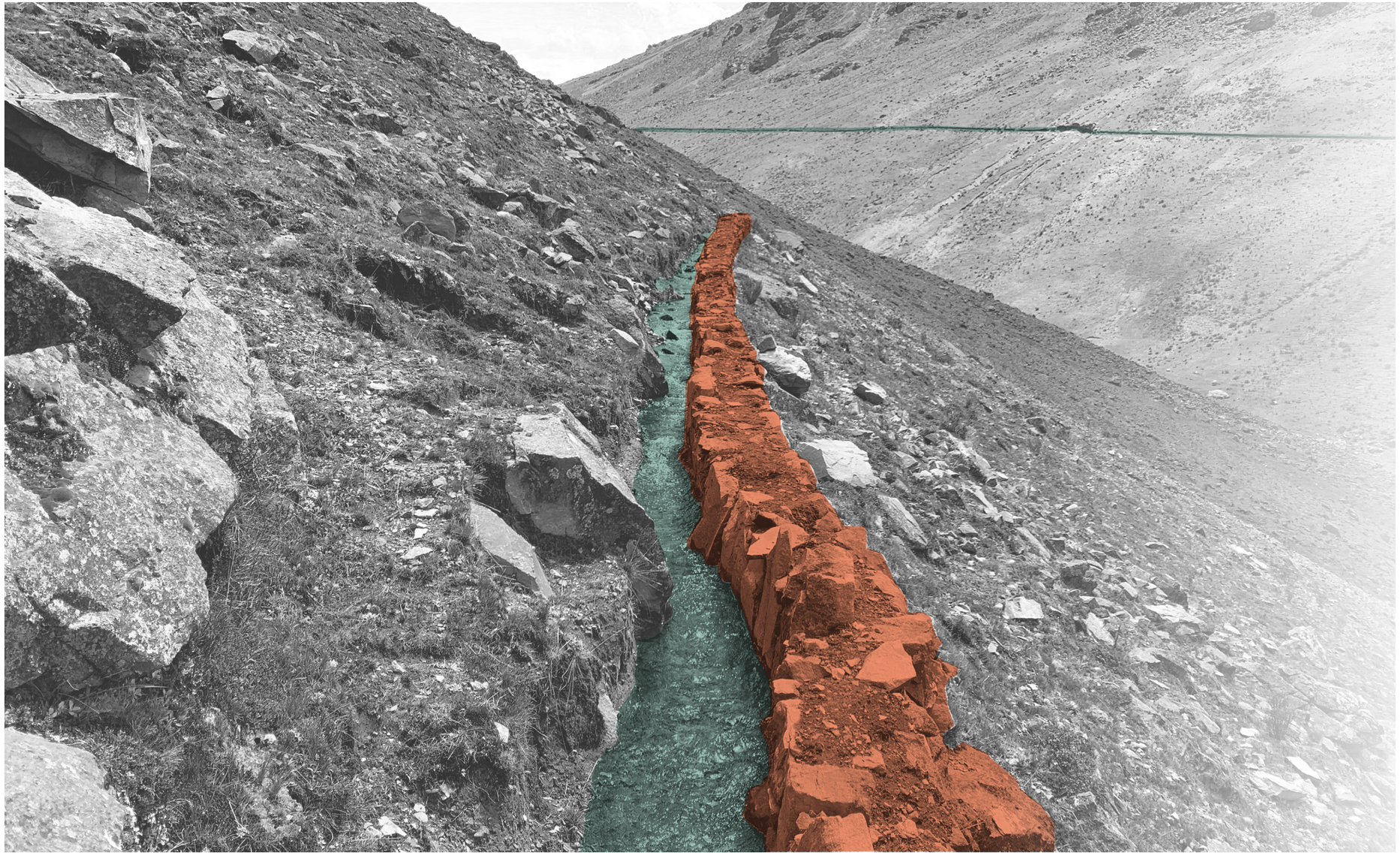


Amunas Water System

An ancient water system in the Andes that delays groundwater reaching rivers until the dry season by sowing runoff into the ground and filtering it down the hill slopes.

Wanning Liang

Figure 1: Amunas system on the Andes

Context.

Location:	Huamantanga, Lima, Peru. San Pedro de Casta, Lima, Peru.
Period:	700 A.D.
Length:	67 kilometers (originally).
Function:	Rainwater storage system (provide water in dry season).
Water Quality:	Fresh aquifer water.
Components:	Infiltration canal (Stone base) , infiltration canal (Soil base), infiltration hillslope, spring, pond
Status:	Still in use, some need restoration

Much of Peru's coastline region is experiencing a water shortage due to seasonal rainfall. The Amunas system, which is located in the province of Lima, was built by the prehistoric Huarochiri people about 1400 years ago for collecting rainwater. Rainfall and water from highland streams are collected through this system during the rainy season, allowed to infiltrate into the mountains, and after months of natural infiltration, gush out of the ground through springs or ponds rather than flowing away through streams.

