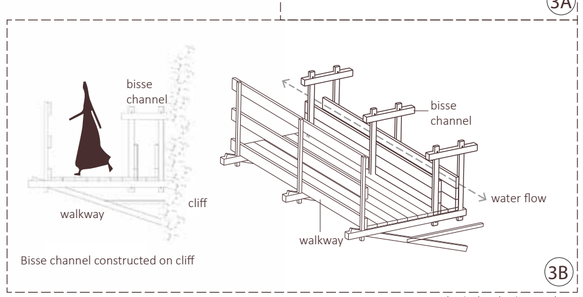




Hardware - Water Channel

- Most bisses channels are cut through a ditch into the valley side. [9]
- In the rock cliff area constructors would construct wood channel along the cliffs.
  Planks of larch wood constructed into cliff and "forming a three-sided channel" to convey water and a wood plank walkway constructed beside the channel in some case. All the materials are from local sources.[10]
- There are two main methods of water distribution associated with bisse irrigation: traditional ruissellement and spray irrigation. [11]
  Ruissellement is a form of border irrigation, the water normally comes from the secondary and tertiary channels, leads to shallow ditches cut across agriculture land.
- Spray irrigation first became available in the 20th century. Spray irrigation uses less water compared to ruissellement. With the process of modernization, and land consolidation, the spray irrigation networks spread. [12]

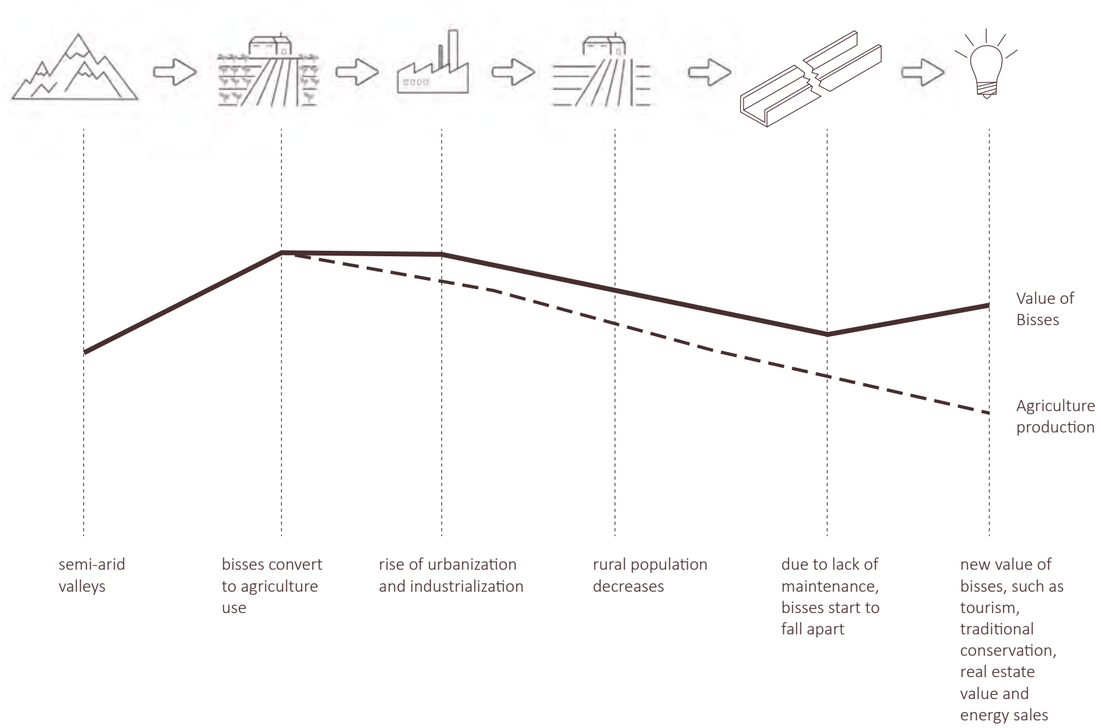




drawing based on internet photos

BISSES

Value Transition of Bisses



• The Bisses are found in low density, mountainous agriculture villages.

• "Low rainfall (an average of 602 mm/y for 1901–1993), high temperatures, and evaporation in the summer months keep create a water deficit of around 70–96 mm for the months of May–August." [13]

• Bisses are planned and built by consortiums set up by communities. Time spent on construction and maintenance for each person is based on their farmland size. [14]

• With the modern engineering techniques, bisses are decreasing in value and use. [15]

• As farmers leave agriculture for chemical and metallurgic industries (secondary industry) or tourism and administration industries (tertiary industry), bisse irrigated lands go out of production and/or the bisses themselves begin to determinate.

Advantages:
• Irrigate agriculture land in low summer precipitation time period
• Lower cost by using local materials
• Easier to construct for local farmers compared to using modern materials

Disadvantages:
• Evaporation due to the open channel system
• Easily damaged because of the land erosion or extreme weather
• Frequent maintenance required because of the material used compared to modern materials like concrete

BISSES

Notes:

1 Canton of Valais official website. https://www.valais.ch/en/activities/hiking/bisses. 2020

2 "Biche", Wiktionary. https://en.wiktionary.org/wiki/biche. 2020

3 "Biscia", Wiktionary. https://en.wiktionary.org/wiki/biscia. 2020

4 Reynard, Emmanuel. "Hill irrigation in Valais (Swiss Alps): Recent evolution of common-property corporations." *Farmer Managed Irrigation System in the Changed Context*, 343-361. 2002

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6 Crook, D., & Jones, A. "Design Principles from Traditional Mountain Irrigation Systems (Bisses) in the Valais, Switzerland." *Mountain Research and Development*, 19(2), 79-99. doi: 10.2307/3674250. April 1999

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12 Crook, D., & Jones, A. "Design Principles from Traditional Mountain Irrigation Systems (Bisses) in the Valais, Switzerland." *Mountain Research and Development*, 19(2), 79-99. doi: 10.2307/3674250. April 1999

13 Crook, D. "The Historical Impacts of Hydroelectric Power Development on Traditional Mountain Irrigation in the Valais, Switzerland." *Mountain Research and Development*, 21(1), 46-53. doi: 10.1659/0276-4741(2001)021[0046:THIOHP]2.0.CO;2. Feb 2001

14 House of Switzerland website. https://www.houseofswitzerland.org/swissstories/history/bisses-valais-irrigation-channels-tourist-hit. 2020

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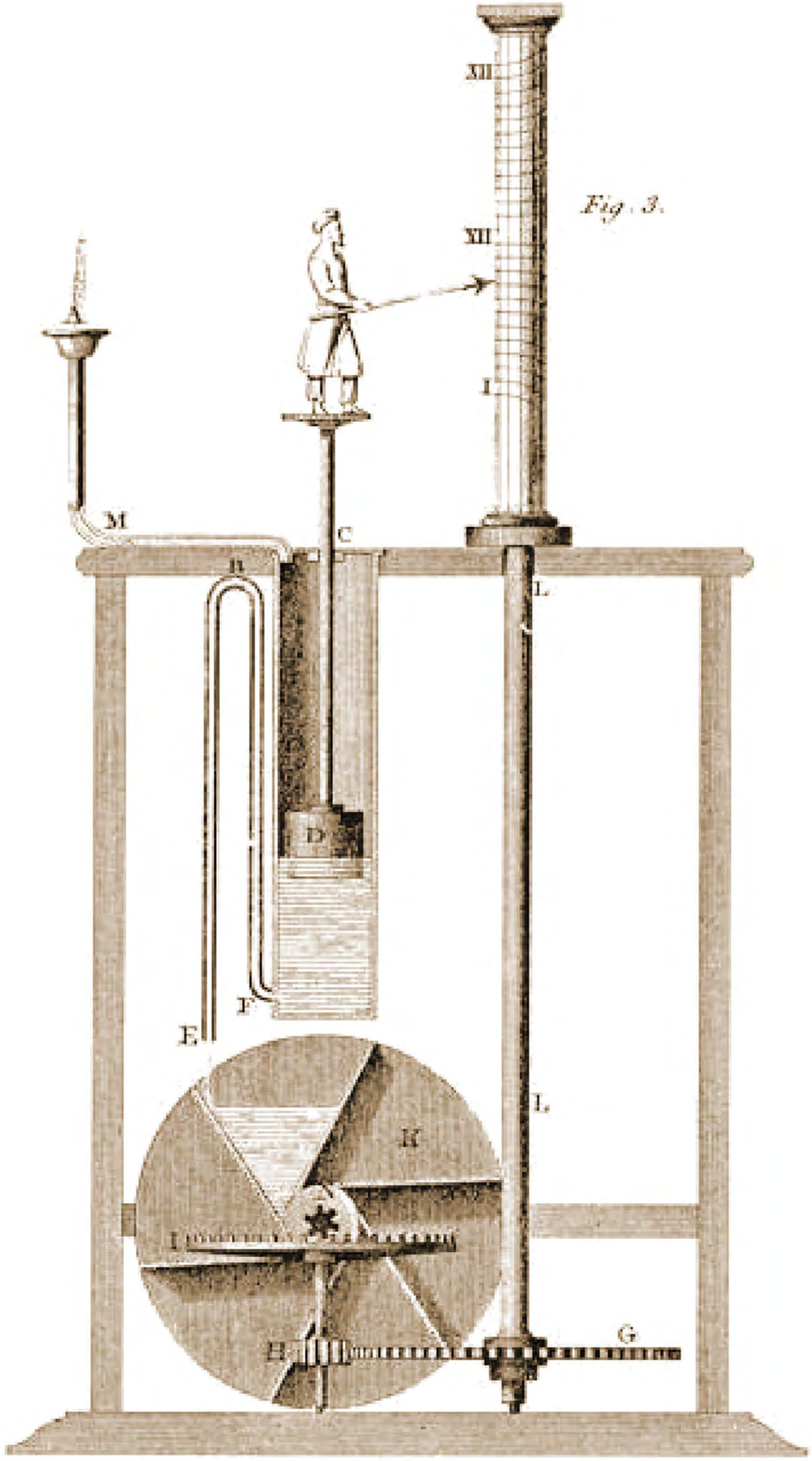


Device For Visualizing Time Driven By Water

Clepsydra, or water-clock, which meaures time by water.

CLEPSYDRA

Clepsydra or Greek water clock.[1] Photo: " A portable water clock used by Herophilus for the purpose of arterial pulse examination."[2]

CLEPSYDRA

Greece. Greco-Roman World. The oldest time measurement device by water[3].
Water Clock. Orignates greek term: Klepsydra, κλέπτειν - kleptein: steal, uδωρ – hydor: water - water thief [4].
Klepsydra/Clepsydra | [Κλεψύδρα]
Related technologies: Egypt: Katnak bowl[4] ; Old Babylon[5]; China: Kelou [刻漏] / Louhu[漏壺]*; India: jala-yantra[7]; Persia: Fenjaan/Blue watch[8]; Medieval Islamic

- How does clepsydra appear?

1 Sundial has disadvantages because it cannot be used in night, cloudy and rainy days. Therefore, water-clock or clepsydra as a physical phenomenon to measure time plays a significant role in ancient civilization.[9]

2 "So, clepsydrae, used in parallel with sundials, were instruments for showing the time in antiquity."[10]

- The evolution of Clepsydra
1 Origin:
❶
The first clepsydra, "Karnank bowl", [11] is considered a timer.

•The equipment consists of two different size bowls: small bowl with hole, and a big bowl with water.

• When people begin to measure time, at this time, people placed the small bowl to float on the big bowl full of water. Water permeates through the small hole of topper bowl. "When the topper bowl filled and sank, time was up !"[12]

❷

• "With a **cylindrical container** the rate of flow diminishes as the head of water within the pot decreases, so the water surface drops more slowly with time".[13]

• V=√2gh[14]

•"Amenhemhet, Egyptian designer, solves the rate of cylindrical container's disadvantages".[15]

❸

• "Water was drawn by a stone conduit. The device was at first a simple outflow clock, a stone tank or cistern accessible through a flight of steps, with a small bronze outlet hole at the bottom which allowed the tank to drain slowly"[16]

❹
"In the 3rd c BCE two supplementary tanks were added to the water clock in the Agtora, set at different levels, which were filled gradually. The time was no longer estimated by emptying the main tank but by the gradual filling of one supplementary tank. At the end of the day the main tank would be emptied through a large outlet hole set at its bottom. With this system all the problems caused by water pressure changes would be avoided. This water installation was dismantled in the 2nd c BCE. It is the forerunner of the water clock in the Tower of the Winds, the clock of the astronomer Andronikos Kyrrestes."[17]

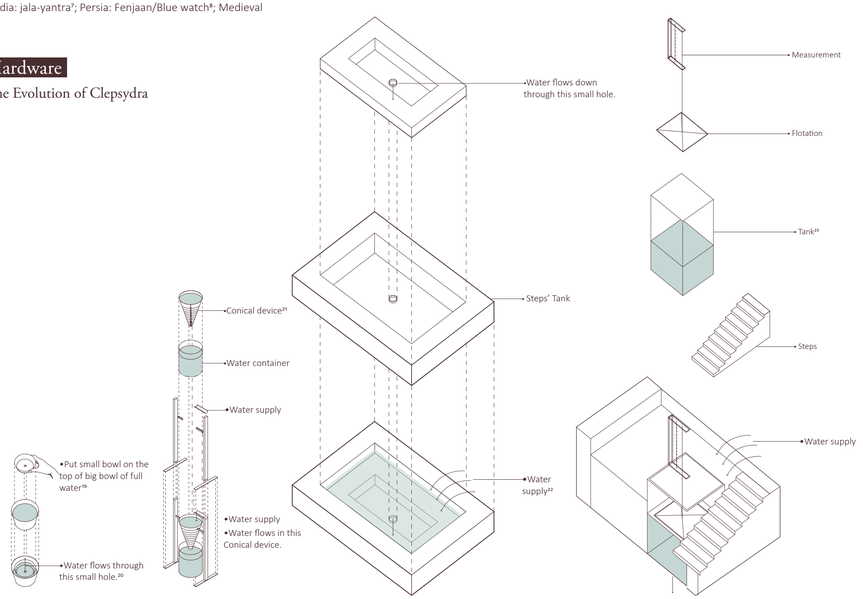
Big Achievements:

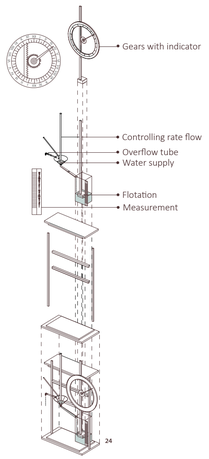
1 Conduits play an important role in the composition of water clock whatever outflow or inflow system.
❸ ❹
• There are typical outflow type of water clock.
❺ ❻ ❼
• The conduits of these devices were developed into "U" shapes.
• Adding floation and measurements, people can get much more correctt time accurancy.
• "Linearity through use of floating devices, which plays a significant role on water clock."[18]

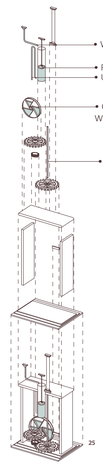
❸ ❹ ❺ ❻ ❼
Multidisciplinary contributions
• **Siphon theory** and **mechanical power** through gears play significant role on physics, mathematics, astronomy, architecture, irrigation.

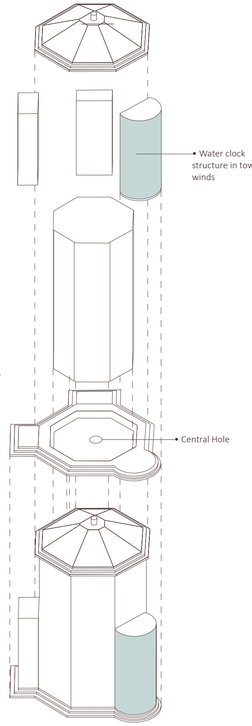
Hardware

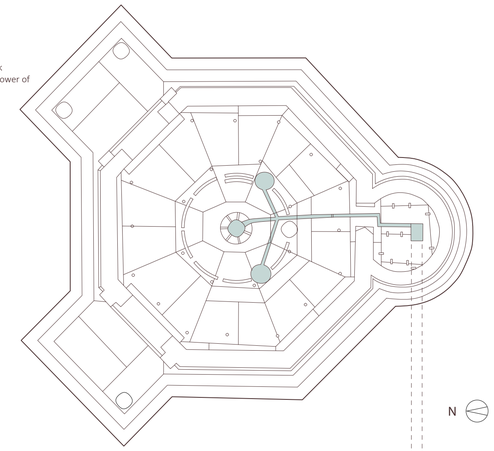
The Evolution of Clepsydra

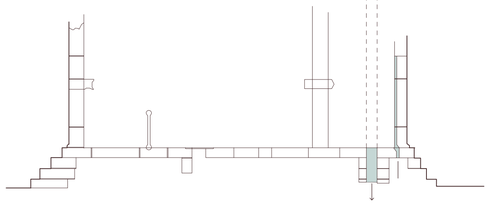


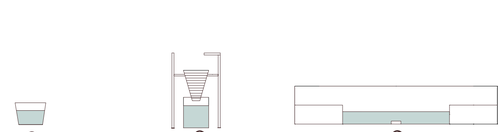


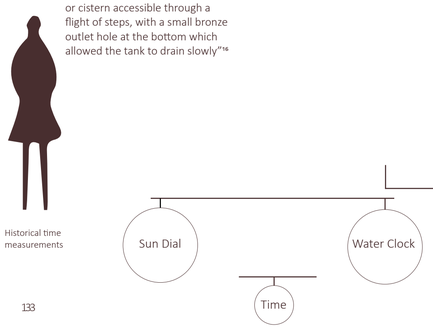












CLEPSYDRA

Software

Timer

the oldest water clock

(Indirect)

Irrigation

Social

Physics

• Iranian water clock plays an important role on agricultural life of Iranian society, because Iran is located at arid area, water is very important and necessary for agriculture, especially in desert regions.[28]

• At the same time, water clock avoids the unfair water distribution.[29]

• Therefore, waterclock is often used with qanat which is ancient irrigation system in Iran region.

Water Clock

Time

Time

Physics

Mathematics

Time

Physics

Mathematics

Time

Physics

Astronomy

Mathematics

Social

Time

Clock

Energy

Siphon theory

•"Since both ends of the siphon move, the rate of flow is independent of the level of water in the container, and the rate of descent is constant."[30]

• Siphon is a device that fills with the flow of liquids. In general, the shape of siphon is "U".
The theory of siphon is to power the water without pump.

• "U shape causes a liquid to flow upward, above the surface of a reservoir, with no pump, but powered by the fall of the liquid as it flows down the tube under the pull of gravity, then discharging at a level lower than the surface of the reservoir from which it came."[31]

Mechanical power

"Mechanical energy is the sum of potential energy and kinetic energy. It is the energy associated with the motion and position of an object."[32]

The core in development of water clock

CLEPSYDRA

Engineer

Inverted Siphon Project in South–North Water Transfer Project

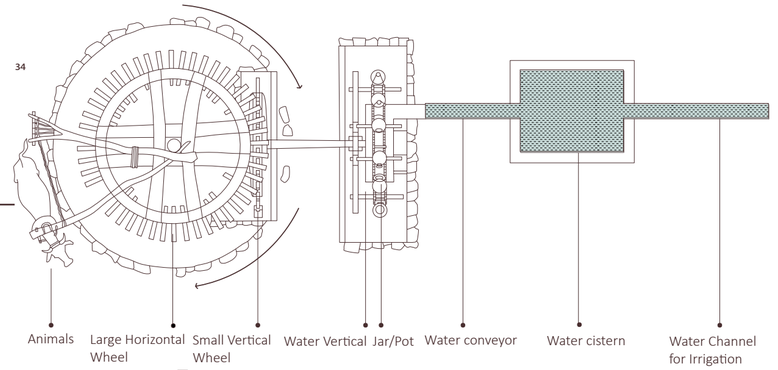
• When the channel is close to the elevation of a road or a ditch, it needs to repair a building to allow water to pass through the road or under the ditch. This building is usually called inverted siphon.

• It is a pressure water pipeline that passes through valleys, rivers, depressions, roads, and other channels. It is a type of channel crossing building, which is mainly a shaft type. Inverted siphon is widely used in farmland water conservancy construction, urban water supply, and large-scale water transfer projects in various countries due to its characteristics such as less engineering volume, convenient construction, saving power and materials, low cost, and easy removal of sediment.[33]

Irrigation

Saqiya

34



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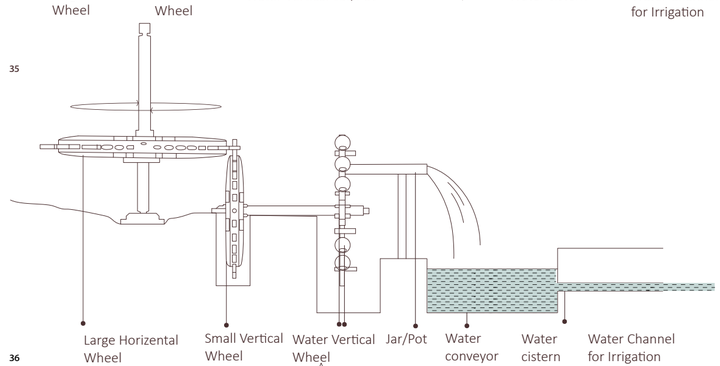

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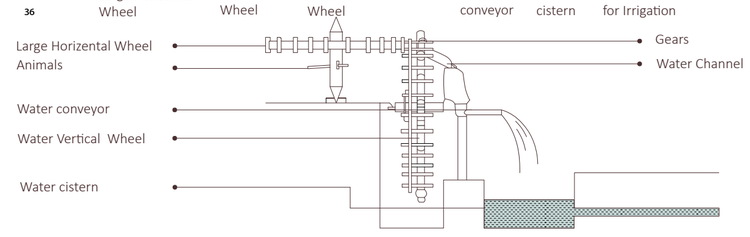

Noria

• Noria has the similar functional system as Saqiya. The difference between Saqiya and Noria, Saqiya use animal force to provide energy, whereas noria just use water power to produce mechnical energy.

