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Glacier retreat, hands at work: WTP for water infrastructure and resource mobilization in Huaraz - Peru

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Declaration

I, Gonzalo Juaquin Ale Pezo, declare that this thesis is the result of my research. Sources of information, other than my own, have been acknowledged and a reference list follows. This work has not been previously submitted to any other university as part of any academic degree.

Signature:
Date: May 14, 2019

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This thesis also reflects the five years I have spent at NORAGRIC - NMBU. My academic home taught me to bend intellectual boundaries, look for answers in unexpected places and take into account the well-being of humans and non-humans. I would like to thank my supervisor Prof. Morten Jerven, for his patience and diligence. Also, recognition is due to Prof. Arild Vatn for sparking my curiosity in blending economics with non-economics.

Finally, I will also thank my family for their support through my career, in special to my aunt Silvia Bolivar Olsen and her family for introducing me to this country.

Abstract

This thesis will estimate the Willingness to Pay (WTP) for water infrastructure in the city of Huaraz - Peru. Huaraz is one of Peru's most vulnerable city to Climate Change. The city lies under the largest concentration of tropical glaciers in Peru: The Cordillera Blanca. Melt water from the glaciers has contributed to an even water supply, and corresponding urban development. However, Climate Change is posed to reduce water supply.

Once glacial melt water stops flowing, water infrastructure such as reservoirs and water tanks will have to compensate for the losses. A Choice Experiment helped to gauge Huaraz residents' interest on these two alternatives. These results were controlled for Climate Change perception and agency.

The results show that people have a strong predilection for reservoirs, being reservoirs the most familiar option in the past. In other words, urban planers need to invest in large infrastructure to adapt to Climate Change. In addition, interviews with water committees show that water fees are too low, and might be insufficient to fund infrastructure expansion.

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Chapter 1

Introduction

Climate Change (CC) will severely affect Peruvian Andean glaciers, especially since Peru contains 80% of the tropical glaciers of the planet. An increase in temperature could eliminate small glaciers, and reduce drastically the size of larger ones. Furthermore, Andean glaciers have accelerated their retreat since the the Little Ice Age (Rabatel et al. 2012). As a consequence, water supply from Andean glaciers will be reduced severely (Mathias Vuille et al. 2008).

Huaraz - Peru, is a city in the middle of the Cordillera Blanca, the mountain range with the largest number of glaciers in Peru. In Huaraz, glaciers are both a boon and a threat. Glacier melt water maintains a regular water supply during both dry and rain seasons. Yet, they also create dangerous glacier lakes uphill. For instance, lake Palcacocha destroyed almost a third of Huaraz in 1941 flood (Carey 2010). CC poses a threat to both the city and the water supply. Therefore, adaptation plans include expansion of the Water Infrastructure (WI) to collect excess melt water and protect the city.

WI planning needs also to involve residents. Measuring the WTP (Willingness to Pay)for WI helps to gauge people interest in WI and what attributes they value. Then, policymakers have an overview on people's preferences and needs. On the other hand, these needs are articulated via communal institutions such as water committees. On this process, users have different service expectations and perceptions of CC. Therefore, subjective and social factors influence the WTP and feasibility of WI planning.

1.1 Research questions

Main Research Question

How do Huaraz residents mobilize resources to improve WI in the face of glacier retreat?

Secondary research questions:

1. How high is the WTP for WI?

2. How does CC perception affects WTP?

3. How do decision makers facilitate WI improvement?

I have: (A) Created a CE (Choice Experiment) survey to answer the first two sub-research questions. My hypothesis sustains that *WTP (Willingness To Pay) for WI depends on the perceptions people have on CC impact*. In the experiment, respondents selected between a Reservoir or Water Tank. Then, WTP is calculated and controlled for CC. (B) Interviewed water committee presidents and water experts. Their positions frame WTP into a context of social conflict, aspirations and history.

1.2 Objectives

First, CC adaptation will disrupt public management and services. Adaptation succeeds when decision makers can gauge public interest beforehand. WTP expresses this interest in currency terms.

Second, WTP should not be the sole indicator for policy. CC adaptation should be socially understood and practiced (W. N. Adger et al. 2005; Benjaminsen and Bryceson 2012; O'Brien et al. 2007). Moreover, in an issue such as CC where information and misinformation abound, the effects of public perception matter. In other words, WTP estimates cannot be taken at face value, and outside an institutional context.

Chapter 2

Previous Knowledge

2.1 Glacier geography

2.1.1 Glaciers

Glaciers are formed in areas where snow fall exceeds melt over the summer(Hooke 2005). Such areas are most likely found at high elevations or polar latitudes. A glacier has two zones: An upper accumulation zone and a lower ablation zone(See Fig. 2.1). As snow layers accumulate, pressure increases at the bottom layers. These layers then solidify, and after several years, snow morphs into solid ice. If snow deposits on steep terrain, ice can move towards lower elevations due to gravity. Then, the ice falls into areas where it quickly melts, often producing a lake. This exposed area becomes the *ablation zone*. Ablation can occur due to melting, wind erosion and calving. The *equilibrium line* lies between the accumulation and ablation areas at the end of the melt season. In terms of net accumulation, Fig 2.1 shows that the equilibrium line corresponds to the point where the net accumulation is equal to zero.

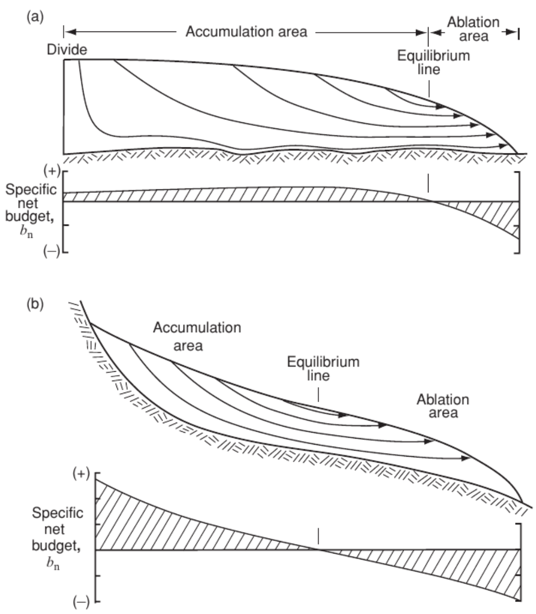

Figure 2.1: Adapted from Hooke (2005), where the upper image shows a typical polar ice cap, and the bottom image shows a valley glacier

The *winter balance* of a glacier is the amount of snow accumulated during the winter (Hooke 2005, pg.23). The *summer balance* is the amount of snow and ice lost by melt, usually accounted with a negative number. The *net balance* is the sum of the winter and summer balances after one year. However, in tropical glaciers, summer and winter seasons are not clearly delimited. Still, (Hooke 2005) sustains that the basic principles still apply on tropical glaciers.

To measure mass balance, one has to measure the snow height (or ice surface level) using stakes planted on the glacier. These measurements are repeated three times: at the end of the last melt season, at the end of the winter, and at the end of the next melting season. We can formalize the relationship between winter and summer balances as follows. Say $b_s(x, y, z)$ is the specific summer balance, $b_w(x, y, z)$ is the specific winter balance. Then, the specific net balance $b_n(x, y, z)$ is by definition:

$$b_n = b_s + b_w \tag{2.1}$$

Then, the net balance B_n is given by:

$$B_n = \int_A (b_s + b_w) dA \tag{2.2}$$

Where A is the area of the glacier. We can also calculate the average balance $\overline{b_n} = B_n/A$. If B_n or $\overline{b_n}$ are positive, then the glacier has a positive mass balance. A retreating glacier is a glacier with negative mass balance.

Glaciers posses natural albedo; they deflect sunlight and keep their surfaces cool. However, as glaciers shrink, they expose the darker ground that absorbs more radiation, and this reinforces melting.

As glaciers descend, they move materials to create moraines. This structure resembles walls, that surround the tongue of the glacier. If the walls enclose a water body, this body is called a moraine lake. Moraine lakes often form over sub-soil rich in clay, sand and ballast, this makes harder for water to filter down. Moraine lakes often form at high altitude, above the 4 000 m (Morante 2018).

Figure 2.2: A moraine lake in the Peruvian Andes. The Spanish name is “Morrenas”. Adapted from Morante (2018, pg.10).

2.1.2 Water and Glaciers

Glaciers matter worldwide, as they store 75% of the global freshwater reserves (Schoolmeester et al. 2018, (National Snow and Ice Data Center, 2018) in). They release water and smooth the transition between rainy and dry seasons. Since these communities are not able to storage the excess water, melt water is lost and/or fills up morraic lakes. Peak water happens when melt water run off reaches its maximum. Tropical glaciers are expected to reach peak water in the following 20 years, and some have already reached this state.

Peru has 159 water basins, according to the Pfafstetter classification (INAIGEM 2018). From these, 36 basins are considered glacial. Peruvian Andean inhabitants rely on glacier melt water to continue with their activities during the dry season. For instance, melt water constitutes 67 % of the water supply in Huaraz during a regular year. Under a drought, melt water contribution jumps to 91% (Schoolmeester et al. 2018). In addition, major cities such as Lima, depend on the water produced on the Andes.

2.1.3 Andean Tropical glaciers

Andean mountains provide water to 75 million people directly, and 20 million indirectly. Most of largest rivers in South America depend on glacier water. For instance, glacier water helped cities on the arid South-American Western coast to expand. The Andes is divided into three regions. The Northern Andes covers Venezuela, Colombia and Ecuador. The Central Andes comprises of Peru and Bolivia. Finally, the Southern Andes comprise of Chile and Argentina. Here, lies the largest number of glaciers (4 000 approx.), on the border between these two countries. The North and Central Andes receive the collective name of Tropical Andes. The Tropical Andes gather 95% of tropical glaciers worldwide [1]. The Peruvian Andes concentrates the highest number of tropical glaciers.

In the Andes, glaciers form above the snow line. The *snow line* lies where snow persists through the year. The snow line location dpeneds on precipitation, latitude and altitude. Temperature raises faster at higher altitudes. Moreover, the mean temperature in the tropical Andes has increased by 0.8 C during the 20^{th} century, and they are expected to increase 2 -5 C by the end of the 21^{th} century. This has resulted in the snow line receding 45 m. on average (Schoolmeester et al. 2018). Andean glaciers are being severly reduced since the Little Ice Age (Rabatel et al. 2012). Many of the currently retreating glaciers are small and at low altitudes, and they could disappear on the near future. This process will accelerate due to irregular rain patterns. IPCC models conclude that Andean glaciers will disappear even under the most conservative scenario, losing up to 79%-97% of their volume.

Humans have lived in the Andes for thousand of years. In Peru, around three million people live on areas close to the Andes, or 10% of the national population. Due to the extension of the Andes, this results in a low population density. However, the earliest settlements date back to 12 000 years. The main economic activities include mining and agriculture. For instance, the Andes concentrates 64% of all farmers in Peru. On the other hand, urbanization has become more widespread. However, rural and indigenous communities remain poor and excluded.

[1] This is, from all the glaciers on the same latitude

2.1.4 Peruvian Glaciers

Peru is home of the largest concentration of tropical glaciers. Peru hosts 71 % of all tropical glaciers (Rabatel et al. 2012). Glaciers in the Peruvian Andes constitute important water buffers. The water flow in the Andes varies strongly among seasons. Melting glaciers ensure that water continues to flow year-around. However, some glacier mountain ranges have lost more than 90% of their glaciers (INAIGEM 2018). For instance; Chila and Chonta are almost extinct.

Peruvian glaciers have two periods: Accumulation and ablation (INAIGEM 2018, Chap. II). Ablation means that ice disappears due to fusion, evaporation or sublimation. Accumulation occurs during the rain season. On the other hand, ablation is a year-long process. In other words, glaciers are constantly on the verge of extinction.

2.2 Water Economics

2.2.1 Willingness to Pay

The study of WTP falls into the area of Welfare Economics. In addition, WTP matters since it speaks from its connections with economic efficiency and markets (Greco 2017). However, in its use we might miss other social objectives such as equity and sustainability. In addittion, the definition of WTP depends on a baseline for measure - the *status quo*. Different income levels will make the status quo more accessible for wealthier classes. Welfare Economics hopes to maximize social welfare via the efficient allocation of resources. We opt for the WTP instead of the Willingness to Accept since the WTP is easier to measure (Johnston et al. 2017).

Water is not a market good, therefore, there is no point in defining producer surplus. Therefore, the demand curve for water can be interpreted to represent its marginal benefit or the WTP for water (Griffin 2006) Integration under the curve, we obtain the total benefit or consumer surplus.

To understand the benefits derived from a project, we construct the following model, taken from Moore (2007, pg.432). Define the consumer consumption by:

$$C_i = \mathbb{R}^n_+ \times Y_i$$

For the i consumer, where Y_i is the public goods consumer space. The elements of C_i are (x_i, y_i). Let us define a consumer demand function h_i on $\Omega \times Y_i$, whose images are $h_i(\mathbf{p}, w_i, y_i)$, and $\mathbf{p}$ is the price vector for private goods and w_i is income.

A policy change is a shift from one demand $(\mathbf{p}^1, \mathbf{w}^1, \mathbf{y}^1)$ to $(\mathbf{p}^2, \mathbf{w}^2, \mathbf{y}^2)$, where c_i denotes consumer i WTP for the project. Then by definition, we should have:

$$(\mathbf{p}^2, w_i^2 - c_i, y_i^2) G_i^* (\mathbf{p}^1, w_i^1, y_i^1)$$

For G_i^* an indirect preference relationship defined to be:

$$\begin{aligned}&(\mathbf{p}^2, w_i^2, y_i^2) G_i^* (\mathbf{p}^1, w_i^1, y_i^1) \\ &\qquad\iff (h_i(\mathbf{p}^2, w_i^2, \mathbf{y}^2), y_i^2) G_i (h_i(\mathbf{p}^1, w_i^1, \mathbf{y}^1), y_i^1)\end{aligned} \tag{2.3}$$

In other words, the consumer needs to be as well off after the project, even if (s)he would loose c_i from their income.

We have a project:

$$C < \sum_{i=1}^{m} c_i$$

Where C is the total cost of the project. Let $\delta > 0$ be such as:

$$0 < \delta \leq \sum_{i=1}^{m} c_i - C$$

We want to compensate each consumer by their lost with δ/m. In addition, we need to tax t_i each consumer to fund the project. Say, $I_1 = \{i \in \{1, \cdots, m\}/c_1 \leq 0\}$. Then, I_1 corresponds to the users who oppose or are indifferent to the project. Users positive to the project are then, $I_2 = \{1, \cdots, m\} \setminus I_1$. Then:

$$\lambda = -\sum_{i \in I_1}^{m} c_i$$

$$\gamma = \sum_{i \in I_2}^{m} c_i$$

And the constant $a = \dfrac{C + \delta + \lambda}{\gamma}$. Therefore, we have the tax level set at $\mathbf{t} = (t_1, \cdots, t_n)$, such as:

$$t_i = \begin{cases} c_i & \text{for } i \in I_1 \\ a \cdot c_i & \text{for } i \in I_2 \end{cases}$$

Finally, the net income for the consumer is

$$\hat{w}_i = w_i^2 + \frac{\delta}{m} - t_i$$

For consumers opposed to the project:

$$(\mathbf{p}^2, \hat{w}_i, y_i^2) P_i^* (\mathbf{p}^1, w_i^1, y_i^1)$$

Therefore, if the aggregate WTP is greater than the cost, and appropriate compensation is paid, society obtains a Pareto improvement.

2.2.2 Public investments in WI

Water infrastructure does not only considers reservoirs, but also the distribution network. According to Turvey (1976), the distribution network can be expanded through small and frequent investments, adequate to the number of new connections. However, the central system (i.e. reservoirs, treatment and catchment plans), can only be expanded on the long-run. In addition, central system expansion requires regulation and careful planning. It is in the latter that the regulator finds its purpose: to screen the needs of society, and to carefully execute them with limited resources. Since water is an indispensable resource, central system expansion is one of the central duties of any government. Costs, on the opinion of

Turvey (1976), only delay or accelerate this expansion. Marginal costs are calculated by future system costs in the demand. However, we also need to understand other motivations for central system expansion. For instance, CC will provide a strong argument for speeding up this expansion, even if CC is not caused by local activity.

Water urban planning needs to consider environmental needs, and keep checks on urban expasion. However, many users believe that water is an open and inextinguishable resource (Marlow et al. 2015). CC will disrupt the water supply with less rain, melting glaciers and uncertainty. In other words, WI is needed and also, a plan to manage risk of service failure. Therefore, asset management needs to include sustainability. While traditional asset management concerns itself with service, cost and risk control, sustainable asset management needs to include social and environmental targets. However, the transition towards sustainability should include users, and to match their expectations and vulnerability.

2.3 Environmental consciousness

Social values predispose individuals and societies in being pro-environmentalists or not (Dunlap and Van Liere 1978). In other words, there is social paradigm for environmentalism. A paradigm scribes the role humans play in nature. During the 1970's America, the movement towards environmentalism started as a reaction against modern values. However, certain environmental paradigms might older and non-Western. For instance, for indigenous Andean religions, textitpacha denotes a non-anthropocentric paradigm (Centeno 2009). In *pacha*, environmental consciousness means awareness of nature both within and outside.

According to Handlbauer (2000), stimuli from the environment become representation of reality, in an efficient manner. For instance, our brains are able to pick up similarities, and create generalizations from a few instances. In other words, we create cognitive maps to group representations, and we use them to perceive, make sense and modify behavior. Cognitive maps bring forth previous important perceptions and make us anticipate different phenomena.. For instance, cognitive maps create relations and order perceptions. Moreover, scientific claims are not isolated either, they interact with political positions.

In Carvalho (2007) highlights the role media has on representation of CC science. Often, media antagonizes, and emphasizes the local environment of the viewer. For instance, the consensus on CC is lost and its global impacts come in second place. Taken together, the American media perspective on CC promotes adaptation before mitigation.

The role of science also reaches policy. Science informs policy-making in an increasing degree. For instance, the CONCYTEC (Council of Science and Technology) has presented a national draft on future scientific work, policy and development for the future (*Política Nacional CTI* 2019).

Nevertheless, the main role of scientific bodies such as universities and research institutions is to give validity to *scientific facts*. The media gives a second validity to these facts. Therefore, the media does not have the power to oppose "research".

On this context, it is likely that people trust the news as informants of the current state of their surrounding ecosystems. Considering that glacier research has also a long history, scientists became validating agents for local cognitive-maps.

However, as scientific knowledge becomes more specialized, people struggle to keep up (Ungar 2000). Media often fails to provide enough details or careful arguments for the positions presented. Therefore, one should take ignorance or very basic knowledge as the standard for CC studies. People approach knowledge on a need to know basis. Therefore, it might be case that people in Huaraz are aware on the consequences of CC if they directly affect their livelihoods.

2.4 On Social Resource Mobilization

2.4.1 A Retake on Institutions

Water, Climate Change and Development are not independent issues, instead they are closely interlinked. The traditional approach to water economics limits this possibility since water optimization treats one problem at a time. In addition, we risk missing the politics involved when looking for solutions (Tanner and Allouche 2011). The economy operates politically: "ideas, power and resources are conceptualized, negotiated and implemented (Tanner and Allouche 2011)" by different interests groups. CC will disrupt human societies and their organization. Therefore, CC mitigation and adaptation plans are often nationally designed. However, in Peru, local needs diverge from centralized plans. Thus, government intervention is not likely to succeed as expected from economic theory.

A central insight from institutional economics is that humans act within an institutional framework. The institutions set up the "rules of the game". Institutions allow access and use of the resource. For instance, a certain institutional background will plant the idea that water is abundant, and therefore, to increase water fees is unjust. In addition,"institutions of a society influence the preferences of the members of that society [pg.7](Arild 2015)". For example, in WI individuals might have a strong predisposition to government-funded infrastructure, and dislike water privatization. Finally, institutions also affect transaction costs. For instance, in WI, when water is considered to be cheap, to enforce a higher water fee might carry increased transaction costs. This is due to the underlying institution that turns water into a endless "open" resource.

2.4.2 What do we mean by resource mobilization?

WTP is matters only within a institutional setting. Moreover, a move towards sustainable WI means that WTP needs to accrue for non-financial considerations as well. Another issue is motivation. Willingness to pay is part of the willingness to improve WI. In the Andes, voluntary work can be done to improve WI, especially in neglected communities (Amigos de Villa 2011). Therefore, organizations and payment methods are both channels for WI improvement.

Organizations exist to serve each participant (Olson 2002, pg.5). A rational individual will be part of an organization as far as the organization serves him or her personally. This view is hardly new nor against common-sense: From Aristotle to the fable of the bees, individual welfare is the measure of all goods in life. People form groups due to the fact that their individual causes coincide in a common interest. As longs at the common interest reflects theirs, the individuals will be part of the group. However, organizations also create discourses. A discourse is a shared meaning of a phenomenon.

According to W. Adger, Benjaminsen, and Brown (2001), there are two CC discourses. A first discourse is the so called “Global Environmental Management”. Here, technology and centralized intervention are central pieces to solve the CC crisis. The second discourse is the “Populist” discourse. Here, people from the Global South have been left out of CC mitigation plans, and suffer from a problem they did not originate. However, one should be careful to victimize people. Huaraz residents are aware of the consequences and responsibilities of CC (The Guardian 2017). Local experts have been monitoring retreating glaciers for decades, and have sounded the alarm quite early. Therefore, discourse needs to be stated by members of the organization themselves.

On the individual level, people have two reasons to volunteer (Hackl, Halla, and Pruckner 2007). Volunteering can be conceived as a consumer good or an investment. Volunteering creates utility, then, it is a good. On the other hand, if people hope to increase their pay in the labor market, they volunteer as an investment in their skills.

Voluntary work has an opportunity cost according to each lost labor hour. The investment model argues that volunteering accumulates human capital - or skills. Hence, volunteering will increase future income. This model matters as volunteering in WI happens to pay off on the future. However, people rarely use WI-building skills in their jobs.

We have the following model:

$$\underset{v(t)}{\text{NPY}} = \int_0^T f(v,h)e^{-rt}dt$$

Subject to:

$$\dot{h}(t) = g(v) - \delta h(t)$$

Where, $f(v,h)$ is a production function, $v(t)$ is the amount of volunteering, $h(t)$ is the accumulated human capital and $\delta h(t)$ is the rate of depreciation of human capital. We also assume that:

$$\frac{\partial f}{\partial v} < 0$$
$$\frac{\partial f}{\partial h} > 0$$
$$\frac{\partial g}{\partial v} > 0$$

In other words, as people do more voluntary work, they produce less. Also, as people gain more human capital, they earn more.

The $g(v)$ function has three interpretations. First, g stands for skills learned from volunteering. Second, g indicates the network making, since people get to know each other during volunteering, and volunteers will likely meet a future employer. Finally, g amplifies positive personal qualities in the volunteer when job-hunting. Volunteers appear to be more committed and generous when applying for a job. In other words, g stands for the personal gain, in terms of Human Capital, from volunteering. Also, since $\delta h(t) < 0$ over time, such as for the temporally unemployed, g is a way to accrue human capital and become a more attractive candidate.

Therefore, volunteering pays off like an investment. While, volunteering today reduces present income, it increases future human capital, and later, income. Solving the optimization problem, we obtain an inverted U-shaped curve. This means that the young are more willing to volunteer than the elderly.

2.4.3 Self-mobilization in rural Peru

Self-mobilization of rural communities matters. Peru has committed 157 million PEN to fight Climate Change. However, red tape binds many projects from realizing. Self-mobilization creates projects, and asks for funding later. In this way, people are involved in the project from the beginning. On this context, WTP will measure people‘s engagement in the project.

Rural Peru has history of self-mobilization and self-reliance. For instance, communal work has a rich tradition in the Andes (Harris n.d.). This is also evidenced in the works of Inca Garcilazo de la Vega, Ciro Alegria and Jose Maria Arguedas. Also communal work provides an opportunity for social communion and amenities. Outside rural areas, marginalization in the cities has foster some type of mobilization. Rural migrants brought some forms of institutions that allowed for communal work. For instance, in the Villa El Salvador district of Lima, neighborhood associations and city planners promoted active neighbor participation in developing infrastructure (Amigos de Villa 2011). Moreover, after the government "donated" the land to the migrants, many neighbors built their houses themselves.

The practice of water harvesting involves local participation (Morante 2018). First, rain or river water is saved on a “qocha” or small lake[2] A qocha is built above a spring, in such a way that the permeable soil allows for slow water recharge. Then, water is “harvested” from the spring, during the dry season. The main purpose of water harvesting is to ensure enough irrigation water during the dry season. Qocha‘s water is not adapt for human consumption, and their construction is simple. Therefore, local communities can built them without much assistance from the government, and using their own resources.

[2] The word Qocha means pond, lake, or small reservoir in Quechua. Qochas were often surrounded by hand-made dams, yet some Qochas exist as natural formations where water accumulates, such as moraine lakes under glaciers.

Chapter 3

Huaraz: Study Case

3.1 The Region of Ancash

3.1.1 Demography

The region of Ancash was created the 12 February 1821. It comprises 20 provinces and 166 districts (INEI 2017a, pg. 15). The province of Huaraz is the capital of the region of Ancash. Ancash had 1 083 519 inhab. by 2017 (INEI 2018a). This represents 3.7% of the total national population. Population has grown from 1961-1972 at a rate of 2%, this has decreased to 0.2% in 2007-2017. On the other hand, population density has increased. On 1940, there were 12.1 $inhab./km^2$, in 2017 this increased to 30.2 $inhab./km^2$. Taken together, these facts indicate that Ancash is becoming increasingly urban. Moreover, 63.4% of population lives in urban areas.

3.1.2 Socio-economic indicators of Ancash

Regional GPD has grown constantly since 2007 (See Fig 3.1). The mining and oil sector account for 50% of the GDP. On the other hand, public utilities maintained their share of GDP. However, income from extractive activities present strong variation over time

The population in Ancash is very mobile. 6.8% of the population born in Ancash left for another department by 2017. This emigration rate is among the highest in the country.

Urban and rural populations have comparable access to education. Students in rural and urban areas have the same possibility to access primary and secondary education. However, the gap remains at the superior (tertiary) education level. 50.7% of the urban population receive superior instruction, while in rural areas only 33.1% of the population do.

Since Ancash is located on the Pacific basin, it has rivers with steep slope. This makes the region suitable for hydropower development. Currently, Ancash has six hydropower plants. The largest one is located on the Cañón del Pato, and feeds from the Santa River.