Figure 2
Lima Province in Peru, South America

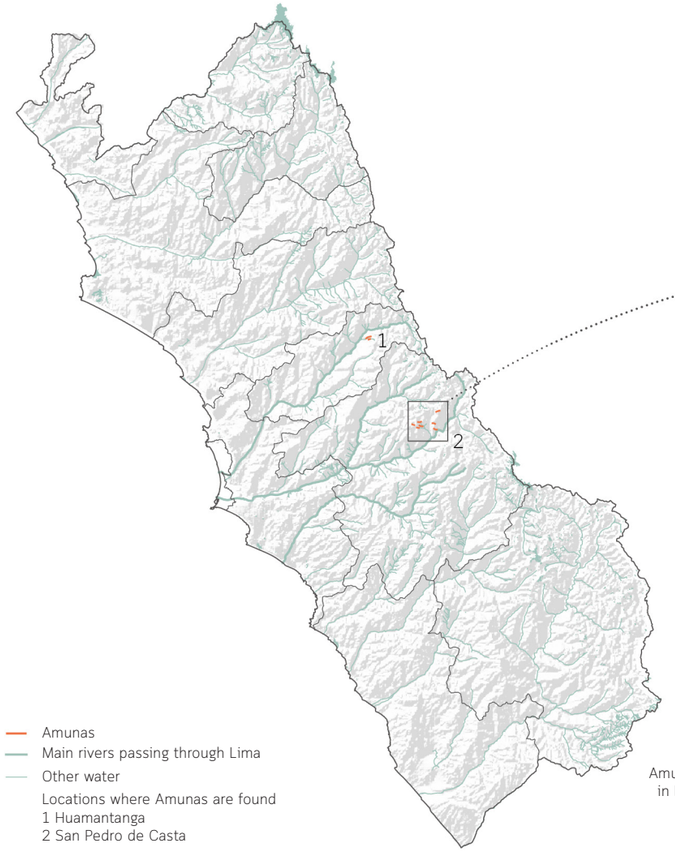


Figure 3
Amunas locations in Lima Province

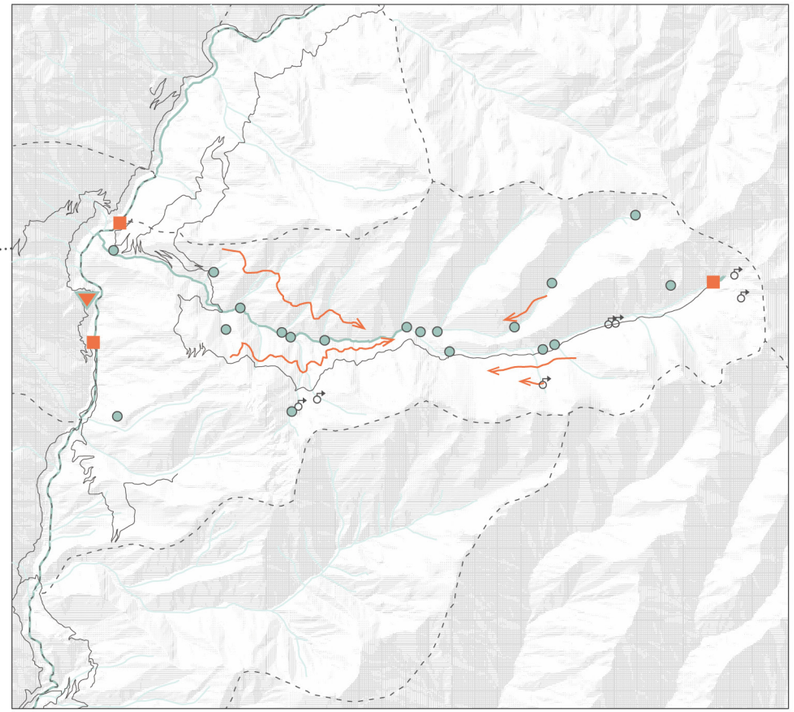


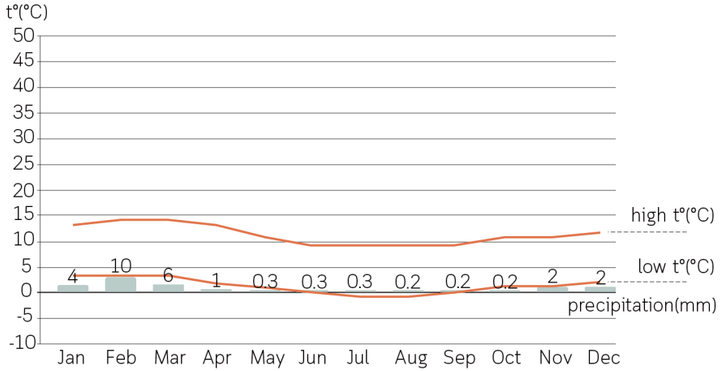
Figure 4
Amunas in San Pedro de Casta District

Climate.

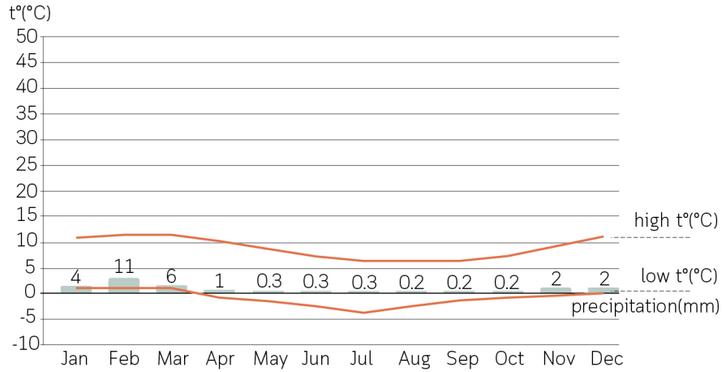
Climate zone: **Tropical**
Sub-climate: Warm semi-arid climate

Climate & Weather Averages
Huamantanga
High t°: 14°C
Low t°: -1°C
Mean t°: 6°C
Precipitation: 2.2 mm
Humidity: 48%
Dew point: 14.16°C
Wind: 6 km/h
Pressure: 1045 mbar
Annual Rainfall: 26.5 mm per year

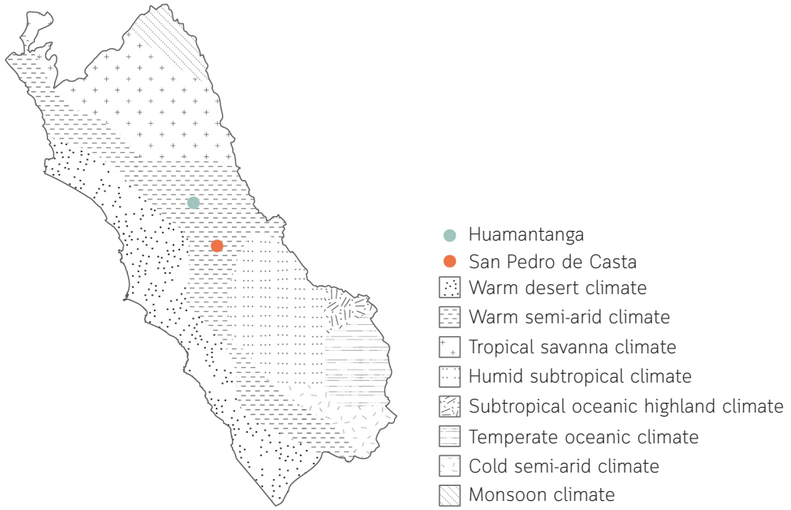
San Pedro de Casta
High t°: 12°C
Low t°: -3°C
Mean t°: 5°C
Precipitation: 2.3 mm
Humidity: 41%
Dew point: 6°C
Wind: 5 km/h
Pressure: 1074 mbar
Annual Rainfall: 27.5 mm per year



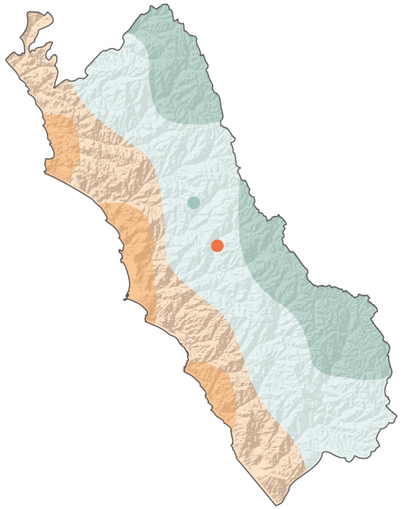
Climate of Huamantanga (Peru)



Climate of San Pedro de Casta (Peru)



Lima map of Köppen climate classification



Precipitation (Dec-Feb)

Precipitation (Jun-Aug)

Figure 5: Annual precipitation and temperature at Amunas locations
Figure 6: Climate mappings of Lima province

Catchment area.