Image:

1 Ghasemzadeh, N. (2011). A Brief Journey into the History of the Arterial Pulse

Notes:

1 Ghasemzadeh, N. (2011). A Brief Journey into the History of the Arterial Pulse

2 Ghasemzadeh, N. (2011). A Brief Journey into the History of the Arterial Pulse

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4 McNown S. J. (1976). When Time Flowed the Story of the Clepsydra.

5 Ajam, M. Pengan Blue Watch Has Been in Use in Iran for More Than 5 years.

6 McNown S. J, page 4.

7 McNown S. J, page 4.

8 Ajam, M. Pengan Blue Watch Has Been in Use in Iran for More Than 5 years.

9 E, T. & E.-M., K. The Ancient Clepsydra of Athens.

10 E, T. & E.-M., K, page 2.

11 McNown S. J, page 1.

12 McNown S. J, page 2.

13 McNown S. J, page 2.

14 McNown S. J, page 2.

15 McNown S. J, page 2.

16 Athens. http://www.romanaqueducts.info/aquasite/athens1/index.html

17 Athens. http://www.romanaqueducts.info/aquasite/athens1/index.html

18 McNown S. J, page 3.

19 McNown S. J, page 3.

20 McNown S. J, page 3.

21 Fluctuare. (2011). The clepsydra and the FInal Goal of the Clockmakers' Art.

22 Athens. http://www.romanaqueducts.info/aquasite/athens1/index.html

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28 Ajam, M. Pengan Blue Watch Has Been in Use in Iran for More Than 5 years.

29 Ajam, M. Pengan Blue Watch Has Been in Use in Iran for More Than 5 years.

30 McNown S. J, page 3.

31 Ramette, Joshua J.; Ramette, Richard W. (July 2011). "Siphonic concepts examined: a carbon dioxide gas siphon and siphons in vacuum".

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35 Venit, M, page 3-5.

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Http://www.romanaqueducts.info/aquasite/athens1/foto28.html

Student Contributor:

Liang, Jiayu

Leiwater is a Shared Water System for Backyard Farming in Dry Periods

Leiwater is a cooperative system of leading water by open channels or furrows to properties in a town or village for the purposes of garden allotment or farm irrigation. Each property with leiwater access rights has a beurt (turn) over a cycle.

Photo: Hadley Arnold, Arid Lands Institute, 2018.

LEIWATER

LEIWATER

Leiwater is a cooperative system of leading water by open channels or furrows to properties in a town or village for the purposes of garden, allotment or farm irrigation. Each property with leiwater access rights has a beurt (turn) over a cycle.

The term may come from Afrikaans meaning ‘lead water’ and/or ‘lei jou water’. In English it means ‘guide/lead your water’.[1]

The Original Leiwater System in VOC Vegetable Garden, Cape Town

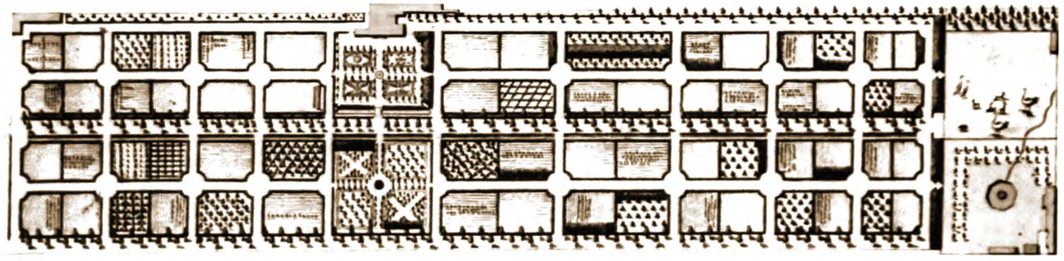


photo: Hadley Arnold, Arid Lands Institute, 2018.

The Renovated Leiwater System in VOC Vegetable Garden, Cape Town

Historic Hardware

• Hydrologic Function

The function of the original Leiwater system in the garden is to irrigate vegetables in those parcels. The system is totally garvity-feed and having a gate controlling the irrigation time.

The VOC Vegetable Garden was likely built by sailors, soldiers, and enslaved native South Africans to provide for the needs (fresh provisions) of the shipping company from 1652.

• A Linear System at Garden Scale

The garden uses water from the Molteno Dam, which uses water from the springs on the lower slopes of Table Mountain.

The water is conveyed through a main channel and then sub divided into smaller channels in order to irrigate every parcel. The excessive water is collected in a pond and then infiltrate to aquifer.

LEIWATER

Leiwater System in Montagu

Photo of the Sluice

photos: Hadley Arnold, Arid Lands Institute, 2018.

Skrit of the Sluice as Park Space

photos: Hadley Arnold, Arid Lands Institute, 2018.

Hardware

• Hydrologic Function

The system has two purposes: conveyance of water by gravity to individual land-holders for irrigation; and fair apportionment of available water to total number of landholders.

Because of the leiwater system, private gardens and agricultural fields thrive in the dry lands.

• A Linear System at Village Scale

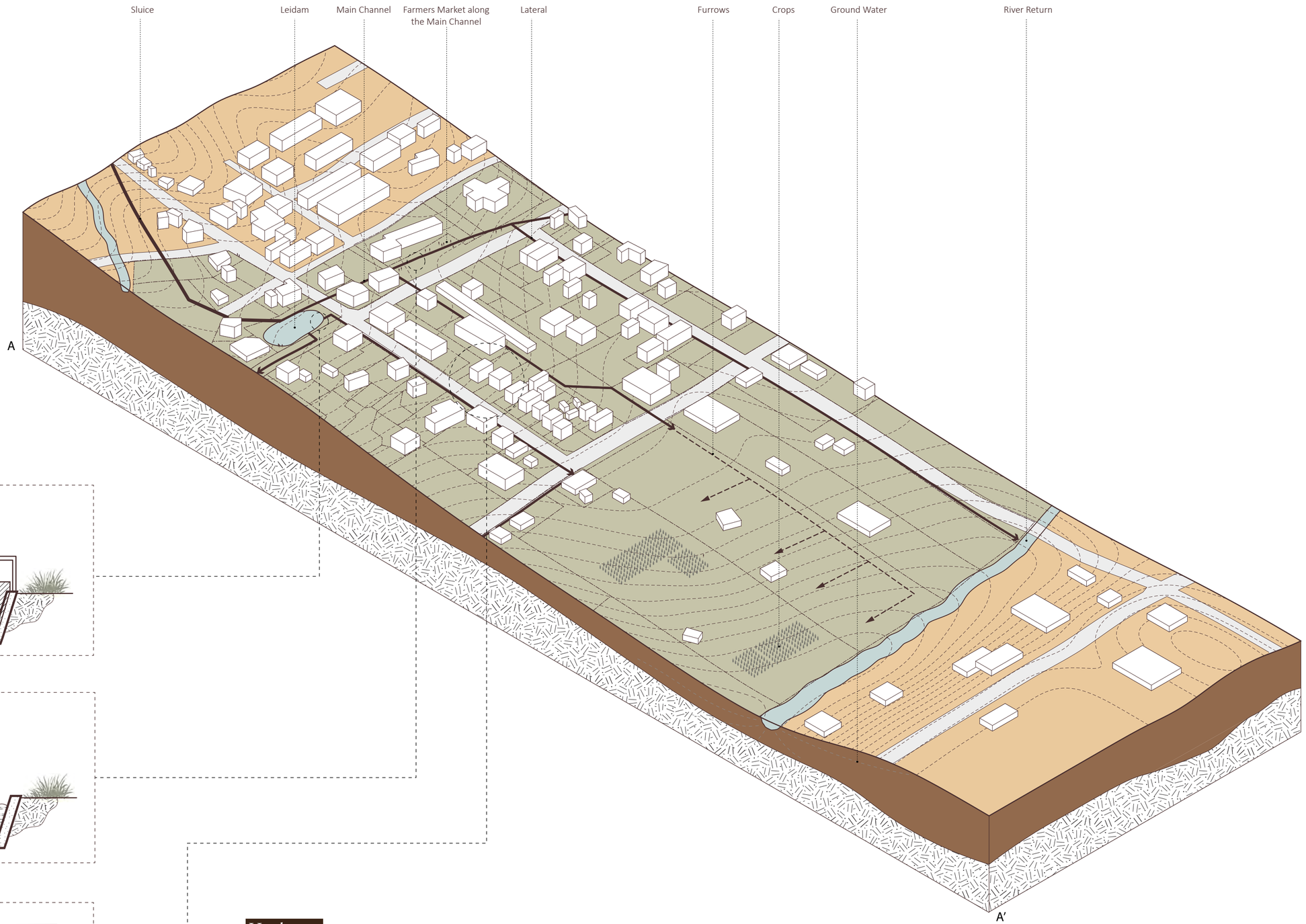
First, it relies on a remote water source: a spring, river, lake.

Next, a constructed channel delivers water to a manmade reservoir where it is held temporarily. From the reservoir, the water is distributed through different water gates to main channels and then laterals.

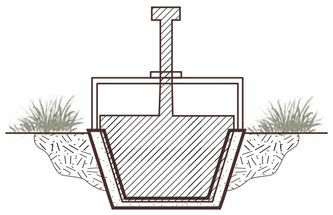
Finally, the excessive water is returned to natural water bodies.

LEIWATER functional system exploration

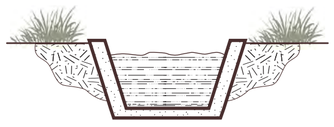
A Zoomed in Axon of Leiwater System in Montagu (A - A')



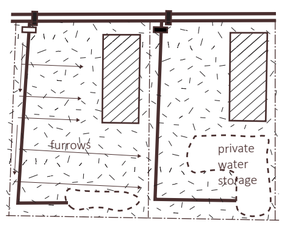
Section of the Water Gate



Section of the Main Channel



Leiwater Conveyed to Properties



Hardware

In Montagu, a still-functioning system with 150 landholder members, the reservoir measures approx. 200ft by 80ft.

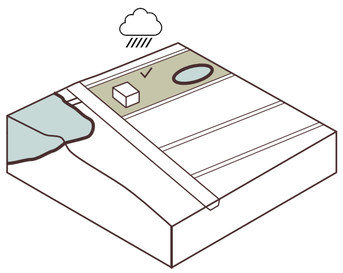
From the reservoir, "sluices let water flow into dams below the canal." And "The same was used to let water into the minor irrigation canals for the properties in the town." [2]

Sluices are often made from iron or wood, and lead to channels

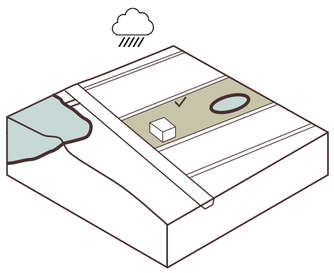
The water channels have various size and depths, but they are all smaller than a canal and they are more like trenches. The leiwater channels are most often reinforced by stones, mud or concrete on both sides in order to guide the water more efficiently; the channels are straight and elegant.

Channels lead to an entrance gate at each property, and from there to minor furrows.
"Most members have a water-collection point too (dams, tanks, fish ponds) to store water for the rest of the week. All water not used goes back into the river, so none of it is wasted." [3]

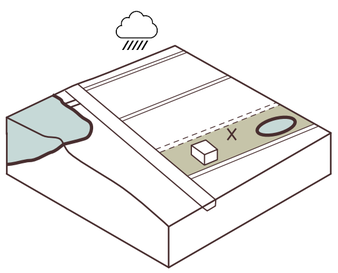
Plentiful Water Situation



Registered for Next Leiwater Season

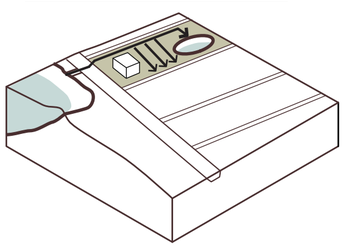


Registered for Next Leiwater Season

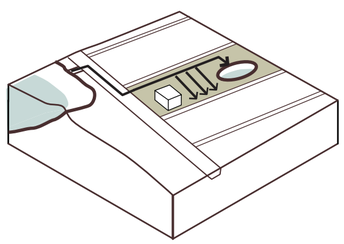


Not Registered for Next Leiwater Season

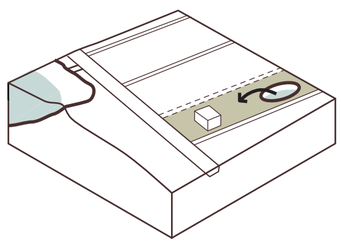
Limited Water Situation



first half hour in a week

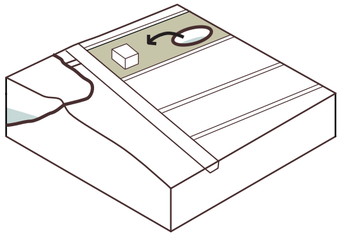


second half hour in a week

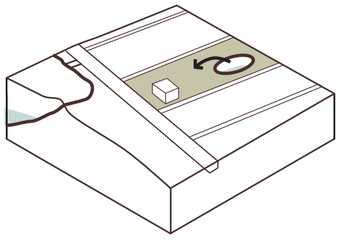


no leiwater access

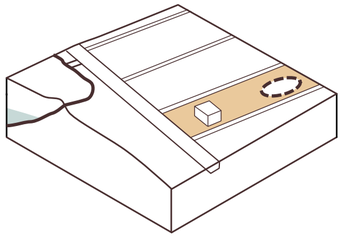
Drought Situation



use water storage



use water storage



no water

Software

• Committee Management

Releases from the reservoir into the sluices are always controlled by the municipality and seldom by the leiwater committee[4] in order to manage the use-turn and enforce sequence of sharing.

• Construction

The construction and operation are in the hands of the coop workers in history, and now “each system is monitored by a specially appointed irrigation Sheriff.” [5]

• Leiwater Turn

The leiwater turn –or amount of run time allocated to each user –is pre-determined. Every year, property owners who have a leiwater in their property need to register for next year’s use and are paid by months. A whole leiwater turn is one week and every property will have equal 30-minutes allotments to fill their own storage ponds by leiwater. [6]

• Benefits

1. The leiwater has a civil value.

Although the original leiwater are only for irrigation, now it has become the heritage in towns and villages. [7] As a part of the city, the leiwater has become an essential piece of public landscape, where children can play with water [8], citizens can enjoy a comfortable view along the street.

2. The leiwater has an ecological value.

As the city is becoming more and more crowded with buildings, the system has an increased value because of its eco-system services. The leiwater are always collected in the resuvior or dam before it reach to the private properties and that place has become a paradise for wildlife, especially birds and fishes. [9] Also, the water source has provided abundant water for trees and vegetations growing there, and that makes a cool and shaded micro climate.

LEIWATER

Notes:

1,2,5 http://towerwateraandebreede.blospot.com/2017/10/the-lure-of-leiwater.html

3,4 https://www.montaguleiwater.co.za/

6 https://twk.gov.za/

7 https://www.stanfordconservationtrust.org.za/2019/02/27/leiwater-application-for-heritage-status/

8 https://capeinfo.com/blogs/beezus/2015/03/17/montagu-is-as-charming-as-ever-but-tourism-authorities-need-a-wake-up/attachment/091/

9 https://www.montagu.org.za/what-to-do/montagu-leiwater-dam/

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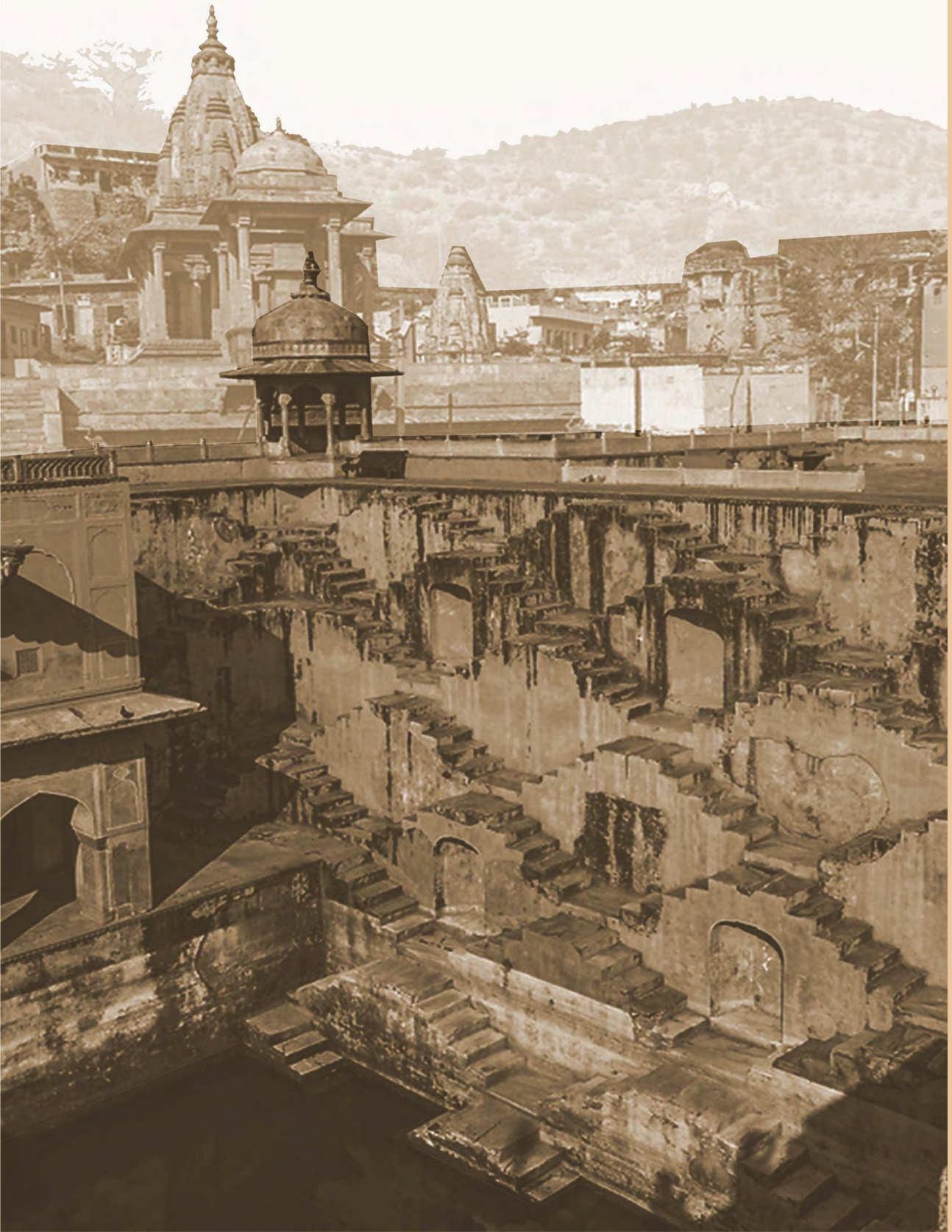
https://www.montagu.org.za/what-to-do/montagu-leiwater-dam/

Student Contributor:

Zhu, Run-Hao



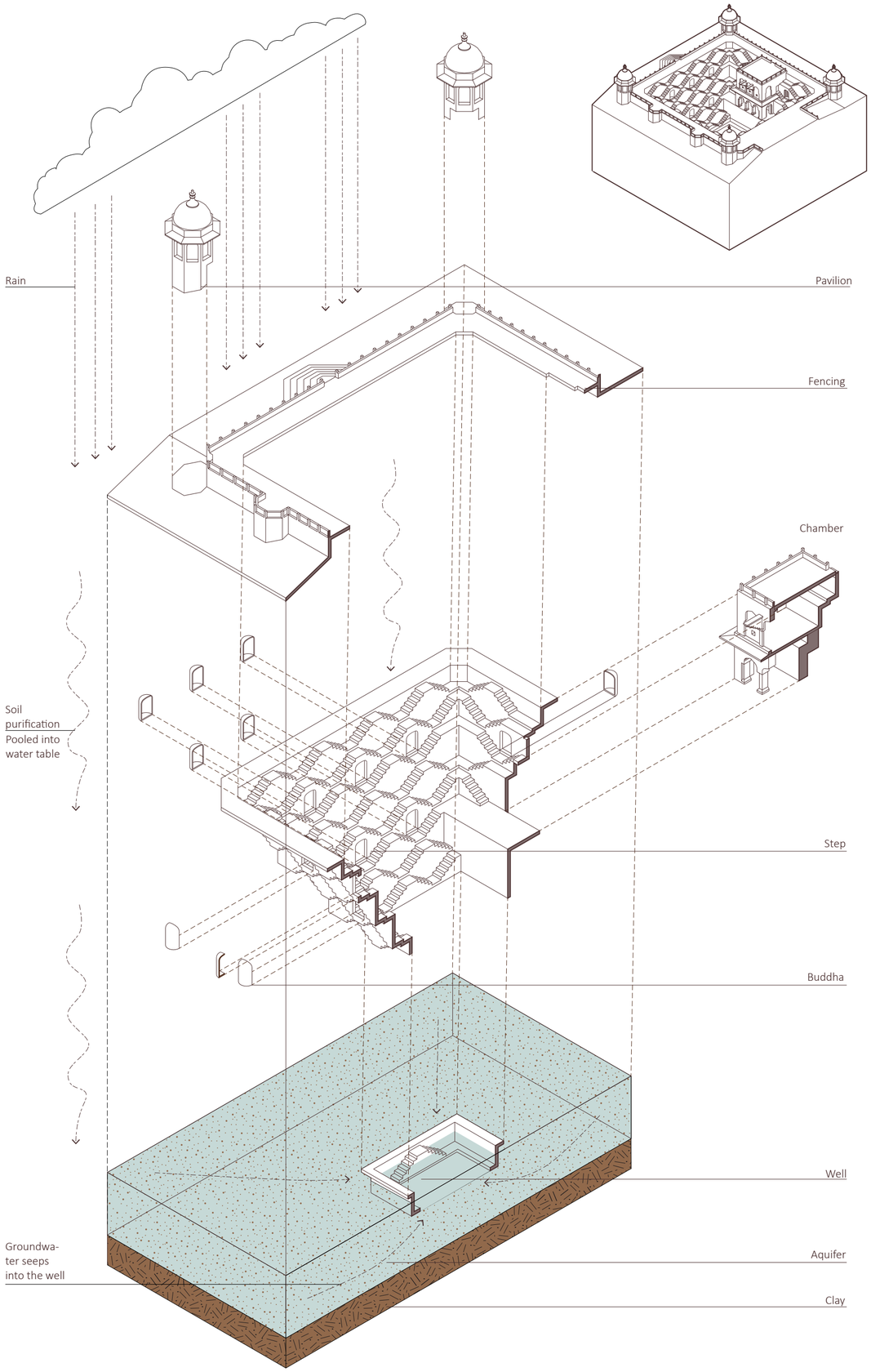
STEPWELL

Monumental Sunken Plaza Providing Drinking Water for All

Stepwells are water suppy systems in India, especially in Gujarat and Rajastan. They can collect drinking water from groundwater, and also can provide public gathering spaces and reglious activities spaces for all.