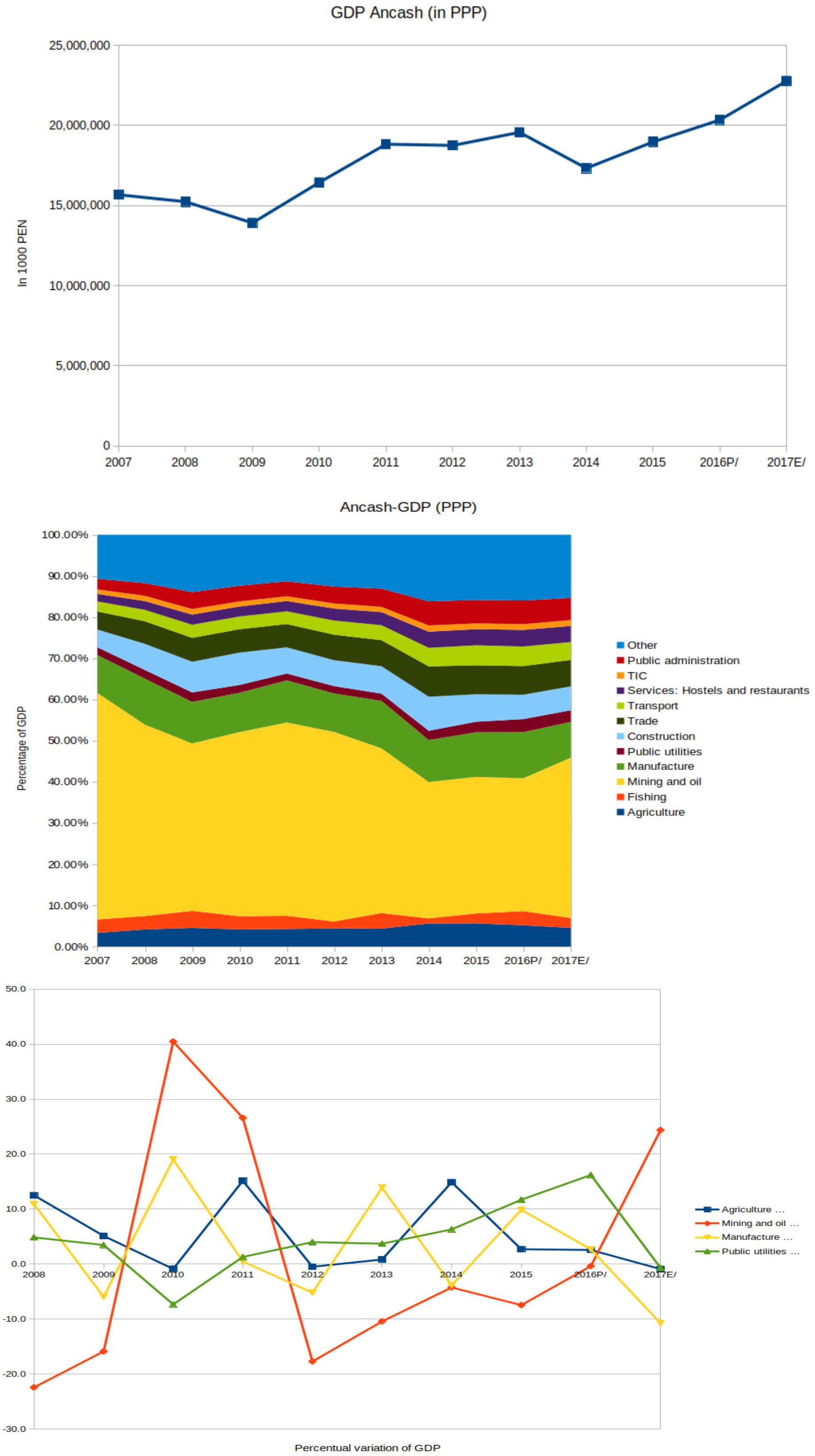

Figure 3.1: Ancash GPD, as a whole and by sector, over the last 10 years. Adapted from INEI (2018b)

3.2 The Cordillera Blanca

3.2.1 Geography

The Cordillera Blanca is located 300 km to the north of Lima in the Ancash region (See Fig. 3.2). It covers 13 602 km^2, and it is 247 km long. The Cordillera [1] encloses 25% of the tropical glaciers in the world, in total 448,81 km^2 (INAIGEM 2018; Mark et al. 2010). Therefore, the Cordillera Blanca is the largest reserve of drinking water in Peru. In addition, it contains 860 lakes, covering 5000 km^2. However, this area has been reduced by 38.20% from 1989 levels. In absolute terms, this loss is considerable since the Cordillera Blanca is the largest glacier Cordillera in Peru. It is estimated that the Cordillera Blanca will loose its glaciers in 2111 (INAIGEM 2018). Furthermore, snow peaks at the Cordillera range from 3000 to 6800 m. above the sea. This altitude makes Cordillera glaciers one of the most resilient. These snow peaks drain into the Santa River.

Snow Peak	Altitude in meters above the sea
Huascaran South	6744
Huascaran North	6655
Huantzan	6288
Huandoy	6231
Huaytapallana	6229

Table 3.1: Tallest peaks in the Cordillera Blanca. Adapted from INEI (2017a)

On its west slope, the Cordillera forms the Santa River Valley, named after the river Santa that runs along [2]. The Cordillera Blanca shields the Santa River valley from eastern trade winds. Therefore, snow accumulates faster at east of the Cordillera, and eastern glaciers tend to be larger. Moreover, the snow line in the Cordillera is much lower than in other Andean peaks. However, El Niño reduces the Cordillera shielding capacity. During El Niño humidity comes from Western winds (because of the warmer Pacific Ocean). In turn, extra humidity increases precipitation on the western side.

In the Valley, precipitation varies across two seasons yearly. Rain season lasts from October-November until April-May. Snow accumulates during this season (Racoviteanu et al. 2008). The dry season spans over the rest of the year.

The Santa river has 347 km in length, and 293.3 m^3/s on average flow. It stretches over the provinces of Huaraz, Recuay, Carhuaz, Yungay, Corongo, Pallasca and Santa. It discharges on the Pacific Ocean, close to the city of Chimbote. Before discharging, the river turns West, and passes the narrow “Cañon del Pato”. The Santa River has important uses such as energy production and irrigation.

Santa River together with its tributaries, lakes and glaciers, constitutes the Santa River basin. The Santa basin comprises of 21 $\times 10^6 m^2$ of rivers, and 245 lakes (INEI 2017a). In turn, the Santa basin can be subdivided into sub-basins:

[1] White Mountain range in English

[2] Also known as the “Callejón de Huaylas” in Spanish

Quitarazca (22 lakes), Catarata Grande, Los Cedros (22 lakes), Coltan, Santa Cruz (22 lakes), Paron, Ranrahirca, Buin, Hualcan, Marcara, Paltay, Mullaca, Llaca, Quilcay (21 lakes), Pariac, Jauna, Negro, Atoc-Huancanca, Yanayacu, Ocollo, Jashjas, Tucto and Pachacoto.

The Santa River basin also contains the most important lakes in Ancash. The largest lake is Pelagatos with a capacity of $111 \times 10^6 m^3$, located in the Pallasca province. Lake Paron contains $52 \times 10^6 m^3$ of water, and it is located in Huaylas province. Then, lakes Auquiscocha and Purhuay contain $49 \times 10^6 m^3$ and $48 \times 10^6 m^3$ respectively, both located in Carhuaz.

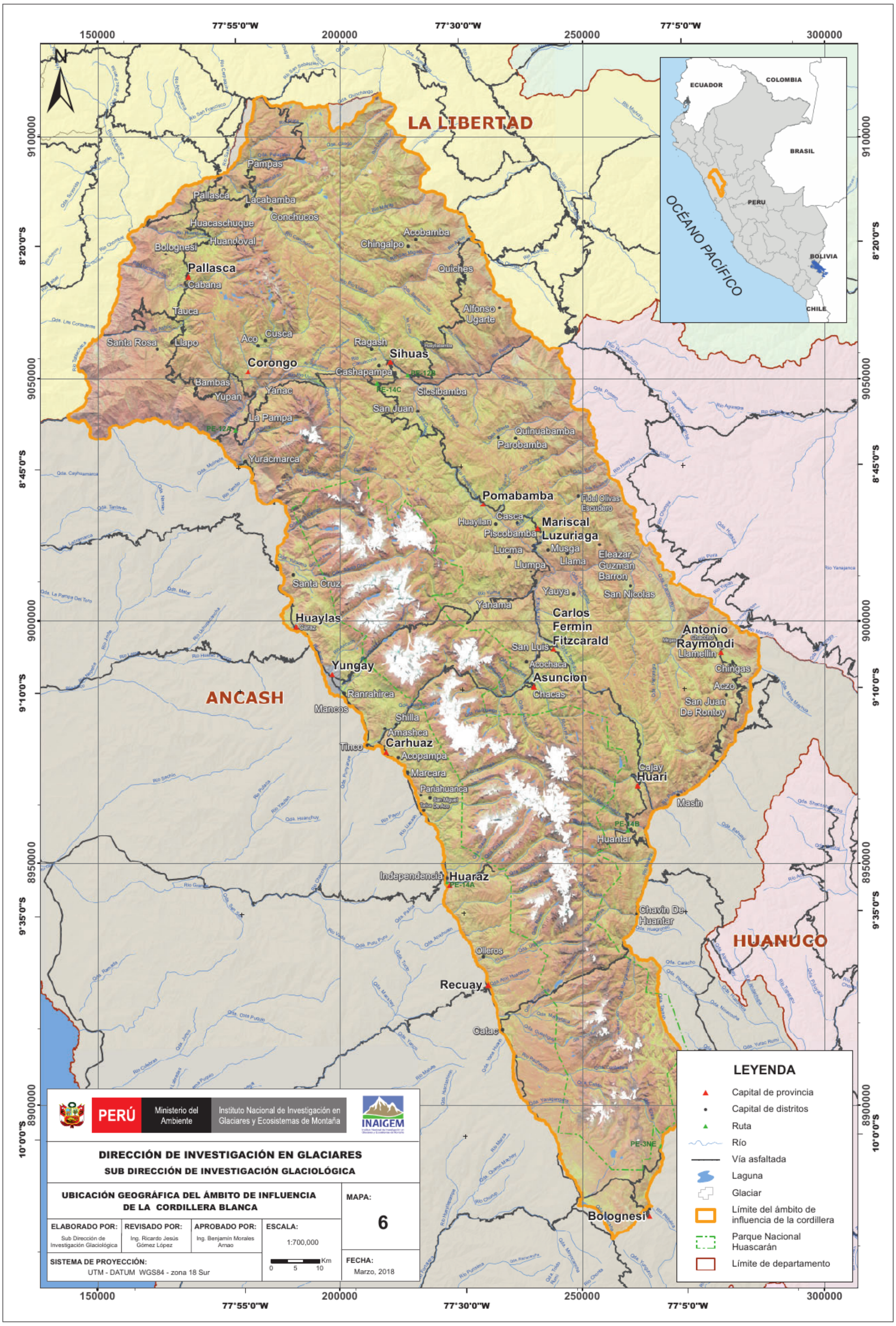

Figure 3.2: The Cordillera Blanca. Adapted from INAIGEM (2018).

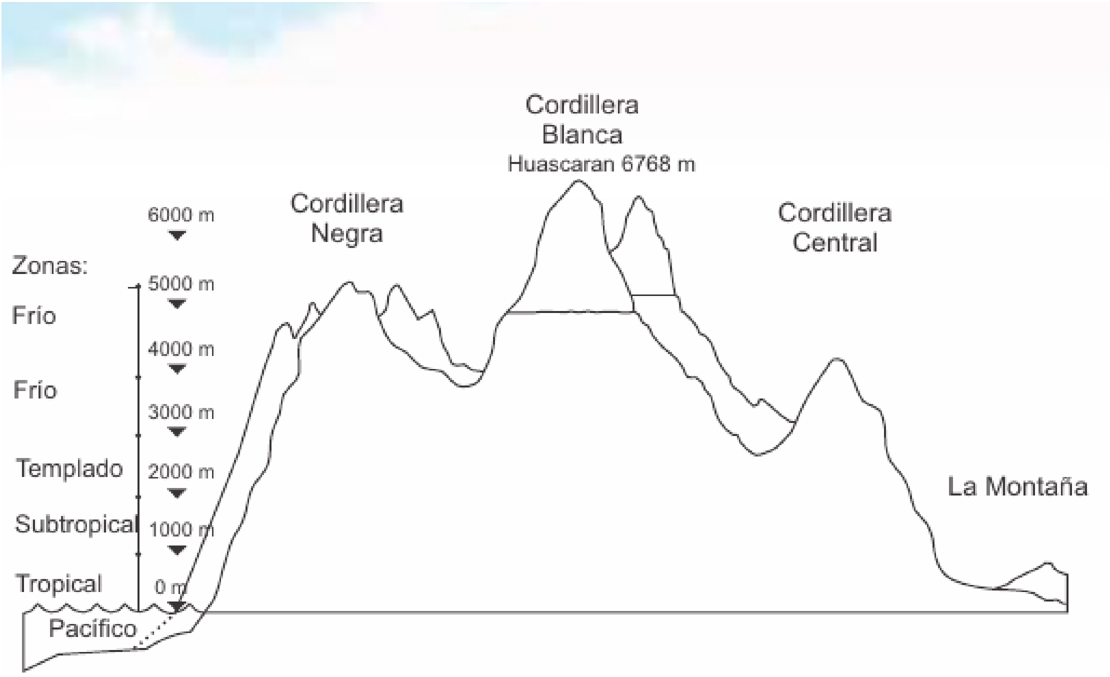

Figure 3.3: Cordillera Blanca: Traversal cut. Adapted from Sevink (2008).

Glaciers in Huaraz Ancash concentrates 28% of the total number of Peruvian glaciers, spanning 808 km^2. Ancash glaciers are grouped into two systems: the Cordillera Blanca and the Cordillera Huayhuash (INEI 2017a). The Cordillera Blanca comprises 530 glaciers in the Pacific basin, and 192 glaciers associated with the Atlantic basin. Most of the Cordillera Blanca glaciers are *mountain glaciers*. The Cordillera Huayhuash includes 177 glaciers.

However, Huaraz is in constant danger from slides due to glaciers. For instance, in 2008 a glacier lake at the Coyup canyon flooded. Therefore, city authorities and private companies (such as mining and energy producers) built safety infrastructure. In total, the Cordillera has 35 dikes and drainage systems.

3.2.2 History

Since the beginning of the XX century, foreign alpinists had their eyes set on the Cordillera. Many scientists were among these explorers, and began to gather data during their expeditions. Product of these trips, today researchers have photographs and maps necessary to compare present and past glaciers.

The central government also became interested in the water resources of Ancash. Geographical knowledge helped build a case to seize these resources (Carey 2010). Glaciers, rivers and lakes became assets to industrialize the nation. Officials planned for the Santa River to become the engine for development in the region. At the hydropower plant of the Cañón del Pato, enough power will be generated to set up an steel refinery in Chimbote. In addition, since the 1950's, the country open up for mass tourism. Huaraz allured travelers with 'unconquered mountains' and breath-taking views.

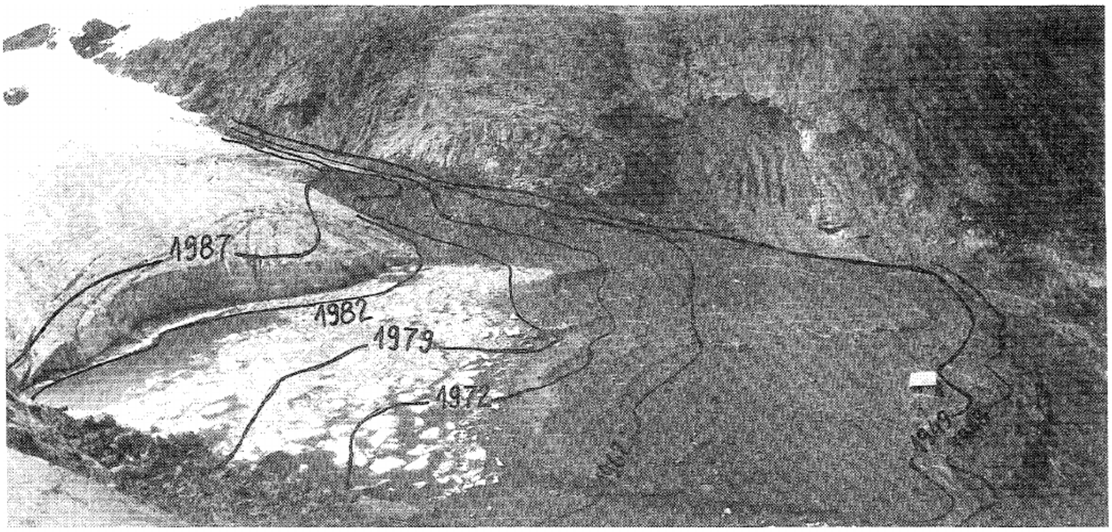

Figure 3.4: A historical perspective on the Yanamarey Glacier from 1948-1987. Adapted from Marquez (1995). Picture from A. Ames.

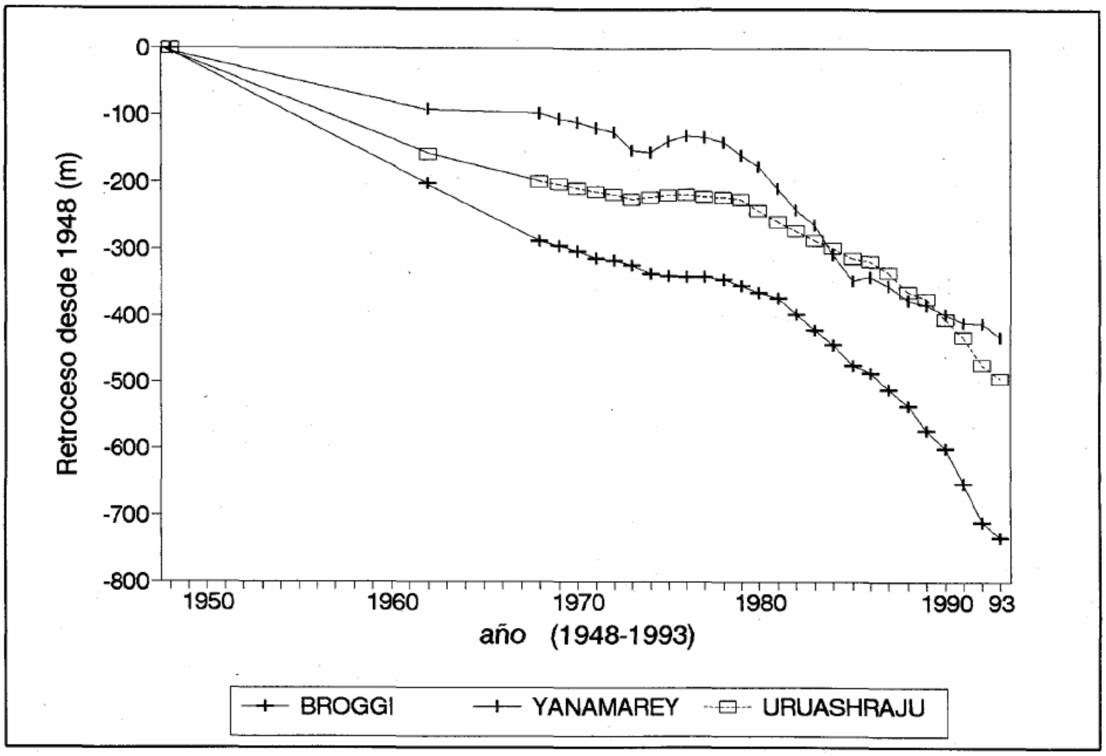

Figure 3.5: Three regressing glaciers in historical data. Adapted from Marquez (1995).

3.2.3 Natural disasters

Since 1764, floods in the Santa River Valley have been recorded. Yet, Inca and pre-Inca architects could have known about the flood risk, since they located their cities above the flood plains. Cosme Bueno was the first to describe a flood caused by a mass of ice falling from the Huandoy snow peak. This flood, caused likely by an earthquake, destroyed incipient Spanish settlements in Ancash. In 1873, Italian geographer Antonio Raimondi wrote one of the earliest treatises about the Cordillera.

The glacier flood that kick-started systematic and continuous glacier studies was the 1941 Huaraz flood. Lake Palcacocha lies at the head of the Cojup canyon, under several glaciers. Palcacocha is a morraine lake, such morraines appeared as the glaciers retreated during the Little Ice Age. As CC also increased the temperature, Palcacocha increased such as to put pressure on the bounding morraines. By 1941, the mother glacier shrank by 0.5 km. Currently, Palcacocha is drained by several pipes. Nevertheless, Palcacocha creates excess water downstream, particularly during the dry season.

By 1941, Lake Palcacocha grew 0.5 km long and 0.25 km wide, containing 14 million m^3 of water (Carey 2010). On december 13, 1941, an ice block crashed into lake Palcacocha. The resulting shock waves ruptured the morraine, and Palcacocha's emptied downstream to Jircacocha lake. The combined volume of Palcacocha and Jircacocha rupture the second moraine, and washed down the canyon to Huaraz. In may 31, 1970 a 7.8 earthquake caused the fall of large ice blocks from the Huascarán. This avalanche buried the city of Yungay, killing 20 thousand people, one of the most deathly on human history. In 2010, an ice block fell over Lake 513, causing alarm, however, the flood did not happen.

Nowadays, lake Palcacocha and lake Paron in Caraz are under constant surveillance since 2011 (Del Aguila 2015). The ANA plans to expand this project to cover the other 830 glacier lakes.

In the city of Huaraz, areas located parallel to the Quilcay river are at most risk from flooding (See Fig. 3.7) Residents are expected to evacuate to higher areas outside the city center. However, some of the most notorious streets lie on the red area. For instance: Av. Fitzcarrald, Av. Luzuriaga and Av. 27 de Noviembre. Moreover, the Quilcay riverside is still inhabited despite official recommendations prohibiting it. These families are often poor, and the area is described as dangerous (See Fig.3.7).

Figure 3.6: The city center of Yungay after the earthquake, only four palm trees stand. Adapted from *10 impactantes imágenes del terremoto de Áncash de 1970* (2017).

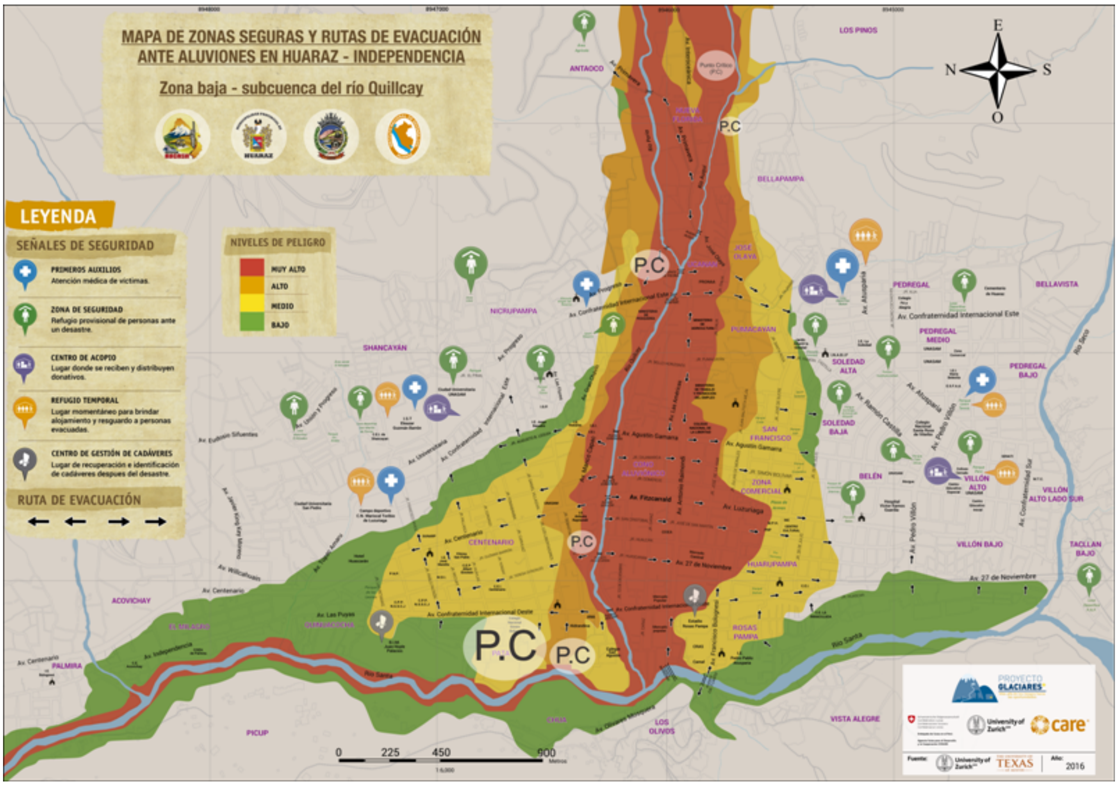

Figure 3.7: Safe and danger sones. The red areas indicate more danger. Adapted from Proyecto Glaciares + (2018).

3.3 The City of Huaraz

The Huaraz Province was founded in 1857. The city of Huaraz is located in the province of Huaraz, in the Ancash region [3]. However, human settlements date back to the pre-Inca era. According to the INEI, the province of Huaraz has a surface of 2492.91 km^2, equivalent to almost 7% of the regional territory. The Province is divided into 12 districts: Huaraz (city), Cochabamba, Colcabamba, Huanchay, Independencia, Jangas, Cajamarquilla, Olleros, Pampas, Pira, Pariacoto and Parica.

The district of Huaraz is the capital of the Province of Huaraz (INEI 2017a). Huaraz has 118 836 residents according to the latest census (INEI 2018a). This is an increase of 19.5% from 2007 -levels. While the term ‘city’ is not official, the ‘city of Huaraz’ often refers to the amalgamation of Independencia and Huaraz districts. These two districts are most urban and densely populated. The Quilcay river passes through the city of Huaraz, and delimits the district of Huaraz and Independencia. The Quilcay river has 25 km in length, and 7.65 m^3/s on average flow. This river has its origin in the Cojup canyon, as the Paria river, and after mixing with the Auqui river, it becomes the Quilcay river. [4] As Fig ?? shows, the dry season spans from June to August.

[3] A region is somewhat equivalent to a “fylke” in Norway. A province is under the administration of the region, and equivalent to a “komunne”. A district is under the province administration, it has no direct Norwegian equivalent, perhaps “tettsted”.