The Chillón-Rímac-Lurín basin is located in the province of Lima, and its primary water system is comprised of the Chillón, Rímac, and Lurín rivers, as well as their tributaries, creeks, and lagoons, among others. The Amunas system can be regarded as an additional recharge system, which contribute 3,275,925.75 m³ water per year.

Chillón-Rímac and Lurín are the principal aquifers that hold groundwater in the region. In contrast to Lurín, the Chillón and Rímac aquifers are interconnected and trade their groundwater. The three aquifers cover roughly 866.46 km² or 10% of the entire land area.

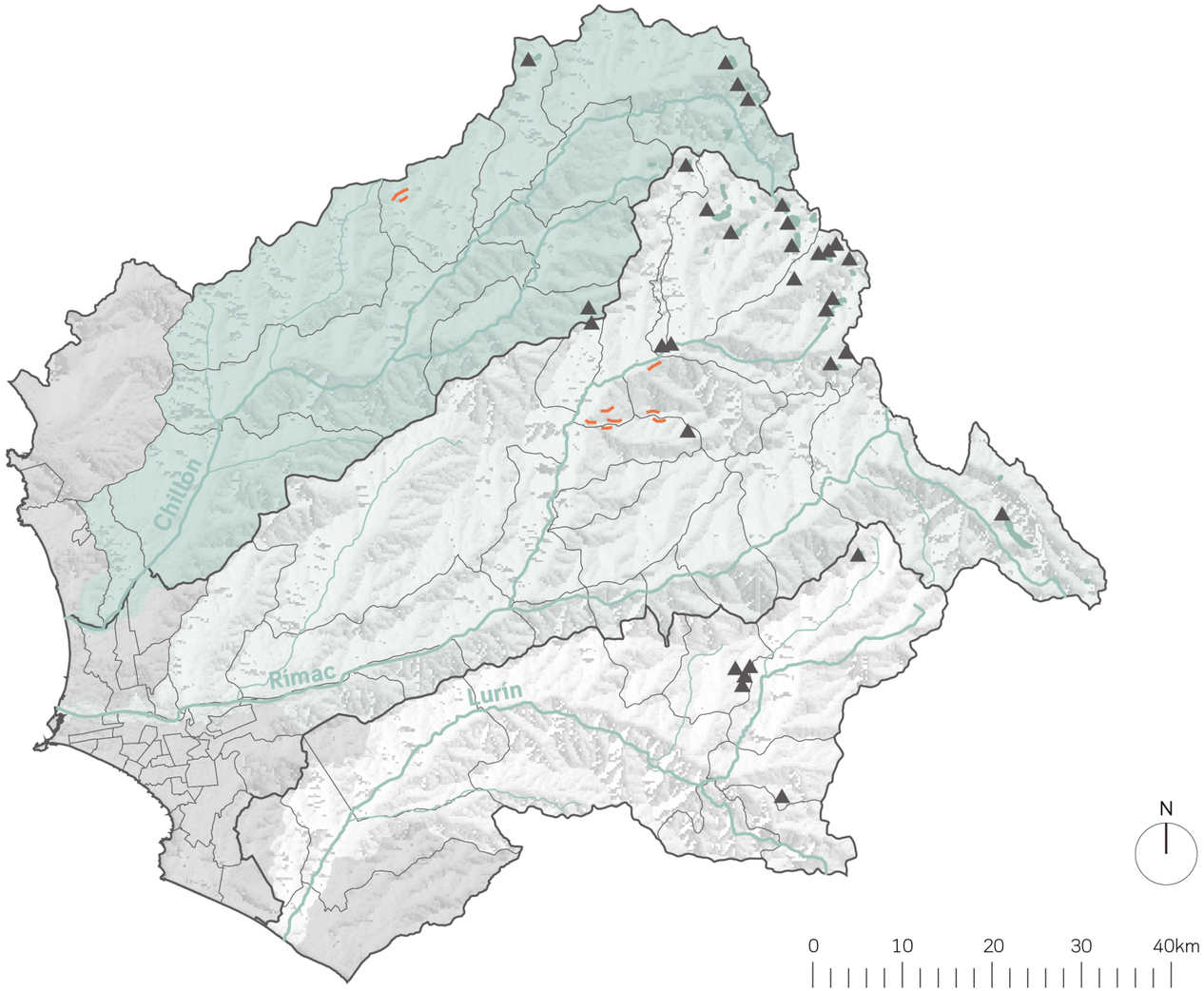


Figure 7: Chillón-Rímac-Lurín basin in Lima province scale
Figure 8: Hydrographic units and main waters in Chillón-Rímac-Lurín basin

Human interaction.

The process of WATER SOWING. Water recharge of soil, subsoil and aquifers, through human interventions aimed at retaining, infiltrating, storing and regulating runoff water from rainfall.

Figure 9: Diversion canals: (1) long canals that divert water flow into infiltration canals and slopes, and (2) short canals that direct the excess water towards basins or other watercourses downstream.
Figure 10: Infiltration canals: These transport water toward the infiltration slopes.
Figure 11: Infiltration canals: These canals allow water to infiltrate into the subsoil.
Figure 12: Infiltration hillslopes: These are rocky or stony areas that receive water from the canals and spread it across the field, effectively using the soil as a natural reservoir of water and at the same time slowing down the water's outflow.
Figure 13: Springs: The water emerges downslope in springs, which form naturally and whose volumes are increased by the resurfacing of infiltrated water.
Figure 14: Ponds: Small bodies of water (around 300m³ each) are used to regulate the flow of water through the infiltration system. They serve two purposes: (1) to store water for direct access, and (2) to further increase subsurface water infiltration.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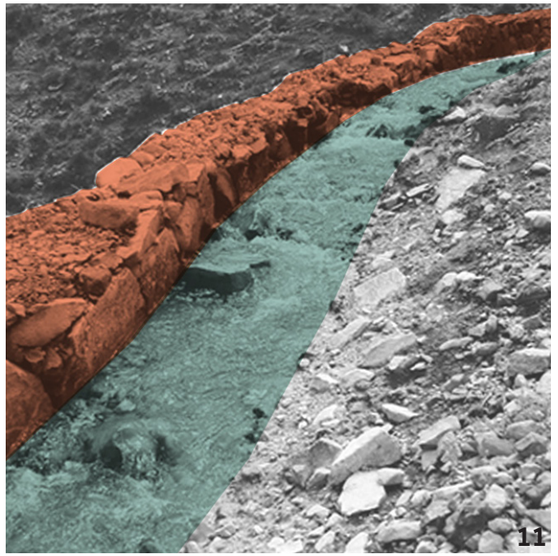
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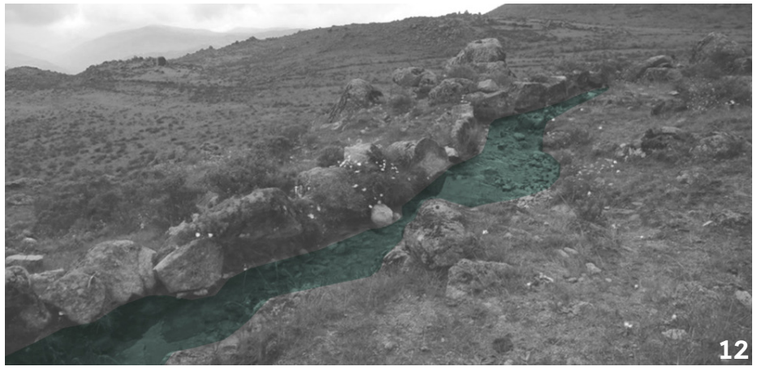
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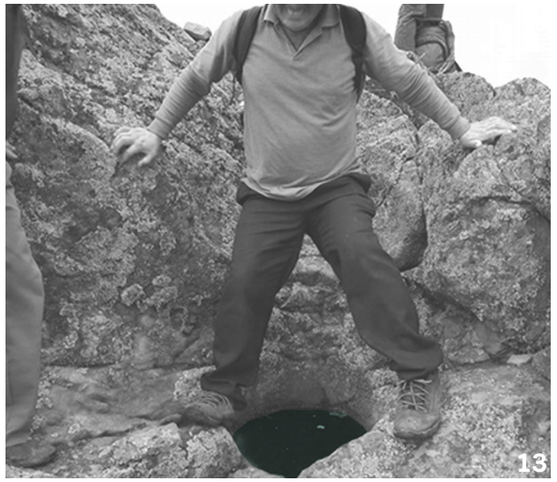
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14