Photo: https://blaineharrington.photoshelter.com/gallery-image/G0000A4mFfS6EcRQ/I0000PIYy7aX7skM/35.

STEPWELL



Case study: Panna Meena Ka Kund, Jaipur, Rajasthan, India

STEPWELL

Hardware

Stepwells, including wells and ponds, are large-scale public buildings that provide water and rich cultural and spiritual significance. They are prominent civic infrastructures which provide public access to groundwater in arid and semiarid regions of India, principally Gujarat and Rajastan, 250 BCE to present.

In Hindi-speaking regions, “it is also known as bawdi, bawri, baoli, bavadi, and bavdi (Rajasthani). In Gujarati and Marwari language, they are usually called vav or vaav. Other names include kalyani or pushkarani (Kannada), baoli (Hindi) and barav (Marathi)”.[2]

The predecessor of Stepwells, rock-cut wells, appeared as early as 250 BCE.[3] Between the 2nd and 4th centuries CE, the earliest stepwell appeared. Over the next five centuries, stepwells spread rapidly from south to the north in Rajasthan, and then to northern and western India.[4] Stepwell development peaked from the 11th to 16th centuries CE, extending to neighboring countries such as Pakistan. In the 19th century, British colonizers believed stepwells would breed bacteria and disease, so they removed many of them.[5] Excessive extraction of groundwater also caused groundwater levels to fall and caused many stepwells to cease functioning.[6]

The structure of stepwells is simple. Sharad Chandra (2015) described in Steps to Water, “Stepwells usually consist of two parts: a vertical shaft—protected from direct sunlight by a full or partial roof—from which the water is drawn; and the surrounding inclined subterranean passageway, chambers and steps which provide access to the well.”[7] Classified by size, layout, material and shape, there are two common types of stepwells: one with a large open top and the other with a narrow and deep descending step.[8] Stepwells are mainly square, rectangular, circular and L-shaped.[9] They are made mostly of stone, rubble and brick [10]. Every stepwell is unique and beautiful.[11]

The working principle of a stepwell is very simple: it is a well that provides access to an aquifer. The stepwell penetrates the aquifer and is filled by “seepage”, without excessive surface water flow.[12] Water in stepwells is mainly used for drinking, because the process of water infiltration into the aquifer is also the process of water purification.[13] Stepwells provide cleaner water than other water facilities in India, such as reservoirs and ponds. Of course, some water is also used for irrigation and bathing, especially during religious ceremonies.[14]

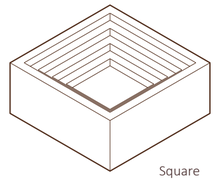
Stepwells are often commissioned by the royal family, monks, wealthy and powerful people, who hire masons to design and build them.[15] There are also many stepwells built by villagers, or through donations from other craftsmen, even prostitutes.[16]

Workers who build stepwells include the design of Brahman theologian, the low caste craftsman sompalas, diggers and masons, and even some female workers.[17]

Stepwell's operation and maintenance are based on people's different functional requirements and expected capacity. For example, if a village builds one, it should also be maintained by them. If the temple commisions a stepwell, it should be maintained by the temple itself. And because its maintenance cycle should be closely related to the monsoon, maintenance should be carried out during the dry season, that is, when the water level is low. In addition, many stepwells are sturdily built, and maintenance intervals can be long.

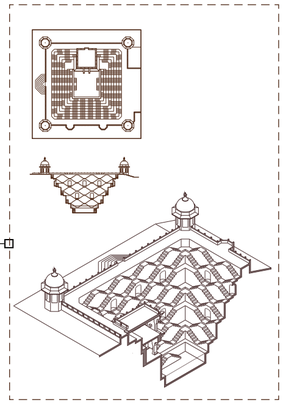
Building Typology

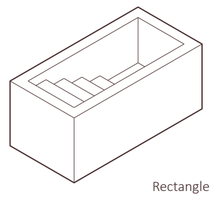
Case Studies



Square

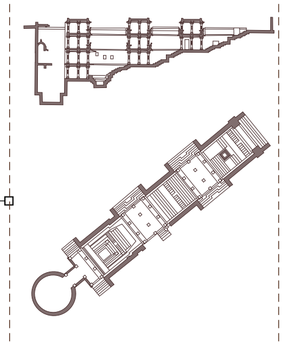
- Panna Meena Ka Kund, Jaipur, Rajasthan, India (16th century)
- Chand Baori, Bandikui, Rajasthan, India (8th-9th century)

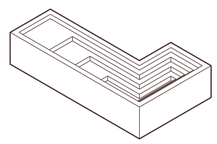




Rectangle

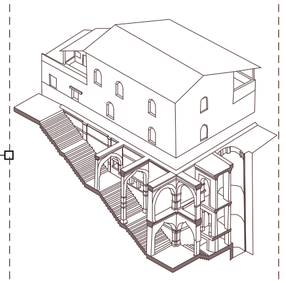
- Maata Bhavani ni Vaav, Asarwa, Ahmedabad, India (11th century)
- Rani ki Vav, Patan, Gujarat , India (11th century)

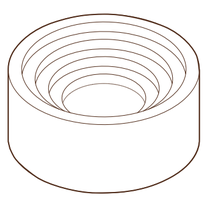




L-shaped

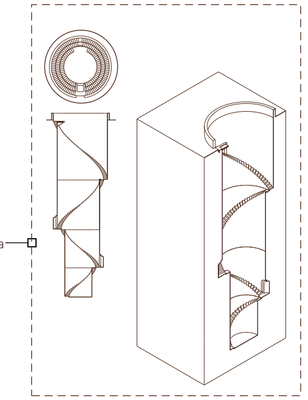
- Amritavarshini Vav, Ahmedabad, Gujarat, India (18th century)





Circle

- Hanuman Dhara, Chitrakoot, India

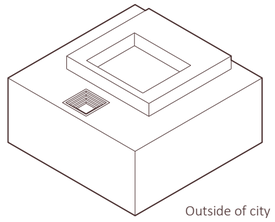


STEPWELL

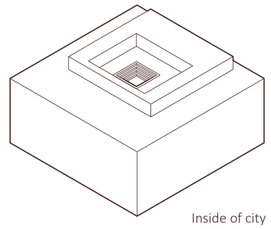
Urban Typology

Stepwell can exist anywhere, including rural, urban, or temple. And it can be built inside or outside the city according to different terrain conditions and functional requirements.[18]

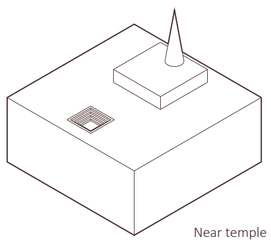
Case study:
Outsite of city/Near the temple--- Rani ki Vav, Patan, Gujarat , India
Insite of city/adjacent to temple--- Panna Meena Ka Kund, Jaipur, Rajasthan, India



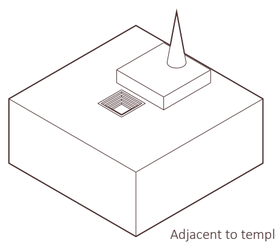
Outside of city



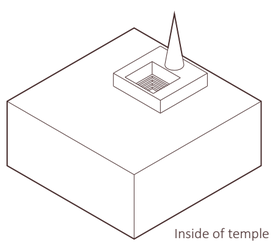
Inside of city



Near temple



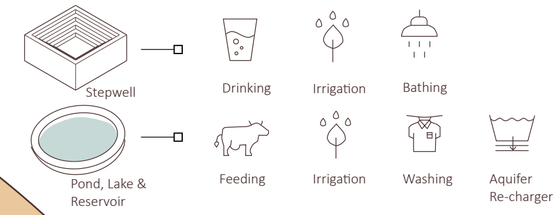
Adjacent to temple

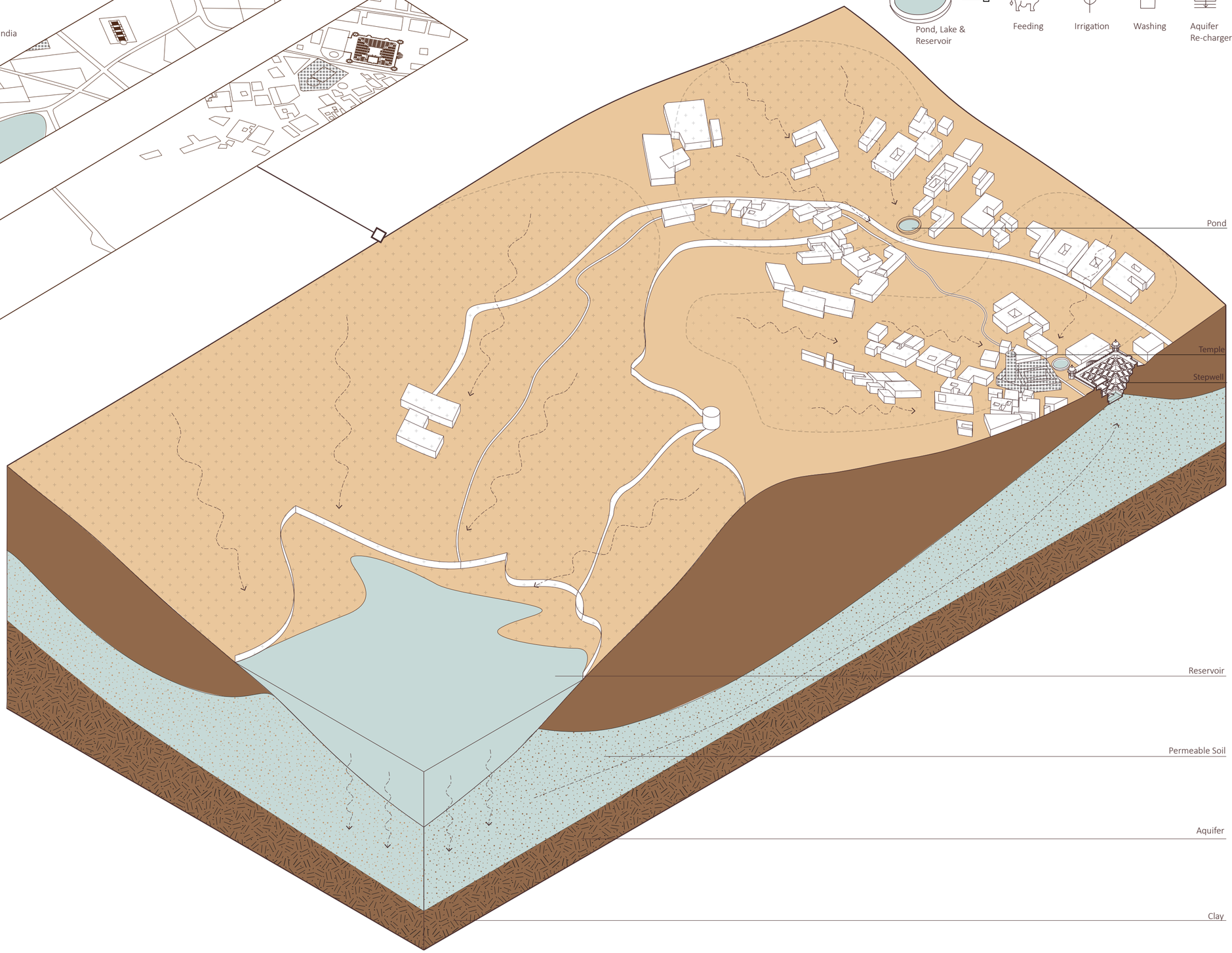


Inside of temple

STEPWELL

Water Useage





Software

Social: Stepwells serve people of all classes, incomes, ages, and genders in India, such as royalty, officials, wealthy businessmen, villagers, and even prostitutes.[19] Lautman (2019) said "They were the ultimate public monuments, available to both genders and every religion—seemingly anyone at all but for the lowest-caste Hindu." [20]

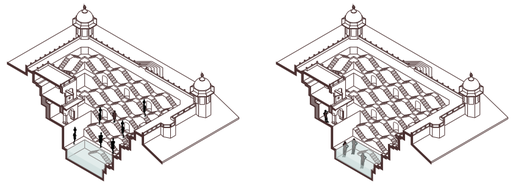
Religious: Stepwells served as underground shrines in Hinduism. The surrounding slopes, steps, and pavilions are full of idol carvings and religious sympbolism, important spiritual backgrounds for ritual bathing, prayer, or sacrifice.[21]

Ceremonial and political: Stepwells serve also as an important vehicle for the royal family or those in power to show off their wealth and record history. The most famous stepwell was created by Queen Udayamati to honor her spouse.[22]

Urban: Because stepwells are cooling underground structures, they provide cool shelter.[23]

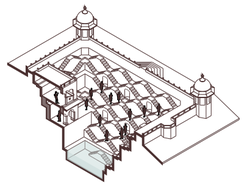
Ecological: The stepwell is also a place where many animals live. It provides valuable water in arid areas for bees, fish, lizards, palm squirrels, parrots, pigeons, and turtles.[24]

Cultural: Stepwells often have complex carvings and paintings as well as buildings and columns which preserve and display Indian culture.[25]

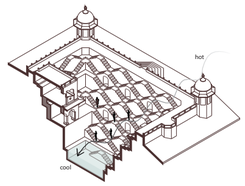


Social
(Collecting

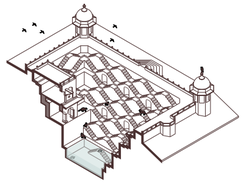
Religious
(Bathing)



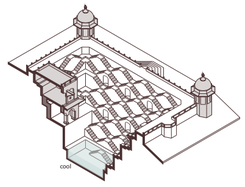
Ceremonial and Political
(Gathering)



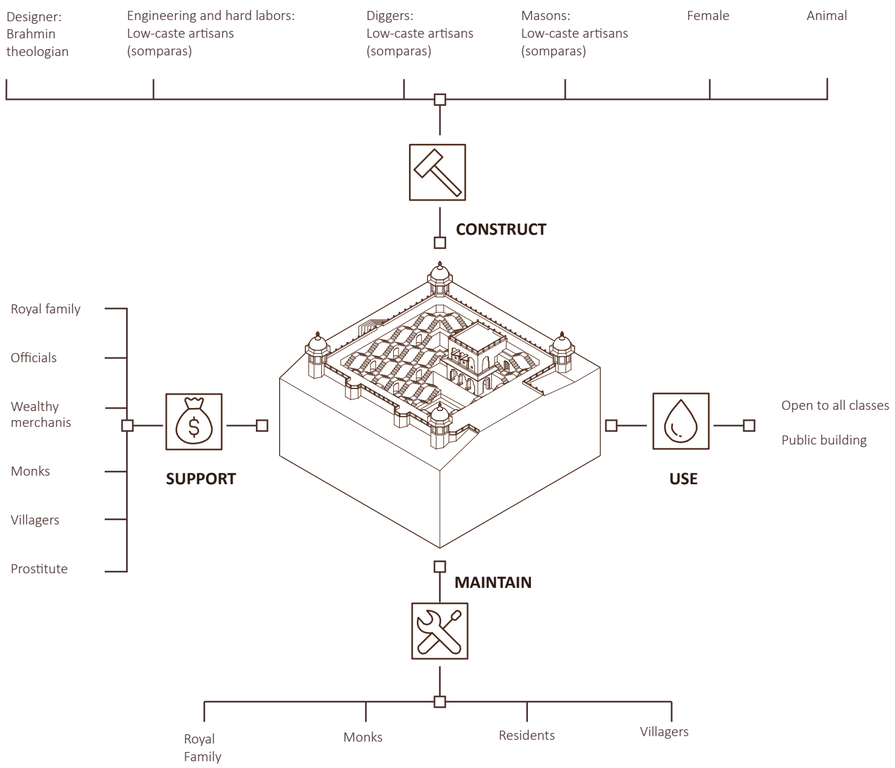
Urban
(Relaxing)



Ecological
(Providing habitat)



Cultural
(Building)



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1 Aparna. "The historic Panna Meena ka Kund in Jaipur" (2018).

2 https://en.wikipedia.org/wiki/Stepwell

3 https://en.wikipedia.org/wiki/Indian_rock-cut_architecture

4 Lautman, V. "Stepwells" (2019).

5 Livingston, M. "History of India's Stepwells" (2003).

6 Sheth, Priyanka, Tanvi Jain, and Riyaz Tayyibji. "Stepwells Of Ahmedabad" - exhibition at Yale Architecture (2018).

7 Chandra, S. "Steps to Water: Stepwells in India" (2015).

8 Jaipur. "Chand Baori" (2018).

9 Lautman, V. "Stepwells" (2019).

10 Lautman, V. "Stepwells" (2019).

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15 Livingston, M. "History of India's Stepwells" (2003).

16 Livingston, M. "History of India's Stepwells" (2003).

17 Livingston, M. "History of India's Stepwells" (2003).

18 Sheth, Priyanka, Tanvi Jain, and Riyaz Tayyibji. "Stepwells Of Ahmedabad - exhibition at Yale Architecture" (2018).

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https://tripnetra.com/blog/panna-meena-ka-kund-jaipur

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Wu, Jing

TEMAZCAL

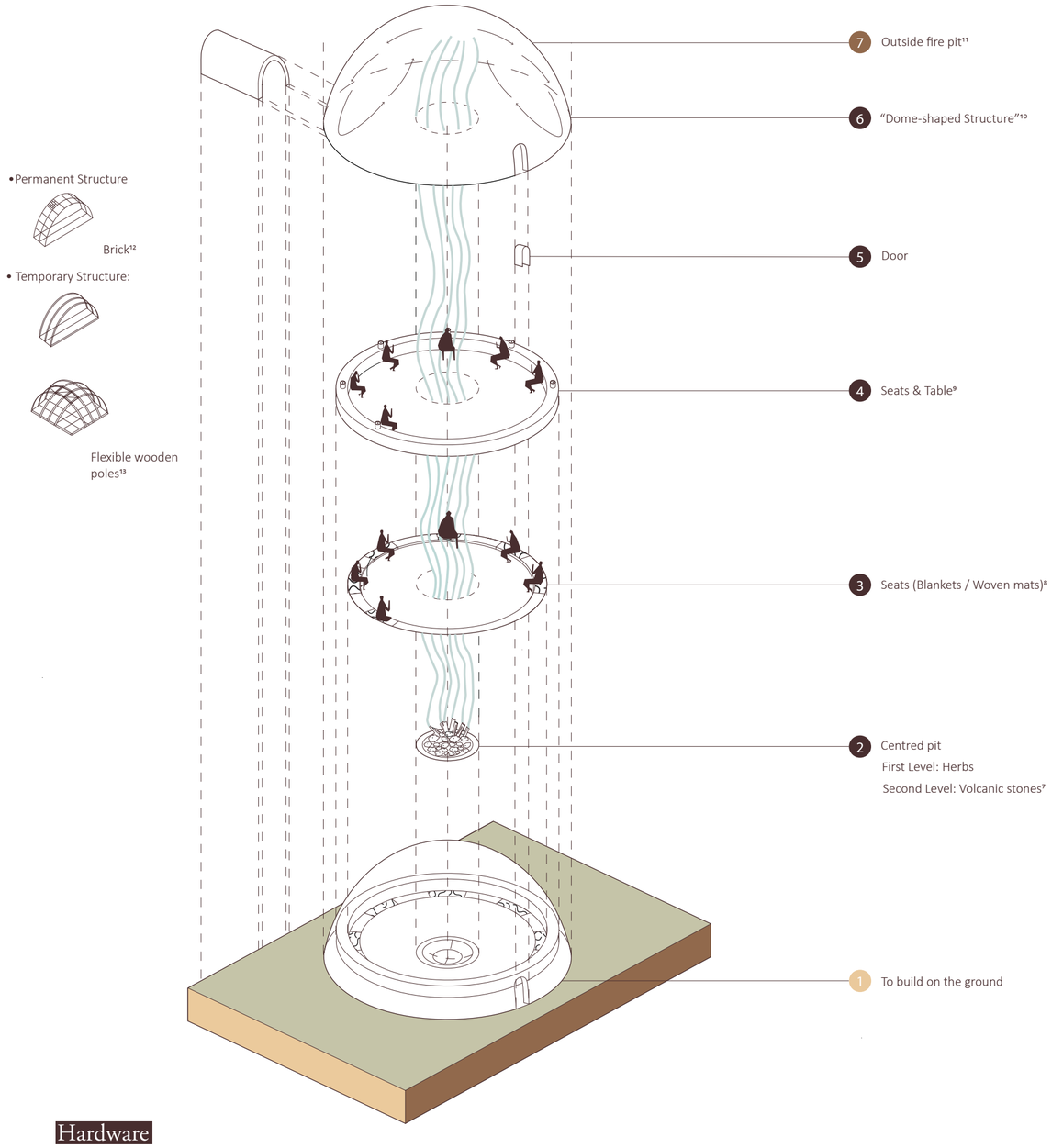
Small Domes Contain Whole Universe

Temazcal is a dome-shaped low heat small lodge. By burning volcanic stones in the centered-pit, heat is generated. Hot water steam fills the entire space.