[4] Independencia used to be part of Huaraz, for many locals, ‘the city of Huaraz’ is used to describe either Huaraz or Independencia.

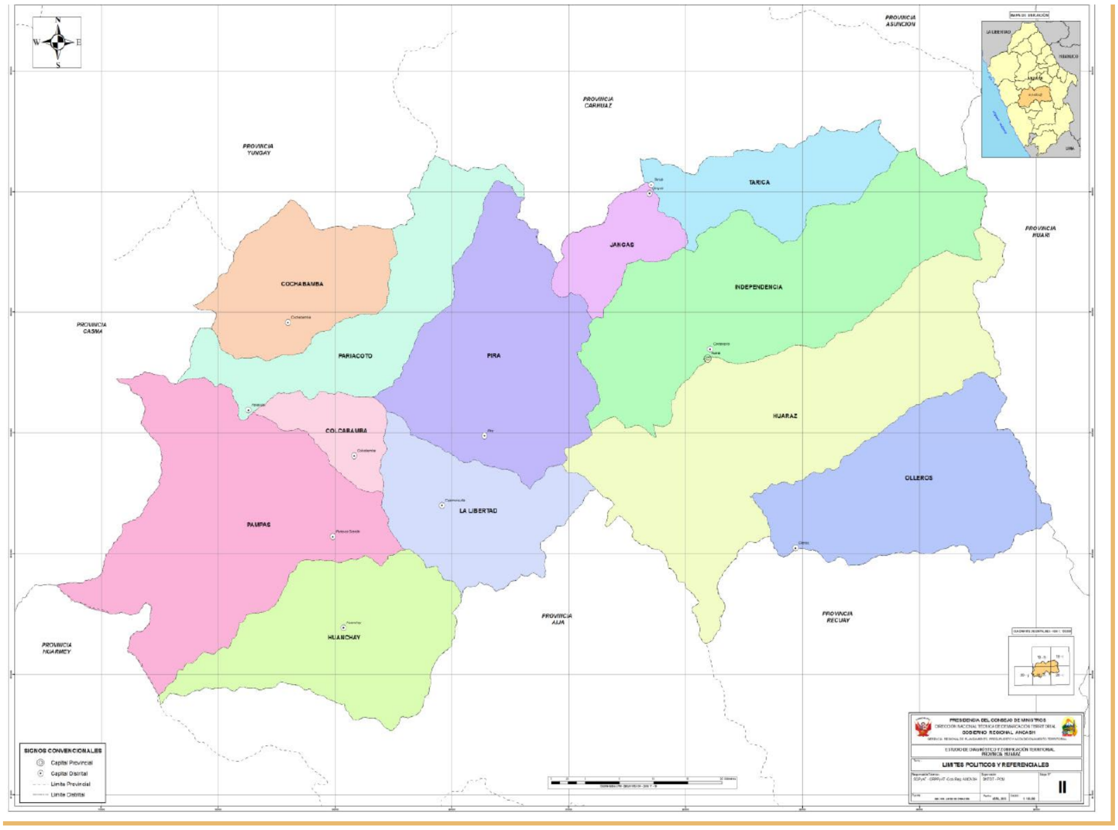

Figure 3.8: Map for the Province of Huaraz. The district of Huaraz appears in light yellow, the city of Huaraz appears as a dot on the border with Independencia. Adapted from Gobierno Regional de Ancash (2014)

3.3.1 Water

The Paria river is the main source of drinkable water in Huaraz city (SUNASS 2015). In addition, there are two water catchment plants: one in Unchus and another in Yarush. The Paria river provides 420 l/s on average. On case of insufficient water flow, the city has access to the Auqui river.

The Paria river originates in Lake Palcacocha, approx. at 23 km. Southwest from Huaraz, with an altitude of 4562 m. (Vilca 2016b) [5]. The lake Palcacocha is located in Cojup canyon in the district of Independencia, part of the Quillcay sub-basin. Palcacoccha has a PH of 7.40 and a flow of 685 l/s (Guerrero 2016). Due to safety concerns, Palcacocha is constantly drained (See Fig. 3.13). Nevertheless, the lake creates an excess water supply of 70% during the dry season. Therefore, water demand remains unaffected by droughts.

The Cojup canyon is a typical glaciar valley, with slopes between 30 °and 40 °The micro-basin Cojup (52 km^2) is the main water source in the Quillcay sub-basin. In turn, Palcacocha drains the Palcaraju and Pucaranra glaciers (See Fig. 3.9) The Palcaraju glacier lies between the 4850 m. and 6110 m. above the sea level, with an area of 3.88 km^2. Palcaraju present hanging ice blocks at the front, but they fall without hitting Palcacocha. The Pucaranra glacier lies between 4830 m. and 6156 m. above the sea, with an area of 2.78 km^2. Pucaranra has no direct contact with Palcacocha either. The reconstructed glacier ((c) in Fig. 3.9) was

[5] Precisely at 9 °23' S and 77 °22' W

formed through ice falling from Palcaraju and Pucaranra. This glacier receives impacts from the two aforementioned glaciers, and acts like a bumper. However, the reconstructed glacier is in direct contact with Palcacocha, and poses an imminent risk. In addition, the melting glaciers will increase Palcacocha volume. The Niño also accelerates glacier fusion, and increases water volume. Therefore, the drainage system needs to be improved.

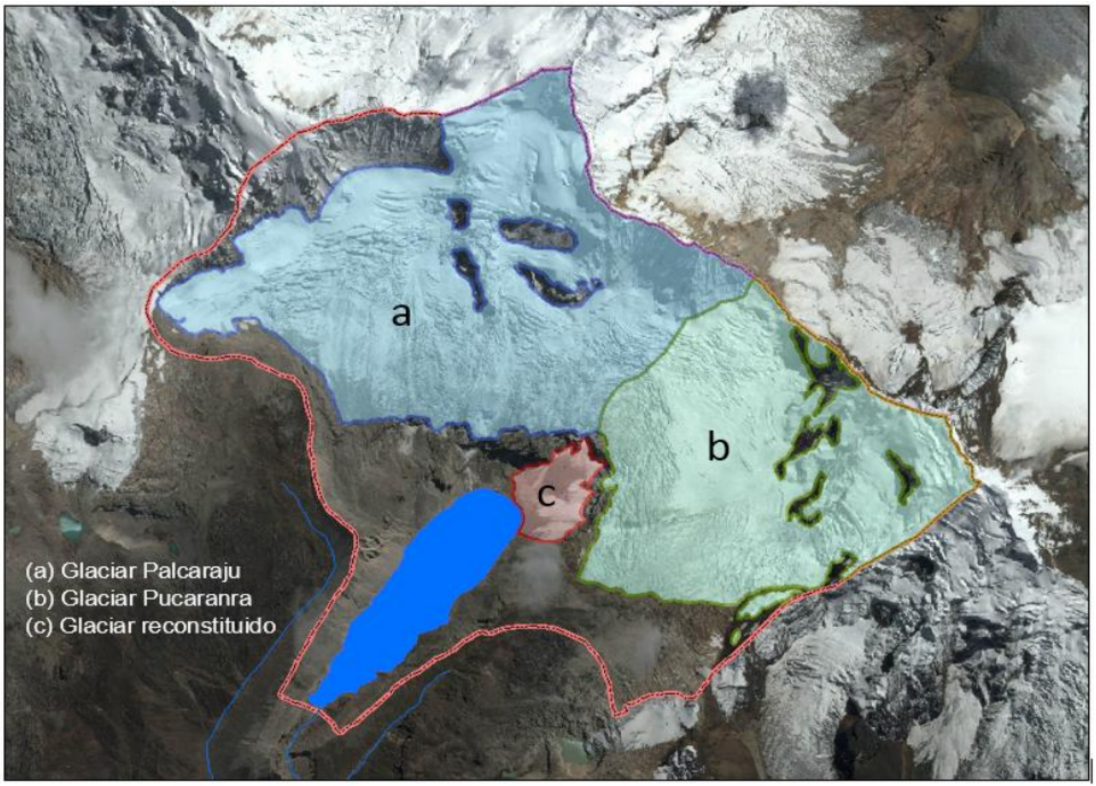

Figure 3.9: Palcacocha Lake. Adapted from Vilca (2016b).

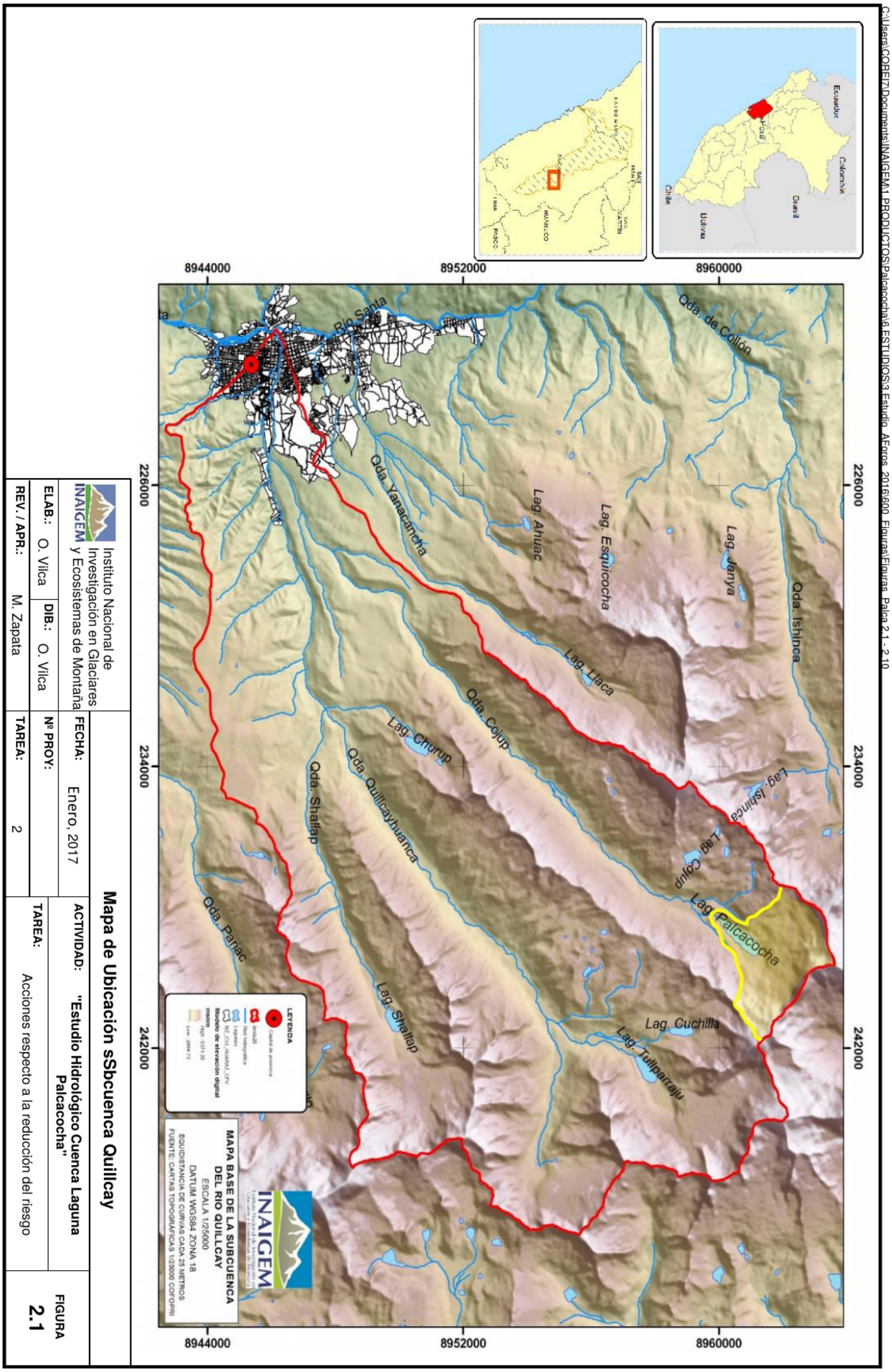

Figure 3.10: The Cojup microbasin brings water from Palcacocha to the city through the Paria River. Adapted from Vilca (2016b).

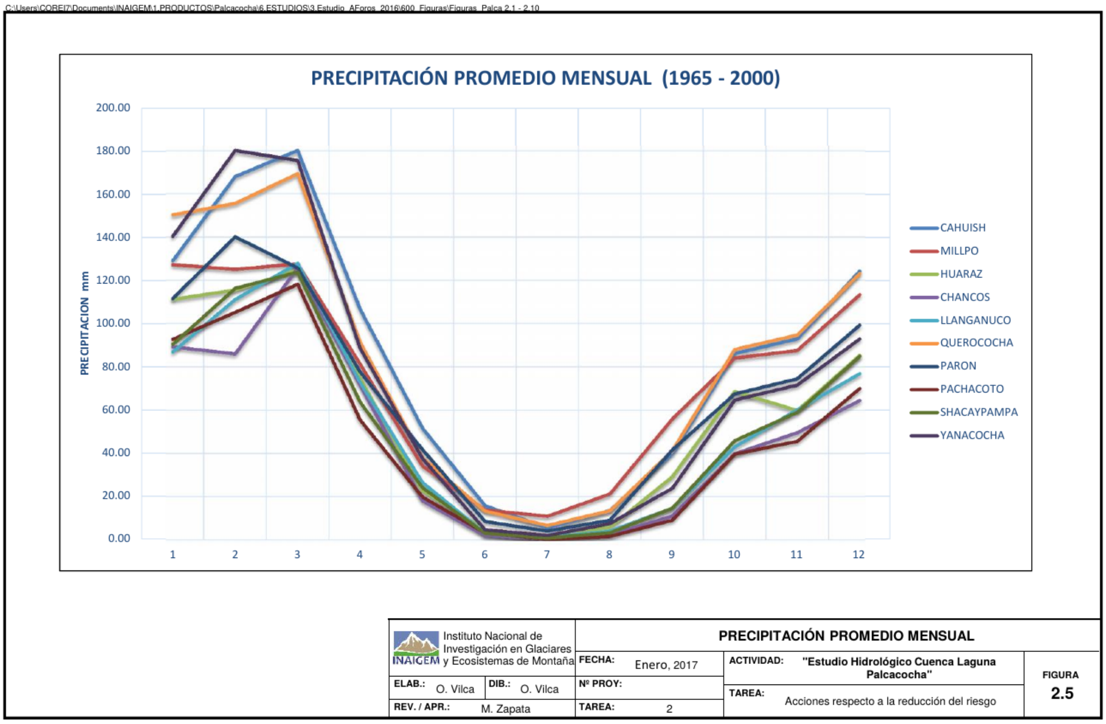

Figure 3.11: Delimitation of local precipitation patterns in lakes nearby Huaraz. Adapted from Guerrero (2016).

Figure 3.12: Four drainage pipes at Palcacocha. Adapted from Vilca (2016a).

Figure 3.13: Water deposit for drained water. Adapted from Vilca (2016a).

3.3.2 Huaraz Water Agents

CHAVIN S.A.

CHAVIN is municipal provider for the city of Huaraz. CHAVIN also delivers water and sanitation to cities of Aija, Chiquian and Caraz (SUNASS 2015). CHAVIN is a municipal public enterprise. This means that representatives of Huaraz, Huaylas, Bolognesi, Aija and Independencia municipalities sit at the board (See Table 3.2).

The following information is gathered from the “Estudio Tarifario” - a document that validates and guides CHAVIN pricing strategy. This documents sets financial and managerial goals for the period 2015-2020.

CHAVIN covers in total 125 256 people in the department of Ancash. 104 949 of this total live in Huaraz (or 84 %). In addition, 26 261 municipal water connections are registered. In peri-urban areas, CHAVIN provides only treated water, not the water network. The JASS - local water committee - is in charge of distributing water in these areas.

The city of Huaraz has 72% coverage rate of water connectivity. CHAVIN provides water to the city on average 23.7 hours/day. Constant rural migration has hinders progress on this front. Despite this challenge, CHAVIN has a record of 98% of all the households, and 92.3% of households in Huaraz have micro water meters. Yet, 44% of water provided never appears on the bill. In addition, in some sectors of the city, such as Los Olivos and Japshan, users have access to water for only 11 hours/day.

By 2013, CHAVIN earned 6.9 million PEN in income. This represented an increase from previous years, mainly due to more water meters and user categorization. Monthly water fees constitute 81 % of the total income, and the city of Huaraz alone provides 90 % of this income. Maintenance and operative costs reached 4.3 million PEN by 2013. On the other hand, administrative costs reached 1.8 million PEN.

Huaraz city has in total six circular reservoirs with a total capacity of $4651m^3$, being built between 7-35 years ago. All of these reservoirs are fully operational and have good prospects.

Shareholder	Number of Shares	Value in the books
Huaraz Municipality	356	3 Mill. PEN
Independencia Municipality	324	2.7 Mill. PEN
Huaylas Municipality	135	1.1 Mill. PEN
Bolognesi Municipality	67	0.5 Mill. PEN
Aija Municipality	36	0.3 Mill. PEN

Table 3.2: Overview of CHAVIN shareholders by 2010.

Water Experts

The ANA in Huaraz The “División de Glaciología” (Glaciology Unit, in English) of the ANA was founded on 1968. The Unit began to assess different glaciers useful to generate energy. The Unit had also to evaluate landslide risk for the main cities along the Callejón. The early records of the Unit show accelerating glacier retreat (See Fig. 3.4).

The INAIGEM The INAIGEM is the research center for glaciers and mountain ecosystems, with an office in Huaraz. The INAIGEM was created by Lay N°30286, and lies under the Ministry of Environment. The INAIGEM aims to promote scientific research in glaciers, mountain ecosystems and sustainable resource management. Experts from the Ministry of Agriculture, Environment, Culture and the ANA sit at its board.

JASS in Huaraz and Independencia

What is a JASS? The JASS are water committees in charge of water distribution to rural and semi-rural areas. A JASS operates as a non-profit, and charges users a fee to cover its administrative costs. A JASS has a board, elected by the users. In addition, JASS enter partnerships with authorities to expand their infrastructure. To reduce labor costs, JASS promote volunteering to build or maintain WI.

JASS-SHANCAYAN The JASS receives water from the Marian water treatment plant, at a rate of 65 l/s. However, this flow is insufficient to satisfy the increasing population since the 1990's. Moreover, the JASS did not install water meters, creating economic and water losses. For instance, a water user at CHAVIN pays 0.82 PEN per m^3 while a Shancayan resident pays only 0.25 PEN. According to MWP, the JASS does not have oversight over the number of connections and lost water (SUNASS 2015). In addition, the JASS does not segment their users, such as both business and household pay a single water fee. CHAVIN estimates its losses to be 245 000 PEN from providing free water and sewage to Shancayan residents. Moreover, the "Estudio Tarifario" suggest the deactivation of the JASS.

Chapter 4

Choice Experiments

4.1 The Random Utility Model

[1]

CE studies generate a Random Utility Model (RUM) (Perman et al. 2011, pg. 432). From Welfare Economics, we assume that participants have consistently selected the alternative that yields the higher level of utility. Our goal is to find the marginal rate of substitution between attributes (a fixed set of characteristics). An alternative is a combination of attributes. Attributes can take values called *Attribute Levels* It is possible to calculate each attribute‘s marginal price, if we include a cost or price attribute. Also, setting up the “Status Quo” as an answer option, allows us to estimate the Marginal Willingness To Pay (MWTP) for each alternative.

In CE, the response variable is a choice. An effect is the impact a particular attribute level has on the choice. A main effect is the direct impact an attribute level has on a choice. An interaction effect is the effect obtained via the combination of several attributes.

In general, CE estimates are unconfounded (Hanley, Wright, and V. Adamowicz 1998). CE designs are orthogonal, since they isolate the effects of single attributes on choice. Therefore, it is easier to estimate the value of attributes, and their marginal value. In addition, designs that are contain too many choices can be partitioned into blocks.

A participant makes a choice that reflects an underlying utility function. Respondents are assumed to choice the alternative that yields the highest utility. This function has two components. The deterministic component is a function of the attributes and the respondent‘s characteristics. The second component is the systematic error ε_{ij}. Therefore, we have the following equation for RUM:

$$V_{ij} = V(x_{ij}, \beta) + \varepsilon_{ij} \tag{4.1}$$

Where, V_{ij} is the observable utility for participant i, when he or she evaluates alternative j. $\mathbf{x} = (x_{ij})$ is the vector of attributes (row) that varies across alternatives. To simplify our calculation, we take V to be linear:

$$V_{ij} = \beta_0 + x_{ij}\beta_1 + (y_i - C_{ij})\beta_2 + \varepsilon_{ij} \tag{4.2}$$

[1]This section is based on Alberini, Longo, and Veronesi (2006)

Here: y_i: Income for person i
C_{ij}: Cost of alternative j to person i. β_2 is the Marginal Utility of Income.

The probability of individual i selecting alternative k from a total of K is given by:

$$\begin{aligned} \pi_{ij} &= Pr(V_{ik} > V_{i1}, V_{ik} > V_{i2}, \cdots, V_{ik} > V_{iK}) \\ &= Pr(V_{ik} > V_{ij}) \quad \forall j \neq k \end{aligned} \tag{4.3}$$

So:

$$\begin{aligned} \pi_{ij} = Pr(\beta_0 + x_{ik}\beta_1 + (y_i - C_{ik})\beta_2 + \varepsilon_{ik} > \beta_0 + x_{ij}\beta_1 + (y_i - C_{ij})\beta_2 + \varepsilon_{ij}) \\ = Pr[\varepsilon_{ij} - \varepsilon_{ik} < (x_{ik} - x_{ij})\beta_1 - (C_{ik} - C_{ij})\beta_2] \end{aligned}$$

Therefore, the probability of selecting an alternative does not depend on income. On the other hand, probability depends on the differences between costs and levels.

4.2 The Conditional Logit Model

The Conditional Logit models a choice depending on the attributes of an alternative, and not on individual characteristics (Hoffman and Duncan 1988). A similar model is the Multinomial Logit model, however, this model works with individual characteristics. These models are often confused since they have the same likelihood function. Both models also assume that the errors are IID and follow an extreme value distribution.

The Independence of Irrelevant Alternatives is a consequence of this last assumption. This means that choice probability ratio for any two alternatives depends only on the characteristics of these two alternatives (Hoffman and Duncan 1988).

To build the Conditional Logit model, we assume that the errors are independent and identically distributed, following a standard Type I extreme value distribution or Gumbell distribution (Hanley, Wright, and V. Adamowicz 1998). $F(\varepsilon) = exp(-e^{-\varepsilon})$ is its cumulative distribution, and $f(\varepsilon_i) = exp(-e_i - e^{\varepsilon_i})$ is the probability density function.

We also know that choosing k means that :

$$\begin{aligned} \varepsilon_k + V_k > \varepsilon_j + V_j \quad \forall j \neq k \\ \varepsilon_j < \varepsilon_k + V_k - V_j \end{aligned}$$

In probability terms:

$$\begin{aligned} \pi_{ij} = Pr(\varepsilon_j < \varepsilon_k + V_k - V_j) \quad \forall j \neq k \\ = \int_{-\infty}^{+\infty} \prod_{j \neq k}^{\infty} F(\varepsilon_{ik} + V_{ik} - V_{ij}) f(\varepsilon_{ik}) d\varepsilon_{ik} \end{aligned}$$

We reduce the expression inside:

$$\begin{aligned} \prod_{j \neq k}^{\infty} F(\varepsilon_{ik} + V_{ik} - V_{ij}) f(\varepsilon_{ik}) \\ = exp[-\varepsilon_{ik} - e^{-\varepsilon_{ik}}(1 + \sum_{j \neq k} \frac{e^{V_{ij}}}{e^{V_{ij}}})] \end{aligned}$$

We set :

$$\lambda_{ik} = log(1 + \sum_{j \neq k} \frac{e^{V_{ij}}}{e^{V_{ij}}})$$
$$= log(\sum_{j=1}^{K} \frac{e^{V_{ij}}}{e^{V_{ik}}})$$

Then π_{ij} is:

$$\int_{-\infty}^{+\infty} exp(-\varepsilon_{ik} - e^{-(\varepsilon_{ik} - \lambda_{ik})}) d\varepsilon_{ik}$$
$$= exp(-\lambda_{ik}) \int_{-\infty}^{+\infty} exp(-\varepsilon_{ik}^{*} - e^{-(\varepsilon_{ik}^{*} - \lambda_{ik})}) d\varepsilon_{ik}^{*}$$

For $\varepsilon_{ik}^{*} = \varepsilon_{ik} - \lambda_{ik}$, also $\int_{-\infty}^{+\infty} exp(-\varepsilon_{ik}^{*} - e^{-(\varepsilon_{ik}^{*} - \lambda_{ik})}) d\varepsilon_{ik}^{*} = 1$ Then:

$$\pi_{ik} = exp(-\lambda_{ik}) = \frac{exp(V_{ik})}{\sum_{j=1}^{K} exp(V_{ij})}$$

In matrix terms, the probability that respondent i selects alternative k out of a total K is:

$$\pi_{ik} = \frac{exp(\boldsymbol{w}_{ik}\boldsymbol{\beta})}{\sum_{j=1}^{K} exp(\boldsymbol{w_{ij}}\boldsymbol{\beta})} \tag{4.4}$$

For:

$$\boldsymbol{w}_{ij} = \begin{bmatrix} x_{ij} \\ C_{ij} \end{bmatrix}$$

In other words, $\boldsymbol{w_{ij}}$ is the vector of all attributes of alternative j.

$$\boldsymbol{\beta} = \begin{bmatrix} \beta_1 \\ -\beta_2 \end{bmatrix}$$

To estimate this model, we use the following log-likelihood function, and then, the Maximum Likelihood method.

$$logL = \sum_{i=1}^{n} \sum_{k=1}^{K} y_{ik} log \pi_{ik}$$

Where y_{ik} is a binary indicator that equals 1 when k is selected, and 0 otherwise. We can reduce even more the expression for π_{ik}:

$$\pi_{ik} = \frac{exp(\boldsymbol{w}_{ik}\boldsymbol{\beta})}{\sum_{j=1}^{K} exp(\boldsymbol{w_{ij}}\boldsymbol{\beta})}$$
$$= exp((w_{i1} - w_{ik})\boldsymbol{\beta}) + \cdots + 1 + \cdots + exp((w_{iK} - w_{ik})\boldsymbol{\beta})^{-1}$$

For large samples, the Maximum Likelihood estimates $(\hat{\beta})$ are normally distributed around the vector of parameters $\boldsymbol{\beta}$. Also, we can obtain the asymptotic co-variance matrix Ω by inverting the Fisher Information matrix given by:

$$I(\beta) = \sum_{i=1}^{n} \sum_{k=1}^{K} \pi_{ik}(w_{ik} - \overline{w}_i)(w_{ik} - \overline{w}_i)^T$$

For:

$$\overline{w}_i = \sum_{k=1}^{K} \pi_{ik} w_{ik}$$

4.3 Model outputs

4.3.1 Modelling the WTP

The marginal value of attribute l is:

$$MP_l = -\frac{\hat{\beta}_l}{\hat{\beta}_2}$$

Where, $\hat{\beta}_2$ corresponds to the cost/price variable. The WTP for a commodity is:

$$WTP_i = -\frac{\boldsymbol{x}_i\hat{\boldsymbol{\beta}}_{\mathbf{1}}}{\hat{\beta}_2}$$

Where, $\boldsymbol{x}_i$ is the vector of attributes associated to the commodity being chosen by person i.