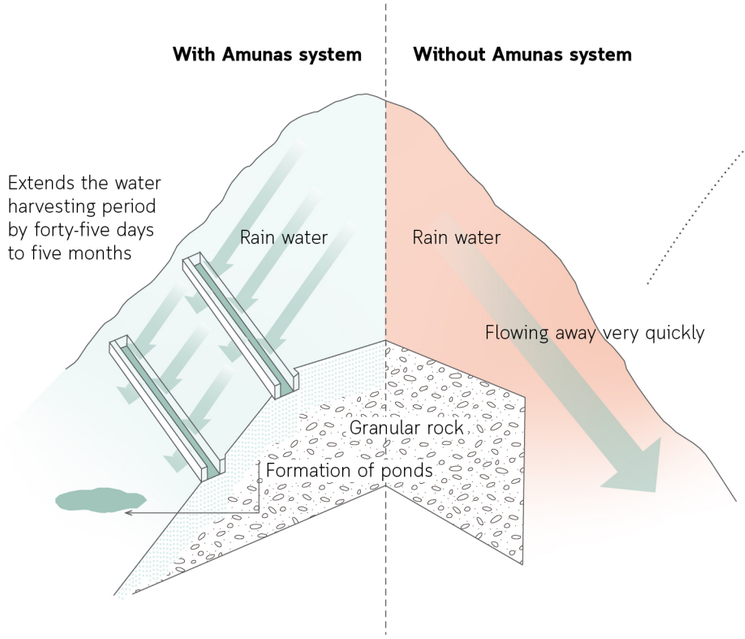
Water system.

The geological structure of the Andes formed the basis for the development of the Amunas, the water-bearing rocks constituting the underground structure of the Amunas, where water gradually moves through cracks in the sediments and rocks until it reaches the springs beneath the slopes.

Water is kept in the soils and flows considerably more slowly below the surface than it would overland(Boris Ochoa-Tocachi, 2019). During the dry season, springs are sustained by water that would have otherwise been lost by flooding.

11 of the original Amunas canals are still in operation, supplying 65 active springs and 14 tiny ponds with water.

In the Peruvian Andes, where water shortage is severe and there are water-bearing rocks for underground storage, the Amunas artificial recharge system would be beneficial. Sand and gravel soils are nearly nonexistent in the Andes; the majority of the area is covered by rocks. These include claystone, which generates the thin and fragile arable soils that sustain agricultural activity in the Andes, and granular rock, which forms the water-supplying rocky hills of the highlands. Thus, it may be stated that dense rocks with low porosity and open fissures allow for the storage and release of water as springs. In the majority of basins, this is the only permanent source of water, hence its significance.