Ancient small sweat lodge[1]. Photo: Rivera P., Sacredness of the Temazcal- A Mayan Tradition, 2016.

TEMAZCAL

Mesoamerica. Mayan Civilization. Generating steam AND cultural symbolism.[2]
Low heat sweat lodge[3]. Orignates from Nahuatl language, Aztec: Temas-"To Bath", Calli-"Housing"[4]. Circa 950- 1539 CE.[5]
Temazales/Temascal/emescal | temāzcalli | [tema:s'kal:i]
Related technologies: North Africa & Turkey: Hammam; Europe: the sauna of Scandinavia; Pompeii: Roman Baths; India: Sweat Lodge.[6]



•Permanent Structure

Brick[12]

• Temporary Structure:

Flexible wooden poles[13]

Hardware

- "Temazcal is a dome-shaped strcuture,"[14] and it has various construction styles in different regions.
- There are two types of structure: one permanent, one temporary.[15]
- Permanent temazcals are constructed from volcanic rocks, bricks, and cement adobe.
- Temporary temazcals are constructed from a frame made of flexible wooden poles covered with blankets, clothes, and mats.[16]
- Participants heat volanic stones in the center or near a wall of the temazcals (outside fire-pit) to produce steam heat.[17]
- "Volanic stones do not explode from the high temperature".[18]

TEMAZCAL

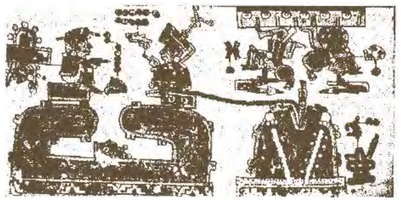


Image [1]: Codex Selden records the picture of earth birth.

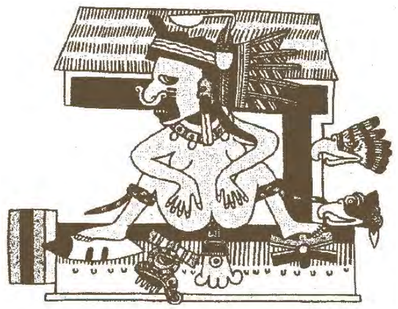


Image [2]: Codex Borgia depicts that "the god Tlazolteotl in birthing position, with flower emerging from vagina."

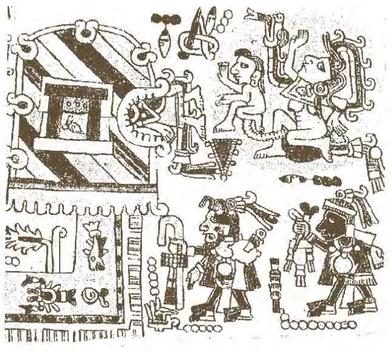


Image [3]: In Codex Nutttall, "Flint- Sheil Quechquemitl entering cave after giving birth."

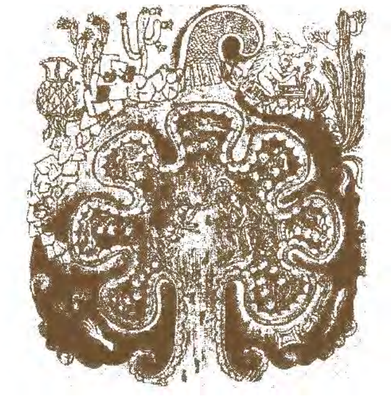


Image [4]: Ancester of Cave: Chicomoztoc.

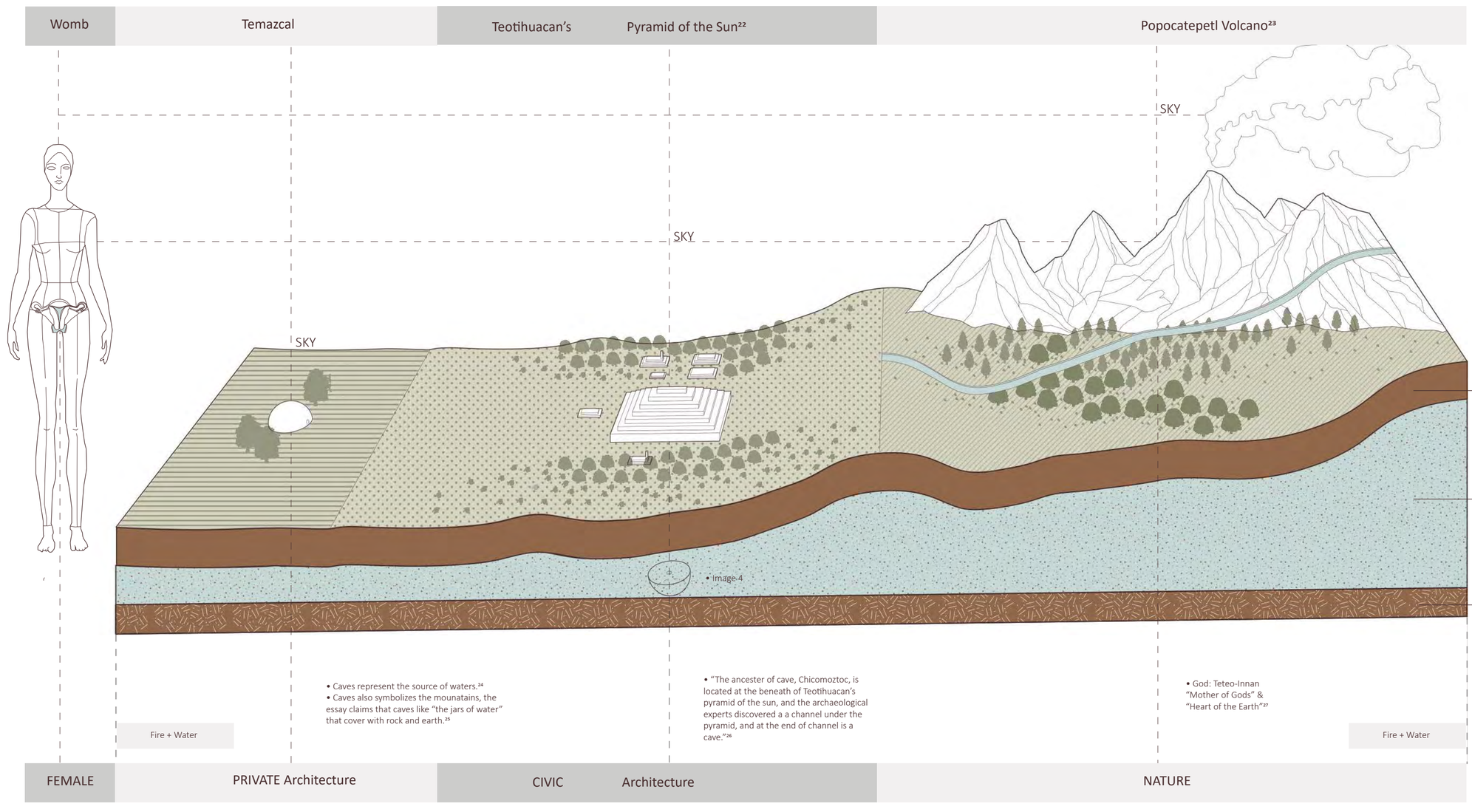
TEMAZCAL

Governed by Mythologyical Symbolism

• The shape of the temazcal represents the uterus, and the dome symbolizes womb.[19]

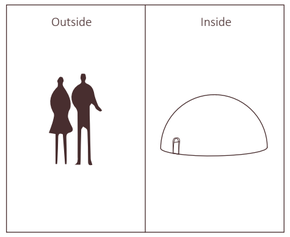
• In ancient Mayan mythology, a dome and hot steam symbolize waters of the earth.[20]

• On the small scale, dome (temazcal) represents the natural mountains that is the source of water.
On the medium scale, the artificial cave "chicomoztoc" is located at the beneath of Teotihuacan's pyramid of the sun, which symbolizes the natural mountains that is the source of water.[21]



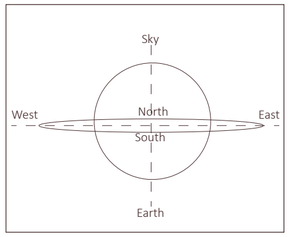
TEMAZCAL

1



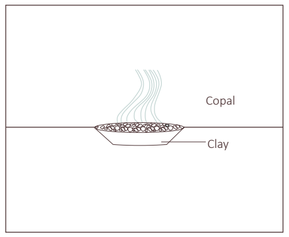
External World "Inner spirtual world[28]"

2



"To gather participants to give repect to 6 directions[29]"

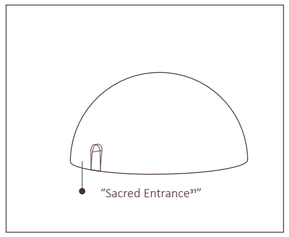
3



Participants do cleansing with traditional copal or tree resins.

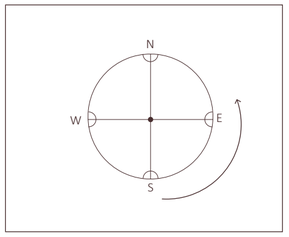
"To blow this smoke over partici-pants'body[30]"

4



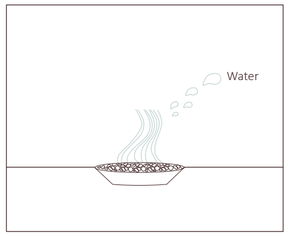
Participants need to kneel to enter the dark entrance[32].

5



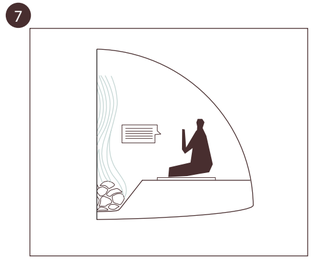
Participants follow clockwise directions through the whole ceremony[33].

6



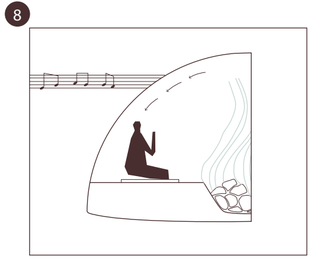
Participants pour water on heated stones to create hot air-flow through dome[34].

7



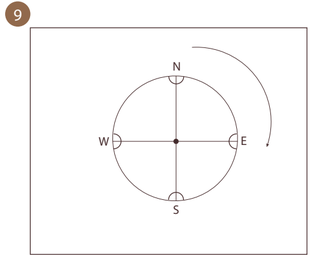
Participants state their name and intention for this purifica-tion ritual[35].

8



Participants sweat at this moment accompared by rhythmic chanting and music inside the dome[36].

9



In the end, participants follow counter-clockwise direction to exit the dome[37].

The Steps of the Purification Ritual

Software

• In Nahuatl culture of central Mexico, "Temazcalteci" symbol-izes "goddess of the sweat bath."[38]

• "Water comes from the earth, which is conceptually related to feminine fluid."[39]

•In other words, thermal cycling also functions inside of a human body.

• Caves and sweat baths are also considered as female.[40] "By extension, entrances to the earth are metaphoric portals into the female body, and water that comes from the earth is conceptually related to feminine fluid."[41]

• The shape of temazcal represents the uterus, and the dome symbolizes womb.[42]

• The shape of temazcal represents "the vagina and womb of the earth mother."[43]

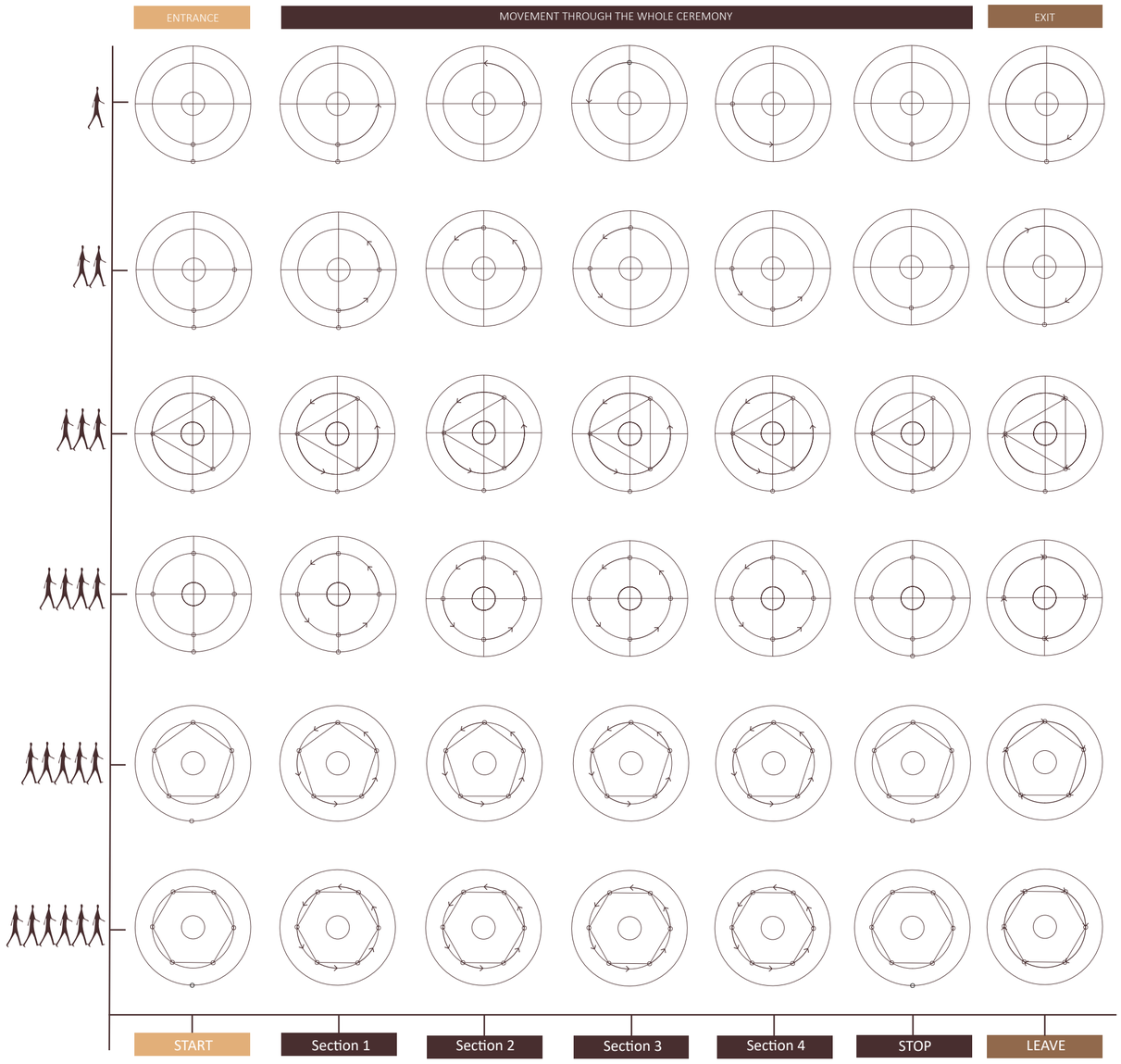
• The top of temazcal represents the sky; the floor of temazcal is formed from the earth and is associated with the womb.[44]

• When people enter, they should enter in the gate that is in south direction.[45]

• Participants move in a clockwise direction from south, west, north, and east.[46]

• Participants focus on their spirtual heart, and at the same time, they produce sweat through this ritual due to the fact that hot steam have cycled inside the temazcal.[47]

TEMAZCAL



Living Ritual : Movement Notation

• Motion and movement in design plays an important role in landscape architecture, which provides this idea by Lawrence and Anna Halprin in the mid-20th century.[48]

• Temazcal is as the significant place for participants who take part in the whole purification ceremony, and the dynamic movement of participants enrichs the interesting potential in the small space.

• Participants take four sections of purification ritual standing in different location, which movement of participant is dynamic.[49]

• Small dome acoomodates up to six people.[50]

• Different number of people in temazcal depicts various movement tracks.

Images:

1 Image 1. McCafferty S.D. & McCafferty G.g. (2008). Back to the Womb: Caves, Sweatbaths and Sacred Water in Ancient Mesoamerica.

2 Image 2. McCafferty S.D. & McCafferty G.g. (2008). Back to the Womb: Caves, Sweatbaths and Sacred Water in Ancient Mesoamerica.

3 Image 3. McCafferty S.D. & McCafferty G.g. (2008). Back to the Womb: Caves, Sweatbaths and Sacred Water in Ancient Mesoamerica.

4 Image 4. [1] https://vistasgallery.ace.fordham.edu/items/show/1738;
[2] McCafferty S.D. & McCafferty G.g. (2008). Back to the Womb: Caves, Sweatbaths and Sacred Water in Ancient Mesoamerica.

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1 Rivera P. (2016). Sacredness of the Temazcal – A Mayan Tradition.

2 Rivera P. (2016). Sacredness of the Temazcal – A Mayan Tradition.

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11 McCafferty S.D. & McCafferty G.g. (2008). Back to the Womb: Caves, Sweatbaths and Sacred Water in Ancient Mesoamerica.

12 Rivera P. (2016). Sacredness of the Temazcal – A Mayan Tradition.

13 Https://www.facebook.com/casitasagrada/

14 [1]. Rivera P. (2016). Sacredness of the Temazcal – A Mayan Tradition.
[2]. McCafferty S.D. & McCafferty G.g, page 1.

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17 McCafferty S.D. & McCafferty G.g, page 1.

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19 McCafferty S.D. & McCafferty G.g, page 1.

20 McCafferty S.D. & McCafferty G.g, page 1.

21 McCafferty S.D. & McCafferty G.g, page 2.

22 [1]. https://en.wikipedia.org/wiki/Pyramid_of_the_Sun#/media/File:Teotihuac%C3%A1n_-_Modell_Sonnenpyramide.jpg
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23 McCafferty S.D. & McCafferty G.g, page 2.

24 McCafferty S.D. & McCafferty G.g, page 2.

25 McCafferty S.D. & McCafferty G.g, page 3.

26 [1]. McCafferty S.D. & McCafferty G.g, page 3.
[2]. Maestri N. (2018). Chicomoztoc, the Mythical Aztec Origins.

27 McCafferty S.D. & McCafferty G.g, page 3.

28 Rivera P. (2016). Sacredness of the Temazcal – A Mayan Tradition.

29 Rivera P. (2016). Sacredness of the Temazcal – A Mayan Tradition.

30 Rivera P. (2016). Sacredness of the Temazcal – A Mayan Tradition.

31 Rivera P. (2016). Sacredness of the Temazcal – A Mayan Tradition.

32 Rivera P. (2016). Sacredness of the Temazcal – A Mayan Tradition.

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36 Rivera P. (2016). Sacredness of the Temazcal – A Mayan Tradition.

37 Rivera P. (2016). Sacredness of the Temazcal – A Mayan Tradition.

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TEMAZCAL

38 Alba R.H. (1996). Temazcal I/III. The Traditional Mexican Sweat Bath

39 McCafferty S.D. & McCafferty G.g, page 3.

40 McCafferty S.D. & McCafferty G.g, page 3.

41 McCafferty S.D. & McCafferty G.g, page 4.

42 McCafferty S.D. & McCafferty G.g, page 4.

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47 Spafinder. (2016). 2016 Spa Trends Report: The Benefits of Temazcal, Living well.
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49 Wasserman J. (2012). A World in Motion: The Creative Synergy of Lawrence and Anna Halprin.