4.4 Goodness of fitness test

According to Alberini, Longo, and Veronesi (2006), our model (unrestricted model) is compared to an restricted model where the coefficients of the attributes are set to cero. Let $logL_U$ be the log-likelihood function of the unrestricted model, and $logL_R$ the same function for the restricted model. We consider the null hypothesis that all the slope coefficients are equal to cero. Then, a test statistic is $-2(logL_R - logL_U)$ which under the null hypothesis is χ^2_q distributed, for q the number of slope coefficients.

Another measure for the goodness of fit is the likelihood ratio index (LRI), proposed by McFadden(1974) in Alberini, Longo, and Veronesi (2006):

$$LRI = 1 - \frac{logL_U}{logL_R}$$

Observe that $0 \leq LRI \leq 1$. If the null hypothesis is true, then $logL_U = logL_R$, and $LRI = 0$. If the model predicts the answers perfectly, then $logL_U = 0$, and $LRI = 1$. However, LRI works only for models using the same sample and alternatives.

The LRI is also denoted by pseudo rho-squared (ρ^2). *As a rule of thumb, a well fitted model means that*: $\rho^2 \geqq 0.2$ (Hoyos 2010).

However, CE pose several challenges in general. For instance, ecosystems are complex: They cannot be easily broken down into orthogonal attributes (Hanley, Wright, and V. Adamowicz 1998). In addition, an attribute A might appear only if some minimum of attribute B is present. Therefore, it is impossible to list an independent and extensive list of attributes.

4.5 Example

(Blamey, Gordon, and Chapman 1999) studies Australian WI, with a population of 450 000. Five alternatives were considered: Coree, Tennent, Large-scale recycling, Demand manage and No-increase. In addition, the authors evaluated six attributes: Reduction in water use, Use of recycled water, Increase in household cost, Improvement in river flows, Endangered Species Losing Habitat, and Appearance of the urban environment. Both alternatives and attributes were selected through focus groups. The No-increase alternative corresponded to the status quo. This is important since consumer surplus and MWTP is defined to be a departure from the initial conditions.

A total of 27 questions were sampled from a 3^6 full factorial design. The CE was of the unlabeled type, comparing two alternatives at a time. The Status Quo alternative was also present, with no attributes being listed. The questionnaire had three blocks, each consisting of 9 questions. For data analysis, the attributes were coded orthogonally. To check internal validity, respondents had to rank the attributes.

Participants report that answering CE questions is not easy. Also, people need some context before answering. Therefore, participants had to read about the alternatives and attributes first. On average, participants were older, male, and had average income. People often stick to a one attribute they value the most, and select accordingly. Also, some alternatives are deemed unrealistic and avoided altogether. Questionnaires with a single answer were eliminated. The study gathered 294 valid questionnaires.

In their results, people avoided compulsory restrictions and costly alternatives. When controlling for age, older people seemed to prefer the Status Quo. The value of 10% reduction in household water consumption is 10 ASD.

Chapter 5

Survey Design, Data Analysis and Results

5.1 Theoretical guidelines

[1]

As a rule, respondents base their answers on information, their own experiences and previous knowledge. Therefore, the survey should provide simple information to avoid fatigue and confusion. The information given to participants should be validated by experts. Also, its formulation should be simple to reach to all educational backgrounds. Usually, if some information is missing or misunderstood, respondents will get back to their own experience to complete the task. Moreover, topics that involve uncertainty are inherently difficult to answer. Finally to evoke realism, the information given should be as complete as possible. In our case, participants need to know how extra costs will be passed, who is responsible for expanding WI, and what is the possibility of real change.

To implement a CE survey, several steps are necessary (Hensher, Rose, and Greene 2005, pg.108). The first step is to create a universe of alternatives for WI. This in accordance to the global utility maximizing rule from Welfare Economics [2]. Second, the researcher needs to refine the list of alternatives. Alternatives have to be uncorrelated to fullfill the IDD condition. For instance, I reduced the possible alternatives to two: Water tanks and Reservoirs. This was doable since a higher number of alternatives requires a larger questionnaire.

Third, we identify the *attributes* or characteristics of the alternatives. Alternatives can have different number of attributes. Also, attributes can be qualitative or quantitative. For simplicity, I have three attributes: Cost, Capacity and Durability. These attributes are the most familiar and relevant for participants. Attributes have to remain meaningful and easy to recognize. For instance, I have originally planned to include an attribute called Participation with levels "Yes" and "No". However, later on, the attribute was dropped since participants have different meanings for Participation.

An attribute takes on certain values denominated *levels*. In theory continuous attributes, such as Cost, allow for infinite values: down to cents and pennies. To skip continuity, the Cost, Capacity and Durability attributes are turned into

[1]These guidelines appear on Mathews, Freeman, and Desvousges (2006).

[2]In statistical terms, this translated into the IID condition for errors

categorical variables, taking low, medium and high levels.

The next step is to choose a design (Hensher, Rose, and Greene 2005, pg. 109). A labeled design shows the name of the alternatives. An unlabeled design uses generic labels. In my case, I will use the labeled design. A full-factorial design is one that considers all the possible combinations for making a choice. This design includes all the possible interactions between attributes. So the total number of choices for a full-factorial design is given by:

$$L^{MA} \quad \text{for labelled CE}$$

Or

$$L^{A} \quad \text{for unlabelled CE}$$

Where L is the number of attribute levels, M is the number of alternatives, and A is the number of attributes. However, it is impractical to use the full-factorial design in a questionnaire. Therefore, we use fractional design - a fraction of the full-factorial design. The fractional design is a sample of the full-factorial design, such as the attributes remain orthogonal.

5.2 Questionnaire design

The questionnaire has three types or blocks, each with different CE-questions[3]. The blocks reduced the number of questions. For instance, without creating any block, and using a single questionnaire for all participants, we obtain 18 CE questions. I allocated each participant to a block beforehand at random. However, the responses were not balanced, since I expected to obtain 35 responses for each block. The final count shows:

- Block 1: 46 answers.
- Block 2: 31 answers.
- Block 3: 28 answers.

The CE questions were presented as part of a scenario, where six expert teams, will visit the house and propose two alternatives for CC-adaptation: a water tank or a reservoir. This encouraged people to select different alternatives for each question, since the attribute levels will change for each question. Also, people became aware that their choices had to be independent from each other.

5.2.1 Alternatives

Reservoirs Reservoirs are large infrastructures that contain water for domestic use. Due to their size, reservoirs are used to provide water to cities. For instance, the Paria reservoir costs 2 million PEN, and can store 1800 m^3 of water. CHAVIN is in charge of their construction, and their cost passes to users via water bills (huarazenlinea.com 2015). This point was made clear to participants. However, CHAVIN can get additional funds from the local municipalities, Regional Government and Ministry of Housing.

[3] For more details see the Appendix.

Water tanks Water tanks are household water reservoirs, often with limited capacity and rely on the public water supply. Water tanks prevent swings in water supply due to shortages. Also, they complement water supply to a house, particularly when such house has a higher than average demand - such as in high-raise apartments. A main feature is that they are privately owned, and serve one single household. In this sense, water tanks are the opposite of reservoirs.

The following images (Fig 5.3 and Fig. 5.6) were used in the survey. In this way, participants could picture the different water tank and reservoirs models.

Figure 5.1: Model from the small-capacity reservoir. Adapted from FONCODES (2019).

Figure 5.2: Model from the medium-capacity reservoir. Adapted from Huaraz Noticias (2019).

Figure 5.3: Model from the large-capacity reservoir. Adapted from Huaraz en Linea (2019).

Figure 5.4: Model of the small water tank. Adapted from Sodimac (2019).

Figure 5.5: Model of the medium sized water tank. Adapted from Sodimac (2019).

Figure 5.6: Model of the large water tank. Adapted from Sodimac (2019).

5.2.2 Attributes and Attribute levels

Cost, Durability and Capacity are the most basic attributes to any WI. However, they are not totally independent from one another, as theory demands (Hoyos 2010). As higher cost results in longer durability and larger capacity, and viceversa. All this data is summarized in Tab 5.1. In addition, coding has to be mean-centering or effect coding. This is easy implemented in R.

Cost

For the Water Tank I obtained a price list from the online store Sodimac (Sodimac 2019) the 22^{th} January. The lowest price for a water tank was 200 PEN and the highest price 1700 PEN, the latter was an outlier. Moreover, I did not consider transport costs, installation costs and additional components. The lowest average cost was 300 PEN. The levels were then: 300, 500 and 700 PEN. The cost depends on the storage capacity of the tank, therefore, the two attributes are not independent. Consumers will pay for the water tank upfront, credit was not an option.

For the Reservoirs The price was obtained directly from CHAVIN infrastructure office. The prices again correlate with capacity and durability. The price range for small, medium and large capacity correspond to 0.5 mill PEN, 1.3 mill. PEN and 2.5 mill. PEN respectively. This price was divided by the number of registered houses (21 607) because these homes will be billed for additional charges [4]. The new price range for reservoirs became: 23.1 PEN, 60.2 PEN, 115.7 PEN. This division was necessary to create more comparable costs between alternatives.

Durability

For the Water Tank According to the producer of water tanks, they have a "lifetime" warranty (Rotoplas Argentina 2017). However, the least amount of years is 5. Therefore, I selected the values: 5,15,25

For the Reservoirs Information was also directly provided from CHAVIN. Therefore, I could not cross-reference this information. The levels were 20, 30 and 50 years.

Storage Capacity

For the Water Tank From the Sodimac webpage, I found water tanks ranging from 250 l. to 2800 l. I set the lower end (500 l.)at the average of the three smallest water tanks. Then, I increased storage capacity by 600: 500, 1100 and 1700 as the Table 5.1 shows. However, the 1700 l. water tank does not exist in reality.

[4] for an undetermined period of time

For the Reservoirs According to CHAVIN, reservoirs have the following capacity: $30m^3$, 900 m^3 and 1800 m^3. This amount was divided by the number of registered users, since the sample unit are households. In addition, some respondents were not familiar with the unit m^3. Therefore, the size scale is 1.4 L., 42 L. and 83 L. per house.

The Status Quo alternative The attributes are defined to be the increment from the present level: in other words, if the infrastructure were built, you would have additional water and also have to pay extra. However, the Status Quo alternative considers no change from the present state. Therefore, you will be charged 0 soles and will receive 0 additional water units.

Attribute	Level	Reservoir	Reservoir p.c.	Tank	Tank average
Price	High	2.5 mill. PEN	115.7 PEN	600-800 PEN	700 PEN
	Medium	1.3 mill PEN	60.2 PEN	400-600 PEN	500 PEN
	Low	0.5 mill PEN	23.1 PEN	200-400 PEN	300 PEN
Durability	High	50 years	50 years	20 -30 years	25 years
	Medium	30 years	30 years	10 -20 years	15 years
	Low	20 years	20 years	0-10 years.	5 years
Capacity	High	1800 m^3	83 L.	1400-2000 L	1700 L.
	Medium	900 m^3	42 L.	800-1700 L	1100 L.
	Low	30 m^3	1.4 L.	200-800 L.	500 L.

Table 5.1: Levels. reservoir p.c $= \frac{Reservoir}{21607}$

5.2.3 Controlling for CC

To control for CC knowledge and/or awareness I created separate questionnaire. This questionnaire included 3 additional questions about glaciers, water supply and the expected effects of CC. The CE-questions remained the same. The CC-questionnaire was distributed at random, and it reached 45/106 participants.

5.2.4 Controlling for Participation

After filling the CE questions, participants were presented with a second scenario. First, they were asked to rank the probability of success for building a reservoir for their neighborhood. Next, the scenario assumed that CHAVIN will build the reservoir. However, CHAVIN suggested the possibility of trading the neighbor's voluntary labor against some discount on their water bills. If the participant accepted the proposition, the follow-up question asked for their motivations.

5.3 Sampling

The sampling method used was random sampling. The sampling units were households, where a household is defined as a single family living in a one-family home. I have used CHAVIN strata in my sample, and randomly selected households from each strata to make up the final sample. This was important to have a balanced sample. In addition, I have identified the following elements:

1. Population: Huaraz city, comprising of both Independencia and Huaraz districts, with a total of 104 949 users (SUNASS 2015).

2. Sampling frame: Listing of domestic water register users at CHAVIN database. The size of this list is 21 607. This list includes several househols without complete adresses such as they could not be reached, and their answers registered. These households were dropped from the sampling frame, resulting in a final $N = 8448$

3. Strata: The CHAVIN database divides the users into three strata according to their consumption level: Low, Medium and High. Low consumption is between $0-8m^3$. From, the sampling frame, 2956 users fall into this category. Medium consumption is between $8-20m^3$. 2627 users fall into this category High consumption is beyond– $20m^3$. 2865 users fall into this category.

4. Sample size: 251. Giving a probability of 3% of being selected. Using the weights for each strata, I selected 88 units from low-consumption households, 78 units from medium-consumption households and 85 units from high-consumption households.

5. Reponses: A number of 105 responses were gathered, with a response rate of 48%.

However, the sampling frame contained specific addresses, targeting single houses. In practice, it was impossible to reach each house. Some of the addresses were hard to locate, or referred to business instead of homes. Therefore, I erased the house numbers, leaving only street names. A street name will appear as many times as the number of houses sampled from that street. For instance, in street with two addresses, the street name will appear twice on the final sample. From these streets, I picked up family homes at random, up to fill the required number. Following the example, I would have chosen two houses at random from said street.

Since I had three kinds of questionnaires, I randomly assigned each home to a questionnaire type beforehand. Similarly, I randomly assigned each participant to the CC or the control group.

Sampling Bias Sampling bias exists when some members of the population have none or little chance to be drawn into the sample. In this survey, not all Huaraz residents have a water meter, and therefore, are not CHAVIN registered users. Also, some households live on unmarked streets, and it was impossible to reach them. In addition, apartment complexes were not part of the sampling frame, since the objective was to select single familiar units. However, this was difficult to achieve since in Peru, related families might live together in single large home. Tenants were part of this survey, provided they had knowledge about their water bill and consumption.

5.4 Questionnaire application

5.4.1 Data gathering

The questionnaire fits into the format of a self-completion questionnaire, with supervision. I visited each street from the sample. Then, I selected a the required number of houses by chance. I avoided selecting "hybrid" buildings i.e. those that function as a business place and a home. In Peru, it is pretty common for a family to take residence on the upper floors while the first floor is rented to a business. I concede for property owners to have small shops on their homes, since shops are not intensive water consumers. However, I decided to leave out households that shared space with mechanic workshops, small factories and hotels, since they do consume substantive amounts of water. Then, I rang the bell and if no answered was produced I moved to the next house, 3-7 houses apart. If someone was unable to fill up the survey, I also declined their participation. In some instances, the participants could ask for the questionnaire and we will agree on a pick up time later. All the participants were older than 18 yrs.

While I encountered positive answers generally, trust was an issue. Some participants, and rightfully so, demanded my personal identification and details (occupation, origin,...). I presented this information using my student card and a letter I received from NMBU, confirming my status as a student. Participants were cautious about opening their door or revealing personal information. In their experience, thieves often make themselves appear as researchers or municipality personnel. However, their minds changed after I ensured them that survey was anonymous. In addition, I also remarked to participants that the survey was easy to fill out, taking no more than 10 minutes.

After introducing myself, and making clear to the participants that I was a student and not a CHAVIN worker, I handed them in the questionnaire, in paper. The elderly have trouble reading the questions, so I had to read them aloud. The questionnaire included instructions, such as to be filled out by the participant alone. However, since I was administering the interview, participants could ask me directly if they needed additional explanation. In my experience, participants struggled the most with the CE questions. This might be due to the unfamiliarity and their strong-held beliefs that investment in WI means building more reservoirs.

For the last three days of my stay, I recruited four additional surveyors. They were local university students, paid by the hour. They received training in administering the questionnaire, and selecting houses. I have quality checked their results. Fortunately, the questionnaire was formulated such as the respondents could answer by their own. Still, it is unclear if the helpers informed to the participants clearly about the study goals and personal data management.

5.4.2 Ethics

Researchers need to be aware of their own role and how they present themselves to their participants (Bryman 2012, Chap. 6). My position, as a middle class Peruvian might have been alienating for some participants. Nevertheless I tried to overcome this barrier by using simple language, and stating my purposes clearly. I have not forced my way into getting an answer, and I hope that my assistants neither required to do so. In addition, I have informed participants in both the survey and the interviews, about what type of data was needed and how it would be stored All participants were aware of the hypothetical nature of the research, and that it did not necessarily represented CHAVIN's plans.

5.4.3 Review

Unfortunately, sampling from a full-factorial design might yield non-sense questions. For instance, in some questions, one option is clearly superior. In other words, an alternative "dominates" the question. This tells us little about individual preferences. Therefore, it is important to carefully screen the choice sets obtained from the software.

Another issue is participant fatigue. Processing and evaluation of questions requires concentration. A large questionnaire is counterproductive. Often participants will stick to a single alternative, for the entire questionnaire. This indicates fatigue, protest answer or that the other alternative is not viewed as relevant. In addition, if cognitive maps do weight in the selecting and imagination, RUM needs to be modified such as to account for previous experiences and expectations. For instance, by creating categories of users or profiles.

5.4.4 On Mixed Methods

5.4.5 Why Mixed Methods?

Mixed Methods Research was important to answer the third research question: *How do decision makers facilitate WI improvement?* This question had to be targeted to specific decision makers. In addition, some insights from the interviews will be used to interpret the estimates from the quantitative part.

5.4.6 Qualitative Sampling

To develop the complementary interviews, I relied on purposive and convinience sampling (Bryman 2012, Chap.8). However, not all the relevant stakeholders were ready for an interview. For instance, infrastructure chief of CHAVIN - Ing. Miguel Rincón. was hard to reach due to his constant trips to disaster areas. On the other hand, information from his office was fundamental in developing the CE-questionnaire.

The quantitative part of this study, covered urban households registered at CHAVIN. Households in the quantitative sample where those with a water meter and a floating water fee. However, houses belonging to recently expanded areas were not included. There users experience different water needs and are organized differently than those connected to CHAVIN. Therefore, I have sampled 3 JASS close to the city of Huaraz. All three of them located on the district of Independencia, which is the newly formed district to the West of the original Huaraz district. [5]

The JASS represent the new emerging city of Huaraz, as they lie on areas of rapid urbanization and migration. While two of the JASS were urban, one was rural-urban, and farming was a predominant activity for its users. A partial list over the JASS in Independencia was obtained from the municipality. The personnel at the Municipality provided me with a contact number of the President of the K'antu JASS. The other JASS were directly contacted by me, when visiting their offices. The President of the Jaapshan JASS recommended the Shirampampa JASS nearby. However, several JASS lie beyond the Huaraz city, and could not be reached. In addition, JASS presidents often work full-time and only work with the JASS on their free time.

5.5 Data Analysis

The Conditional Logit analysis unit are not individual preferences, but the alternatives available to each individual (Hoffman and Duncan 1988). Consider N individuals, each of whom has K alternatives. Individual responses result into K records, each one representing an alternative.

The support.CE package includes the function `make.dataset` to generate a data set compatible with the `clogit` function in R. The package combines the answer data set and the design matrix of the questionnaire. The package "normalizes" both the Status Quo and N.A. answers.

We work with the basic model:

$$V_{in} = ASC_i + \beta_{ij} Medio_{ij} + \beta'_{ij} Alto_{ij} \tag{5.1}$$

In `R` this means:

```
clogit(RES~ASC1+ASC2+Medio_dur1+Alto_dur1+Medio_cap1+Alto_cap1+Medio_costo1+Alto_costo1+Medio_dur2+Alto_
    dur2+Medio_cap2+Alto_cap2+Medio_costo2+Alto_costo2+strata(STR), data=dataset1)
```

Listing 5.1: R code for the most basic model

`ASC` refers to unobserved utility sources for each alternative (Hoyos 2010). It can be interpreted as the Status Quo bias or utility premium from moving away from it. Socio-economic variables can be interact with either `ASC` or the attributes. However, some socio-economic variables that take the same value for all the options have to be interacted with the `ASC` since they cannot predict choice (Blamey, Gordon, and Chapman 1999).

To calculate the Marginal Willingness to Pay, we need at least one numerical attribute. This attribute creation process is illustrated in Table 5.2. The objective is to create a single vector of numerical values for both Reservoir and Water Tank alternatives. In the original survey, they took a "Low", "Medium" and "High" categorical value. This categories were in turn transformed into numerical values,

[5]Originally, both the city and the district of Huaraz were synonyms. However, as urban expansion continued, it was decided to split the city of Huaraz into two, following the Quillcay river. The western part became known as the Independencia district, and the eastern part remained as the Huaraz district. I have name both district collectively as the city of Huaraz, even if "city" is not part of the official terminology.

here under the column “Reserv p.c” and “Tank average”. The process of this coding is explained in the Appendix.

A single price vector is created by taking the average of the numerical codes in each category: “Low”, “Medium” and “High”. Therefore, we have three elements in the Cost vector to input into the data analysis: 161 PEN, 280 PEN and 408 PEN.

However, a problem is that this numerical vector requires a complete model matrix. In addition, this price levels are not part of the original questionnaire and participants have not interacted with them. In other words, they exist for study purposes only. This might decrease the internal validity of the study.

Level	Reserv. p.c.	Tank average	Cost single vector
Low Cost	115.7 PEN	700 PEN	408 PEN
Medium Cost	60.2 PEN	500 PEN	280 PEN
High Cost	23.1 PEN	300 PEN	161 PEN

Table 5.2: Calculation of a single cost vector to obtain MWTP

5.6 Results

I will be reporting results significant at the 10% cut off. For a complete list of the output, see Appendix B.2.

5.6.1 Using Categorical Levels

VARIABLE	COEF	exp(COEF)	se(COEF)	Z	P
ASC1	1.004335	2.730092	0.239014	4.202	2.65e-05
ASC2	0.378323	1.459834	0.264859	1.428	0.1532
Medio_dur1	0.334958	1.397882	0.213612	1.568	0.1169
Alto_dur1	0.519518	1.681217	0.216891	2.395	0.0166
Medio_cap1	-0.185812	0.830430	0.214072	-0.868	0.3854
Alto_cap1	-0.028066	0.972324	0.215214	-0.130	0.8962
Medio_costo1	-0.090138	0.913805	0.213355	-0.422	0.6727
Alto_costo1	0.071157	1.073750	0.216074	0.329	0.7419
Medio_dur2	0.147733	1.159204	0.238907	0.618	0.5363
Alto_dur2	0.438142	1.549825	0.233676	1.875	0.0608
Medio_cap2	-0.009015	0.991025	0.235513	-0.038	0.9695
Alto_cap2	0.162653	1.176628	0.234058	0.695	0.4871
Medio_costo2	0.101731	1.107086	0.233337	0.436	0.6628
Alto_costo2	-0.071040	0.931425	0.234371	-0.303	0.7618

Table 5.3: Results for No-CC controlled

Here, $\rho^2 = 0.11$. High duration is the only significant level. According to the signs, high duration increases the likelihood of selection of either the water tank or the reservoir.

I have also controlled for expectations ($\rho^2 = 0.16$). The reservoir and the water tank are preferred by the groups with medium-high expectations, with respect to the group with lower expectations. When controlling for consumption level in the Capacity attribute ($\rho^2 = 0.13$)., people with lower consumption are less likely to select the medium and/or high capacity water tanks. Participation is significant for the cost of reservoir only ($\rho^2 = 0.13$). As expected, people with lower participation scores are less likely to volunteer in medium-high expensive reservoirs. On the other hand, people with the highest participation score are twice as likely to select high-cost reservoirs. Finally, the water fee level had no bearing on the cost, neither for the reservoir nor for the water tank ($\rho^2 = 0.13$).

5.6.2 CC for Categorical Levels

Variable	Coef	exp(coef)	se(coef)	z	p
ASC1	1.15398	3.17079	0.26804	4.305	1.67e-05
ASC2	0.61351	1.84690	0.29400	2.087	0.0369
Medio_dur1	0.33219	1.39402	0.21352	1.556	0.1198
Alto_dur1	0.51562	1.67468	0.21680	2.378	0.0174
Medio_cap1	-0.18519	0.83095	0.21395	-0.866	0.3867
Alto_cap1	-0.02850	0.97190	0.21506	-0.133	0.8946
Medio_costo1	-0.09145	0.91260	0.21324	-0.429	0.6680
Alto_costo1	0.07093	1.07351	0.21599	0.328	0.7426
Medio_dur2	0.14381	1.15467	0.23903	0.602	0.5474
Alto_dur2	0.43030	1.53772	0.23407	1.838	0.0660
Medio_cap2	-0.01032	0.98973	0.23571	-0.044	0.9651
Alto_cap2	0.16224	1.17614	0.23427	0.693	0.4886
Medio_costo2	0.10078	1.10603	0.23365	0.431	0.6662
Alto_costo2	-0.07222	0.93033	0.23463	-0.308	0.7582
ASC1:ENV1	-0.31554	0.72939	0.24593	-1.283	0.1995
ASC2:ENV1	-0.52187	0.59341	0.26876	-1.942	0.0522

Table 5.4: CC control for categorical variables only.

Here, ($\rho^2 = 0.11$). There is no statistical significance fore the reservoir and the control. On the other hand, people in the CC questionnaire, are less likely to select the water tank. I have also controlled for perceived service loss due to glacier retreat (IMPACT). Here, ($\rho^2 = 0.20$). People most concerned with water supply (score:2-5) are more likely to select the reservoir. Also, the highest scoring group is interested in the water tank.