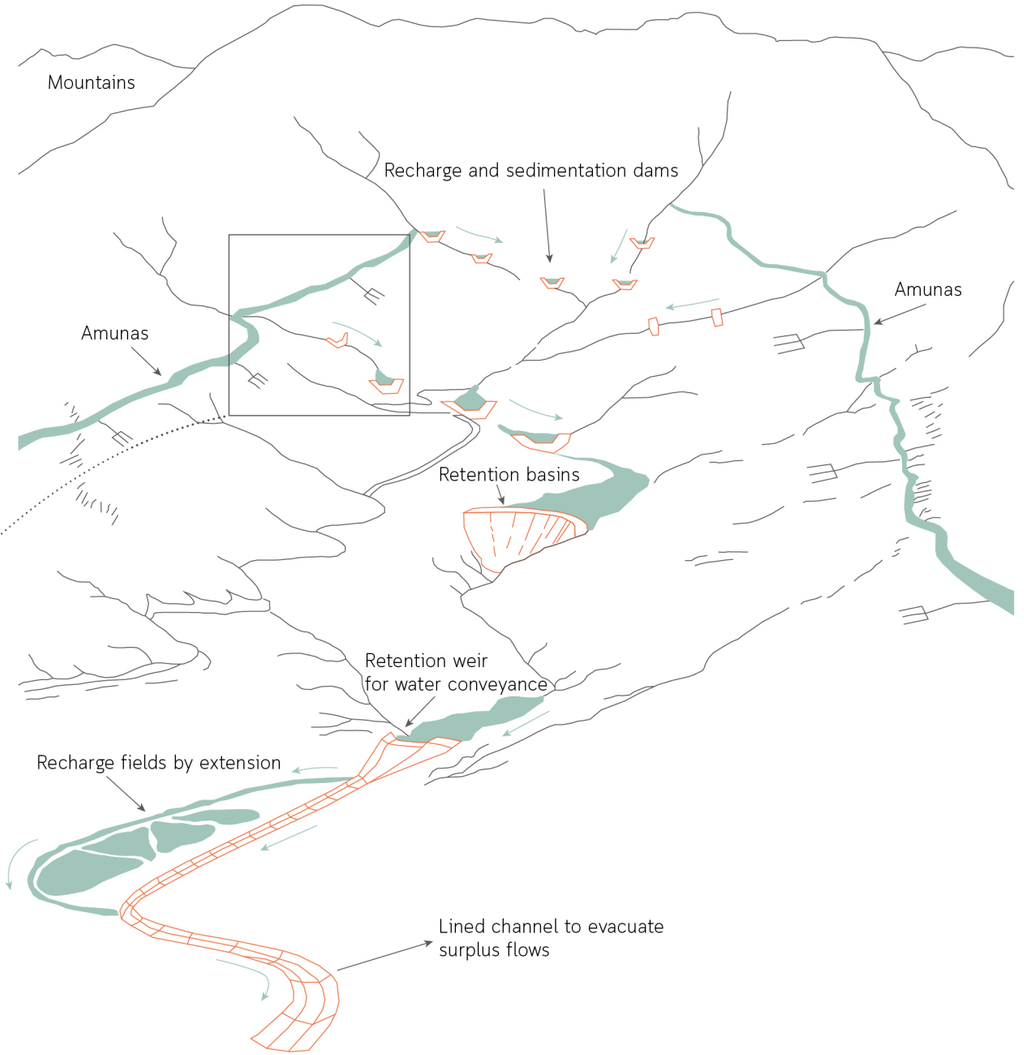
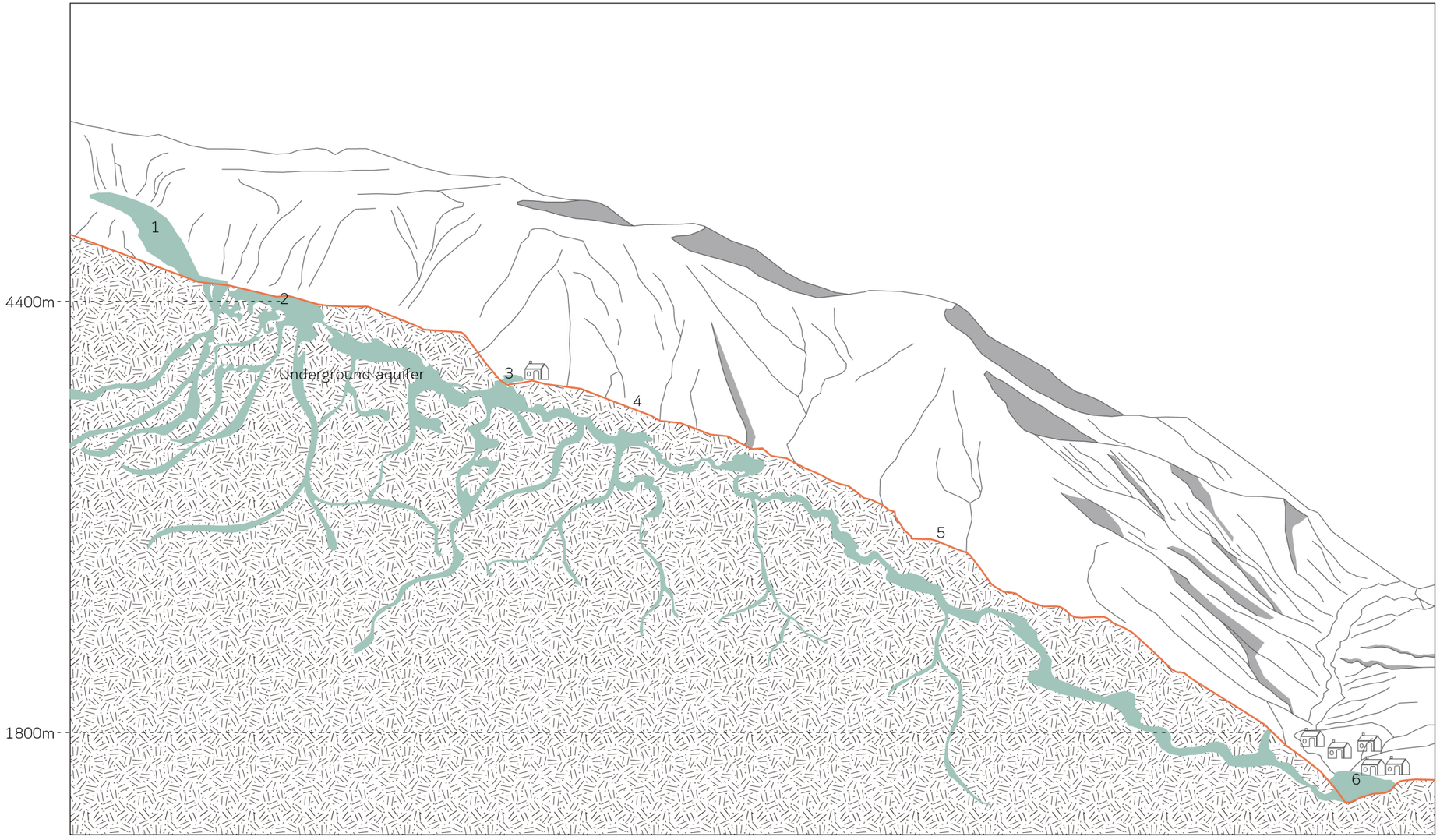


Figure 15: Comparison with and without the Amunas system
Figure 16: Recharge systems in basins

Water system sections.

The Amunas, which catch water from streams and direct it via permeable terrain, allowing water to filter into the subsoil during the rainy season, which is known precisely as water sowing. Geological and scientific research demonstrates that the water gathered by the Amunas has the ability to infiltrate beyond a community and even reach the cities.



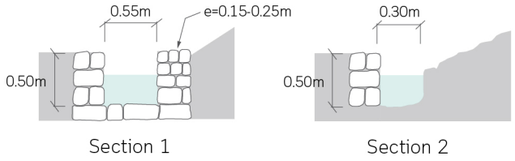
1 Valley Creek 2 Amunas system 3 Towns for building and managing the Amunas, access to water from amunas through ponds. 4 Down the mountain, the outcropping of springs and the increase of flora around these areas begins. 5 From this area, water is more easily available from springs, depressions or water eyes. 6 Downstream towns and cities