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TINAJA

Unseen Landscape Water Bowls in the Wilderness

Tinajas are natural bedrock depressions in dry and arid areas, formed through erosion caused by streams, wind, or other weathering processes.[1]

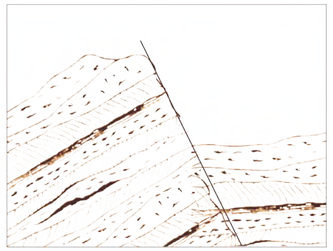
Photo: Ernst Tinaja, Big Bend National Park, TX. Photo credit: Brent Clark

TINAJA

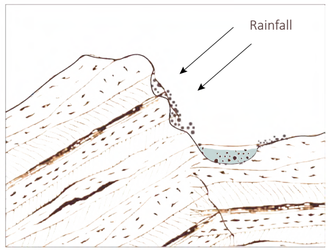
Tinaja, a Spanish term, a translates to bowl or jar in English. It is a term originating in the American Southwest for bedrock depressions, also called water catchment areas, developed through erosion by streams, wind, other weathering processes.[2]
One such example of series of tinajas is “Tinajas Altas Mountians” in Arizona. The geology of the Tinajas Altas played a significant role in providing a source of water to early travelers. Tinajas are formed due to the natural unequal erosion of the streambed.[3] In some ephemeral streams, these tanks fill up with water after a rainfall and water remains there for a prolonged period, serving as a major water source.[4]

Formation of Tinaja

Sedimantary rocks



Faulting process

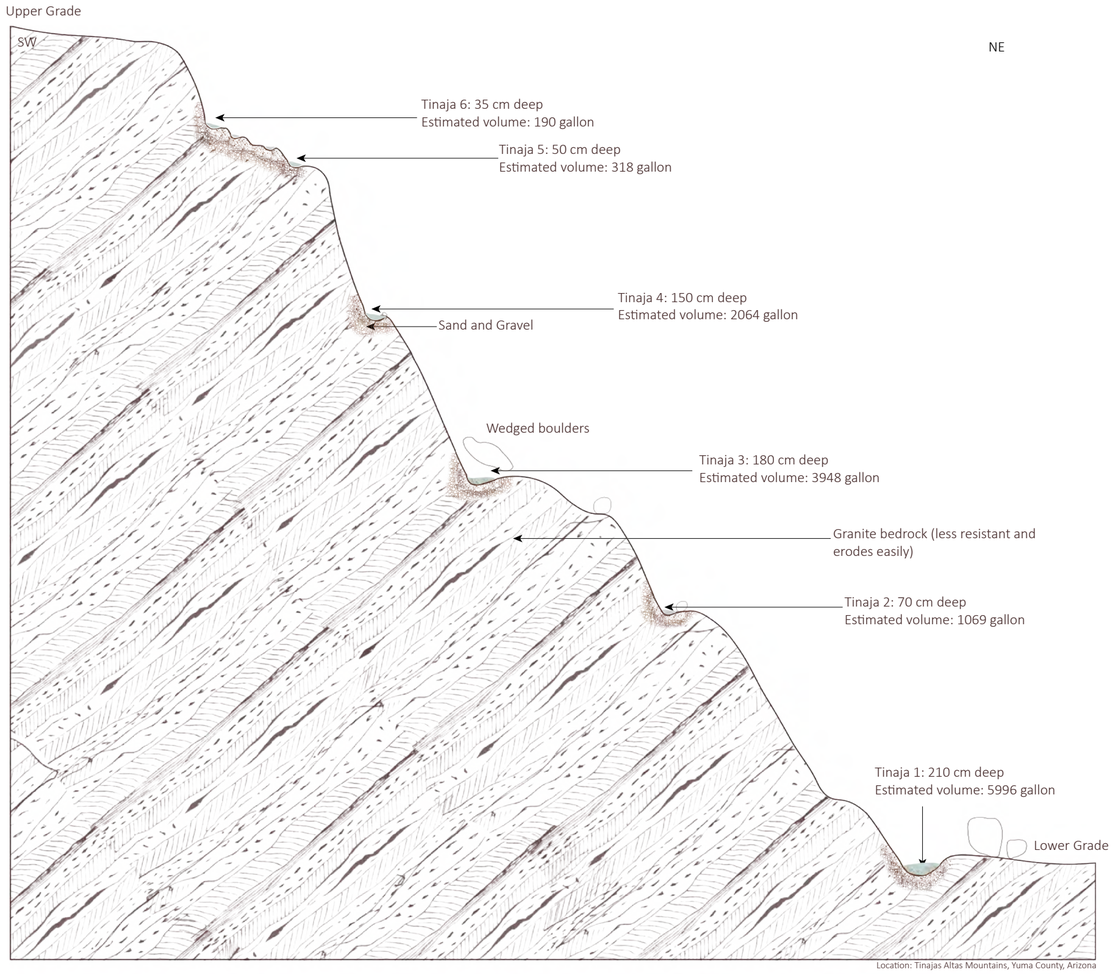


Tinaja forms due to weathering of softer rocks

Tinajas are made of natural elements like sandstone, granite and often filled with sand and debris from storm runoff. The mountain surrounding tinajas are comprised of coarse-grained granites that are actively weathering, and the rock is extremely friable in many places.[5]
They can be categorized as Exposed tinaja: one that receives virtually no shade during the day from vegetation or adjacent landscapes. And Protected tinaja: one that is shaded for some or most of the day, while a very protected tinaja would rarely receive direct sunlight .[6]

A catchment area is an immediately adjacent outcrop of exposed bedrock that catches rainfall and funnels it into the tinaja. They collect rainwater from the mountains above them and hold and store the water for an extended period.[7] The period of water stored depends on the size, placement, temperature, and amount of rainfall in the area. They replenish over time (6 months) through rainfall and runoff. Deep tinajas are usually filled with sand and are stored for a longer time than the ones without sand because without sand water seeps underground and evaporates easily.[8]

Section Profile



TINAJA

Network of Trails Transmitted Orally

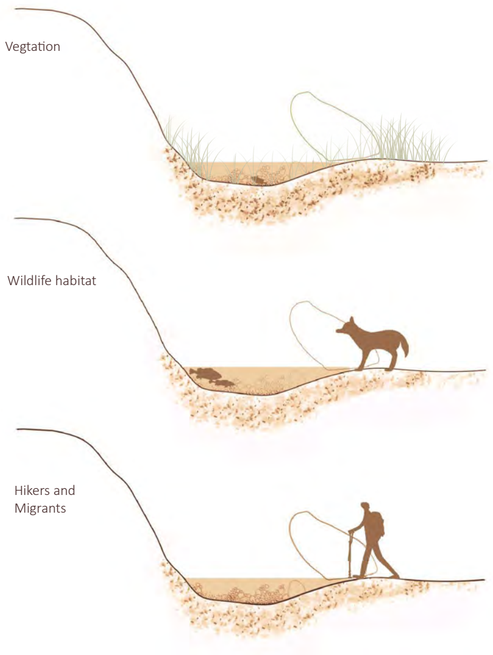
The nearly perennial water at Tinajas Altas attracted humans as early as the Middle Archaic period. Although considerable archaeological evidence suggests the people using this region were Yuman, historical documentation also indicates use by Hia C-ed O'odham.[9] In conclusion the site ranged from brief forays to longer use as seasonal camps, and that much of the use was focused in the late prehistoric and early Historic periods.

Five types of tinajas occurring in stream channels in the southwestern United States include[10]
- joint-block irregularities
- normal potholes
- scour depressions
- riffle hollows
- plunge pools

The longevity of water can be classified as:[11]
- Ephemeral tinajas are arbitrarily restricted to those containing water for consecutive periods of less than one month per year.
- Intermittent tinajas are those containing water for consecutive periods of more than one month but less than a year.
- Perennial tinajas, water is present throughout the year.

TINAJA

Uses



Prior to 11,000 years ago in the middle and late Wisconsin-Period, ice age woodlands with Single-leaf pinyon, California juniper, Utah juniper, Sonoran scrub oak and Joshua tree were found at the Tinajas Altas and elsewhere in Sonoran Desert lowlands. Tinajas have also served cave fish species in the area along with the native wildlife.[12]

Tinajas (Natural Potholes in Other Regions

Fig. 1 Tinaja de la Papagos, Mexico

Fig. 2 Dry tinaja (pothole) at Sandstone Bluffs at El Malpais National Monument, New Mexico

Fig. 3 Water holes, on the Schronbach creek, Schronbachtal valley, Isarwinkel, near Lenggries, Bavaria

Fig. 4 Guelta Afilal, waterhole in the desert of the Hoggar, Ahaggar Mountains, Wilaya Tamanrasset, Algeria, Sahara, North Africa

TINAJA

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Image Sources

Fig. 1 https://serturista.com/mexico/el-pinacate-y-gran-desierto-de-altar/

Fig. 2 https://scenicusa.net/080906.html. Photo credits: Ben Prepelka

Fig. 3 https://www.bromba.com/berge/bn150718.htm

Fig. 4 http://www.alpimages.net/mobile_archive.php?archive=2010010483

Student Contributor:

Godhani, Yashoda

Do-It-Yourself Modular Farming With Local Materials

A dry farming technique used by Zuni people to grow crops in arid regions in Arizona, US around 900 CE.[1]

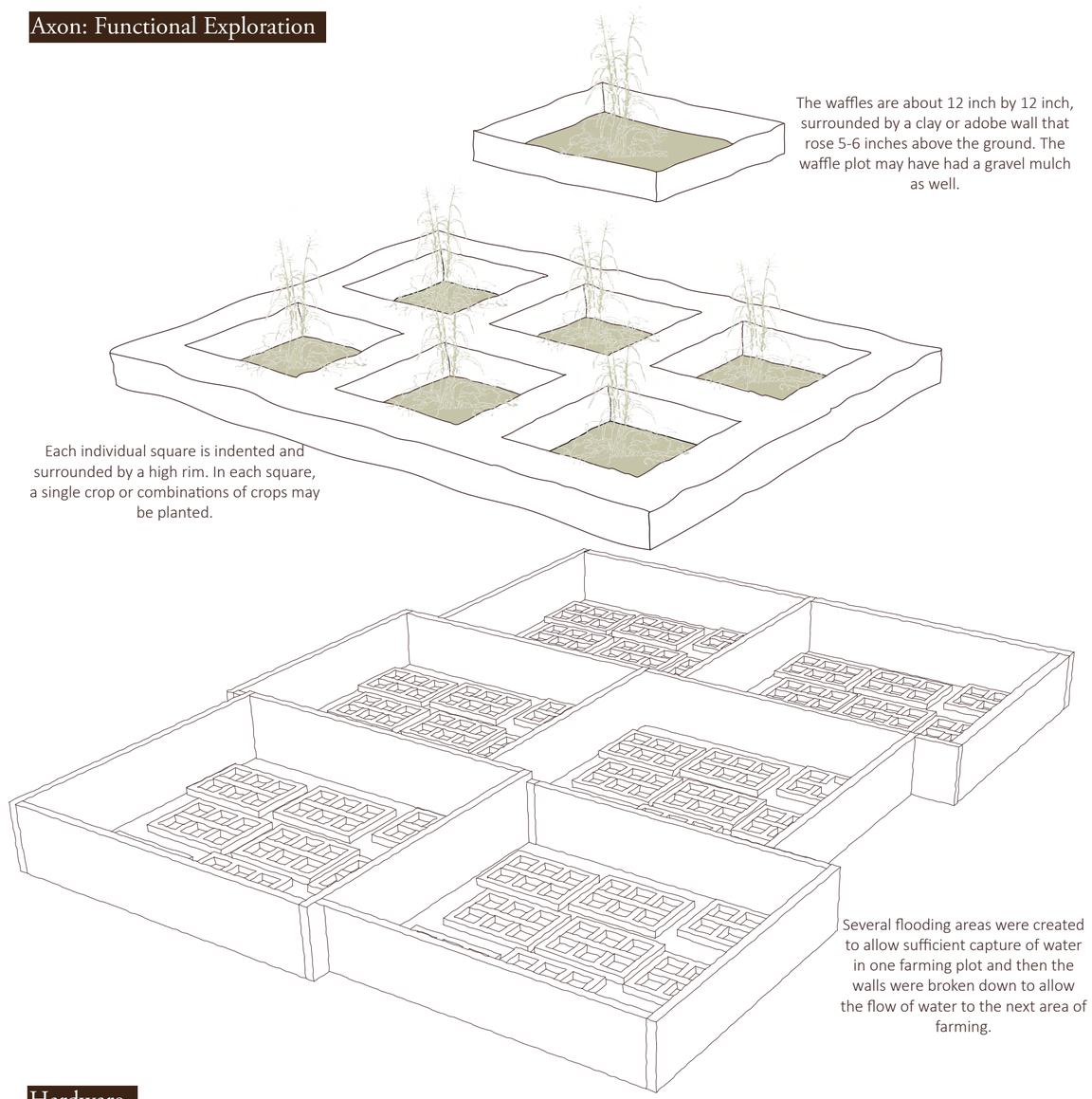
photo: Photographer: T. H. O'Sullivan. Expedition of 1873.

WAFFLE GARDEN

WAFFLE GARDEN

- Definition: A dry farming technique used by Zuni people to grow crops in arid regions of southwestern US around 900 CE.
  Zuni: A:shiwi; formerly spelled Zuñi are Native American Pueblo people native to the Zuni River Valley (in modern day Arizona).[2]
- Etymology: known as the floodwater farming by Zuni people
- Synonyms: bordered garden, wall garden, Zuni farming, basket garden, grid garden

Axon: Functional Exploration



The waffles are about 12 inch by 12 inch, surrounded by a clay or adobe wall that rose 5-6 inches above the ground. The waffle plot may have had a gravel mulch as well.

Each individual square is indented and surrounded by a high rim. In each square, a single crop or combinations of crops may be planted.

Several flooding areas were created to allow sufficient capture of water in one farming plot and then the walls were broken down to allow the flow of water to the next area of farming.

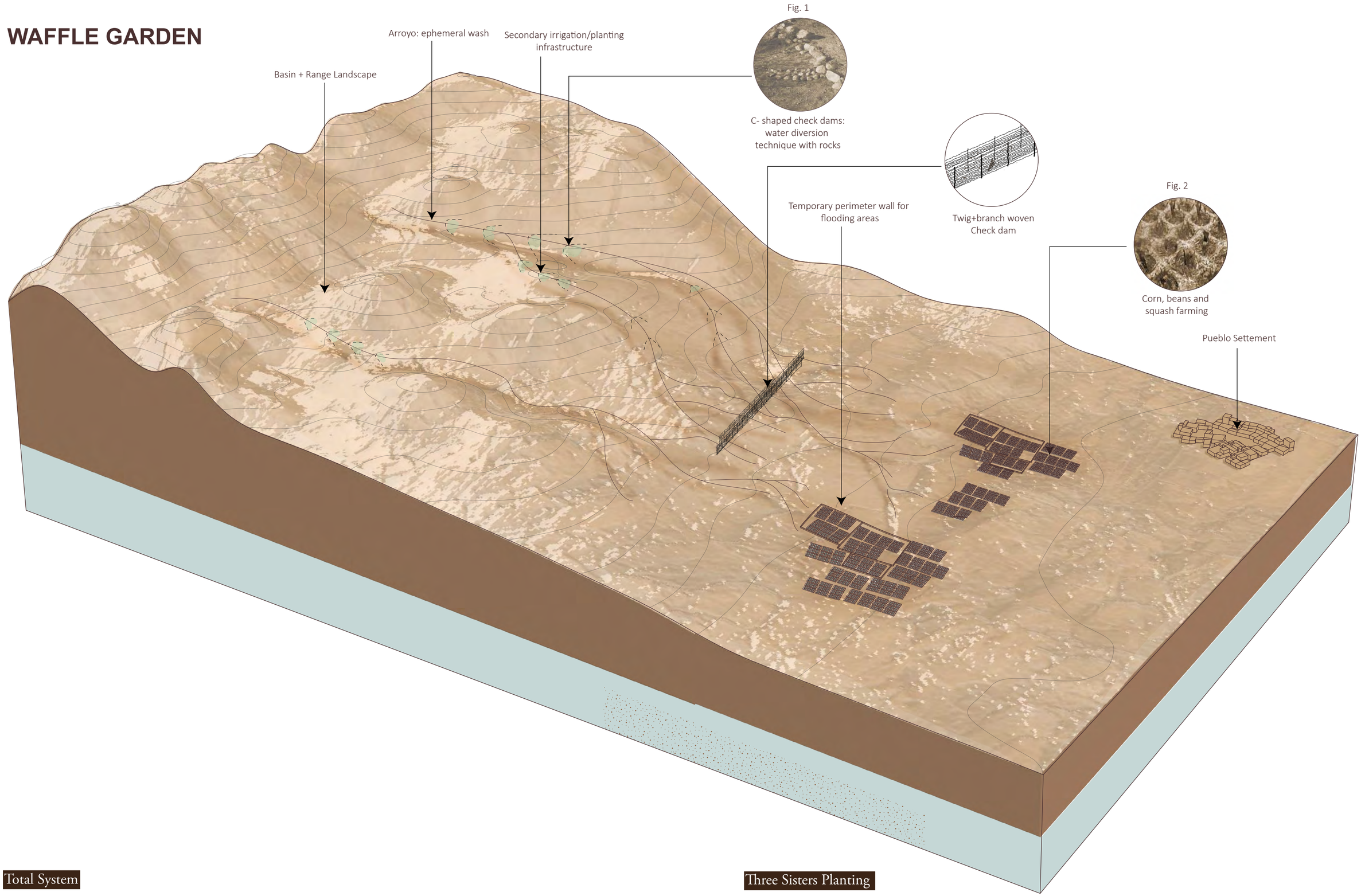
Hardware

The Zuni people developed this waffle-garden design, which is still used today as an ecological method of conserving water. This garden design will work anywhere in the country where there are dry summer conditions. This method served to hold the water in the soil longer because of the sunken beds, to retard evaporation.[3]

The depressions catch and hold water close to the plants' roots. Grid gardens are similar, with 10-foot-square grids bordered with rocks. Larger versions of grid gardens have been used in the Southwest and for dryland farming throughout the world.[4] The bordered walls help in protecting plants from rabbits and other animals as well as the wind.[5]

The bordered walls help in retaining water and preventing plants from rabbit's and other animals as well as protecting them from the wind.

WAFFLE GARDEN



Total System

• Traditionally the Zunis relied on runoff, taking floodwater along ephemeral streams and arroyos and diverting it via swales, constructed from brush piles and other natural impediments.[6]

• Several flooding areas were created to allow sufficient capture of water in one farming plot and then the walls were broken down to allow the flow of water to the next area.

• The successes of the crop depend on the slope of the field containing the beds.[7]

• They have been used for capturing, storing and manipulating water from precipitation as well as rain runoff.[8]

Three Sisters Planting

Companion planting is a technique for growing certain vegetables together to take advantage of their natural tendencies and relationships. This is an idea that has been practiced for centuries, and most famously with the “Three Sisters” method.[9]

The plants grown in the waffle garden work together to support growth:[10]

- Sister Beans –deposit nitrogen from the air into the soil, in a form that the plants can use.
- Sister Corn–provides support for beans vines to climb upon.
- Sister Squash –shades the ground with its large leaves to provide a good growing environment for all the sisters.

WAFFLE GARDEN

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https://www.off-grid.net/irrigation-secrets-of-the-ancients/

Image Sources

Fig. 1 Stone Check Dam, Goat Hill, Safford Valley AZ, photo by Peter Arnold, Arid Lands Institute

Fig. 2 https://www.denverpost.com/2005/05/20/irrigation-wisdom-from-the-ancients

Student Contributor:

Godhani, Yashoda

UB-HUMIDS

SUB-HUMID

Drylands

Sub-humid areas

⑤ chinampa

⑦ chultun

㉒ tianjing

Self-sufficient Super Productive Floating Garden.

The Chinampa system is very versatile and productive, allowing permanent cropping the whole year round.