5.6.3 MWTP

First, we run the regression with the Cost vector, constructed for this purpose. We have:

VARIABLE	COEF	exp(COEF)	se(COEF)	Z	P
ASC1	0.9236226	2.5183971	0.3183486	2.901	0.00372
ASC2	0.4709432	1.6015040	0.3488342	1.350	0.17700
Medio_dur1	0.3193756	1.3762682	0.2128887	1.500	0.13356
Alto_dur1	0.5080106	1.6619815	0.2164156	2.347	0.01891
Medio_cap1	-0.1884350	0.8282543	0.2136644	-0.882	0.37782
Alto_cap1	-0.0123664	0.9877097	0.2141503	-0.058	0.95395
Costo1	0.0002790	1.0002790	0.0008730	0.320	0.74931
Medio_dur2	0.1641643	1.1784080	0.2383865	0.689	0.49104
Alto_dur2	0.4632074	1.5891629	0.2323949	1.993	0.04624
Medio_cap2	-0.0141825	0.9859176	0.2351731	-0.060	0.95191
Alto_cap2	0.1455846	1.1567156	0.2331616	0.624	0.53237
Costo2	-0.0003122	0.9996878	0.0009397	-0.332	0.73967

Table 5.5: Results for no CC-Controlled MWTP

Here, ($\rho^2 = 0.10$). Despite the change in the Cost levels, long-lasting WI remains attractive. When controlling for Participation ($\rho^2 = 0.14$), we observe that people who participate more are more likely to select the reservoir than the water tank. We can calculate the MWTP using the `mwtp` function, and the Krinsky and Robb method.

Variable	MWTP	2.5%	97.5%
Medio_dur1	-1144.86	-6067.91	5523.02
Alto_dur1	-1821.06	-8657.92	8600.08
Medio_cap1	675.48	-3749.82	3832.57
Alto_cap1	44.33	-2968.77	2967.22
Medio_dur2	525.77	-3939.72	3704.60
Alto_dur2	1483.51	-8094.70	7244.55
Medio_cap2	-45.42	-3016.74	3079.91
Alto_cap2	466.26	-3877.24	-3653.28

Table 5.6: MWTP

5.6.4 CC and MWTP

Variable	Coef	exp(coef)	se(coef)	z	p
ASC1	1.0728926	2.9238248	0.3411183	3.145	0.00166
ASC2	0.7072699	2.0284458	0.3721485	1.901	0.05737
Medio_dur1	0.3165792	1.3724249	0.2127876	1.488	0.13681
Alto_dur1	0.5044514	1.6560768	0.2163303	2.332	0.01971
Medio_cap1	-0.1877047	0.8288594	0.2135564	-0.879	0.37943
Alto_cap1	-0.0128540	0.9872282	0.2139927	-0.060	0.95210
Cost1	0.0002775	1.0002776	0.0008726	0.318	0.75046
Medio_dur2	0.1591228	1.1724819	0.2385747	0.667	0.50479
Alto_dur2	0.4548129	1.5758785	0.2328201	1.953	0.05076
Medio_cap2	-0.0155602	0.9845602	0.2353943	-0.066	0.94730
Alto_cap2	0.1455281	1.1566503	0.2333747	0.624	0.53290
Costo2	-0.0003175	0.9996826	0.0009407	-0.337	0.73576
ASC1:ENV1	-0.3152026	0.7296411	0.2458878	-1.282	0.19988
ASC2:ENV1	-0.5216747	0.5935257	0.2686907	-1.942	0.05219

Table 5.7: CC control for MWTP

Here, ($\rho^2 = 0.11$). Again, people are less likely to select the water tank with respect to the non-CC controlled group. The MWTP is then:

VARIABLE	MWTP	2.5%	97.5%
Medio_dur1	-1140.77	-5087.90	5124.31
Alto_dur1	-1817.75	-8178.16	7560.02
Medio_cap1	676.38	-3762.77	-3553.89
Alto_cap1	46.32	-2654.78	2715.07
Medio_dur2	501.25	-3762.12	3735.35
Alto_dur2	1432.69	-7263.70	7513.20
Medio_cap2	-49.02	-2844.32	3171.00
Alto_cap2	458.42	-3445.14	3506.67

Table 5.8: MWTP after CC-control

Chapter 6

Discussion

6.1 Theoretical issues

Answers do not seem to be independent from one another. One expects for answers to change as the attribute levels do. However, in this exercise, I have observed that many answers come in "blocks". Several participants have selected the Reservoir (or the Water Tank) in every instance. These responses could be interpreted as a "protest" responses. However, due to my small sample size, I could not erase such responses.

We can explain "block" answers by people's expectations. WI is public infrastructure, to shift the burden to users will create cognitive dissonance. Therefore, private solutions to a future water crisis might not be deemed realistic.

Another issue steams from defining the water status quo. The status quo and the "none of the above" answers were not separated during the analysis. This is problematic. The status quo is a valid alternative since it yields some utility to the participant. In other words, other alternatives might have increased utility.

6.2 Realism

6.2.1 Sample limitations

My sampling frame only included users at the CHAVIN database. Therefore, I have not sampled JASS-served households. In addition, some houses were difficult to reach since they lack proper numbering and/or several households live in a single house. Since the survey was administered in person, urban places were easy to reach. Semi-urban and rural houses were at the loosing end. Also, completing the questionnaire depended on time and reading skills. Senior citizens experienced difficulty with reading the questionnaire, and required assistance. In addition, during morning hours, women became the number one respondents since they were at home taking care of children, preparing food,... However, gender was not controlled in the survey.

6.2.2 Attributes and levels

Level delimitation, and in particular, cost calculation was tricky. Under an informal conversation with a CHAVIN retired worker, it emerged that building additional reservoirs will require a change in the water network. Old pipes become narrow under extra water inflow. The cost for shifting new pipes was not part of the cost calculation for the survey. However, pipe shifting is inexpensive and faster when compared to reservoir construction.

In addition, the attributes might have not been what most people value. (Blamey, Gordon, and Chapman 1999) conducted focus groups to find out relevant attributes. Due to time and budget constraints, the attributes were determined apriori by the author alone.

6.2.3 Conflict depictions

Conflict is likely to emerge as houses and business mix. Huaraz has an heterogeneous landscape, where high raise buildings are located next to small stores/houses (See Fig. 6.1). Large houses and hotels demand more water, and this excess demand creates a “race to the bottom”. City growth is another possible source of conflict. Huaraz is expanding towards the Cordillera Negra, across the Santa River (See Fig. 6.2) As mentioned before, the Cordillera Negra does not have glaciers, and requires additional water from the Cordillera Blanca. With decreasing melt water, this conflict is likely to escalate. Finally, flat water fees hinder WI expansion, particularly for some JASS Users typically oppose water fee increments, particularly if they consume plenty.

Figure 6.1: City center photograph. Source: The author.

Figure 6.2: View from the Huaraz to the opposite side of the Santa River. Source: The author.

6.3 Interviews with stakeholders

6.3.1 Interview with the ANA - Huaraz

Format: 30 min. interview with Ing. Gilbert Gonzales Lizamo, in charge of Glaciers Unit at the ANA - Huaraz.

The interviewee suggest that CC was already visible for locals since the 60's and 70's. Locals recall that in the 60's the snow cover of nearby mountains was permanent. However, as time passed by, the covered created, and faster during the dry season. For instance, the San Cristobal mountain lost completely is snow cover. On average, glaciers have been retreating at 16 -22 m on average, However, this retreat rate depend on exogenous factors such as the ENSO.

The Cordillera Negra lies in front of the Cordillera Blanca, on the opposite side of the Santa River. The Cordillera Negra (Black Mountainrange) receives its name from its snow barren peaks. Here, farmers use rain-fed irrigation, as well as artificial springs. In addition, some water is being pumped into to Cordillera Negra from the Cordillera Blanca. However, this has resulted in conflict.

The ANA‘s glacier studies unit started in Huaraz in 1942. The central government decided to open the ANA a year after the Palcacocha lake outburst. Glacier melting forms glacier lakes, and their increase in volume puts Huaraz at higher avalanche risk.

The ANA takes upon itself the "social responsibility" to communicate its research to academia, and specialized institutions on water management. Authorities work with the ANA to draft CC adaptation policy, both local and regional. Glaciers matter for water supply since they storage water and release it over time.

For the past fifty years, the ANA has collected evidence of glacier retreat the Cordillera Blanca. Glacier retreat coincides with the increase of CO_2 that has been accelerating since the 60-70‘s. Photographs over time evidence this retreat, for instance, in the Broggi glacier. Later, topographic and batimetric studies confirmed this results. In the Cordillera Blanca, snow peaks lie above 5000 meters above the sea. CC will make snow peaks under 5000 m. disappear, and create new lakes from melting water. For instance, the southern part of the Cordillera Blanca already is part of this process. In addition, these lakes have high hydropower potential due to their altitude.

Civil society has been aware of glacier retreat, mainly since this increases risk against their livelihoods. Authorities have relied on experts (such as the ANA) to draft CC adaptation policies. To prevent loss of human life, authorities have also the duty to elaborate evacuation plans for the city. However, in practice, some parts of the population still expose themselves to flood risk. This in part to incredulity and little knowledge about the flood risk. Risk exposure has also increased due to growing urbanization.

Four micro-basins are able to meet drinking water demand in Huaraz. However, only one of them is readily treatable. Two present high PH level, and the other one presents fine sediments that make filtration expensive. Glacier reduction will decrease the water level in all four basins. However, increased investment could turn the three unused micro-basins into usable.

Lake Palcacocha receives 400 l/s - 500 l/s water inflow. This is not enough to meet the demand at 500 l/s. Therefore, other sources are needed, particularly during the dry season when water inflow ebbs out. In addition, it is important to secure regular water inflow to downstream economic activity. Glaciers create water buffs to even out differences between seasons. On the Cordillera Negra, the absence of such water buffs requires additional coordination among water users. The Cordillera Negra inhabitants rely on small lakes and springs that refill themselves with rain. Once the glaciers of the Cordillera Blanca are gone, this technique might become useful to manage the newly formed lakes.

CC will also present development opportunities for the region. For instance, lake Paron will have a $80 \times 10^6 m^3$ capacity. Therefore, the lake will become an important water reservoir for both human and industrial uses (agriculture and power generation) Development in the area will have to balance risks and opportunities. However, this transformation is also framed by conflict. Local authorities might be slow to pick up on local users complains. Therefore, national authorities have to take advantage of the new opportunities.

Next, I will resume the main points of the three interviews to the JASS in Huaraz-Independencia. These JASS are important since they lie outside the sample frame, and point to the problem of growing urbanization in the outskirts of Huaraz. In other words, the neighborhoods that composes the JASS are a blend of rural/urban contexts.

6.3.2 Interview with the JASS- Kantu

Format: 15 min. interview with Hugo Salazar - President of the JASS Kantu

The community has two reservoirs, built in 1986 and 2007 respectively. The nonprofit CARE helped to build the older reservoir. The Independencia Municipality helped built the other. To access official help, the JASS leaders needed to present a project to the municipality, and be subjected to qualification. The municipality provided building materials, and the locals, labor. The JASS leaders called for a general meeting and divided labor tasks among families.

The Independencia municipality funds the expansion of water infrastructure. A family fee is collected to cover operational costs. In addition, each family is expected to participate in communal work ("faena" in Spanish). Families missing on the communal work will pay a non-compliance fee equal to the price of missing man-hours worked.

Community meetings help to envision the future of water supply. However, poor families that are not able to pay the monthly fee do not participate in the meetings. Neither do they receive treated water from the JASS. On these cases, these users receive direct help from nonprofits or the municipality.

CC discussions were started by nonprofits through education campaigns and visits. According to the interviewee, without glaciers it will be impossible to live in the community. This will also increase conflict with other communities.

6.3.3 Interview with the JASS- Jaapshan

Format: 15 min. interview with Pedro - President of the JASS Jaapshan

The JASS is comprised of 3 100 users. The JASS is in charge of the distribution of treated water. It buys the water from CHAVIN at a monthly cost of 7 600 PEN. It operates with a flat fee of 3.50 PEN. This fee is determined by the JASS, independently from the regulator. Maintenance relies on both hired employees and communal work. The workforce consists of 9 employees, including repairmen and administrative personnel. The JASS covers their salaries using their own resources.

The JASS leadership is organized in a board. The board sits for a two-year period. However, decisions are taken in general meetings open to the neighbors.

The flat fee poses several challenges to the JASS. According to the President, the 3.50 PEN fee does not cover the running costs. To raise the fee is also difficult since the general assembly has to approve such raise. Consensus and deliberation matters for the JASS. While the board is positive towards a fee raise, their hopes might not be mirrored by the assembly. In addition, neighbors often raise political leftist points to argue for independence and flat water fees. Therefore, the JASS is poorly prepared to meet future demand increase due to low income.

The JASS currently works with rationed water. A part of the population receives day-time service, and the other, night-time service.

For the future, the JASS plans to install water meters for all households, and leave behind the flat fee. Also, the JASS needs to expand its coverage taking into account increased population density. Urban areas are growing towards the North, and even on the Eastern slope of the Cordillera. Therefore, the President has suggested to install a treatment and catchment water plant. This will most likely provide water during the 24 hours. On the other hand, CC does not seem to be an immediate priority. Locals users seem to be more concerned about infrastructure.

However, the future for Jaapshan is not clear. A recently issued policy [1] suggests that if a JASS has more than two thousand members, then it has be integrated into the MWP. The Jaapshan JASS asked for a government grant, but this policy has caused delays. Moreover, the President manifested that the JASS has no desired to integrate.

6.3.4 Interview with the JASS- Shirampampa- Shancayan

Format: 15 min. interview with Jesus Lumbe - President of the JASS Shirapampa

The Shirampapa-Shancayan JASS covers 4 sectors: Campo Alegre, Shirapampa, Eucaliptos and Huayrahilca. This represents 630 users in total.

The JASS faces several challenges. For instance, reduced water supply due to glacier retreat and degrading water quality. Another challenge is the growing user numbers. Unfortunately, according to the interviewee, users still lack awareness of taking care of the environment.

According to the President, the current flat water fee does little to cover operating costs. The fee stays at 3.00 PEN. Moreover, due to this limited budget, the JASS struggles to expand its infrastructure. The JASS has not implemented water meters. In addition, the administration lacks means to sanction abusive users. For instance, late fees are not collected timely, payments being delayed 1-3 years in some cases. Also, some users receive subsidized water from other JASS and/or Chavin. Therefore, they have little loyalty to JASS Shirapampa-Shancayan.

According to the President, new generations are less interested in communal work. New-generation users prefer to not deal with the issues themselves, but to delegate to the JASS. A possible solution is to educate users about the local natural resources state and pollution. In addition, the JASS will need additional investment in reservoirs, and better technology.

Unfortunately, the President views the Independencia Municipality as uncooperative. Municipal authorities are slow to revise and accept WI projects. In addition, the projects can be remitted to the Ministry of Housing, Development and Sanitation. This increases the waiting time for the JASS.

The JASS struggles to go through with price reforms. Since its origin, 30 years ago, the JASS operated with minimal costs for few users. The older generations were able to provide themselves labor force, and drive down costs. Current users would like to preserve the status quo, however, this is unsustainable due to the increased number of users. To expand the WI, the JASS needs technical assistance, and to invest heavily.

6.3.5 Final messages

Information matters, people often gathered CC information through observing the barren mountain tops. While official information is available on the internet, CC-informed decisions are rare to come by. Also, other channels of knowledge matter, beyond the established ones. For instance, water harvesting and rain-collection might be small-scale alternatives that could link users to CC demands.

Huaraz locals are capable of organizing themselves. They pull both official and local resources to keep an standard of living. However, coordination is still an

[1] A "Decreto Legislativo" in Spanish

issue. Urban planning failure is a sign of weak institutions. This also complicates the necessary water fee raise. Many people might view themselves as entitled to water, but still open to do the hard work of improving WI.

In conclusion, Huaraz presents a case where institutions, previous practice and hopes for development interact with technical/official versions of CC. WTP hard to determine in this complex context, and more research in needed to understand people values and expectations for CC-resilient WI. However, people are not ignorant. CC is visible, and the need to adapt is ever-present. The only thing lacking is to materialize this adaptation.

Appendix A

Water on the Peruvian Context

A.1 Water statistics

Peru is a water-rich country: according to INEI (2017b), Peru produced 2 482 351 hm^3 of water in 2012. 98.2% of this water corresponded to the Atlantic basin. In 2016, Peru used 41 841.731 hm^3 of superficial water (ANA 2016).

The most water-intensive sectors are agriculture, hydro power and domestic (See Fig. D.1). From the 41 thousand hm^3 of water used in Peru in 2016, the energy sector represented 63 % of the demand. Agriculture represents 31% of the total national water use. Finally, human consumption represents 3%.

However, water use varies across AAA (Administrative Water Units in Spanish). Mantaro AAA used the most water with 12 188.686 hm^3, most of it linked to hydropower. Jequetepeque-Zarumilla AAA uses the most water in agriculture, with 3 646.983 hm^3. Canete-Fortaleza AAA uses the most water for human consumption at 603.016 hm^3.

Peru has a system of water licenses ("Derechos de uso de agua" in Spanish). Each private actor with a stake on the local water supply, needs a license. Licenses are issued to hydropower, agriculture, industry, and human consumption. Hydropower has been issued the most licenses. Moreover, the number of licenses varies accross AAA. For instance, Jequetepeque-Zarumilla AAA is responsible for about 50% of the total licenses emitted on 2016. On the other hand, Amazonas AAA accounted for only 0.14%. This might be because Jequetepeque-Zarumilla AAA concentrates the largest dams in the country.

In total, authorities gathered 172 005 338 PEN from water use in 2016, nationwide. [1] The non-agricultural sector provided 54% of this income, while agriculture only provided 9% . From the 14 AAA, 8 have the non-agriculture sector as the most profitable. In other words, agriculture uses under priced water.

A.2 Issues

Water supply Dwindling water supply threatens the Peruvian economy. As we saw before, hydropower is the main consumer of superficial water in Peru. If Andean upstream water supply will reduce, it is expected that Peruvian energy capacity will be negatively affected . In 2016, hydro power accounted for 8% of

[1] For a complete national overview, refer to the Appendix D.4.

the total energy supply (Ministerio de Energia y Minas 2018). If gone, Peru will have to depend even more in fossil fuels to supply its increasing energy demand.

In Lima, population grow will create a greater demand for water. Andean fountainheads might not be able to cope once the glaciers are gone.

Water quality According to the ANA (ANA 2009), water quality is at risk due to poor waste management. Moreover, waste dumping is not monitored. According to ANA (2016), Peru has 582 emitted sewage licenses in 2016. From this total, 68% of licenses are given to the industry. 28% of licenses are dedicated to domestic use. Canete-Fortaleza is the AAA concentrating 16% of the licenses. On the other hand, Madre de Dios, only has 1.4% of the licenses, despite the AAA having aquaculture as an important activity. Industrial licenses are also skewed in favor of AAA in the coast. Quite surprisingly, the number of licenses given to the mining sector is almost insignificant:0.34% (2 licenses from a total of 584).

Natural disasters and CC Natural disaster such as landslides and droughts affect water supply and infrastructure. Climate Change will only worsen the effects of these disasters, and make them more frequent. Again, the main issue is poor coordination and monitoring to implement preventive measures.

Social inequalities The most important cities of Peru, lie on its coast. Consequently, water infrastructure in the Andes has been neglected. This means that there is little investment in upstream projects. However, rural areas are increasingly becoming more urban (Oblitas 2010, pg.17). For instance, 1996-2007, small municipal water providers increased their coverage by 22%. This is, they added 22% of the population. However, rural areas are still falling behind: Only 36% of rural users had access to sanitation, and 61 % have access to drinking water by 2018.

In addition, growing demand in cities posses several challenges. For instance, marginalized communities such as slums, lack access to safe drinking water. Oswald et al. (2007) found evidence of fecal contamination in drinking water for peri-urban households. While water from the tap was clean, poor water storage resulted in contamination. In addition, poor water users tend to spend more of their income in water fees (OXFAM 2018).

Conflict for water is started to become widespread. In the Piura, water became a rival resource once biofuel plantations began to displace small farmers (Crovetto 2013). Moreover, two antagonistic discourses emerged: water as both available and scarce. The official version was that water was plenty to allow for biofuel plantations. However, local farmers were more skeptic and backed a conservative water distribution. Therefore, water scarcity and access depends not only on infrastructure, but on discourse and interests.

Regulation is not enough to prevent conflict. Water policy, compliance systems and social organization are already mainstream on water Peruvian law. However, practice and law diverge. This issue is called “para-legalism”: Hereby, two parallel legal systems exist independent from each other (Guevara-Gil 2010). In other words, there a two legal systems: one official and the other informal, one urban and the other rural. This necessarily creates conflict, but also people become skilled in navigating both systems.

A.3 Water administration

A.3.1 The Water Resources Law - 2009

[2] Originally called “Ley de recursos hidricos” in Spanish. This law comprehends the use and governance of *all water resources*: Superficial water, underground water, continental water, the sea and the atmosphere.

The Water Law (referred here as such, from now on) is based on the following principles. (1) The multiple value of water: Water has an economic, social, environmental value. (2)The right to water: Human use is of main priority. (3) Popular participation in water governance. (4) Access to law and rights regime. (5) Respect to rural/indigenous water governance. (6) Sustainability. (7) Single authority for the public system: The SNGRH (National System for the Governance of Water Resources). (8) Precautionary Principle. (9) Principle of efficient water use and conservation. (10) Participatory governance. (11) The state has the ultimate right of water ownership.

A.3.2 At the national level

The National System of Water Resource Governance (SNGRH) According to Water Law, this council is the top authority in national water policy. The SNGRH gathers public institutions with a stake on water governance (ANA 2018a). The SNGRH includes: The Ministry of Environment, the Ministry of Agriculture, Ministry of Mining and Energy, Ministry of Health, Ministry of Production, and the Ministry of Housing. It also includes regional and local governments. Its policy is implemented by the National Water Authority (ANA) [3]

Furthermore, policy-making at the National System level follows Policy Nº33 (from the National Convention on Public Policy for Water Resources of 2012). The National convention was an open space to elaborate and approve public water policy. It gathered political parties, organized civil society, national, regional and local representatives. Policy Nº33 is the backbone of all water public policy, and guides the implementation of the Water Law. Moreover, Policy Nº33 prioritizes water for human consumption and pluricentral water governance.

The National Policy and Strategy of Water Resources (Decreto Supremo º06-2016-MINAGRI) is the most important policy guideline in water affairs. A national state policy remains unaffected by the succession of authorities. The National Policy drafting started in 2004. The National Policy gathers the insights from the National Convention and emphasized long-term planning. The National Policy has 5 objectives: First, to preserve water-provisioning ecosystem services. Second to protect and recover water quality. Third, to expand access to drinking water. Fourth, to promote efficient water management. Finally, adaptation to CC and vulnerability reduction.

The National Water Authority The ANA (National Water Authority) is the national regulator and highest technical body of the SNGRH - according to the

[2]This information is gathered from the compendium of the ANA (Autoridad Nacional del Agua (ANA) 2018).

[3]The National System’s most important principles and documents are gathered in ANA (2017).

Water Law Nº29338 (ANA 2018c). The ANA lies under the Ministry of Agriculture and Irrigation.

The ANA is conformed by the 14 AAA's, subdivided into 71 local water administrations (ALA), and 12 Water Basin Councils.

The ANA was created March 13th of 2008 by the Legislative Decree Nº997 to protect, conserve and promote sustainable water use. The ANA is responsible for (1) monitoring and administrating water sources. (2) It creates a"national water budget", regulating how much water a municipal water providers and water committees can use. (3)Emits water and/or sewage licenses. (4)Authorizes new infrastructure in water sources. (5) Finally, the ANA presides over the SNGRH.

The SUNASS The SUNASS is the public and decentralized regulator created by Law Nº25965, conjoined to the Prime Minister office (SUNASS 2018). Its main objective is to regulate water and sanitation services accross the country. The SUNASS links the State, investors and users The SUNASS enforces and drafts regulation and other control mechanisms. For instance, the SUNASS will set the water price for each water provider. Finally, the SUNASS also mediates conflicts between users and providers.

A.3.3 At the local level

Water Administrative units (AAA) Geographically speaking, the National Water Authority has divided the country into Water Administrative units (AAA in Spanish)(ANA 2009), following Water Law Nº29338. An AAA is in charge of a basin. The AAA's result from the integration of two or more nearby water basins with similar characteristics. Administration means right assignments, pollution control, use, planning, coordination and participatory development of the water basin. For instance, the AAA approves technical studies on water use and supply, emits water licenses and approves new infrastructure.

There are 14 AAA on (see Appendix D.3):

1. Maranon
2. Jequetepeque-Zarumilla
3. Huallaga
4. Huarmey-Chicama
5. Ucayali
6. Amazonas
7. Canete-Fortaleza
8. Mantaro
9. Pampas-Apurimac
10. Chaparra-Chincha
11. Caplina-Ocona

12. Urubamba-Vilcanota

13. Madre de Dios

14. Titicaca

A.4 Peruvian Andean Glaciers

The Andes concentrates from than 90% of the tropical glaciers on the planet. Peru contains 70% of this total (Rabatel et al. 2012; Mathias Vuille et al. 2008). In countries like Peru and Bolivia, Andean glaciers create a water buffer to allow continuous water supply through the dry season (Vergara et al. 2007). Moreover, since these glaciers provide up to 80% of drinking water to downstream communities, it is expected a severe water crisis on the medium-long term: Glacial melting will increase run-off, then such run-off will plateau, and finally cease completely. Also, glacial melt water increases overflowing risk.

Andean glaciers are particularly vulnerable to Climate Change, being naturally locked on tropical melting conditions. For instance, the Peruvian glaciers of Yanamarey, Broggi, Pastoruri, Uruashraju and Gajap have been retreating since the mid 1970's, yet this transition is not smooth (Mathias Vuille et al. 2008). CC is likely to affect the principal factors behind this retreat: precipitation, humidity and temperature

The report Schoolmeester et al. (2018) summarizes many relevant issues. First, water storage is a ecosystem service. For instance, some ecosystems such as wet paramos, are very good at conserving water. However, these ecosystems are under threat. Second, water harvesting infrastructures need to be sized down such as micro-dams. Third, the current water supply still has many losses due to poor infrastructure and recycling. Demand caps on water use will also increase efficiency. In irrigation, water efficiency means adoption of new techniques such as dripping and sprinklers. Fourth, glacier lakes pose a threat of flooding to downstream communities. Retreating glaciers increase both the number and the size of these lakes. Dams and tunnels in these lakes help to control their volume. Early warning systems (such as in Laguna 513 in the Cordillera Blanca) also reduce risk of human life loss. Finally, authorities should prioritize water security.

