Appendix

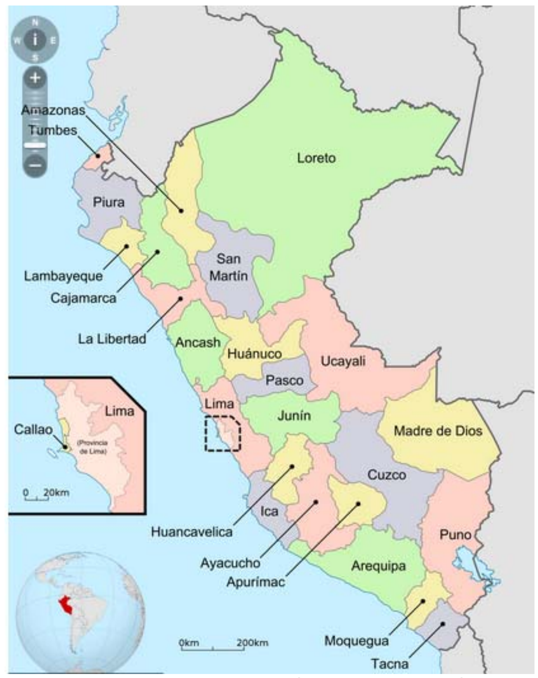
Table of Contents

Appendix 1 Location of the Irrigation District of La Joya Antigua

The Republic of Peru is divided into 25 departments, which are the first-level administrative subdivisions. Each department is further divided into provinces and each province has different districts. Politically, the irrigation district of La Joya Antigua is located in the District of La Joya in the Province and Department of Arequipa.

In **Map A1-1**, the topography of Peru is shown. In the southwest of Peru, the Department of Arequipa can be seen (**Map A1-2**). The Department of Arequipa has eight provinces and the Province of Arequipa is one of them. The location of the Province of Arequipa in the Department of Arequipa is shown in **Map A1-3**. Located in the south of the Province of Arequipa, the District of La Joya is shown in **Map A1-4**. In **Map A1-5**, the layout of the Chili-Quilca river basin and the location of the irrigation district of La Joya Antigua are shown.

Map A1-1 Topography of Peru and the Location of Areauipa[1]



Map A1-2 Geographical Location of the Department of Arequipa[2]

Map A1-3 Department of Arequipa and the Location of the Province of Arequipa[3]

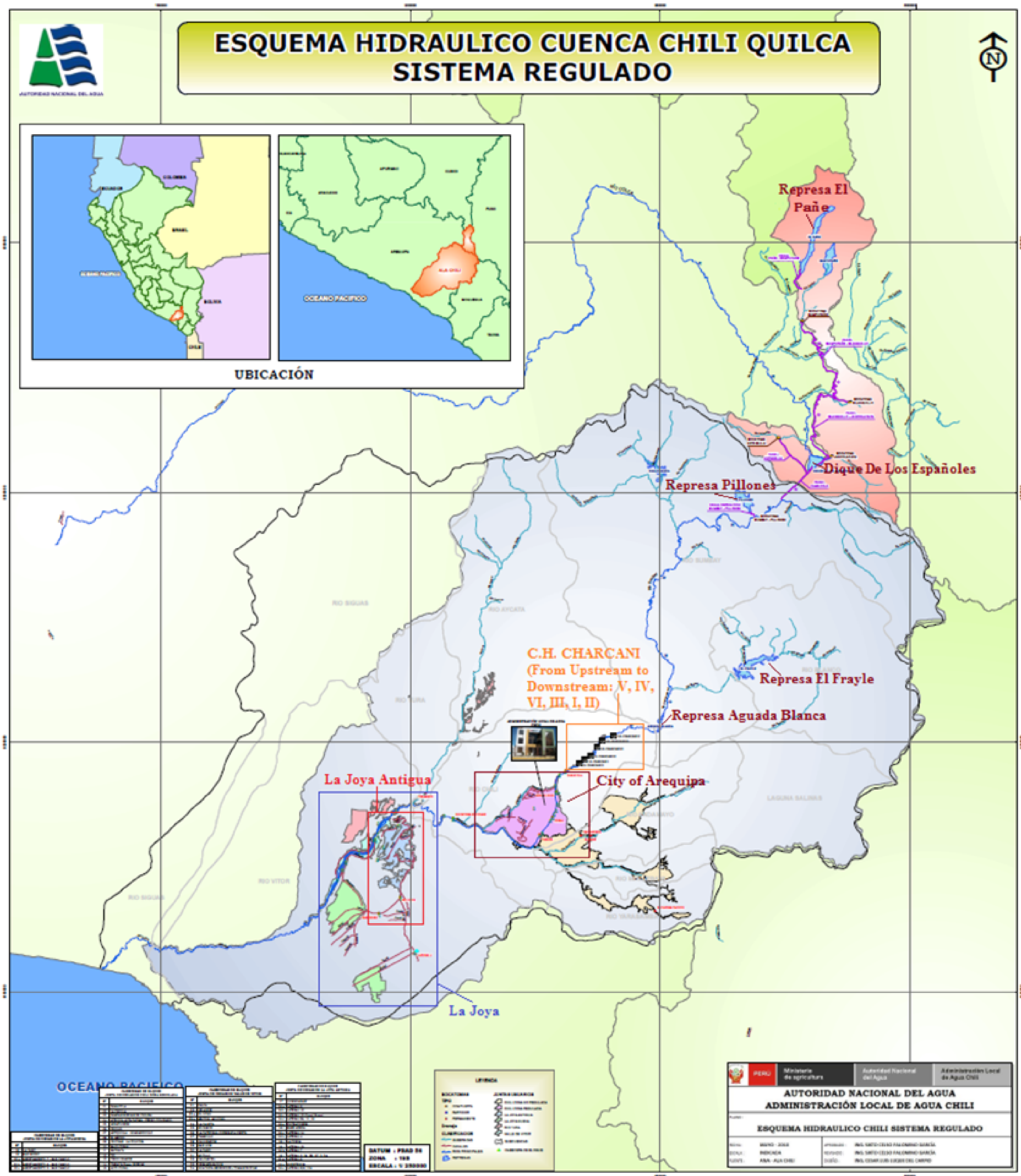
Map A1-4 Province of Arequipa and the Location of the District of La Joya[4]