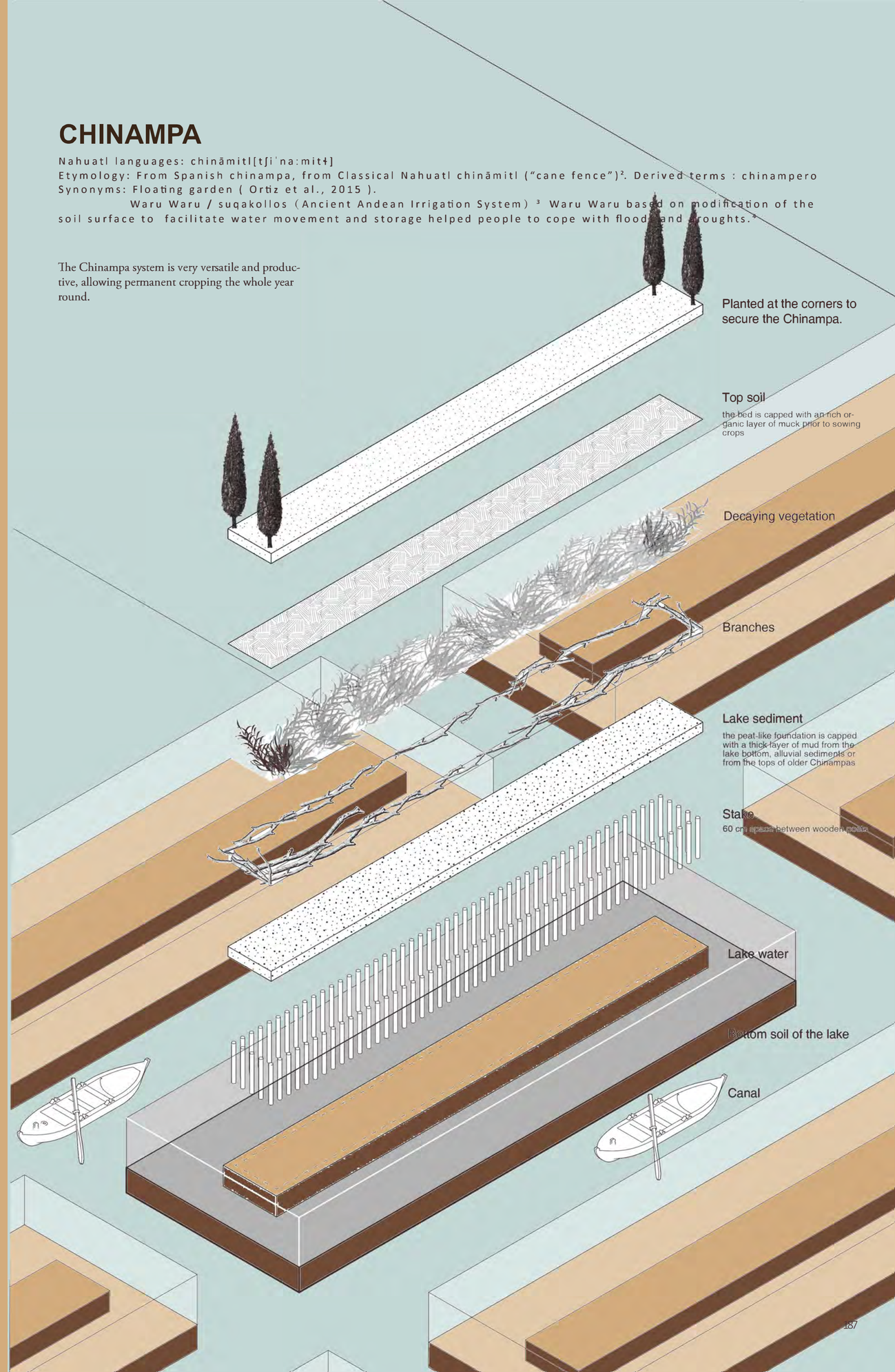
CHINAMPA

Photo: https://onlinelibrary.wiley.com/doi/pdf/10.1002/ird.2310

CHINAMPA

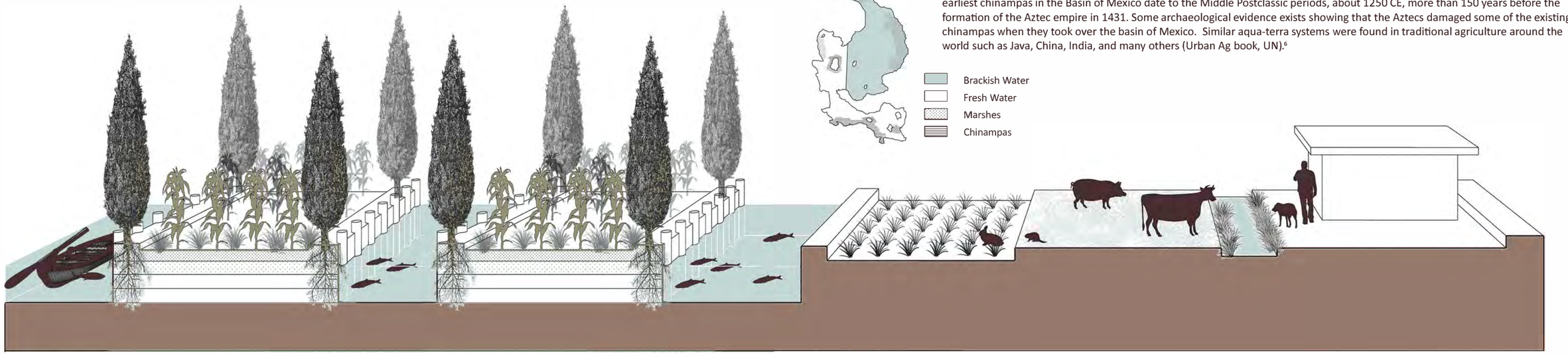
Nahuatl languages: chināmitl[tʃiˈnaːmitɬ]
Etymology: From Spanish chinampa, from Classical Nahuatl chināmitl (“cane fence”)[2]. Derived terms : chinampero
Synonyms: Floating garden (Ortiz et al., 2015).
Waru Waru / suqakollos (Ancient Andean Irrigation System) [3] Waru Waru based on modification of the soil surface to facilitate water movement and storage helped people to cope with floods and droughts.[4]

The Chinampa system is very versatile and productive, allowing permanent cropping the whole year round.



CHINAMPA

Chinampa Community Self-suffciency



- Evolution: The earliest fields that have been securely dated are from the Middle Postclassic period, 1150 – 1350 CE .[5] The earliest chinampas in the Basin of Mexico date to the Middle Postclassic periods, about 1250 CE, more than 150 years before the formation of the Aztec empire in 1431. Some archaeological evidence exists showing that the Aztecs damaged some of the existing chinampas when they took over the basin of Mexico. Similar aqua-terra systems were found in traditional agriculture around the world such as Java, China, India, and many others (Urban Ag book, UN).[6]

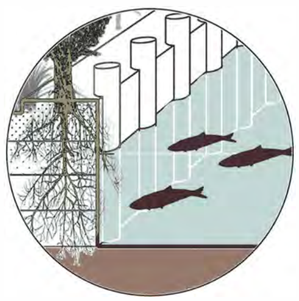
Chinampa Working Detial

Canal

When creating chinampas, in addition to building up masses of land, a drainage system was developed.Transportation among the chinampas is normally by boat along the canals.

Willow (Salix lasiolepis)

Chinampas must be surrounded with some kind of vegetation to hold the mud in place. The roots are adapted to swampy conditions, and grow into a dense enough tangle to hold the mud in place.[7]



Cultivate Edible Fish

Indeed it is critical to raise fish if you live in a swamp, since they are the best way to kill mosquito larvae.

Plant

well-watered beds had very high crop yields with up to 7 harvests a year. Among the crops grown on chinampas were maize , beans , squash , amaranth , tomatoes , chili peppers , and flowers.

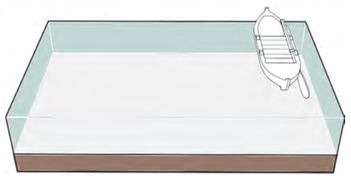
Small Ranch

The circulation of water supporting an abundance of swamp life makes the mud quite fertile, so the constant movement of mud onto the islands produces extremely fertile farm plots.

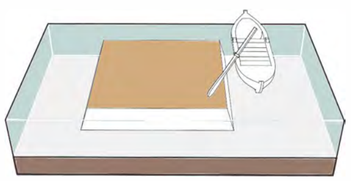
Domestic Drainage

ICanals are subject to becoming clogged with a range of water plants, interfering with navigation, fishing, and chinampa maintenance.

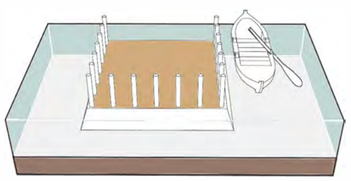
Chinampa Construction Diagram



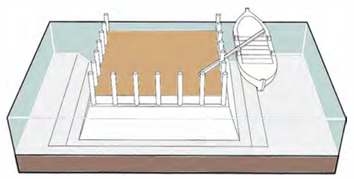
1. Shallow lake or basin with water



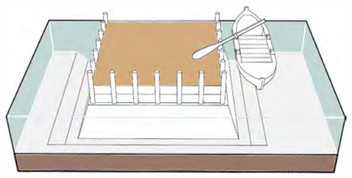
2. Raise the bottom of the lake



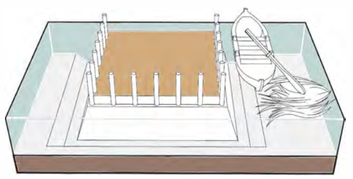
3. Insert stakes on the base



4. Dig the lake along the base



5. Pile the excavated soil on the foundation

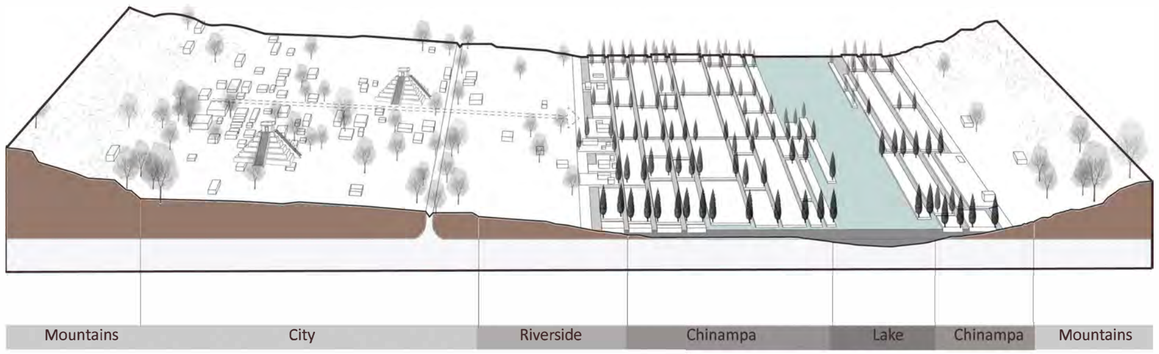


6. Collect surrounding aquatic plants

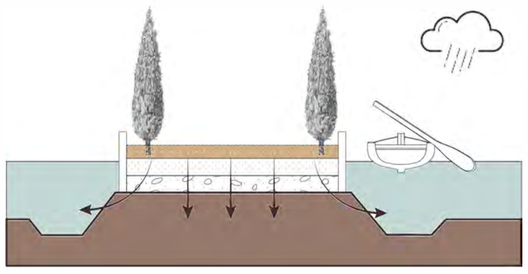
- Physical condition: Chinampa originally created for semi dry climates as a water harvesting and food production system. (With the use of this technique the Aztecs took up most of the Lake of Xochimilco, and its combination with other techniques such as irrigation channels and terracing, allowed them to support a dense population of more than 230,000 people) [8]
- Manufacture: Chinampas are artificial islands created in swampy areas by piling up mud from the bottom of a shallow swamp to make islands with clear canals running between them.

- A chinampa is an artificial island made with logs, sticks and living trees called “Ahuejotes” or willows. The trees hold the soil of the island together and after the tree grows, the root system of this tree creates an area upon which is deposited topsoil properly selected in layers of biodegradable materials such as; grass, leaves, shells of different fruits and vegetables, composting aquatic plants and other materials.
Source (The first step in the construction of a chinampa is locating a firm floor in a shallow canal area. Chinampas are constructed with mud scraped from the surrounding swamps or lakes (Altieri and Koohafkan, 2004). [9]

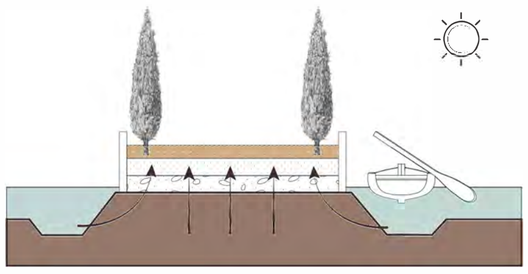
Chinampa Community Self-suffciency



Chinampa Water Function

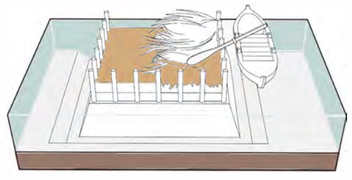


Rainy season

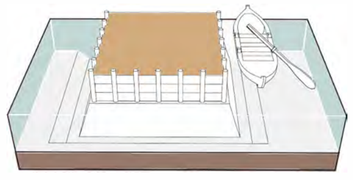


Dry season

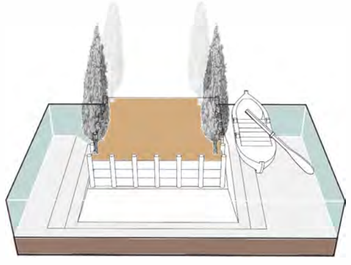
- Water function: Chinampa provided farmers with better drainage, soil aeration, moisture retention during the dry season, high and long-term fertility, and high productivity per area and input (Renard et al., 2012 ; Torres et al., 1994). Chinampa is a food production system that functions as a water purification system as well as a very effective climate modifier.



7. Pile these nutrients on the substrate

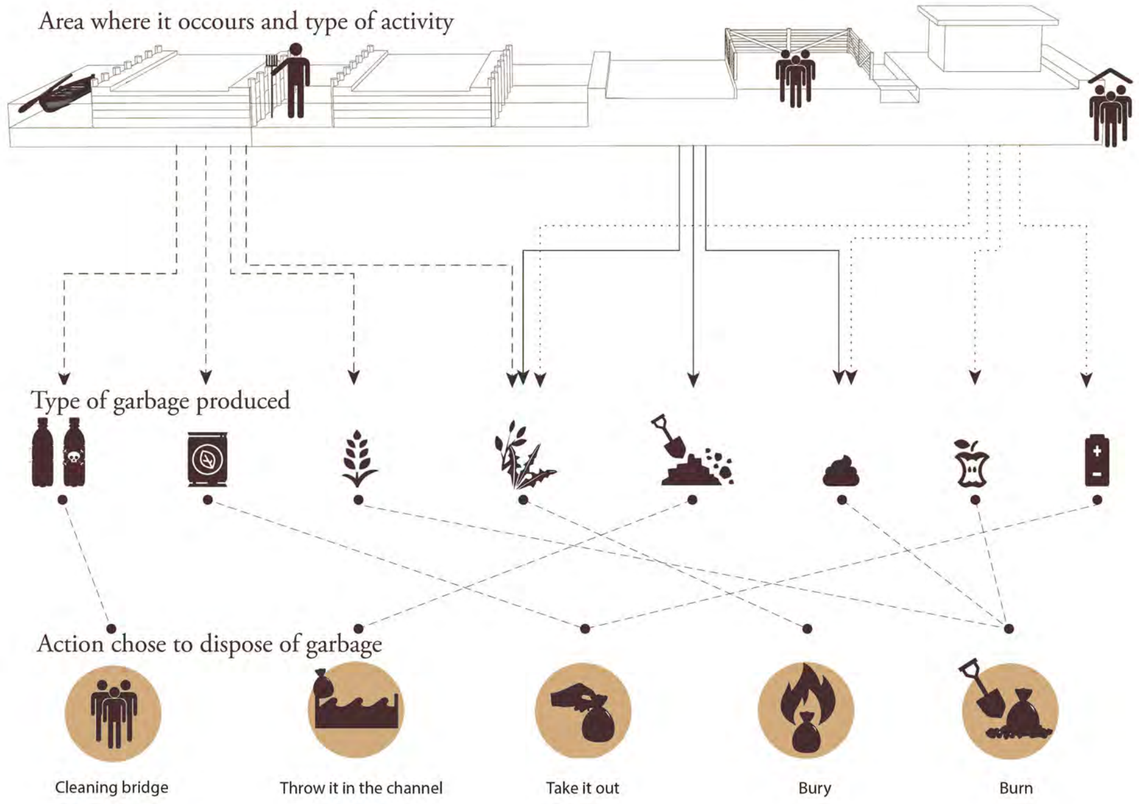


8. Place and compact the top soil



9. Planting willows at the corner to ☐x the soil layer

- The corners of a field are delimited by solid posts. Around each field, a fence made of ahuejotes (bonpland willow) is built. The use of this local willow species is common because it grows quickly and effectively fixes the borders of the mounds. Additionally, ahuejotes provide shade, create a protective barrier against wind and pests, and serve as trellises for vine crops. After the planting, the willow is interwoven with reeds and branches of other plants.[10] The result is the chinamil (a solid fence) that is continuously fortified with floating mud and plant material. When the chinamil is stable and the raised mud reaches a height of 50 cm, the top layer must dry for several weeks. Later, more mud, compost, or other organic materials are added (Martínez, 2004).)



- This drawing shows the route of the garbage in the wetland, where the Chinampera area is located. Some Chinamperos producers use technology packages that include pesticides and commercial fertilizers, greenhouses and plastic blankets to cover production beds. [11]The types and quantities of waste they generate may be similar in food and production materials, but they use different inputs that require different treatments.

- Being far from the avenues where the collection trucks pass, the inhabitants must dispose of their waste themselves. They can request assistance from community brigades to clean the canals, but they must always decide if: 1. they take their garbage to where the trucks and carts pass; 2. they bury or burn it in situ; 3. They throw it into the channels; 4. throw it on a street or road.[12]

Softwar

- Mexico-Tenochtitlan was a city of many kilometers made of artificial islands.

- In addition to their economic and environmental contributions, chinampas also provide cultural benefits to southern Mexico City (Merlín-Uribe et al., 2013). The role of the chinampas as a recreational resource is becoming increasingly important because the combination of tourism and agriculture has provided the impetus for a revitalization of pre-Hispanic traditions (Losada et al., 1998).

- Chinampas can exist in urban or rural areas. Higher productivity and Agrobiodiversity enable Chinampas to support a very dense population. Achieve self-sufficiency.[13]

- Transportation among the chinampas is normally by boat along the canals. This attracts people to visit.

- Chinampa soils sequester large quantities of carbon (Renard et al., 2012) and are becoming a relevant strategy in Mexico City's efforts to reduce greenhouse gas (GHG) emissions.

- Domestic wastewater, feces, and municipal waste can be used as fertilizer for Chinampa, which has purified urban sewage. [14]

- In addition, agroforestry elements and the channels serve to control flooding when excess water in the rainy season is diverted from Mexico City, working as regulation vessels. Also, the humidity generated by the water in the channels and wetlands promotes climate control and reduces aggressive wind erosion in the southern zone of the city.[15]

CHINAMPA

Notes:

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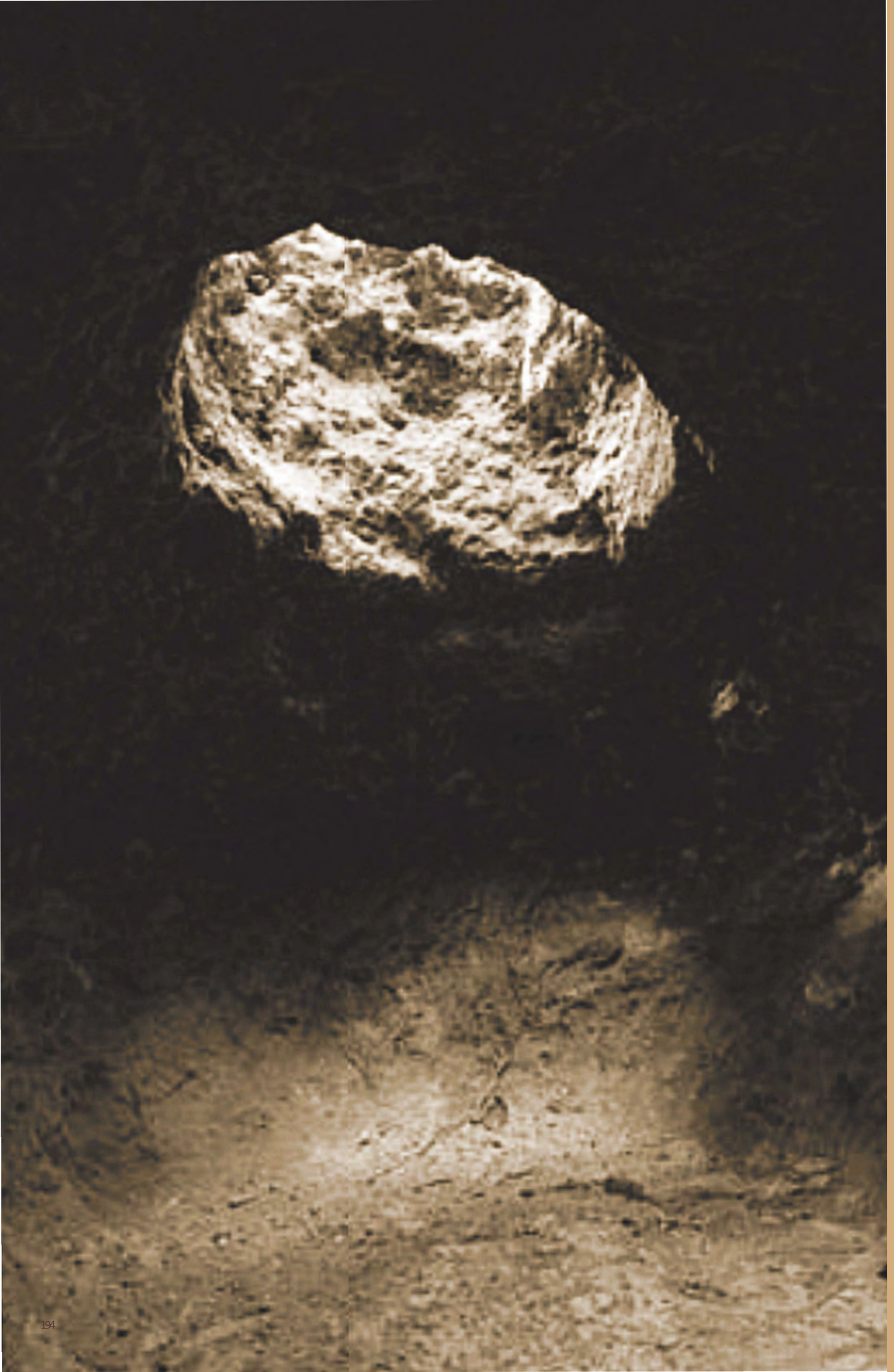


CHULTUN

Versatile Water Storage For Your Home Or Town

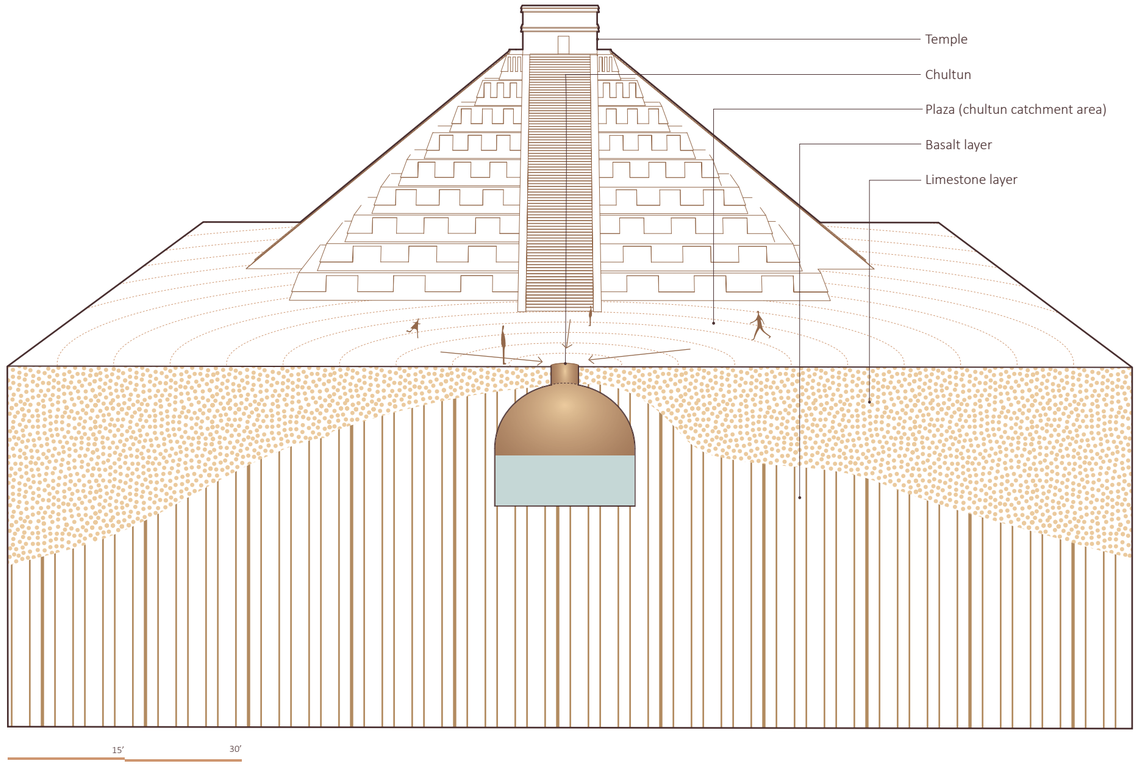
Chultuns are water suppy systems of the Mayan empire. They are underground cisterns with a variety of shapes, usages and scales. They can be divided into 2 groups: bottle-shaped and shoe-shaped.