In other words, glaciers are providing important ecosystem services that will have to be supplied by humans once they disappear. For instance, Vergara et al. (2007) shows that for the next 20 years, 100 million USD are required to cover the loss from retreating glaciers that supply Quito city. Another impact of decreasing glacial runoff is less power generating capacity. The Andean region is a hub for hydro power generation. For instance, in the Canon del Pato hydro power plant, a loss of glacial input will decrease output from 1540 gigawatt-hours to 970 gigawatt-hours (±14.2%) (Vergara et al. 2007). More data about the estimates costs are indicated on Figure A.2. In addition, glaciers are important touristic destination. In other words, these services flow to multiple stakeholders: residents, engineers, water developers, city planners, tourists, ... that depend on glaciers. .

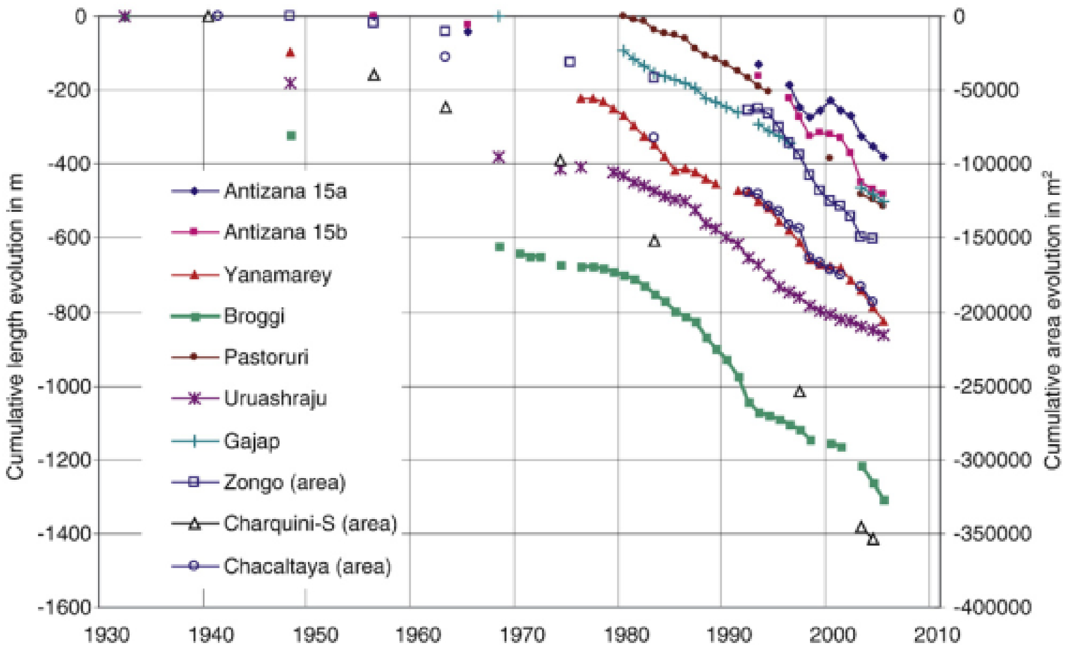

Figure A.1: Change in length and surface area of 10 Tropical Andean Glaciers. Adapted from Mathias Vuille et al. (2008)

	Cañon del Pato Power Plant		National Estimates	
	Reduced Glacier Runoff	No Glacier Runoff	Reduced Glacier Runoff	No Glacier Runoff
Wholesale price	5.7	11.5	60.0	120.0
Opportunity cost	10.1	20.3	106.0	212.0
Rationing cost	71.5	144.0	748.0	1,503.0

Figure A.2: The cost of glacier retreat for energy sector, Peru (Million USD/year). Adapted from Vergara et al. (2007)

Appendix B

Building Choice Experiments using R: Step by Step

B.1 Setting up the CE model

To enable data analysis and collection, the package Support.CEs created by Aizaki (2012) was crucial. This section summarizes, and describes how the steps outlined by Aizaki (2012) were implemented.

B.1.1 Creating a CE questionnaire in R

To create a questionnaire, first, we need to fill out the following template in the command `Lma.design`:

```
des1<-Lma.design(attribute.names=list(
Costo=c("Bajo_costo", "Medio_costo", "Alto_costo"),
 Durabilidad=c("Bajo_dur", "Medio_dur", "Alto_dur"),
 Capacidad = c("Bajo_cap","Medio_cap","Alto_cap")),
  nblocks=3,nalternatives=2, seed=383)
```

Where, I have selected the number of blocks to obtain 3 sets of questionnaires with 6 questions each. The `seed` argument corresponds to a random number. Then, the `questionaire` function applied to the `des1` template yields three types of questionnaires.

```
> questionnaire(choice.experiment.design = des1)

Block 1

Question 1
alt.1        alt.2
Costo       "Bajo_costo" "Bajo_costo"
Durabilidad "Bajo_dur"   "Bajo_dur"
Capacidad   "Bajo_cap"   "Bajo_cap"

Question 2
alt.1         alt.2
Costo       "Medio_costo" "Medio_costo"
Durabilidad "Medio_dur"   "Medio_dur"
Capacidad   "Medio_cap"   "Medio_cap"

Question 3
alt.1        alt.2
Costo       "Alto_costo" "Alto_costo"
Durabilidad "Alto_dur"   "Alto_dur"
Capacidad   "Alto_cap"   "Alto_cap"

Question 4
alt.1        alt.2
Costo       "Alto_costo" "Alto_costo"
Durabilidad "Bajo_dur"   "Bajo_dur"
Capacidad   "Medio_cap"  "Medio_cap"

Question 5
alt.1         alt.2
Costo       "Medio_costo" "Medio_costo"
Durabilidad "Alto_dur"    "Alto_dur"
```

```
Capacidad   "Bajo_cap"    "Bajo_cap"

Question 6
alt.1        alt.2
Costo       "Bajo_costo" "Bajo_costo"
Durabilidad "Medio_dur"  "Medio_dur"
Capacidad   "Alto_cap"   "Alto_cap"
```

Listing B.1: Output example for a questionnaire of the first type.

In the output, `alt.1` stands for Reservoir and `alt.2` stands for Water Tank. Notice that we have to translate each attribute level into meaningful values for respondents. Therefore, we use the following Table 5.1. For instance, in Question 6, `alt.1`, we observe "Bajo Costo" or low price in English. This corresponds to the number in "Low" row of "Price", and under the "Reserv.p.c" column. Then, "Bajo Costo" becomes 23 PEN in the paper survey.

Finally, we need to create a design matrix that to specify what type of CE model are we using. We use the function `make.design.matrix`.

```
desmat1<-make.design.matrix(choice.experiment.design = des1,
optout = TRUE,
categorical.attributes = c("Durabilidad","Capacidad", "Costo"),
unlabeled =FALSE)
```

We indicate that we are using a labeled CE, that all attributes are categorical and that we include the "None of the above" option (`optout=TRUE`).

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
	BLOCK	QES	ALT	ASC1	ASC2	Medio_dur1	Alto_dur1	Medio_cap1	Alto_cap1	Medio_costo1	Alto_costo1	Medio_dur2	Alto_dur2	Medio_cap2	Alto_cap2	Medio_costo2	Alto_costo2
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
3	1	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	2	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0
5	1	2	2	0	1	0	0	0	0	0	0	1	0	1	0	1	0
6	1	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	3	1	1	0	0	1	0	1	0	1	0	0	0	0	0	0
8	1	3	2	0	1	0	0	0	0	0	0	0	1	0	1	0	1
9	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	4	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0
11	1	4	2	0	1	0	0	0	0	0	0	0	0	1	0	0	1
12	1	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	5	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0
14	1	5	2	0	1	0	0	0	0	0	0	0	1	0	0	1	0
15	1	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	6	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0
17	1	6	2	0	1	0	0	0	0	0	0	1	0	0	1	0	0
18	1	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	2	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0
20	2	1	2	0	1	0	0	0	0	0	0	0	1	1	0	0	0
21	2	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	2	2	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0
23	2	2	2	0	1	0	0	0	0	0	0	0	1	0	1	1	0
24	2	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	2	3	1	1	0	1	0	0	1	1	0	0	0	0	0	0	0
26	2	3	2	0	1	0	0	0	0	0	0	0	0	0	0	0	1
27	2	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	2	4	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0
29	2	4	2	0	1	0	0	0	0	0	0	1	0	0	0	0	1
30	2	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	2	5	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0
32	2	5	2	0	1	0	0	0	0	0	0	0	0	0	1	1	0
33	2	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	2	6	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0

Figure B.1: Design matrix, obtained in `R`

B.1.2 Creating a respondent data set

The respondent dataset (Fig. B.2) has to be filled out manually using the coded responses from the survey. The dataframe was named `database`. I have also included a new column to the right, "ID", as it is standard practice. The second column, BLOCK, contains the block number of each answered questionnaire. The following six columns contain the answers for each participant, in the same order as they were presented. Finally, I have included all the remaining covariates.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	ID	BLOCK	q1	q2	q3	q4	q5	q6	ENV	CONSUM	HOUSE	FEE	EXP	PAR	IMPACT
2	1	2	1	1	1	1	1	1	1	2	2	5	1	3	3
3	2	1	1	1	1	1	1	1	0	1	1	5	3	1	0
4	3	2	1	1	1	1	1	1	1	3	2	5	3	3	3
5	4	2	1	1	1	1	1	1	1	2	2	3	3	3	2
6	5	2	2	2	1	1	2	1	0	2	2	3	3	3	0
7	6	1	1	1	1	1	1	1	1	2	3	4	2	2	3
8	7	2	1	1	1	1	1	1	0	0	2	1	4	3	0
9	8	1	1	1	1	1	1	1	0	0	1	5	1	3	0
10	9	3	2	2	2	2	2	2	0	0	1	0	2	1	0
11	10	2	1	1	1	1	1	1	0	1	1	2	4	3	0
12	11	2	1	1	1	1	1	1	1	2	2	5	3	3	3
13	12	3	2	2	2	2	2	2	0	3	4	5	3	2	0
14	13	2	1	1	1	1	1	1	0	1	2	3	3	3	0
15	14	1	1	1	1	1	1	1	0	1	1	1	3	3	0
16	15	1	1	1	1	1	1	1	0	2	1	2	4	4	0
17	16	3	2	2	2	2	2	2	0	2	2	5	4	3	0
18	17	3	1	1	1	1	1	1	0	3	1	5	4	2	0
19	18	1	1	1	1	1	1	1	0	2	1	5	1	1	0
20	19	3	1	1	1	1	1	1	0	1	1	5	4	3	0
21	20	2	2	2	2	2	1	1	1	1	1	2	3	3	4
22	21	1	1	1	1	1	1	1	0	2	1	4	2	3	0
23	22	1	1	1	1	1	1	1	0	1	1	2	2	3	0
24	23	1	1	1	1	1	1	1	0	2	3	4	3	3	0
25	24	3	2	2	2	2	2	2	0	0	2	3	3	3	0
26	25	3	1	1	1	2	1	1	0	1	2	3	2	2	0
27	26	1	1	1	1	1	1	1	0	3	3	3	4	4	0
28	27	2	2	2	4	2	2	1	0	2	2	3	3	3	0
29	28	1	4	4	4	4	4	2	0	2	2	5	2	4	0
30	29	1	1	1	1	1	1	1	0	0	1	0	2	4	0
31	30	1	1	2	4	2	2	2	1	3	1	5	2	4	4
32	31	1	2	2	2	2	2	2	0	0	2	3	2	1	0
33	32	2	2	2	2	1	1	1	1	2	2	5	3	3	0
34	33	2	2	2	1	1	2	2	1	0	1	0	2	1	0
35	34	3	2	2	3	2	2	1	0	2	2	4	2	1	0
36	35	1	4	4	4	4	4	4	0	0	2	4	2	1	0
37	36	1	4	4	4	4	4	4	0	0	1	2	4	1	0
38	37	2	4	2	3	2	2	4	1	2	2	5	2	4	0

Figure B.2: Questionnaire answers

However, the covariates have to be codded following deviation or mean-centering coding (Hoyos 2010). This is accomplished using the `contrasts` and `cont.sum()` operations in `R` (Bruin 2019). I have used the "Deviation Coding" since it resembles orthogonal coding from Hensher, Rose, and Greene (2005, pg. 121).

```
contrasts(database$ENV)=contr.sum(2)
contrasts(database$CONSUM)=contr.sum(4)
contrasts(database$HOUSE)=contr.sum(4)
contrasts(database$FEE)=contr.sum(6)
contrasts(database$EXP)=contr.sum(5)
contrasts(database$PAR)=contr.sum(4)
contrasts(database$IMPACT)=contr.sum(6)
```

Listing B.2: Deviation coding following orthogonal design

Finally, the dataset is ready for the conditional logit analysis:

```
> dataset1[1:6,]
  ID ENV CONSUM HOUSE FEE EXP PAR IMPACT BLOCK QES ALT   RES ASC1 ASC2 Medio_dur1 Alto_dur1 Medio_cap1 Alto_cap1 Medio_costo1
1  1   1      2     2   5   1   3      3     2   1   1  TRUE    1    0          0         0          0         1            1
2  1   1      2     2   5   1   3      3     2   1   2 FALSE    0    1          0         0          0         0            0
3  1   1      2     2   5   1   3      3     2   1   3 FALSE    0    0          0         0          0         0            0
4  1   1      2     2   5   1   3      3     2   2   1  TRUE    1    0          0         0          1         0            0
5  1   1      2     2   5   1   3      3     2   2   2 FALSE    0    1          0         0          0         0            0
6  1   1      2     2   5   1   3      3     2   2   3 FALSE    0    0          0         0          0         0            0
  Alto_costo1 Medio_dur2 Alto_dur2 Medio_cap2 Alto_cap2 Medio_costo2 Alto_costo2 STR
1           0          0         0          0         0            0           0 101
2           0          0         1          1         0            0           0 101
3           0          0         0          0         0            0           0 101
4           0          0         0          0         0            0           0 102
5           0          0         1          0         1            1           0 102
6           0          0         0          0         0            0           0 102
```

Figure B.3: Dataset ready usable in the Conditional Logit model

B.2 Raw results

B.2.1 For categorical levels

No-CC controlled

```
 clogit(RES ~ ASC1 + ASC2 + Medio_dur1 + Alto_dur1 + Medio_cap1 +
Alto_cap1 + Medio_costo1 + Alto_costo1 + Medio_dur2 + Alto_dur2 +
Medio_cap2 + Alto_cap2 + Medio_costo2 + Alto_costo2 + strata(STR),
data = dataset1)

             coef       exp(coef)   se(coef)    z       p
ASC1          1.004335  2.730092  0.239014  4.202 2.65e-05
ASC2          0.378323  1.459834  0.264859  1.428   0.1532
Medio_dur1    0.334958  1.397882  0.213612  1.568   0.1169
Alto_dur1     0.519518  1.681217  0.216891  2.395   0.0166
Medio_cap1   -0.185812  0.830430  0.214072 -0.868   0.3854
Alto_cap1    -0.028066  0.972324  0.215214 -0.130   0.8962
Medio_costo1 -0.090138  0.913805  0.213355 -0.422   0.6727
Alto_costo1   0.071157  1.073750  0.216074  0.329   0.7419
Medio_dur2    0.147733  1.159204  0.238907  0.618   0.5363
Alto_dur2     0.438142  1.549825  0.233676  1.875   0.0608
Medio_cap2   -0.009015  0.991025  0.235513 -0.038   0.9695
Alto_cap2     0.162653  1.176628  0.234058  0.695   0.4871
Medio_costo2  0.101731  1.107086  0.233337  0.436   0.6628
Alto_costo2  -0.071040  0.931425  0.234371 -0.303   0.7618

Likelihood ratio test=130.6  on 14 df, p=< 2.2e-16
n= 1890, number of events= 543

> gofm(output.log)

Rho-squared = 0.1094995
Adjusted rho-squared = 0.08603113
Akaike information criterion (AIC) = 1090.45
Bayesian information criterion (BIC) = 1150.609
Number of coefficients = 14
Log likelihood at start = -596.5465
Log likelihood at convergence = -531.2249
```

Listing B.3: The most basic model

```
clogit(RES ~ ASC1 + ASC2 + EXP:ASC1 + EXP:ASC2 + Medio_dur1 +
Alto_dur1 + Medio_cap1 + Alto_cap1 + Medio_costo1 + Alto_costo1 +
Medio_dur2 + Alto_dur2 + Medio_cap2 + Alto_cap2 + Medio_costo2 +
Alto_costo2 + strata(STR), data = dataset1)

               coef     exp(coef)   se(coef)     z      p
ASC1           1.405e+00  4.075e+00  5.338e-01  2.632 0.00849
ASC2           5.365e-01  1.710e+00  5.892e-01  0.911 0.36255
Medio_dur1     3.634e-01  1.438e+00  2.190e-01  1.659 0.09706
Alto_dur1      5.591e-01  1.749e+00  2.225e-01  2.513 0.01198
Medio_cap1    -2.035e-01  8.159e-01  2.195e-01 -0.927 0.35392
Alto_cap1     -3.830e-02  9.624e-01  2.205e-01 -0.174 0.86207
Medio_costo1  -9.971e-02  9.051e-01  2.187e-01 -0.456 0.64840
Alto_costo1    6.868e-02  1.071e+00  2.213e-01  0.310 0.75630
Medio_dur2     1.374e-01  1.147e+00  2.429e-01  0.566 0.57172
Alto_dur2      4.639e-01  1.590e+00  2.369e-01  1.958 0.05025
Medio_cap2    -9.578e-03  9.905e-01  2.393e-01 -0.040 0.96807
Alto_cap2      1.686e-01  1.184e+00  2.373e-01  0.710 0.47741
Medio_costo2   9.964e-02  1.105e+00  2.363e-01  0.422 0.67330
Alto_costo2   -9.460e-02  9.097e-01  2.381e-01 -0.397 0.69116
ASC1:EXP2     -8.569e-01  4.245e-01  5.588e-01 -1.534 0.12513
ASC1:EXP3     -9.071e-01  4.037e-01  5.178e-01 -1.752 0.07984
ASC1:EXP4      1.565e+00  4.781e+00  7.090e-01  2.207 0.02733
ASC1:EXP5      1.597e+01  8.630e+06  2.174e+03  0.007 0.99414
ASC2:EXP2     -3.823e-02  9.625e-01  6.029e-01 -0.063 0.94944
ASC2:EXP3     -7.242e-01  4.847e-01  5.716e-01 -1.267 0.20516
ASC2:EXP4      1.422e+00  4.147e+00  7.551e-01  1.884 0.05962
ASC2:EXP5      1.699e+01  2.393e+07  2.174e+03  0.008 0.99376
```

```
Likelihood ratio test=189.1  on 22 df, p=< 2.2e-16
n= 1890, number of events= 543
> gofm(output_exp.log)

Rho-squared = 0.1584756
Adjusted rho-squared = 0.1215966
Akaike information criterion (AIC) = 1048.017
Bayesian information criterion (BIC) = 1142.553
Number of coefficients = 22
Log likelihood at start = -596.5465
Log likelihood at convergence = -502.0084
```

Listing B.4: Controlling for expectations

```
clogit(RES ~ ASC1 + ASC2 + Medio_dur1 + Alto_dur1 + CONSUM:Medio_cap1 +
CONSUM:Alto_cap1 + Medio_costo1 + Alto_costo1 + Medio_dur2 +
Alto_dur2 + CONSUM:Medio_cap2 + CONSUM:Alto_cap2 + Medio_costo2 +
Alto_costo2 + strata(STR), data = dataset1)

                    coef     exp(coef)   se(coef)    z        p
ASC1                 1.00592   2.73444  0.24110  4.172 3.02e-05
ASC2                 0.36338   1.43819  0.26739  1.359   0.1741
Medio_dur1           0.34978   1.41875  0.21566  1.622   0.1048
Alto_dur1            0.54761   1.72912  0.21887  2.502   0.0124
Medio_costo1        -0.07902   0.92402  0.21630 -0.365   0.7149
Alto_costo1          0.04800   1.04917  0.21829  0.220   0.8260
Medio_dur2           0.18579   1.20417  0.24320  0.764   0.4449
Alto_dur2            0.48321   1.62127  0.23780  2.032   0.0422
Medio_costo2         0.11441   1.12121  0.23818  0.480   0.6310
Alto_costo2         -0.10008   0.90477  0.23904 -0.419   0.6755
CONSUM0:Medio_cap1 -0.33278   0.71693  0.33861 -0.983   0.3257
CONSUM1:Medio_cap1 -0.24177   0.78524  0.37543 -0.644   0.5196
CONSUM2:Medio_cap1 -0.12431   0.88311  0.31415 -0.396   0.6923
CONSUM3:Medio_cap1  0.01704   1.01719  0.45569  0.037   0.9702
CONSUM0:Alto_cap1  -0.05745   0.94417  0.32954 -0.174   0.8616
CONSUM1:Alto_cap1  -0.34778   0.70626  0.37545 -0.926   0.3543
CONSUM2:Alto_cap1   0.16638   1.18102  0.32808  0.507   0.6121
CONSUM3:Alto_cap1   0.02426   1.02456  0.44611  0.054   0.9566
CONSUM0:Medio_cap2  0.35352   1.42407  0.34222  1.033   0.3016
CONSUM1:Medio_cap2 -1.02760   0.35787  0.49430 -2.079   0.0376
CONSUM2:Medio_cap2  0.02528   1.02560  0.35061  0.072   0.9425
CONSUM3:Medio_cap2  0.35199   1.42190  0.46164  0.762   0.4458
CONSUM0:Alto_cap2   0.64232   1.90089  0.34298  1.873   0.0611
CONSUM1:Alto_cap2  -0.99828   0.36851  0.49691 -2.009   0.0445
CONSUM2:Alto_cap2   0.39424   1.48326  0.33614  1.173   0.2409
CONSUM3:Alto_cap2  -0.05790   0.94375  0.50562 -0.115   0.9088

Likelihood ratio test=151.2  on 26 df, p=< 2.2e-16
n= 1890, number of events= 543

> gofm(output_cons.log)

Rho-squared = 0.1266871
Adjusted rho-squared = 0.08310293
Akaike information criterion (AIC) = 1093.943
Bayesian information criterion (BIC) = 1205.668
Number of coefficients = 26
Log likelihood at start = -596.5465
Log likelihood at convergence = -520.9717
```

Listing B.5: Controlling for Consumption in Capacity attribute

```
Call:
clogit(RES ~ ASC1 + ASC2 + Medio_dur1 + Alto_dur1 + Medio_cap1 +
Alto_cap1 + PAR:Medio_costo1 + PAR:Alto_costo1 + Medio_dur2 +
Alto_dur2 + Medio_cap2 + Alto_cap2 + PAR:Medio_costo2 + PAR:Alto_costo2 +
strata(STR), data = dataset1)

                  coef      exp(coef)   se(coef)      z    p
ASC1               1.00889   2.74256  0.24164  4.175 2.98e-05
ASC2               0.38837   1.47457  0.26657  1.457  0.14515
Medio_dur1         0.34348   1.40984  0.21933  1.566  0.11734
Alto_dur1          0.55691   1.74528  0.22317  2.495  0.01258
Medio_cap1        -0.19477   0.82303  0.22021 -0.884  0.37644
Alto_cap1         -0.04355   0.95739  0.22146 -0.197  0.84411
Medio_dur2         0.15598   1.16880  0.24191  0.645  0.51908
Alto_dur2          0.43387   1.54322  0.23632  1.836  0.06637
Medio_cap2        -0.01964   0.98055  0.23916 -0.082  0.93455
Alto_cap2          0.12222   1.13000  0.23890  0.512  0.60894
PAR1:Medio_costo1 -0.67421   0.50956  0.41578 -1.622  0.10490
PAR2:Medio_costo1 -0.10724   0.89831  0.53971 -0.199  0.84250
PAR3:Medio_costo1 -0.15632   0.85529  0.25863 -0.604  0.54558
PAR4:Medio_costo1  0.75330   2.12401  0.45207  1.666  0.09565
PAR1:Alto_costo1  -1.30897   0.27010  0.46055 -2.842  0.00448
PAR2:Alto_costo1   0.94720   2.57848  0.62295  1.521  0.12838
PAR3:Alto_costo1   0.08713   1.09104  0.26181  0.333  0.73929
PAR4:Alto_costo1   0.97010   2.63820  0.48178  2.014  0.04406
PAR1:Medio_costo2 -0.07199   0.93054  0.42974 -0.168  0.86696
PAR2:Medio_costo2 -0.42775   0.65198  0.71288 -0.600  0.54849
PAR3:Medio_costo2  0.17448   1.19063  0.28008  0.623  0.53331
PAR4:Medio_costo2  0.50826   1.66239  0.48254  1.053  0.29220
PAR1:Alto_costo2  -0.40624   0.66615  0.44370 -0.916  0.35988
PAR2:Alto_costo2  -0.23503   0.79055  0.63092 -0.373  0.70951
PAR3:Alto_costo2  -0.03893   0.96182  0.28206 -0.138  0.89023
PAR4:Alto_costo2   0.42710   1.53281  0.48400  0.882  0.37753
```

```
Likelihood ratio test=155.5  on 26 df, p=< 2.2e-16
n= 1890, number of events= 543
> gofm(output_cons.log)

Rho-squared = 0.1266871
Adjusted rho-squared = 0.08310293
Akaike information criterion (AIC) = 1093.943
Bayesian information criterion (BIC) = 1205.668
Number of coefficients = 26
Log likelihood at start = -596.5465
Log likelihood at convergence = -520.9717
```