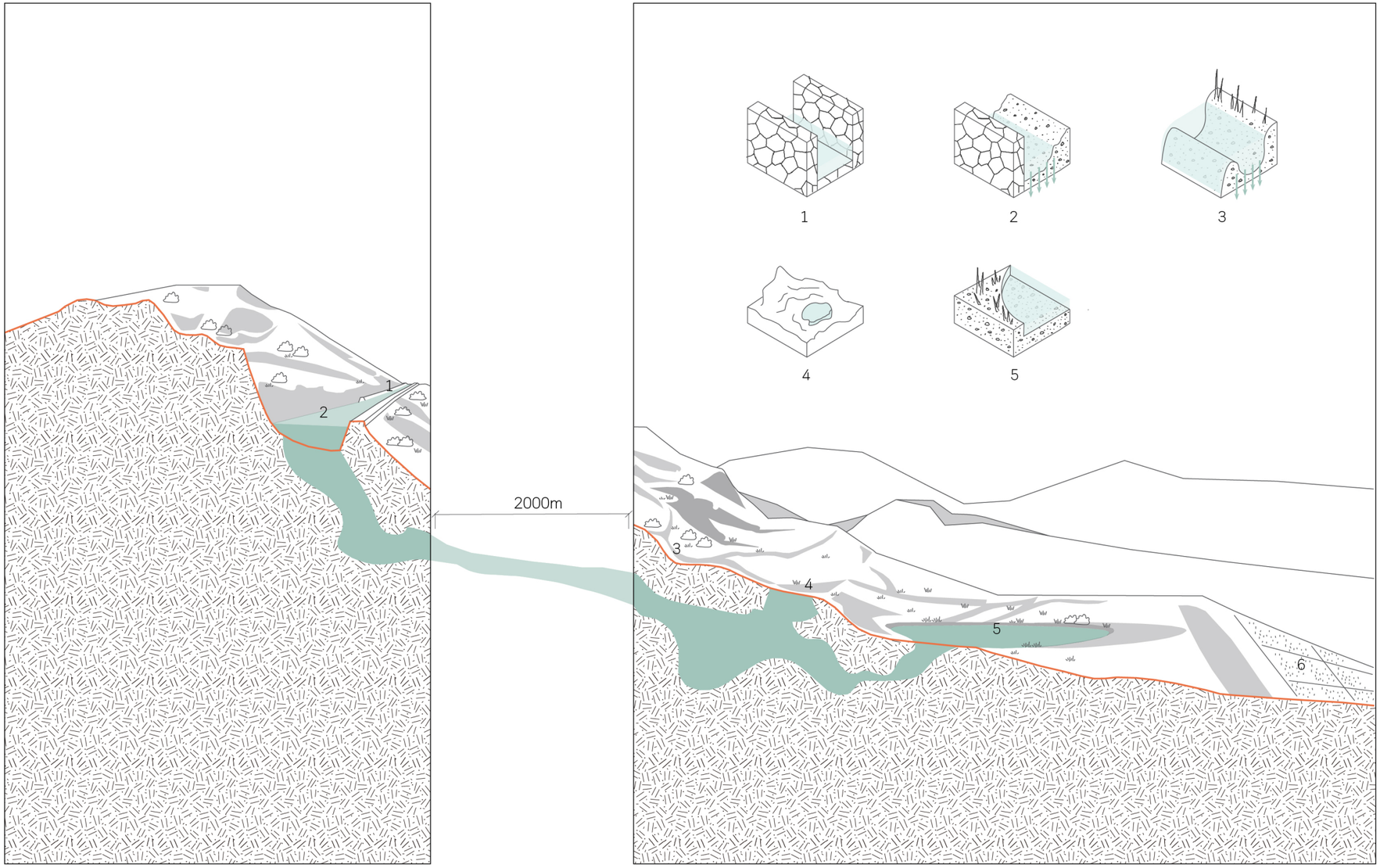
Figure 17: Upstream - downstream scale section

Water system sections.

The traditional Amunas are comprised of five components: infiltration canal (stone base), infiltration canal (soil base), infiltration hillslope, spring and pond, the first two of which require man-made construction and the last three of which are predominantly natural, but also include the locally-made Qochas (Water reservoir).

This type of infrastructure not only benefits the infiltration of water into the soil feeding the aquifer but also protects the slopes from water erosion, reducing the impact of natural disaster such as the huaycos.





1 Infiltration canal (Stone base) 2 Infiltration canal (Soil base) 3 Infiltration hillslope 4 Spring 5 Pond 6 Farmland

Figure 18: Amunas detail sections
Figure 19: Upstream scale section

Water circularity.

The existence of the community is essential for the Amunas to function, as it is a crucial factor in the physical and organizational aspects of planting, harvesting, conducting, and infiltrating rainwater into the mountain in order to 'humanely' recharge the aquifers.

In the district of San Pedro de Casta, where the Amunas are protected, where there are no snow-capped mountains, and where everything depends on precipitation, the inhabitants continue to practice this traditional method of water collection and agriculture. According to the statements of the settlers, the Amunas preserve the water in the springs and streams during the dry or water-scarce seasons for domestic and agricultural use, as well as for public services; as a result, they organize annually, with a sense of reverence and ritual, a large community celebration of gratitude and dedication.