Photo: view from inside a one chambered chultun, 2017[1]

CHULTUN

Chultuns are water supply systems of the Mayan empire, located on the Yucatan peninsula from 900 BCE to 1500 CE.
Chul – “wet” or “being wet”
Tsul – “to clean-out or excavate”
Tun – “rock” or “stone”
Chultun – “wet rock” or “rock that becomes wet” or “rock place that becomes wet”

“The term chultun is used to refer to a man made hole in the ground that is wet or contains water.”[2]



Maya Water Supply Invention In Sub-humid Climate Zone

Although precipitation is abundant in the sub-humid rainforest of the Yucatan , the geological formation of the peninsula consists of a permeable soft limestone layer, which cannot hold water. Underneath is a large water basin, leaving no surface water above ground.[3,4]

Cenotes are a natural sink holes in the karst geology. Chultuns are constructed where there are no cenotes.

We can roughly divide chultuns into 2 groups, bottle-shaped and shoe-shaped. Bottle-shaped chultuns occur most frequently in the northern Yucatan pennisula and shoe-shaped chultuns occur in the southern Yucatan. Bottle-shaped chultuns serve as water cisterns, while shoe-shaped chultuns have a variety of usages.[5]

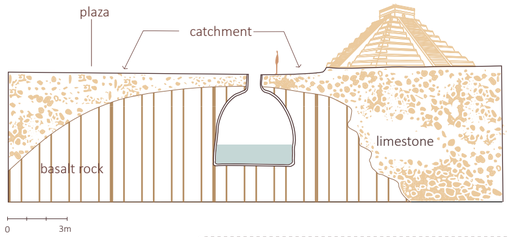
CHULTUN

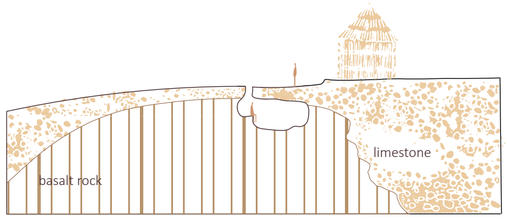
Bottle-shaped Chultun

Location: under temples or ceromonial plazas[6]
Size: 6m deep, 7500 gallons[7]
Material: plastered with thick layer of cement[8]
Usage: water storage
Serving capacity: around 25 people[9]
Maintenaned by the government

Shoe-shaped Chultun

Location: around the houses[10]
Size: 2m deep[11]
Material: some are plastered and some are not[12]
Usage: water storage, food storage and fermentation, construction material storage, garbage pit, ritual[13]
Serving capacity: from houshold to village[14]
Maintenanec by household[15]





PLAN

SECTION

1 chamber

water storage

water storage

water storage

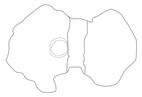
1 chamber

water storage
(lined with plaster)

garbage pit

construction material
storage

historic sites- storage use



served as water well or as a
place for preparing different
construction mixes

garbage pit

2 chambers

3 chambers

food storage

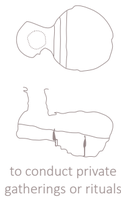
ritual

ritual

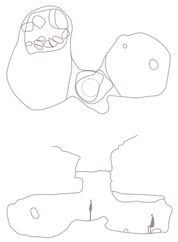
private gathering

historic sites- ritual and gathering use

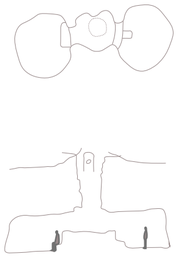
used to celebrate ritual
gatherings or activities



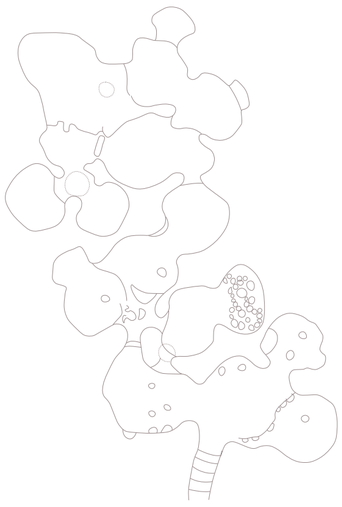
to conduct private
gatherings or rituals



used to celebrate ritual
gatherings or activities



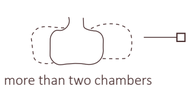
private civic or ceremonial
activity



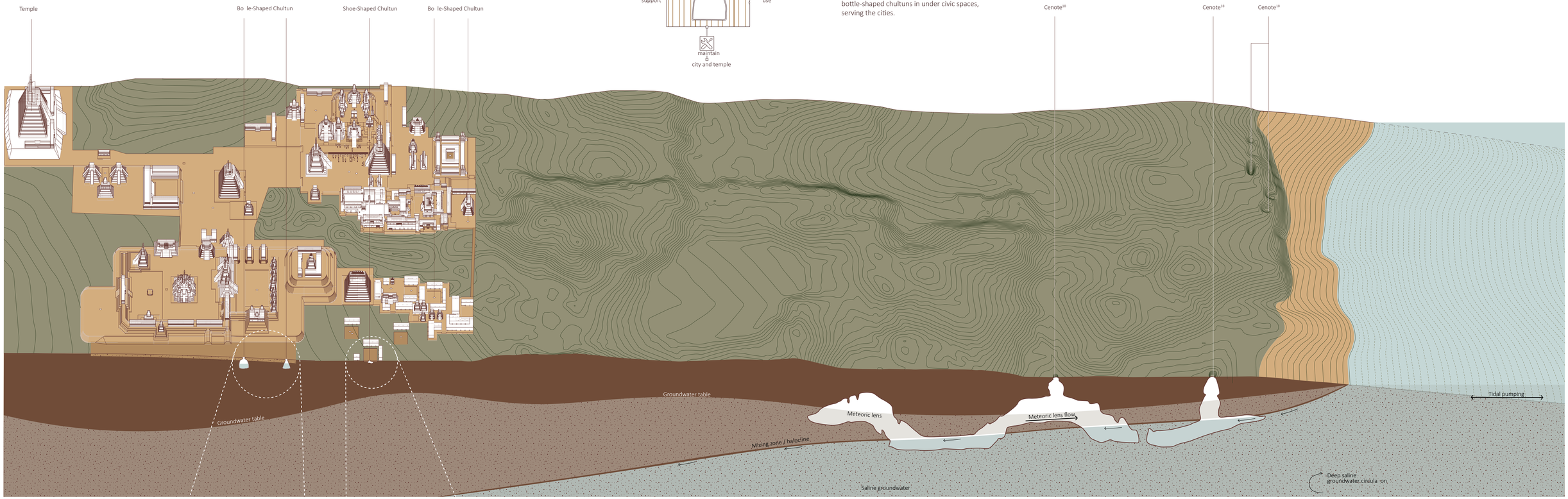
network of underground
chamber

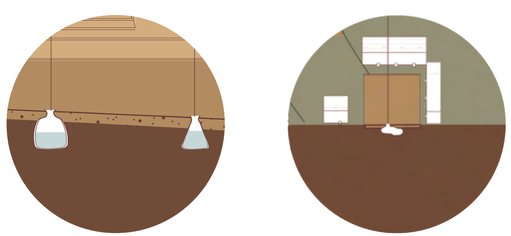
Shapes, Chambers, Materials and Functions

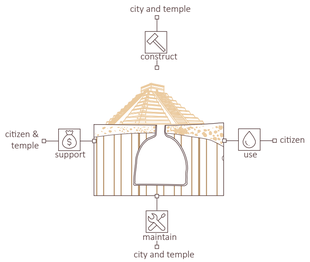
Chultuns that have 2 or more chambers appear to have civil gathering and ritual activities. Chultuns that are plastered with cement layers are used for water storage. Shoe-shaped chultuns are also used for food storage and alcoholic beverage fermentation.[16,17]



CHULTUN surrounding and natural inspiration

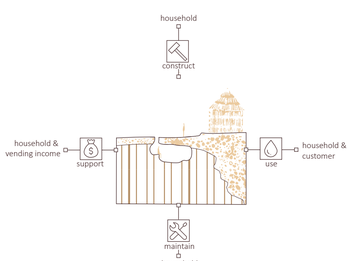






Civic Use Bottle-shaped Chultuns

Bottle-shaped chultuns are the most popular chultuns. They are mostly in northern Yucantan pennisula and are located under civic plazas and temples. One bottle-shape chultun can serve up to 25 people per year. It is common to see multiple bottle-shaped chultuns in under civic spaces, serving the cities.



Multi-functional Family Use Shoe-shaped Chultuns and the Vending Mechanism

Shoe-shaped chultuns are located at the souther Yucantan pennisula, and around private households. Shoe-shaped chultuns serves variety of usages beside water storage, such as alcoholic fermentaion and food storage. At some cities, like Tikal, multiple shoe-shaped chultuns are found in some bigger households, but not every household has chultun, indicating the possibility of a vending mechanism for chultuns.

Cenote: Chultuns' Natural Inspiration

"Cenote is a natural sinkhole, resulting from the collapse of limestone bedrock that exposes groundwater underneath. Especially associated with the Yucatán Peninsula of Mexico, cenotes were used by the ancient Maya for water dupply and sacrificial offerings. The term derives from a word used by the low-land Yucatec Maya—ts'onot—to refer to any location with accessible groundwater."[19]

Chultuns are only found where there are no cenotes in the area, alongside with the similar form, indicating chultuns are inspired by cenote.

CHULTUN

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12 Dahlin, Bruce H., and William J. Litzinger. pp.721-734

13 Dahlin, Bruce H., and William J. Litzinger. pp.721-734

14 Dahlin, Bruce H., and William J. Litzinger. pp.721-734

15 Calderón, Zoila & Hermes, Bernard. pp.24

16 Dahlin, Bruce H., and William J. Litzinger. pp.721-734

17 Calderón, Zoila & Hermes, Bernard. pp.24

18 Pohlman, J.W., and Brankovits, David, "Water column physical and chemical properties of Cenote Bang, a component of the Ox Bel Ha cave network within the subterranean estuary coastal aquifer of the Yucatan Peninsula, from December 2013 to January 2016" U.S. Geological Survey data release, 2017, https://doi.org/10.5066/F7DJ5DJW.

19 Tim Scoones (producer), Jeff Goodman (photography), Dominique Rissolo (scientific adviser), Tom Iliffe (sci adv), Patricia Beddows (sci adv), Jill Yager (sci adv) (2005). Secrets of the Maya Underworld

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TIANJING

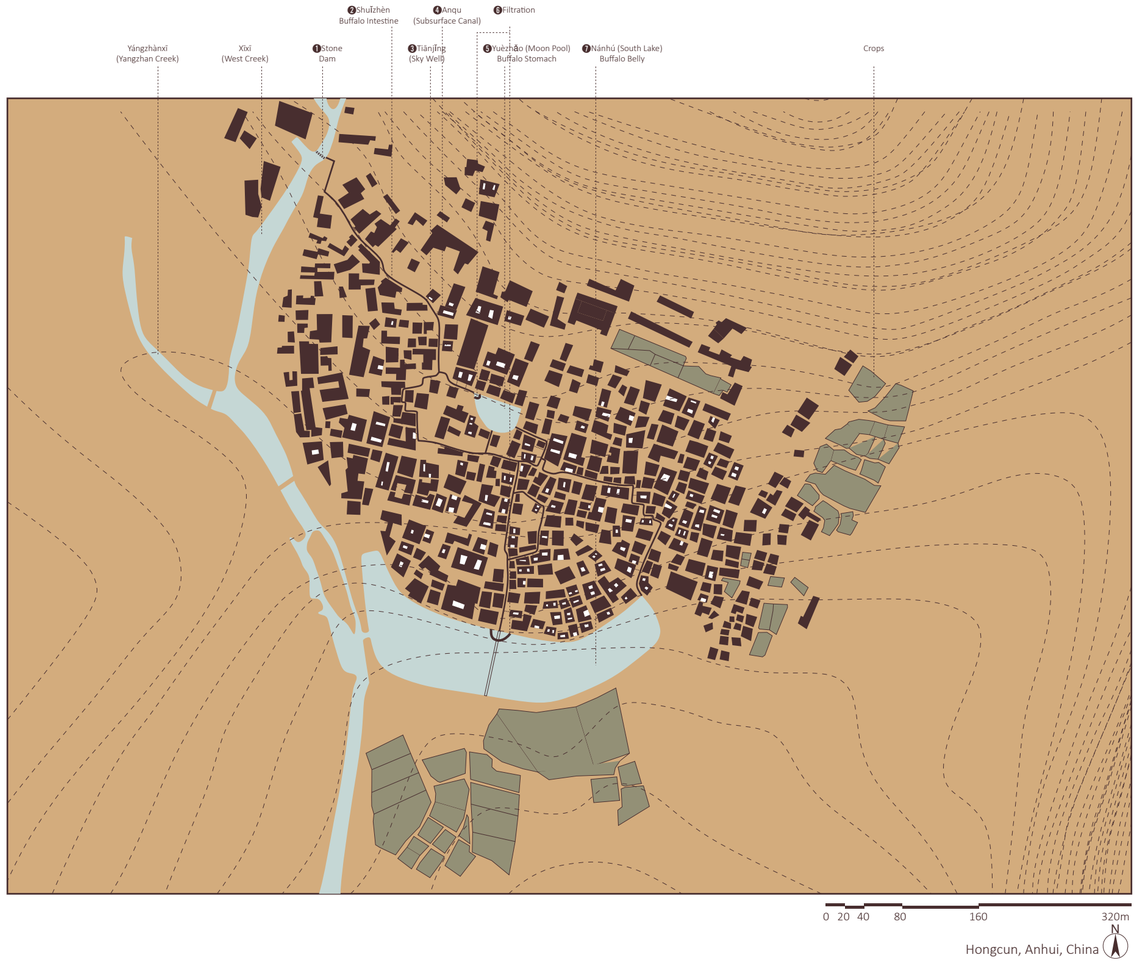
A House Courtyard that Works as A Water Catchment

Tianjing refers to the open sky enclosed by rooms or walls of a house .

Photo: Tank with Water in Tianjing, China Cultural Relics, 2016.

TIANJING

Tianjing (天井, literally means sky well in Chinese) represents a courtyard; a small yard; an air shaft.[1] It often exists in Huipai Jianzhu (徽派建筑, literally means Huizhou-Style Architecture). The most well-preserved Huipai Jianzhu is located in Hongcun Village and Xidi Village (both situated in South Anhui Province, China), with a history dates that back to the Ming Dynasty (1368-1644 CE)[2] and the Qing Dynasty (1644-1911 CE)[3].



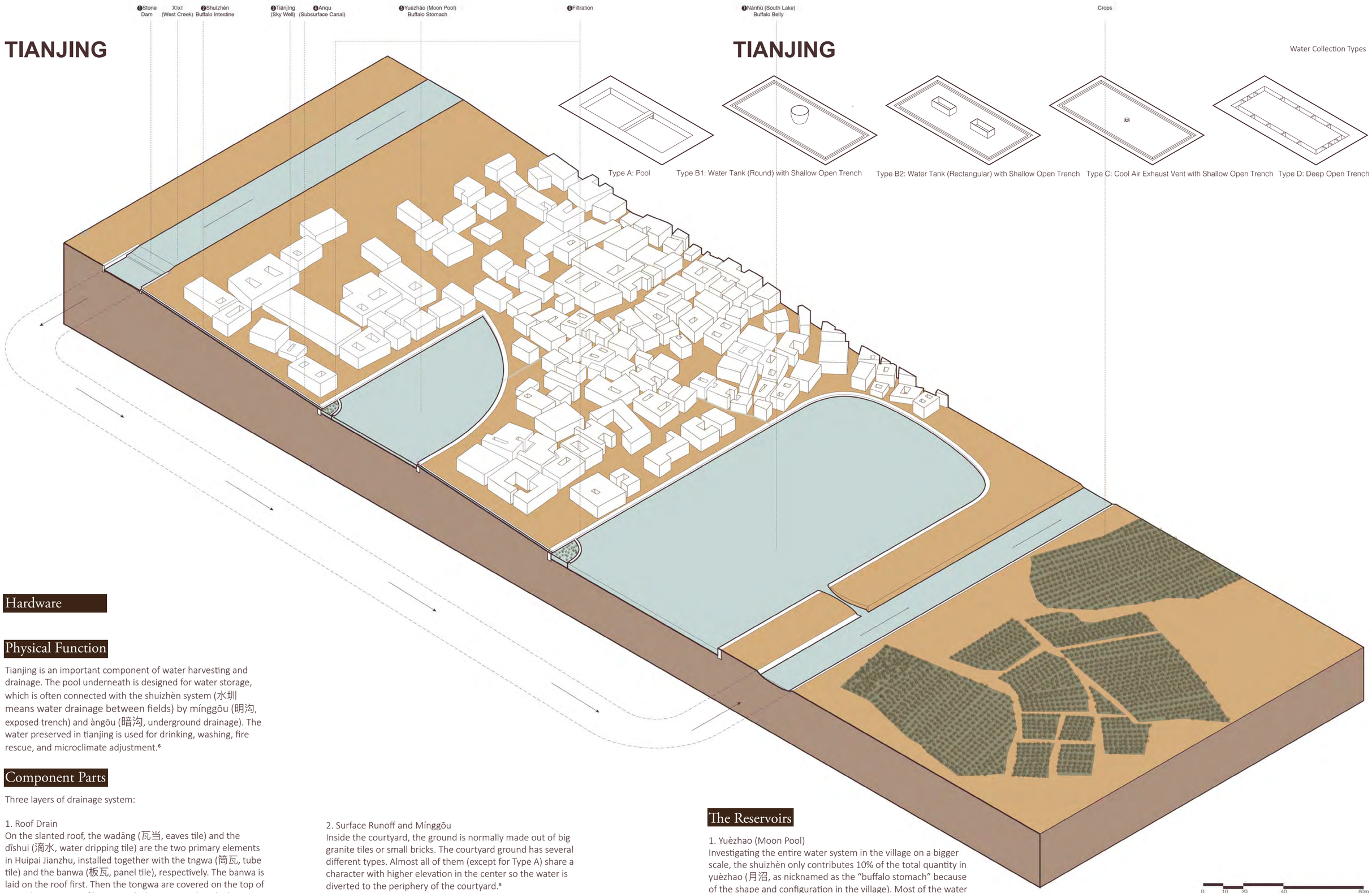
World Heritage

In 2000, UNESCO listed Hongcun Village and Xidi Village as a world heritage site. “The two traditional villages of Xidi and Hongcun preserve to a remarkable extent the appearance of non-urban settlements of a type that largely disappeared or was transformed during the last century. Their street plan, architecture and decoration, and the integration of houses with comprehensive water systems are unique surviving examples.”[4]

Terrain and Regional Climate

Huizhou (徽州) is located in the south of Anhui Province, within the proximity of the interface of three provinces: Anhui, Zhejiang, and Jiangxi. This is a mountainous area where Huangshan (Chinese: 黄山, literal meaning: Yellow Mountain) and Mount Qiyun (齐云山) cross over and extend all the way to Yangtze River (长江), which formed the hilly terrain of South Anhui. Additionally, Xin’an River (新安江) runs over the south of Huangshan and multiple creeks have spread out over Huizhou.[5] Because of its location in the central subtropical monsoon climate region and the unique terrain, warm and humid weather is prevalent here.