Listing B.6: Controlling for Participation in Cost

```
clogit(RES ~ ASC1 + ASC2 + Medio_dur1 + Alto_dur1 + Medio_cap1 +
Alto_cap1 + FEE:Medio_costo1 + FEE:Alto_costo1 + Medio_dur2 +
Alto_dur2 + Medio_cap2 + Alto_cap2 + FEE:Medio_costo2 + FEE:Alto_costo2 +
strata(STR), data = dataset1)

                    coef    exp(coef)   se(coef)      z       p
ASC1                1.02507   2.78729  0.24136  4.247 2.17e-05
ASC2                0.38146   1.46442  0.26764  1.425   0.1541
Medio_dur1          0.33570   1.39892  0.21661  1.550   0.1212
Alto_dur1           0.51897   1.68029  0.21986  2.360   0.0183
Medio_cap1         -0.20959   0.81092  0.21785 -0.962   0.3360
Alto_cap1          -0.03296   0.96758  0.21933 -0.150   0.8805
Medio_dur2          0.12798   1.13653  0.24252  0.528   0.5977
Alto_dur2           0.44065   1.55372  0.23713  1.858   0.0631
Medio_cap2         -0.00129   0.99871  0.23976 -0.005   0.9957
Alto_cap2           0.18897   1.20801  0.23883  0.791   0.4288
FEE0:Medio_costo1 -0.47728   0.62047  0.73227 -0.652   0.5145
FEE1:Medio_costo1  0.15023   1.16210  0.73237  0.205   0.8375
FEE2:Medio_costo1  0.28359   1.32789  0.45648  0.621   0.5344
FEE3:Medio_costo1 -0.06396   0.93804  0.38787 -0.165   0.8690
FEE4:Medio_costo1 -0.56944   0.56584  0.49690 -1.146   0.2518
FEE5:Medio_costo1 -0.11137   0.89461  0.28462 -0.391   0.6956
FEE0:Alto_costo1  -0.98566   0.37319  0.75916 -1.298   0.1942
FEE1:Alto_costo1   1.04793   2.85175  0.80411  1.303   0.1925
FEE2:Alto_costo1   0.38907   1.47561  0.47151  0.825   0.4093
FEE3:Alto_costo1   0.32562   1.38490  0.41085  0.793   0.4280
FEE4:Alto_costo1  -0.54324   0.58086  0.49586 -1.096   0.2733
FEE5:Alto_costo1   0.01814   1.01830  0.28950  0.063   0.9500
FEE0:Medio_costo2  0.22944   1.25789  0.73789  0.311   0.7558
FEE1:Medio_costo2  0.50624   1.65904  0.83453  0.607   0.5441
FEE2:Medio_costo2 -0.79330   0.45235  0.59862 -1.325   0.1851
FEE3:Medio_costo2  0.24044   1.27181  0.41533  0.579   0.5626
FEE4:Medio_costo2 -0.64417   0.52510  0.57517 -1.120   0.2627
FEE5:Medio_costo2  0.38082   1.46349  0.30101  1.265   0.2058
FEE0:Alto_costo2  -0.70539   0.49391  0.85979 -0.820   0.4120
FEE1:Alto_costo2   0.85780   2.35796  0.75657  1.134   0.2569
FEE2:Alto_costo2  -0.73679   0.47865  0.59322 -1.242   0.2142
FEE3:Alto_costo2  -0.10530   0.90005  0.44789 -0.235   0.8141
FEE4:Alto_costo2  -0.63848   0.52810  0.57700 -1.107   0.2685
FEE5:Alto_costo2   0.19320   1.21313  0.29813  0.648   0.5170

Likelihood ratio test=152.1  on 34 df, p=< 2.2e-16
n= 1890, number of events= 543
> gofm(output_fee_cost.log)
Rho-squared = 0.1274648
Adjusted rho-squared = 0.07047012
Akaike information criterion (AIC) = 1109.016
Bayesian information criterion (BIC) = 1255.117
Number of coefficients = 34
Log likelihood at start = -596.5465
Log likelihood at convergence = -520.5078
```

Listing B.7: Controlling for Fee in Cost

CC-Controlled

```
clogit(RES ~ ASC1 + ASC2 + ENV:ASC1 + ENV:ASC2 + Medio_dur1 +
Alto_dur1 + Medio_cap1 + Alto_cap1 + Medio_costo1 + Alto_costo1 +
Medio_dur2 + Alto_dur2 + Medio_cap2 + Alto_cap2 + Medio_costo2 +
Alto_costo2 + strata(STR), data = dataset1)

              coef      exp(coef)   se(coef)  z     p
ASC1           1.15398   3.17079  0.26804  4.305 1.67e-05
ASC2           0.61351   1.84690  0.29400  2.087   0.0369
Medio_dur1     0.33219   1.39402  0.21352  1.556   0.1198
Alto_dur1      0.51562   1.67468  0.21680  2.378   0.0174
Medio_cap1    -0.18519   0.83095  0.21395 -0.866   0.3867
Alto_cap1     -0.02850   0.97190  0.21506 -0.133   0.8946
Medio_costo1  -0.09145   0.91260  0.21324 -0.429   0.6680
Alto_costo1    0.07093   1.07351  0.21599  0.328   0.7426
Medio_dur2     0.14381   1.15467  0.23903  0.602   0.5474
Alto_dur2      0.43030   1.53772  0.23407  1.838   0.0660
Medio_cap2    -0.01032   0.98973  0.23571 -0.044   0.9651
Alto_cap2      0.16224   1.17614  0.23427  0.693   0.4886
Medio_costo2   0.10078   1.10603  0.23365  0.431   0.6662
Alto_costo2   -0.07222   0.93033  0.23463 -0.308   0.7582
ASC1:ENV1     -0.31554   0.72939  0.24593 -1.283   0.1995
ASC2:ENV1     -0.52187   0.59341  0.26876 -1.942   0.0522

Likelihood ratio test=134.4  on 16 df, p=< 2.2e-16
n= 1890, number of events= 543
```

```
> gofm(outputcc.log)
Rho-squared = 0.1126798
Adjusted rho-squared = 0.08585876
Akaike information criterion (AIC) = 1090.655
Bayesian information criterion (BIC) = 1159.409
Number of coefficients = 16
Log likelihood at start = -596.5465
Log likelihood at convergence = -529.3277
```

Listing B.8: Simple CC control

```
clogit(RES ~ ASC1 + ASC2 + IMPACT:ASC1 + IMPACT:ASC2 + Medio_dur1 +
Alto_dur1 + Medio_cap1 + Alto_cap1 + Medio_costo1 + Alto_costo1 +
Medio_dur2 + Alto_dur2 + Medio_cap2 + Alto_cap2 + Medio_costo2 +
Alto_costo2 + strata(STR), data = dataset_impact)

                  coef     exp(coef)    se(coef)       z     p
ASC1          -8.655e-01  4.208e-01  5.224e-01 -1.657 0.097542
ASC2          -5.490e-01  5.776e-01  4.987e-01 -1.101 0.270982
Medio_dur1     3.119e-01  1.366e+00  3.588e-01  0.869 0.384747
Alto_dur1      4.280e-01  1.534e+00  3.646e-01  1.174 0.240512
Medio_cap1    -1.641e-01  8.487e-01  3.574e-01 -0.459 0.646128
Alto_cap1     -7.614e-02  9.267e-01  3.643e-01 -0.209 0.834437
Medio_costo1  -3.170e-01  7.283e-01  3.552e-01 -0.893 0.372054
Alto_costo1    2.846e-01  1.329e+00  3.648e-01  0.780 0.435353
Medio_dur2     1.597e-01  1.173e+00  3.996e-01  0.400 0.689371
Alto_dur2      5.522e-01  1.737e+00  3.901e-01  1.415 0.156957
Medio_cap2     1.448e-01  1.156e+00  3.934e-01  0.368 0.712810
Alto_cap2      2.479e-01  1.281e+00  3.916e-01  0.633 0.526713
Medio_costo2   1.103e-01  1.117e+00  3.944e-01  0.280 0.779734
Alto_costo2    1.206e-01  1.128e+00  3.900e-01  0.309 0.757108
ASC1:IMPACT1   2.187e+01  3.155e+09  1.585e+04  0.001 0.998899
ASC1:IMPACT2   2.662e+00  1.433e+01  1.150e+00  2.316 0.020571
ASC1:IMPACT3   1.626e+00  5.085e+00  4.882e-01  3.331 0.000865
ASC1:IMPACT4   2.084e+01  1.126e+09  5.312e+03  0.004 0.996870
ASC1:IMPACT5   2.774e+00  1.602e+01  6.738e-01  4.116 3.85e-05
ASC2:IMPACT1   1.057e-01  1.111e+00  2.244e+04  0.000 0.999996
ASC2:IMPACT2   1.476e+00  4.375e+00  1.174e+00  1.257 0.208611
ASC2:IMPACT3  -3.181e-01  7.276e-01  4.909e-01 -0.648 0.517071
ASC2:IMPACT4   1.945e+01  2.798e+08  5.312e+03  0.004 0.997079
ASC2:IMPACT5   1.664e+00  5.280e+00  6.517e-01  2.553 0.010675

Likelihood ratio test=105  on 24 df, p=4.245e-12
n= 810, number of events= 230
> gofm(outputcc_impact.log)
Rho-squared = 0.2076771
Adjusted rho-squared = 0.1126957
Akaike information criterion (AIC) = 448.4096
Bayesian information criterion (BIC) = 530.9235
Number of coefficients = 24
Log likelihood at start = -252.6808
Log likelihood at convergence = -200.2048
```

Listing B.9: Controlling for Impact

B.2.2 MWTP

No-CC controlled

```
clogit(RES ~ ASC1 + ASC2 + Medio_dur1 + Alto_dur1 + Medio_cap1 +
Alto_cap1 + Costo1 + +Medio_dur2 + Alto_dur2 + Medio_cap2 +
Alto_cap2 + Costo2 + strata(STR), data = dataset2)

              coef     exp(coef)   se(coef)      z       p
ASC1        0.9236226  2.5183971  0.3183486  2.901 0.00372
ASC2        0.4709432  1.6015040  0.3488342  1.350 0.17700
Medio_dur1  0.3193756  1.3762682  0.2128887  1.500 0.13356
Alto_dur1   0.5080106  1.6619815  0.2164156  2.347 0.01891
Medio_cap1 -0.1884350  0.8282543  0.2136644 -0.882 0.37782
Alto_cap1  -0.0123664  0.9877097  0.2141503 -0.058 0.95395
Costo1      0.0002790  1.0002790  0.0008730  0.320 0.74931
Medio_dur2  0.1641643  1.1784080  0.2383865  0.689 0.49104
Alto_dur2   0.4632074  1.5891629  0.2323949  1.993 0.04624
Medio_cap2 -0.0141825  0.9859176  0.2351731 -0.060 0.95191
Alto_cap2   0.1455846  1.1567156  0.2331616  0.624 0.53237
Costo2     -0.0003122  0.9996878  0.0009397 -0.332 0.73967
> gofm(output2.log)
Rho-squared = 0.1086638
Adjusted rho-squared = 0.08854804
Akaike information criterion (AIC) = 1087.447
Bayesian information criterion (BIC) = 1139.012
Number of coefficients = 12
Log likelihood at start = -596.5465
Log likelihood at convergence = -531.7235
#MWTP
               MWTP     2.5%    97.5%
Medio_dur1 -1144.86 -6067.91  5523.02
Alto_dur1  -1821.06 -8657.92  8600.08
Medio_cap1   675.48 -3749.82  3832.57
Alto_cap1     44.33 -2968.77  2967.22
Medio_dur2   525.77 -3939.72  3704.60
Alto_dur2   1483.51 -8094.70  7244.55
Medio_cap2   -45.42 -3016.74  3079.91
```

```
Alto_cap2    466.26 -3877.24  3653.28

method = Krinsky and Robb
```

Listing B.10: Finding the MWTP for the basic model

```
clogit(RES ~ ASC1 + ASC2 + PAR:ASC1 + PAR:ASC2 + Medio_dur1 +
Alto_dur1 + Medio_cap1 + Alto_cap1 + Costo1 + Medio_dur2 +
Alto_dur2 + Medio_cap2 + Alto_cap2 + Costo2 + strata(STR),
data = dataset2)

            coef      exp(coef)     se(coef)    z      p
ASC1       -0.1416932  0.8678874  0.3991493 -0.355  0.72260
ASC2       -0.0368567  0.9638142  0.4142511 -0.089  0.92910
Medio_dur1  0.3363724  1.3998602  0.2189156  1.537  0.12441
Alto_dur1   0.5706636  1.7694409  0.2229137  2.560  0.01047
Medio_cap1 -0.1940208  0.8236408  0.2195571 -0.884  0.37686
Alto_cap1  -0.0115248  0.9885413  0.2197108 -0.052  0.95817
Costo1      0.0003105  1.0003106  0.0008964  0.346  0.72902
Medio_dur2  0.1741928  1.1902851  0.2393840  0.728  0.46681
Alto_dur2   0.4681078  1.5969696  0.2334309  2.005  0.04493
Medio_cap2 -0.0278106  0.9725725  0.2361591 -0.118  0.90626
Alto_cap2   0.1346949  1.1441877  0.2341601  0.575  0.56514
Costo2     -0.0002892  0.9997108  0.0009433 -0.307  0.75912
ASC1:PAR2   1.6058579  4.9821321  0.5125035  3.133  0.00173
ASC1:PAR3   0.9385174  2.5561888  0.3043870  3.083  0.00205
ASC1:PAR4   2.9834306 19.7554730  0.6441109  4.632 3.62e-06
ASC2:PAR2   0.5743519  1.7759791  0.5642493  1.018  0.30872
ASC2:PAR3   0.5023758  1.6526430  0.3133198  1.603  0.10885
ASC2:PAR4   2.0293055  7.6088003  0.6631824  3.060  0.00221

Likelihood ratio test=170.6  on 18 df, p=< 2.2e-16
n= 1890, number of events= 543

> gofm(output_part_mwtp.log)

Rho-squared = 0.1429557
Adjusted rho-squared = 0.112782
Akaike information criterion (AIC) = 1058.534
Bayesian information criterion (BIC) = 1135.882
Number of coefficients = 18
Log likelihood at start = -596.5465
Log likelihood at convergence = -511.2668

#MWTP
               MWTP     2.5%    97.5%
Medio_dur1 -1083.15 -5533.88  5533.76
Alto_dur1  -1837.59 -8868.41  9402.51
Medio_cap1   624.77 -4027.51  3977.70
Alto_cap1     37.11 -2735.99  2798.72
Medio_dur2   602.25 -4084.78  3692.26
Alto_dur2   1618.41 -7639.45  6784.06
Medio_cap2   -96.15 -2909.53  3376.19
Alto_cap2    465.69 -3500.54  3322.86

method = Krinsky and Robb
```

Listing B.11: Controlling for Participation

CC-Controlled

```
clogit(RES ~ ASC1 + ASC2 + ENV:ASC1 + ENV:ASC2 + Medio_dur1 +
Alto_dur1 + Medio_cap1 + Alto_cap1 + Costo1 + Medio_dur2 +
Alto_dur2 + Medio_cap2 + Alto_cap2 + Costo2 + strata(STR),
data = dataset2)

            coef        exp(coef)   se(coef)     z       p
ASC1        1.0728926  2.9238248  0.3411183  3.145 0.00166
ASC2        0.7072699  2.0284458  0.3721485  1.901 0.05737
Medio_dur1  0.3165792  1.3724249  0.2127876  1.488 0.13681
Alto_dur1   0.5044514  1.6560768  0.2163303  2.332 0.01971
Medio_cap1 -0.1877047  0.8288594  0.2135564 -0.879 0.37943
Alto_cap1  -0.0128540  0.9872282  0.2139927 -0.060 0.95210
Costo1      0.0002775  1.0002776  0.0008726  0.318 0.75046
Medio_dur2  0.1591228  1.1724819  0.2385747  0.667 0.50479
Alto_dur2   0.4548129  1.5758785  0.2328201  1.953 0.05076
Medio_cap2 -0.0155602  0.9845602  0.2353943 -0.066 0.94730
Alto_cap2   0.1455281  1.1566503  0.2333747  0.624 0.53290
Costo2     -0.0003175  0.9996826  0.0009407 -0.337 0.73576
ASC1:ENV1  -0.3152026  0.7296411  0.2458878 -1.282 0.19988
ASC2:ENV1  -0.5216747  0.5935257  0.2686907 -1.942 0.05219

Likelihood ratio test=133.4  on 14 df, p=< 2.2e-16
n= 1890, number of events= 543
> gofm(outputcc_mwtp.log)

Rho-squared = 0.1118437
Adjusted rho-squared = 0.08837526
Akaike information criterion (AIC) = 1087.653
Bayesian information criterion (BIC) = 1147.813
Number of coefficients = 14
Log likelihood at start = -596.5465
Log likelihood at convergence = -529.8265
#MWTP
                MWTP      2.5%     97.5%
```

```
Medio_dur1   -237.101  -3252.655  2544.857
Alto_dur1    -317.708  -3631.770  3290.157
Medio_cap1    152.617  -2415.794  2882.456
Alto_cap1       3.797  -2394.513  2375.878
Medio_dur2   -522.892  -3370.498  3520.729
Alto_dur2   -1385.890  -5682.956  5645.213
Medio_cap2   -318.952  -3113.924  3325.639
Alto_cap2    -494.001  -3466.686  3522.157

method = Krinsky and Robb
```

Listing B.12: MWTP for CC

Appendix C

Survey

C.1 Coding for answers

C.1.1 Codes for both control and trial groups

I call "control" survey, the survey that lacks CC-related questions. To mark the CC-related survey, I have created the dummy variable ENV. $ENV = 0$ for the control group, and $ENV = 1$ for the CC-survey. The missing questions will be used to contextualize the results, and are not part of the data set itself. For instance, Question 3 of the CASE II part delves into the individual motivation to participate in voluntary work.

WATER CONSUMPTION (CONSUM)		
Alternative	Value	Code
a	0-8 m^3	1
b	8-20 m^3	2
c	more than 20 m^3	3
d	I do not remember	0

Table C.1: Codes for the Question 1 in the control survey

FAMILY SIZE (HOUSE)		
Alternative	Value	Code
a	1 - 4 people	1
b	5 - 8 people	2
c	8 - 12 people	3
d	More than 13 people	4

Table C.2: Codes for the Question 2 in the control survey

LAST MONTHLY PAYMENT (FEE)		
Alternative	Value	Code
a	0 - 5 PEN	1
b	5 - 10 PEN	2
c	10 - 15 PEN	3
d	15 - 20 PEN	4
e	>= 20 PEN	5
f	I do not remember	0

Table C.3: Codes for the Question 3 in the control survey

EXPECTATIONS (EXP)		
Alternative	Value	Code
e	Very low	1
d	Low	2
c	Average	3
b	High	4
a	Very High	5

Table C.4: Codes for the Question 1 from the CASE II part

PARTICIPATION (PAR)		
Alternative	Value	Code
a	High	4
b	Above Average	3
c	Bellow Average	2
d	Low	1

Table C.5: Codes for the Question 2 from the CASE II part

C.1.2 Codes the trial group

Again, the analysis of the missing questions is part of the Discussion chapter. The only dummy variable created is IMP, standing up for Impact in Question 5. To work with a single and complete data set, whenever $ENV = 0$, then $IMP = 0$.

IMPACT (IMP)		
Alternative	Value	Code
a	90% reduction	5
b	70% reduction	4
c	50 % reduction	3
d	30 % reduction	2
e	10 % reduction	1
f	N.A.	0

Table C.6: Codes for Question 5 in the CC questionnaire

C.2 Translated questionnaires

Both CC and non-CC versions appear under the same block number. CC-controlled surveys include additional questions related to CC and perception. However, the Choice Experiment questions remained the same for both control and trial.

TRANSLATION FROM THE SPANISH ORIGINAL – SURVEY OF TYPE BLOCK III

TRANSLATION OF THE INSTRUCTIONS PRESENTED TO EACH RESPONDED. VALID FOR CC OR WITHOUT CC. ORIGINAL IN SPANISH.

Norges miljø- og biovitenskapelige universitet

INSTRUCTIONS

- This survey is part of the thesis: "Measuring the Willingness to Pay water storage infrastructure in Huaraz" to be defended at the Norwegian University of Life Sciences.
- This survey is about the future of the water supply to the Huaraz
- You will be shown two cases about the future of water supply (from now to 5 -10 years on wards).
- No personal data will be asked
- You can drop the questions you do not want or cannot answer.
- Ask the interviewer in case of doubt

You can ask for more information about the thesis, how your data is stored and handled, by contacting directly the author:

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www.nmbu.no

THANK YOU!

SURVEY WITHOUT CC

ID:

1. Select your water consumption level for the last month (1 m^3 = 1000 l.):

a) From 0 to 8 m^3

b) More than 8 m^3, less than 20 m^3

c) More than 20 m^3

d) I do not recall

2.How many people are covered by your water bill (including minors)?

a) 1-4 individuals.

b) 5-8 individuals.

c) 8-12 individuals.

d) More than 13 individuals.

3. How much did you pay for you last water bill?

a) From 0 to 5 soles

b) From 5 soles, but less than 10 soles.

c) From 10 soles, but less than 15 soles.

d) From 15 soles, but less than 20 soles.

e) More than 20 soles.

f) I cannot recall

CASE I- INSTRUCTIONS

Suppose that 6 technical teams visit your neighborhood to determine the future of water supply to meet Climate Change.

- **Each team proposes you one type of reservoir and one type of household water tank. You cannot choose both.**
- **Each team will show you the Cost, Durability and Storage Capacity of types of reservoir and water tank. The Cost and Storage capacity are calculated per household.**
- **Each team wants you to select the alternative (I-IV) that is best for you. In other words, you have to provide 6 answers, one for each team.**
- **If you believe that no further modification is necessary to the current state, select alternative (III).**

- **If you believe that neither the reservoir not the water tank are adequate proposals (or if you lack enough information), select alternative (IV).**

Proposal of Team 1

	RESERVOIR 1	WATER TANK 1
Cost	60 soles	700 soles
Durability	20 years	15 years
Storage	1.4 l. extra	1700 l. extra

Your Answer:

I. I choose Reservoir 1
II. I choose Water Tank 1
III. The current water storage infrastructure is enough.
IV. None of the Above

Proposal of Team 2

	RESERVOIR 2	WATER TANK 2
Cost	23 soles	700 soles
Durability	30 years	25 years
Storage	1.4 l. extra	1100 l. extra

Your Answer:

I. I choose Reservoir 2
II. I choose Water Tank 2
III. The current water storage infrastructure is enough.
IV. None of the Above

Proposal of Team 3

	RESERVOIR 3	WATER TANK 3
Cost	116 soles	500 soles
Durability	20 years	15 years
Storage	83 l. extra	500 l. extra

Your Answer:

I. I choose Reservoir 3
II. I choose Water Tank 3
III. The current water storage infrastructure is enough.
IV. None of the Above

Proposal of Team 4

	RESERVOIR 4	WATER TANK 4
Cost	116 soles	300 soles
Durability	30 years	25 years
Storage	42 l. extra	500 l. extra

Your Answer:

I. I choose Reservoir 4

II. I choose Water Tank 4

III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 5

	RESERVOIR 5	WATER TANK 5
Cost	60 soles	300 soles
Durability	50 years	5 years
Storage	42 l. extra	1700 l. extra

Your Answer:

I. I choose Reservoir 5

II. I choose Water Tank 5

III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 6

	RESERVOIR 6	WATER TANK 6
Cost	23 soles	500 soles
Durability	50 years	5 years
Storage	83 l. extra	1100 l. extra

Your Answer:

I. I choose Reservoir 6

II. I choose Water Tank 6

III. The current water storage infrastructure is enough.

IV. None of the Above

CASE II- INSTRUCTIONS

The neighborhood association has decided that the neighborhood needs a new reservoir to improve drinking water supply. The neighbors will present a proposal to the Municipal Water Provider (MWP).

1.- According to your experience and expectations, what is the probability of success of the neighborhood association?

a) Very High
b) High
c) Medium
d) Low
e) Very Low

The MWP has decided to build the reservoir for your neighborhood. Nevertheless, the MWP suggest to the neighbors an arrangement: If the neighbors voluntarily clean and maintain the reservoir, the water bills will not increase as much.

2.- According to your experience and expectations, you:

a) Will participate in the cleaning and maintaining, even if the MWP did not offer you any discount on the water bill.
b) Will participate in the cleaning and maintaining, only if the MWP provides a discount.
c) Will not participate in the cleaning and maintaining, but you are interested in the discount.
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****(ONLY IF YOU ANSWER "WILL PARTICIPATE" IN THE LAST QUESTION)**
If you are willing to volunteer, or have volunteered, in a similar project, your main motivation is to:

a) Reduce the final cost for the users
b) Accelerate the construction of the reservoir
c) The sense of duty towards your community/organization/neighborhood.
d) Socialize

e) None of the above

SURVEY WITH CC

ID:

1. Select your water consumption level for the last month (1 m^3 = 1000 l.):

a) From 0 to 8 m^3

b) More than 8 m^3, less than 20 m^3

c) More than 20 m^3

d) I do not recall

2.How many people are covered by your water bill (including minors)?

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b) 5-8 individuals.

c) 8-12 individuals.

d) More than 13 individuals.

3. How much did you pay for you last water bill?

a) From 0 to 5 soles

b) From 5 soles, but less than 10 soles

c) From 10 soles, but less than 15 soles.

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e) More than 20 soles.

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4. Select the option that better completes the following proposition, according to your opinion:
"Glaciers close the city of Huaraz are important to drinking water suppply because..."

a) Water from the glaciers is pure

b) If glaciers disappear, Huaraz will lose all drinking water.

c) Glaciers will provide water to future generations

d) Glaciers are allow for regular water supply even in the dry season

e) None of the above

5. Select the alternative that you think is correct:

a) Climate Change will reduce water supply to Huaraz down to 90%.

b) Climate Change will reduce water supply to Huaraz down to 70%.

c) Climate Change will reduce water supply to Huaraz down to 50%.

d) Climate Change will reduce water supply to Huaraz down to 30%.

e) Climate Change will reduce water supply to Huaraz down to 10%.

f) None of the Above

6. If you consider that Climate Change will affect the water supply, the main lose will be:

a) Worse water quality

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CASE I- INSTRUCTIONS

Suppose that 6 technical teams visit your neighborhood to determine the future of water supply to meet Climate Change.

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➤ **If you believe that neither the reservoir not the water tank are adequate proposals (or if you lack enough information), select alternative (IV).**

Proposal of Team 1

	RESERVOIR 1	WATER TANK 1
Cost	60 soles	700 soles
Durability	20 years	15 years
Storage	1.4 l. extra	1700 l. extra

Your Answer:

I. I choose Reservoir 1

II. I choose Water Tank 1

III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 2

	RESERVOIR 2	WATER TANK 2
Cost	23 soles	700 soles
Durability	30 years	25 years
Storage	1.4 l. extra	1100 l. extra

Your Answer:

I. I choose Reservoir 2

II. I choose Water Tank 2

III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 3

	RESERVOIR 3	WATER TANK 3
Cost	116 soles	500 soles
Durability	20 years	15 years
Storage	83 l. extra	500 l. extra

Your Answer:

I. I choose Reservoir 3

II. I choose Water Tank 3

III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 4

	RESERVOIR 4	WATER TANK 4
Cost	116 soles	300 soles
Durability	30 years	25 years
Storage	42 l. extra	500 l. extra

Your Answer:

I. I choose Reservoir 4

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III. The current water storage infrastructure is enough.