Figure 20: Rituals of water gratitude

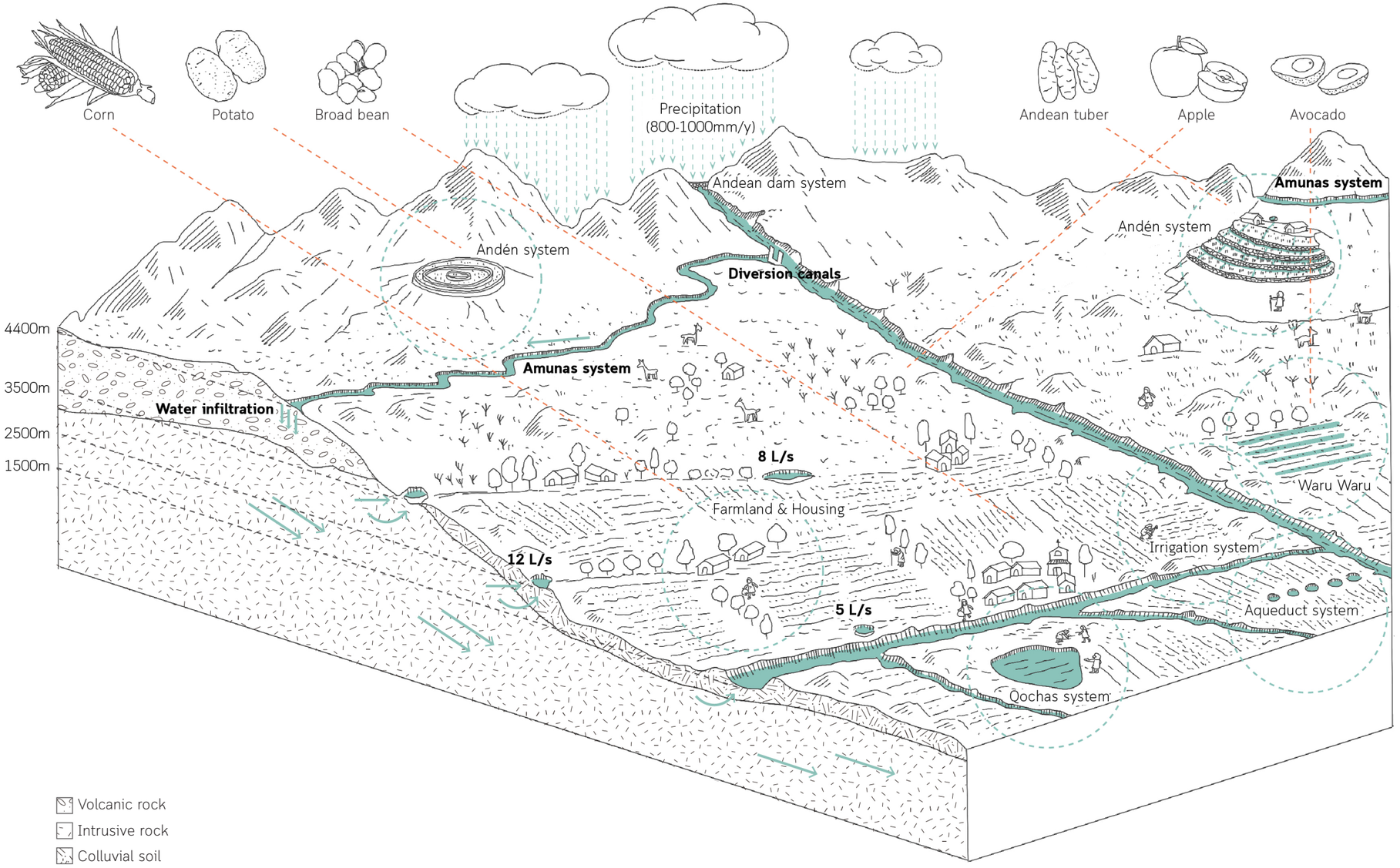


Figure 21: Water system and circularity

Water stories.

Restoration of Amunas
The people of the town leave their homes very early in the day and arrive at the top of the mountain three hours later to begin the restoration of Amunas in almost zero degrees Celsius. They sing hualinas like Euphronio, use cigarettes to keep warm, and make offerings to the mountain. They bring picks, shovels and a small amount of food. In their communities, they are trained to use the techniques of this project. Their goal is to rebuild what was there before.

Periodic dredging
The people who live here are called *comuneros*: members of agricultural collectives. They have rituals surrounding the cleaning and blessing of the canals, as they know that removing the silt each year keeps them functioning properly.

Harvesting water from Amunas
In the dry season, as the water collected by Amunas flows out of sprints and ponds, people use the water for daily life, agricultural production and grazing.

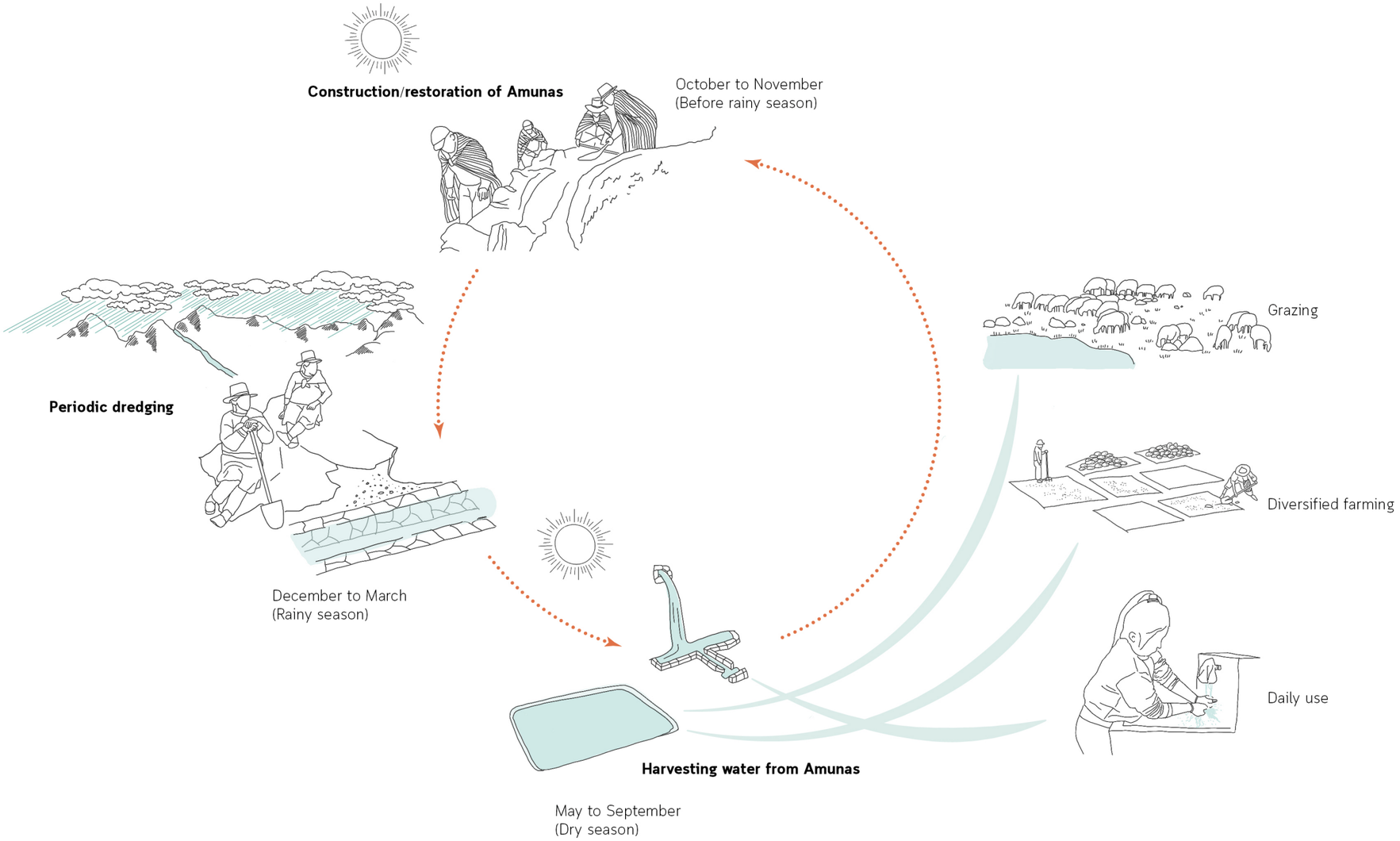


Figure 22: Restoration of Amunas by local residents

Conclusion.

This research seeks to understand the structural characteristics of the ancient Amunas water system located in the Andes, how it works, the importance of its existence in the past, and the interaction between this water system and the productivity and lives of the people.

This water system is situated in the Huamantanga and San Petro de Casta districts of Lima province, in the respective basins of the Chillón and Rimac rivers. The major water system's structures are located 3800 meters above sea level, and they have a number of outlets nearby in the upper, middle, and downstream regions, including springs, natural ponds, and partially man-made water reservoirs at an altitude of 1500 meters. The majority of Amunas have been abandoned, however, as a result of inadequate administration and maintenance.