TIANJING



TIANJING

Water Collection Types

Type A: Pool | Type B1: Water Tank (Round) with Shallow Open Trench | Type B2: Water Tank (Rectangular) with Shallow Open Trench | Type C: Cool Air Exhaust Vent with Shallow Open Trench | Type D: Deep Open Trench

Hardware

Physical Function

Tianjing is an important component of water harvesting and drainage. The pool underneath is designed for water storage, which is often connected with the shuizhèn system (水圳 means water drainage between fields) by mínggōu (明沟, exposed trench) and àngōu (暗沟, underground drainage). The water preserved in tianjing is used for drinking, washing, fire rescue, and microclimate adjustment.[6]

Component Parts

Three layers of drainage system:

1. Roof Drain
On the slanted roof, the wadāng (瓦当, eaves tile) and the dīshui (滴水, water dripping tile) are the two primary elements in Huipai Jianzhu, installed together with the tngwa (筒瓦, tube tile) and the banwa (板瓦, panel tile), respectively. The banwa is laid on the roof first. Then the tongwa are covered on the top of two adjacent rows of banwa with the seam enclosed. The wadāng is the occlusion on the end of tongwa covering the wooden structure yuántiáo (椽条, wooden margin strip) underneath. The dīshui has a similar function as the wadāng. By using them synthetically, wooden structures are protected from rot and the walls are protected from stain.[7]

2. Surface Runoff and Mínggōu
Inside the courtyard, the ground is normally made out of big granite tiles or small bricks. The courtyard ground has several different types. Almost all of them (except for Type A) share a character with higher elevation in the center so the water is diverted to the periphery of the courtyard.[8]

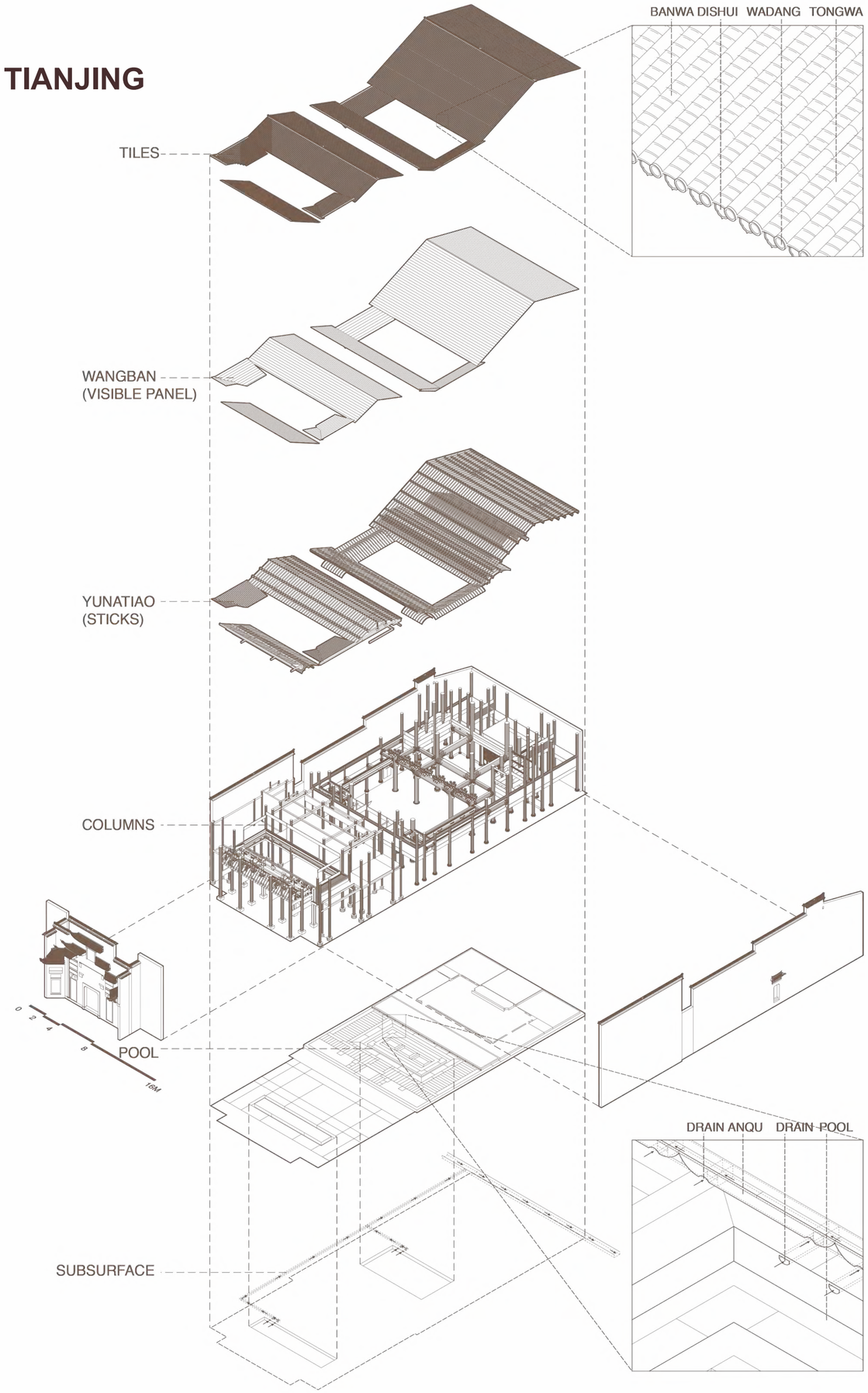
3. Àngōu
The àngōu is the underground part that connect the shuizhèn and the courtyard drainages. The àngōu is normally no less than 50 cm wide and no less than 60 cm in depth.[9]

The Reservoirs

1. Yuèzhao (Moon Pool)
Investigating the entire water system in the village on a bigger scale, the shuizhèn only contributes 10% of the total quantity in yuèzhao (月沼, as nicknamed as the “buffalo stomach” because of the shape and configuration in the village). Most of the water is from xīxī (西溪, “West Creek”). The water depth is about 0.8 to 1.1m.[10]

2. Nánhú (South Lake)
Nánhú (南湖) is a manmade reservoir (0.8 to 1.1m) in the south of the village, adjacent to the fields. It was built in 1607 with an area of 20,247 sqm. Due to its configuration, it is nicknamed as “níudu, 牛肚, meaning buffalo belly)”.[11]

TIANJING



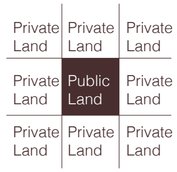
TIANJING

Software

Etymology

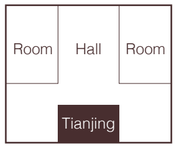
“天 (tiān, meaning sky)” was found on the excavated oracle bone script (甲骨文) from the Shang Dynasty (1766- 1122 BCE). It is believed to be related with early sacrifice activity and spatial orientation.[12]

As for “井”, it is a hieroglyphic character that originated from the well-field system. The well-field system was a Chinese land redistribution method existing between the ninth century BC (late Western Zhou dynasty) to around the end of the Warring States period. Its name comes from the Chinese character 井 (jǐng), which means “well” and looks like the # symbol; this character represents the theoretical appearance of land division: a square area of land was divided into nine identically-sized sections; the eight outer sections (私田; sītián) were privately cultivated by serfs and the center section (公田; gōngtián) was communally cultivated on behalf of the landowning aristocrat.[13]

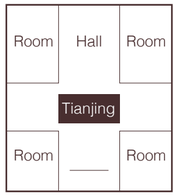


井

The dark border between the farms resembles the character for well (井)



Layout A:



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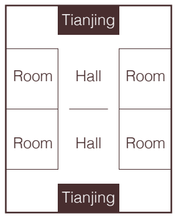
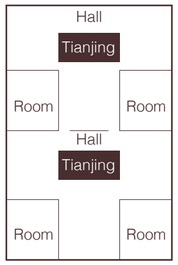


Layout C:

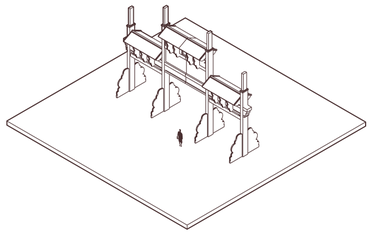


Layout D:

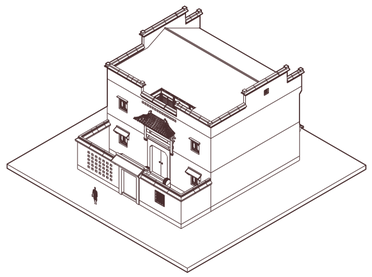
Tianjing in Huipai Vernacular Dwelling

The Layout Based on Confucianism

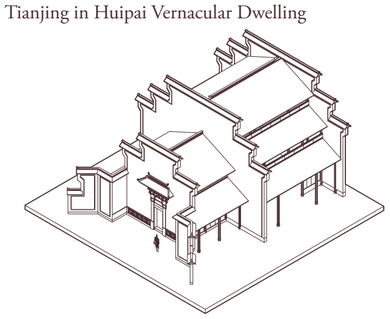
An enclosure circles the tiānjing. Due to the rise of the patriarchal society and rites, the layout indicates the differences of seniority rules among the family members. The dwelling culture in Huipai Jianzhu has infiltrated with Confucianism- filial piety is one of the virtues to be held above all else.[14] [15]



Paifang
(Torii)



Shuyuan
(Academy)



Citang
(Ancestral Shrine)

The Hydraulic Wisdom

Chong Hu, the wife of Qigong Si (who is a senor official in Beijing), led the people in the village to transform the small muddy ponds to shuizhèn system, yuèzhao, and nánhú. Additionally, she led the construction of barrages to regulate the creek and tree planting on the mountains to fix the soil.[16]

The Career as A Government Official

Education hs been emphasized for a long time in Huizhou. Students who changed their life in Beijing by becoming government officials, they come back to their hometown with wealth after retirement. Their hometown is where they invested in the infrastructure to improve the living standard.[18] [19] [20]

The Wealth Accumulated by Business

The businessmen came back to their hometown Huizhou after their success to invest infrastructures and build cítáng (祠堂, ancestor shrine) and páifang (牌坊, honorific arches), which brought them great reputation across the country. The prosperity allowed the development of water management.[17]

The Honorific Structure

Páifang, residential buiding, and cítáng are categorized as the three biggest specialties in Huipai Architecture. Páifang is a traditional style of Chinese architectural arch or gateway structure in honor of achievements.[21]

TIANJING

Notes:

1 “天井.” 天井的英文_天井的英语翻译_天井用英语怎么说_爱词霸在线词典, www.iciba.com/%E5%A4%A9%E4%BA%95.

2 “Ming Dynasty.” Wikipedia, Wikimedia Foundation, 23 Jan. 2020, en.wikipedia.org/wiki/Ming_dynasty#cite_note-9.

3 “Qing Dynasty.” Wikipedia, Wikimedia Foundation, 29 Jan. 2020, en.wikipedia.org/wiki/Qing_dynasty.

4 Centre, UNESCO World Heritage. “Ancient Villages in Southern Anhui – Xidi and Hongcun.” UNESCO World Heritage Centre, whc.unesco.org/en/list/1002/.

5 Zhang, Chao. Comparative Study on Form of “Courtyard” Between Traditional Vernacular Dwellings in the Area South Yangtze River and Ancient Roma [master’s thesis]. [Jilin, China]: Jilin Jianzhu University; 2018. pp. 18.

6 Zhang, Chao. Comparative Study on Form of “Courtyard” Between Traditional Vernacular Dwellings in the Area South Yangtze River and Ancient Roma [master’s thesis]. [Jilin, China]: Jilin Jianzhu University; 2018. pp. 81.

7 Liu, Yi. “瓦当”与“滴水” [“Wǎdāng” and “Dīshuǐ”]. History Education, no. 7, July. 1993, pp. 16.

8 Shan, Qixiang, 故宫排水系统营造与维护中的工匠精神 [Craftsmanship in the construction and maintenance of the Forbidden City drainage system]. Planning and Construction of Beijing, no. 3, March. 2017, pp. 64.

9 Wang, Wei. The Planning and Design of Water Supply and Drainage Systems of the Ancient Town Renewal Projects. [master’s thesis]. [Jiangsu, China]. Southeast University Press; 2018. pp. 86.

10 Liu, YapinWater. The Water Context of Hongcun Village-The Exploration on Water Culture of Hongcun Village in Anhui [master’s thesis]. [Hunan, China]: Hunan Normal University; 2007. pp. 6.

11 Wu, Yifan. 中国建筑遗产图鉴 [Atlas of Chinese Architectural Cultural Heritage]. Huangshan International Press, 2016.
pp. 115.

12 Zhang, Chao. Comparative Study on Form of “Courtyard” Between Traditional Vernacular Dwellings in the Area South Yangtze River and Ancient Roma [master’s thesis. [Jilin, China]: Jilin Jianzhu University; 2018. pp. 53.

13 Zhufu, Fu (1981), "The economic history of China: Some special problems", Modern China, 7 (1): 3–30, doi:10.1177/009770048100700101.

14 Zhang, Chao. Comparative Study on Form of “Courtyard” Between Traditional Vernacular Dwellings in the Area South Yangtze River and Ancient Roma [master’s thesis]. [Jilin, China]: Jilin Jianzhu University; 2018. pp. 54.

15 The center of the tingtang (厅堂, means living room in Chinese) is normally reserved for ancestor worship, facing against the tiānjǐng. The tingtang is the axis of symmetry in the entire layout. In custom of vernacular dwelling, people on the left side are considered as superior guests. Thus, the grandparents’ room is traditionally located on the left, whereas the right is reserved for the parents. Meanwhile, male relatives and female relatives are living on the second floor separately. Zhang, Chao. Comparative Study on Form of “Courtyard” Between Traditional Vernacular Dwellings in the Area South Yangtze River and Ancient Roma [master’s thesis]. [Jilin, China]: Jilin Jianzhu University; 2018. pp. 30.

16 The strong family concept is prevalent in Huizhou. In order to protect the family assets away from the natural hazards and the aspiration for a great life, Chong Hu planned this ecological water environment. Liu, YapinWater. The Water Context of Hongcun Village-The Exploration on Water Culture of Hongcun Village in Anhui [master’s thesis]. [Hunan, China]: Hunan Normal University; 2007. pp. 17.

17 One way to accumulate wealth in Huizhou is through business. Historically, the order “scholar, peasant, worker and businessman” was the hierarchy in the traditional Chinese society. The society used to despises the businessman. However, education was extremely emphasized in Huizhou in Ming and Qing Dynasty. Due to these businessmen’s education background, they have a belief of Confucianism and act accordingly. Besides, a large population from Huizhou choose to trading merchandise (brush pens, paper, ink, salt, wood, and tea, primarily) national wide and become very successful with the convenience brought by Xin’an River. Feng, Jianhui. A Study of the Mordern Huizhou Merchants with Focuses on 1830-1949 [Doctoral Dissertation]. [Shandong, China]: Shandong University; 2008. pp. 37.

18 During Ming and Qing Dynasty, public get educated through sīshú (private schools, 私塾) or shūyuàn (书院, academy). Mei, Liqiao. Study on Ecology of Huizhou Culture in Late Qing Dynasty [Doctoral Dissertation]. [Jiangsu, China] Soochow University; 2013. pp. 111.

19 The Cheng–Zhu school (Chinese: 程朱理學; pinyin: Chéng Zhū lǐxué), is one of the major philosophical schools of Neo-Confucianism originated from Huizhou due to the development of education. It is based on the ideas of the Neo-Confucian philosophers Cheng Yi, Cheng Hao, and Zhu Xi.

20 The advancement of education has resulted in many students’ good performance in national exams and many of them became officers in Beijing through exam. Chan, Wing-tsit. A source book in Chinese philosophy. Princeton University Press, 2008. pp. 545–546.

21 Because many locale males are working as government officers in other cities, páifang are build to honor their wives’ chastity. Other purposes include accentuating the solemnity when worshiping the ancesters, celebrating an examinee ranked at no.1 through out the entire country, commemorating someone has huge contribution to the town, or someone’s probity when working as a governmental official. Wang, Tingting. The Commerce and Education Study of Huizhou Merchants during Ming and Qing Dynasty. [Master’s Thesis]. [Jiangsu, China]: Nanjing Normal University; 2016. pp. 16.

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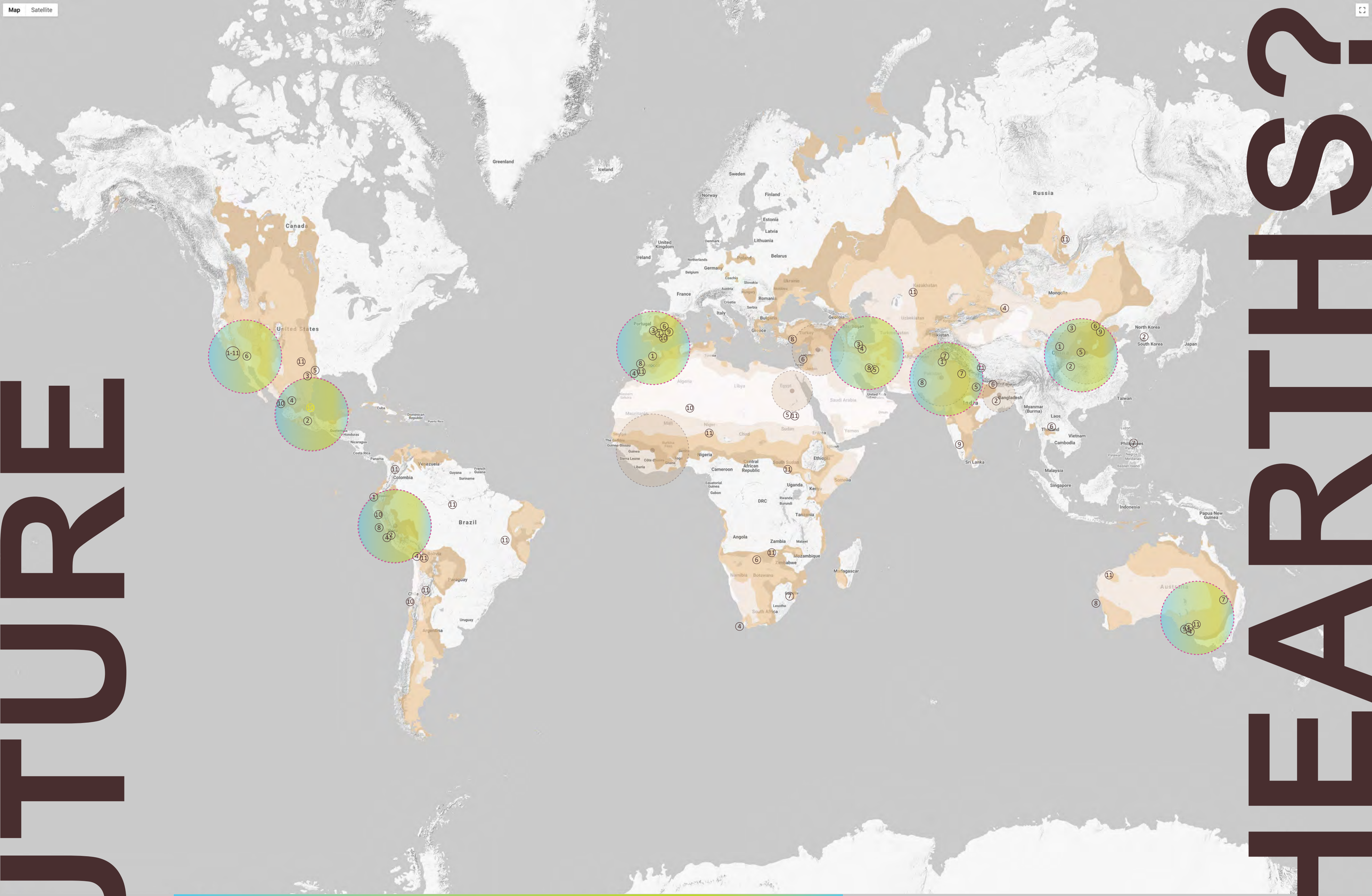

What If...

① Albarrada as Urban Acupuncture
② Benching as Urban Green Infrastructure
③ Clepsydra as Public Art
④ Mamanteo as Water Trail
⑤ Maqsam as Water Divider
⑥ Maqsam As Water Monument
⑦ Paradise as Benched Burial Landscape
⑧ Stepwell as Sunken Oasis
⑨ Tianjing as Secondary Watershed
⑩ Tinaja as Micro-Habitat for Wildlife
⑪ Yakhchal as Seed Bank

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In this volume, eleven USC School of Architecture students in their final year of the Master's in Landscape Architecture and Urbanism program set out to retrieve, document, and analyze the world's traditional water systems. The first goal was to study how these systems functioned physically, how they operated socially, and how they organized landscapes and societies spatially. The second was to imagine new variations of these old systems and test them on the urban landscapes of water-stressed Los Angeles. The premise? By building a richer, more robust lexicon of pre-carbon drylands design systems, we might build capacity, in ourselves and others, for inspired design vision in a post-carbon world.