IV. None of the Above

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	RESERVOIR 5	WATER TANK 5
Cost	60 soles	300 soles
Durability	50 years	5 years
Storage	42 l. extra	1700 l. extra

Your Answer:

I. I choose Reservoir 5

II. I choose Water Tank 5

III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 6

	RESERVOIR 6	WATER TANK 6
Cost	23 soles	500 soles
Durability	50 years	5 years
Storage	83 l. extra	1100 l. extra

Your Answer:

I. I choose Reservoir 6

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III. The current water storage infrastructure is enough.

IV. None of the Above

CASE II- INSTRUCTIONS

The neighborhood association has decided that the neighborhood needs a new reservoir to improve drinking water supply. The

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e) None of the above

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INSTRUCTIONS

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- **This survey is about the future of the water supply to the Huaraz**
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You can ask for more information about the thesis, how your data is stored and handled, by contacting directly the author:

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+51 923 068 976 (Perú)
UNIVERSITY WEBSITE:
www.nmbu.no

THANK YOU!

SURVEY WITHOUT CC

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CASE I- INSTRUCTIONS

Suppose that 6 technical teams visit your neighborhood to determine the future of water supply to meet Climate Change.

- **Each team proposes you one type of reservoir and one type of household water tank. You cannot choose both.**
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➢ **If you believe that neither the reservoir not the water tank are adequate proposals (or if you lack enough information), select alternative (IV).**

Proposal of Team 1

	RESERVOIR 1	WATER TANK 1
Cost	60 soles	300 soles
Durability	20 years	25 years
Storage	83 l. extra	1100 l. extra

Your Answer:

I. I choose Reservoir 1

II. I choose Water Tank 1

III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 2

	RESERVOIR 2	WATER TANK 2
Cost	23 soles	500 soles
Durability	20 years	25 years
Storage	42 l. extra	1700 l. extra

Your Answer:

I. I choose Reservoir 2

II. I choose Water Tank 2

III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 3

	RESERVOIR 3	WATER TANK 3
Cost	60 soles	700 soles
Durability	30 years	5 years
Storage	83 l. extra	500 l. extra

Your Answer:

I. I choose Reservoir 3

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IV. None of the Above

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	RESERVOIR 4	WATER TANK 4
Cost	23 soles	700 soles
Durability	50 years	15 years
Storage	42 l. extra	500 l. extra

Your Answer:

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IV. None of the Above

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	RESERVOIR 5	WATER TANK 5
Cost	116 soles	500 soles
Durability	30 years	5 years
Storage	1.4 l. extra	1700 l. extra

Your Answer:

I. I choose Reservoir 5

II. I choose Water Tank 5

III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 6

	RESERVOIR 6	WATER TANK 6
Cost	116 soles	300 soles
Durability	50 years	15 years
Storage	1.4 l. extra	1100 l. extra

Your Answer:

I. I choose Reservoir 6

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IV. None of the Above

CASE II- INSTRUCTIONS

The neighborhood association has decided that the neighborhood needs a new reservoir to improve drinking water supply. The neighbors will present a proposal to the Municipal Water Provider (MWP).

1.- According to your experience and expectations, what is the probability of success of the neighborhood association?

a) Very High
b) High
c) Medium
d) Low
e) Very Low

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2.- According to your experience and expectations, you:

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d) Socialize

e) None of the above

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"Glaciers close the city of Huaraz are important to drinking water suppply because..."

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e) None of the above

5. Select the alternative that you think is correct:

a) Climate Change will reduce water supply to Huaraz down to 90%.

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c) Climate Change will reduce water supply to Huaraz down to 50%.

d) Climate Change will reduce water supply to Huaraz down to 30%.

e) Climate Change will reduce water supply to Huaraz down to 10%.

f) None of the Above

6. If you consider that Climate Change will affect the water supply, the main lose will be:

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CASE I- INSTRUCTIONS

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Proposal of Team 1

	RESERVOIR 1	WATER TANK 1
Cost	60 soles	300 soles
Durability	20 years	25 years
Storage	83 l. extra	1100 l. extra

Your Answer:

I. I choose Reservoir 1

II. I choose Water Tank 1

III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 2

	RESERVOIR 2	WATER TANK 2
Cost	23 soles	500 soles
Durability	20 years	25 years
Storage	42 l. extra	1700 l. extra

Your Answer:

I. I choose Reservoir 2

II. I choose Water Tank 2

III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 3

	RESERVOIR 3	WATER TANK 3
Cost	60 soles	700 soles
Durability	30 years	5 years
Storage	83 l. extra	500 l. extra

Your Answer:

I. I choose Reservoir 3

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III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 4

	RESERVOIR 4	WATER TANK 4
Cost	23 soles	700 soles
Durability	50 years	15 years
Storage	42 l. extra	500 l. extra

Your Answer:

I. I choose Reservoir 4

II. I choose Water Tank 4

III. The current water storage infrastructure is enough.

IV. None of the Above

Proposal of Team 5

	RESERVOIR 5	WATER TANK 5
Cost	116 soles	500 soles
Durability	30 years	5 years
Storage	1.4 l. extra	1700 l. extra

Your Answer:

I. I choose Reservoir 5

II. I choose Water Tank 5

III. The current water storage infrastructure is enough.

IV. None of the Above

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	RESERVOIR 6	WATER TANK 6
Cost	116 soles	300 soles
Durability	50 years	15 years
Storage	1.4 l. extra	1100 l. extra

Your Answer:

I. I choose Reservoir 6

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IV. None of the Above

CASE II- INSTRUCTIONS

The neighborhood association has decided that the neighborhood needs a new reservoir to improve drinking water supply. The

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If you are willing to volunteer, or have volunteered, in a similar project, your main motivation is to:

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IV. None of the Above

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Proposal of Team 2

	RESERVOIR 2	WATER TANK 2
Cost	60 soles	500 soles
Durability	30 years	15 years
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Proposal of Team 3

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Your Answer:

I. I choose Reservoir 6

II. I choose Water Tank 6

III. The current water storage infrastructure is enough.

IV. None of the Above

CASE II- INSTRUCTIONS

The neighborhood association has decided that the neighborhood needs a new reservoir to improve drinking water supply. The

neighbors will present a proposal to the Municipal Water Provider (MWP).

1.- According to your experience and expectations, what is the probability of success of the neighborhood association?

a) Very High
b) High
c) Medium
d) Low
e) Very Low

The MWP has decided to build the reservoir for your neighborhood. Nevertheless, the MWP suggest to the neighbors an arrangement: If the neighbors voluntarily clean and maintain the reservoir, the water bills will not increase as much.

2.- According to your experience and expectations, you:

a) Will participate in the cleaning and maintaining, even if the MWP did not offer you any discount on the water bill.
b) Will participate in the cleaning and maintaining, only if the MWP provides a discount.
c) Will not participate in the cleaning and maintaining, but you are interested in the discount.
d) Will not participate in the cleaning and mantaining, even if you got the discount.

****(ONLY IF YOU ANSWER "WILL PARTICIPATE" IN THE LAST QUESTION)**
If you are willing to volunteer, or have volunteered, in a similar project, your main motivation is to:

a) Reduce the final cost for the users
b) Accelerate the construction of the reservoir
c) The sense of duty towards your community/organization/neighboorhod.
d) Socialize
e) None of the above

Appendix D

Figures

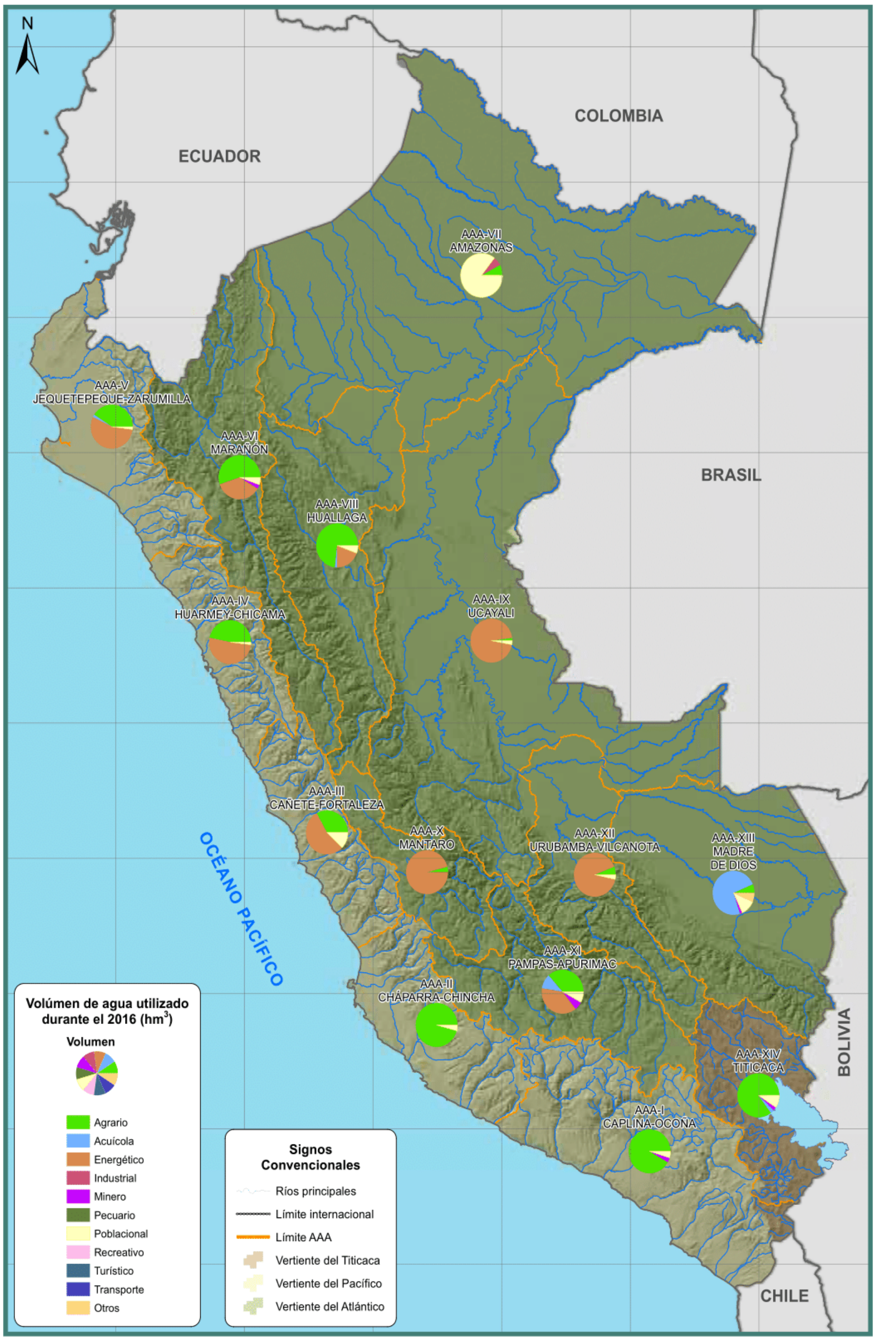


Figure D.1: Water supply in 2016, according to use. Adapted from ANA (2016). Green means agricultural use, brown, energetic use (hydro power), and vanilla means human consumption

Empresa	Departamento	2011	2012	2013	2014	2015	2016 P/
Total		**1 320 838**	**1 325 110**	**1 358 263**	**1 374 624**	**1 404 668**	**1 411 027**
Empresa (Más de 1 millón de conexiones potables administradas)							
Sedapal S.A.	Lima y Callao	683 246	682 449	679 940	683 525	713 459	714 745
EPS Grandes (Más de 40 mil hasta 250 mil conexiones de agua potable administradas)		-	-	-	-	-	-
Emapa San Martín S.A.	San Martín	13 128	13 219	12 988	12 748	12 792	13 416
Emapica S.A.	Ica	19 984	21 157	20 160	20 792	19 360	17 951
EPS Aguas de Tumbes S.A.	Tumbes	17 844	19 003	20 576	19 229	19 354	19 047
EPS Grau S.A.	Piura	74 869	75 044	79 248	79 913	80 733	78 022
EPS Seda Cusco S.A.	Cusco	17 362	19 107	20 452	21 217	20 650	21 860
EPS Tacna S.A.	Tacna	16 927	19 686	20 518	20 223	20 541	21 760
Epsasa	Ayacucho	15 599	13 166	14 566	16 636	17 664	18 157
Epsel S.A.	Lambayeque	53 012	53 966	51 482	51 592	51 639	52 012
Sedacaj S.A.	Cajamarca	8 187	8 640	9 185	8 936	9 273	9 375
Seda Chimbote S.A.	Áncash	28 757	27 087	26 822	29 898	32 251	30 981
Seda Huánuco S.A.	Huánuco	16 608	16 344	16 765	16 813	16 369	16 319
Seda Juliaca S.A.	Puno	8 262	8 199	10 007	10 340	10 641	10 319
Sedalib S.A.	La Libertad	49 538	51 231	50 452	53 370	56 014	57 143
EPS Seda Loreto S.A.	Loreto	34 386	31 183	34 694	36 550	34 307	35 807
Sedam Huancayo S.A.C.	Junín	33 295	29 269	26 599	30 410	29 800	30 785
Sedapar S.A.	Arequipa	54 042	59 199	67 163	66 283	73 757	75 398
Semapach S.A.	Ica	15 613	17 086	18 202	17 090	13 651	11 341
Empresas medianas (Más de 15 mil hasta 40 mil conexiones de agua potable administradas)		-	-	-	-	-	-
Emapa Cañete S.A.	Lima	9 789	10 838	13 057	12 240	12 085	12 612
Emapa Huacho S.A.	Lima	6 797	6 958	7 534	7 725	7 358	7 541
Emapa Huaral S.A.	Lima	5 956	5 977	6 685	6 883	6 888	6 656
Emapacop S.A.	Ucayalí	11 797	12 377	14 198	15 876	12 735	12 014
Emapat S.R.Ltda.	Madre de Dios	2 877	4 401	4 918	4 631	4 972	5 285
Emapa Pisco S.A.	Ica	9 361	8 324	12 499	10 077	6 181	6 391
Emsa Puno S.A.	Puno	7 050	7 706	9 258	7 969	8 144	8 284
EPS Chavín S.A.	Áncash	12 496	10 556	11 172	11 950	11 451	12 837
EPS Ilo S.A.	Moquegua	5 699	6 029	6 519	6 846	6 617	6 948
EPS Mantaro S.A.	Junín	7 426	7 599	7 985	8 466	9 165	8 408
EPS Marañon S.R.Ltda.	Cajamarca	5 588	5 412	8 984	6 248	7 360	8 194
EPS Moquegua S.R.Ltda.	Moquegua	7 553	7 405	7 159	7 304	7 605	7 559
EPS Selva Central S.A.	Junín - Pasco	13 099	13 157	13 915	14 724	16 736	18 647
Semapa Barranca S.A.	Lima	9 477	8 986	9 529	9 066	8 594	9 005
EPS Pequeñas (Hasta 15 mil conexiones de agua potable administradas)		-	-	-	-	-	-
Emapa Huancavelica S.A.C.	Huancavelica	3 898	3 819	3 637	3 640	3 680	3 660
Emapa Moyobamba S.R.L.	San Martín	3 720	2 419	3 438	3 553	3 609	3 639
Emapa Pasco S.A.	Pasco	1 587	2 040	2 028	1 929	1 973	1 722
Emapa Yunguyo S.R.Ltda.	Puno	993	993	1 076	1 040	1 086	1 041
Emapab S.R.L.	Amazonas	3 021	2 942	2 997	2 593	2 226	2 427
Emapavigs S.A.C.	Ica	3 498	2 148	2 400	2 694	2 401	2 254
Emaq S.R. L.	Cusco	6 957	6 890	7 355	7 351	8 063	7 709
Empssapal S.A.	Cusco	3 096	3 099	3 105	3 115	3 326	3 564
Emsapa Calca	Cusco	1 104	1 983	...	...	1 464	1 514
Emsapa Yauli S.R.L.	Junín	552	594	659	663	545	556
Emusap Abancay S.A.C.	Apurímac	4 540	4 684	4 681	5 124	5 042	4 449
Emusap Amazonas S.R.L.	Amazonas	1 588	1 787	1 767	1 749	1 749	1 808
EPS Aguas del Altiplano S.R.L.	Puno	1 103	1 156	1 247	891	1 394	1 256
EPS Emsap Chanka	Apurímac - Ayacucho	1 302	1 240	1 251	1 144	1 507	1 356
EPS Nor Puno S.A.	Puno	1 147	1 169	1 205	1 268	1 217	1 203
EPS Sierra Central S.R.L.	Junín	3 855	3 944	3 971	8 466	3 946	3 965
Epssmu S.R.L.	Amazonas	1 859	1 797	2 501	2 459	1 920	1 997
Sedapar S.R.L. (Rioja)	San Martín	1 394	1 646	1 714	1 375	1 374	2 088

Fuente: Superintendencia Nacional de Servicios de Saneamiento (SUNASS).

Figure D.2: Water supply for each EPS, by size, in million cubic meters. Adapted from INEI (2017b)

Figure D.3: AAA in Peru. Adapted from ANA (2016)

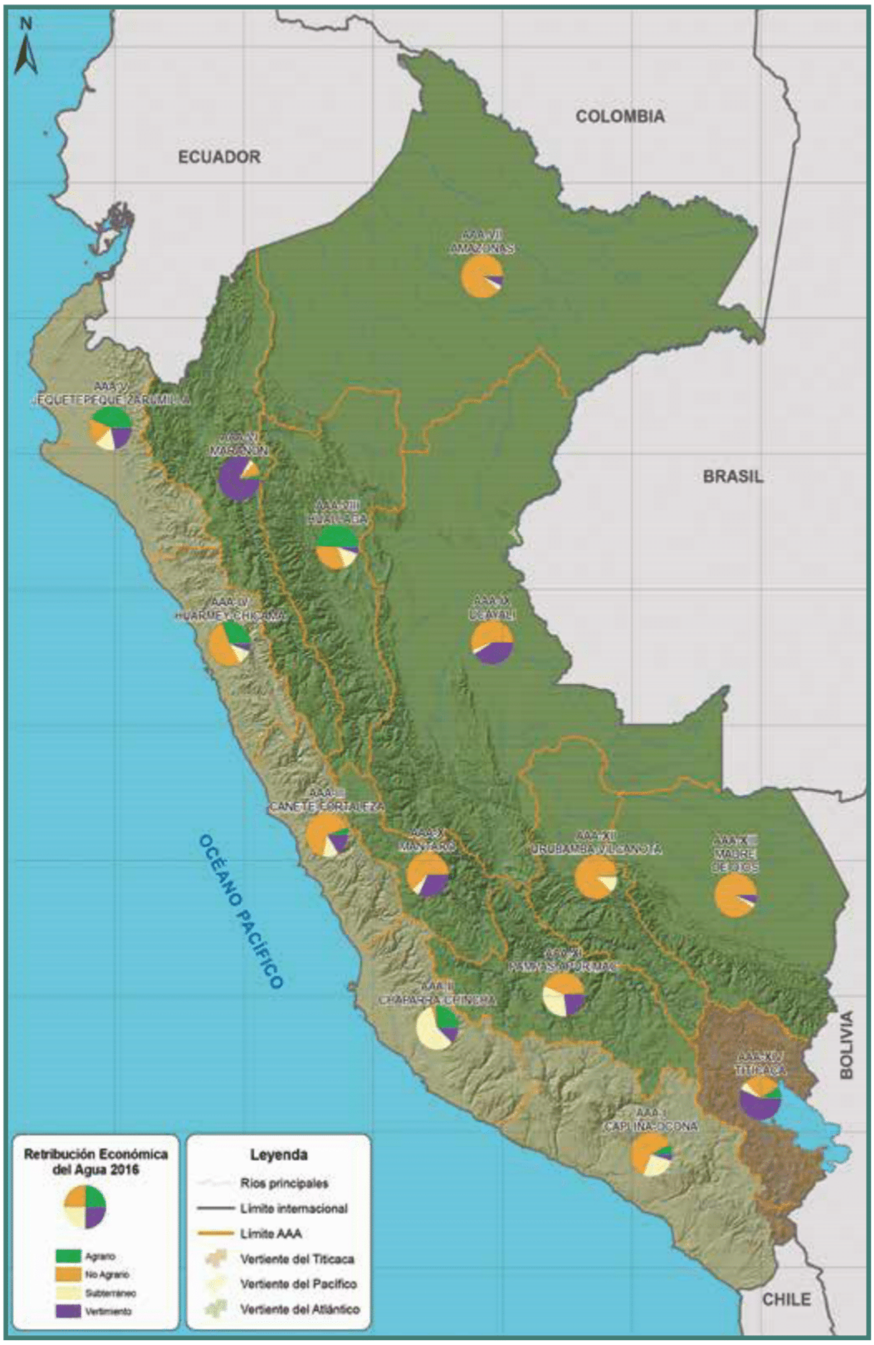
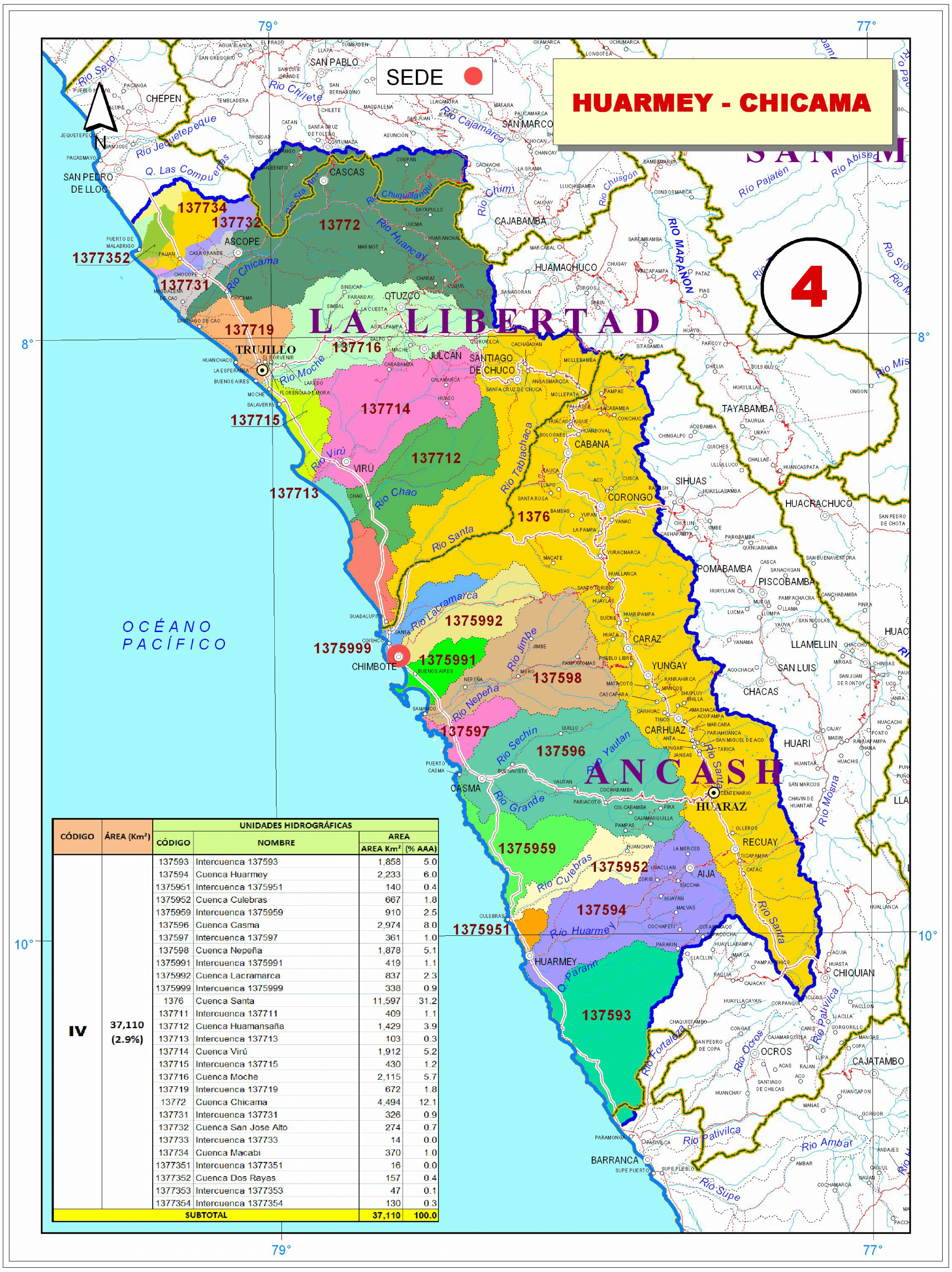


Figure D.4: Profits from Water in 2016. Adapted from ANA (2016)



CÓDIGO	ÁREA (Km²)	UNIDADES HIDROGRÁFICAS			
		CÓDIGO	NOMBRE	AREA Km²	(% AAA)
IV	37,110 (2.9%)	137593	Intercuenca 137593	1,858	5.0
		137594	Cuenca Huarmey	2,233	6.0
		1375951	Intercuenca 1375951	140	0.4
		1375952	Cuenca Culebras	667	1.8
		1375959	Intercuenca 1375959	910	2.5
		137596	Cuenca Casma	2,974	8.0
		137597	Intercuenca 137597	361	1.0
		137598	Cuenca Nepeña	1,878	5.1
		1375991	Intercuenca 1375991	419	1.1
		1375992	Cuenca Lacramarca	837	2.3
		1375999	Intercuenca 1375999	338	0.9
		1376	Cuenca Santa	11,597	31.2
		137711	Intercuenca 137711	409	1.1
		137712	Cuenca Huamansaña	1,429	3.9
		137713	Intercuenca 137713	103	0.3
		137714	Cuenca Virú	1,912	5.2
		137715	Intercuenca 137715	430	1.2
		137716	Cuenca Moche	2,115	5.7
		137719	Intercuenca 137719	672	1.8
		13772	Cuenca Chicama	4,494	12.1
		137731	Intercuenca 137731	326	0.9
		137732	Cuenca San Jose Alto	274	0.7
		137733	Intercuenca 137733	14	0.0
		137734	Cuenca Macabi	370	1.0
		1377351	Intercuenca 1377351	16	0.0
		1377352	Cuenca Dos Rayas	157	0.4
		1377353	Intercuenca 1377353	47	0.1
		1377354	Intercuenca 1377354	130	0.3
SUBTOTAL				37,110	100.0

Figure D.5: AAA Huarmey-Chicama. Adapted from ANA (2018b)

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