The district where the Amunas site is located has been actively engaged in the restoration of this ancient water system since 2015 under a law on Compensation Mechanisms for Ecosystem Services (2014), and it is anticipated that all 67 kilometers of the Amunas will be fully restored by 2025. The Amunas system itself and its restoration have numerous values.

Landscape Values - The Amunas system, which was constructed 1400 years ago to store rainwater, has both cultural and ecological landscape significance. These ancient structures, which are located in the Andes, are regarded as landmarks and significant sites of Andean civilization. Moreover, this water system serves the purpose of purifying water and nourishing the animals and plants along the way.

Strategic values - Due to seasonal precipitation, the province of Lima faces a severe water shortage. The ancient ancestors obtained water during the dry season through the Amunas system, which not only supplies the inhabitants of the communities from upstream to downstream, but also further downstream to the cities.

Values of sustainability and circularity - In the Amunas system, water is sown and harvested as the most sustainable form of feedback. Instead of immediately flowing down the slopes during the rainy season, rainwater is held in the soil and re-emerges in the dry season to support agricultural production and everyday consumption. Additionally, this highest expressions of this ancient Andean water culture, enables agricultural sustainability.

Ethnographic and identity values - The Andean people place a high priority on the connection between man and nature. Even inanimate things are venerated as Andean nobility, as the Andean world views life as a whole, nothing is isolated, its utilization of resources is founded on reverence for its divinity. The intelligent utilization of rainwater in the Amunas system embodies the Andean respect for water and fosters a sense of cultural identity among the local inhabitants.

Lessons to learn - Through the research of Amunas, we have discovered the eco-friendly potential of rainwater storage in arid regions. The present Amunas contribute 3,275,925.75 m³/year to the basins of the rivers Chillón and Rimac, making this system more economical, environmentally friendly, and efficient than the urban grey industrial water storage facilities. After the rehabilitation of all 67 kilometers of the Amunas, an estimated 15,000,000 m³/year might be supplied. This is a very enormous volume of water that could be used everyday to supply 300,000 people.

During the course of the investigation, we also discovered that overgrazing and deforestation were detrimental to the system's effectiveness and water quality, and it is worth considering how to improve soil compaction. The next phase for the government and landscape architects is to maximize the landscape's benefits using the vegetation along the Amunas path.

In addition, we acknowledge that all parts of the construction, management, maintenance, and usage of the Amunas system are integrally tied to human activity, and that the Andean people's respect for water and other natural resources is instructive.

Figure 23: Restoration of Amunas by local residents

References.

Project X - Amunas water system

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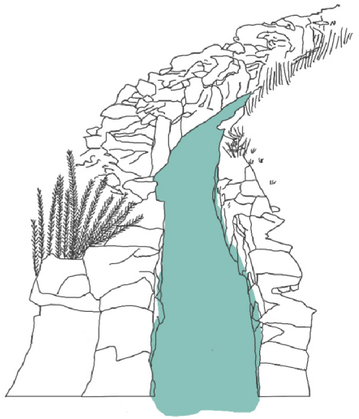
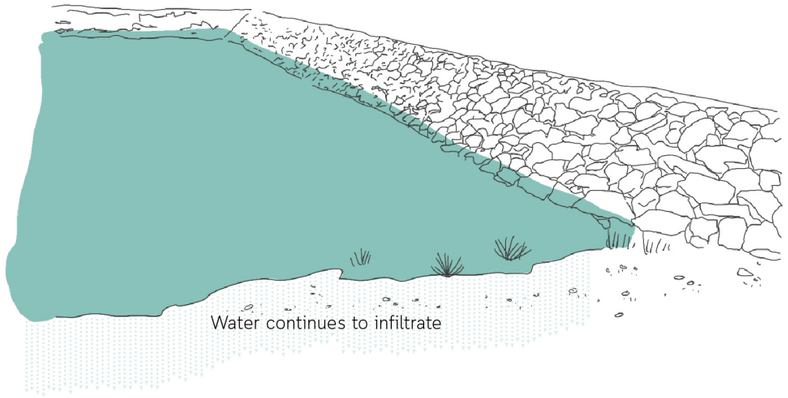
Glossary.



Amunas
The amunas are an ancestral system that allows the sowing, harvesting and supplying of rainwater, helping to reduce water stress in villages that do not have sufficient access to drinking water.

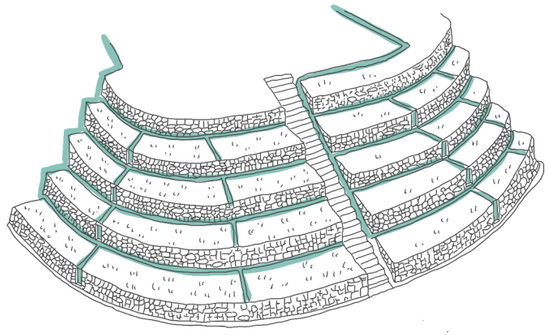
Project Name: Amunas water system, Lima province, Peru
Climate: warm semi-arid climate
Year: 700
Water type: rain water, river water
Landscape Type: Mountain landscape
Altitude: around 4400 m.a.s.l (meters above sea level)
Water Workers and Users: farmer
Accessibility: Public
Materials: stone, soil
Period: fixed
Form: line
Use or Functions: aids the process of filtering water down the slopes on its route to the river and allows the filtered water to rise to the surface at the mountain's base during the dry season



Qochas
The qochas are small reservoirs or artificial lagoons that are built in natural depressions in the ground, allowing rainwater to be stored and infiltrated.

Project Name: Amunas water system, Lima province, Peru
Climate: warm semi-arid climate
Year: 250 - 380
Water type: rain water, river water
Landscape Type: Mountain landscape
Altitude: around 4000 m.a.s.l (meters above sea level)
Water Workers and Users: farmer
Accessibility: semi-Public
Materials: local materials such as stones and clods of earth
Period: fixed
Form: squares and circles
Use or Functions: store rainwater for farming

Glossary.



Andén
A stair-step like terrace dug into the slope of a hillside for agricultural purposes

Project Name: Amunas water system, Lima province, Peru
Climate: warm semi-arid climate
Year: Around 1500
Water type: ground water
Landscape Type: Mountain landscape
Altitude: 3200 - 3500 m.a.s.l (meters above sea level)
Water Workers and Users: farmer
Accessibility: semi-Public
Materials: underground or bedrock foundations, retaining wall, large stones, sand or gravel, topsoil
Period: fixed
Form: stepped
Use or Functions: agriculture

Waru Waru
a highland field agriculture consisting of alternating parallel canals and raised planting beds.

Project Name: Amunas water system, Lima province, Peru
Climate: warm semi-arid climate
Year: 300 B.C.
Water type: ground water
Landscape Type: agricultural landscape
Altitude: around 3800 m.a.s.l (meters above sea level)
Water Workers and Users: farmer
Accessibility: private
Materials: soil
Period: seasonal
Form: lines
Use or Functions: agriculture