1 Athahualpa's Weblog. Available online: http://athahualpa.wordpress.com/peru/

2 Peru Regions And Departments. Peru Maps. Mapsof.net. Available online: http://mapsof.net/map/peru-regions-and-departments#.TwUPcDXOXuN

3 Procesos programados para el año 2006 del de partamento de AREQUIPA . Sistema Electrónico de Contrataciones del Estado.Available online: http://app.seace.gob.pe/mon/ProcesoReporteGrafPb.jsp?tipo_cons=1&dep_codigo=04&tipo_cons_sub=3&anhoentidad=2006&anho_rep=

4 Procesos programados para el año 2006 del de partamento de AREQUIPA. Sistema Electrónico de Contrataciones del Estado. Available online: http://app.seace.gob.pe/mon/ProcesoReporteGrafPb.jsp?tipo_cons=1&dep_codigo=04&tipo_cons_sub=1&anhoentidad=2006&anho_rep=



Map A1-5 Layout of the Regulated System of the Chili-Quilca River Basin and the Location of the Irrigation District of La Joya Antigua[5]

5 Map from Administración Local de Agua Chili.

Appendix 2 Administrative Structures of Water

A2.1 Administrative Organizations of Water

The administrative organizations of water in Peru are based on the regional levels.

The highest level of the administrative organizations of water is the Autoridad Nacional del Agua (ANA), which "is the governing agency and the highest technical regulation authority of the National System of Water Resources Management" (Article 14, Act Nº 29338).[6] ANA is "responsible for functioning the system under the provisions of the Act" (Article 14, Act Nº 29338).[12]

The Autoridades Administrativas del Agua (AAA) are the decentralized organizations of ANA at Peru's 14 hydrographic regional level. It "resolves in the first administrative level of competition issues of the Autoridad Nacional" (Article 23, Act Nº 29338).[7] "The Autoridad Nacional, via the Autoridades Administrativas del Agua, has the presence at the national level" (Article 23, Act Nº 29338).[13] The decentralized organizations at Peru's 14 hydrographic regional level are shown in **Map A2-1**.

Based on the regional level, the AAA are further decentralized into the local administrative organizations named the Administracions Local de Agua (ALA) according to the different river basins within the region.

"The regional governments and local governments, via their appropriate bodies, are involved in the drafting of the management plans of the water resources of the basins. Participating in the Basin Councils and developing control actions and monitoring, in coordination with the National Authority to ensure the sustainable use of water resources.

The highest public hydraulic infrastructure that transfers the national government to regional governments is operated under the guidelines and principles of the Act (Act Nº 29338), and the directives that emitted by the National Authority." (Article 25, Act Nº 29338)[8]

The Administracions Local de Agua Chili (ALA Chili), within which basin the irrigation district of La Joya Antigua is located, is one of the decentralized organization of the Autoridades Administrativas del Agua Caplina Ocoña (AAA Caplina Ocoña). The location of the AAA Caplina Ocoña (Roman Number I on **Map A2-1**) and ALA Chili (Arabic Number 5 on **Map A2-2**) are shown in **Map A2-1** and **Map A2-2**, respectively.

A2.2 Organizations of Water Users

Under the administrative organizations of water, the water users also formed into several organizations to implement their duty and protect their rights of water use. "The user organizations are civil associations that aim at the organized participation of the users in the multi-sectoral management and sustainable use of water resources." (Article 27, Act Nº 29338).[9]

"The forms of the organization of the users that shares a surface water or groundwater source and a common hydraulic system are committees, commissions and boards of users." (Article 26, Act Nº 29338).[10]

"Junta de Usuarios (Board of Users) is organized on the basis of a shared hydraulic system, in accordance with the technical criteria of the National Authority." Junta de Usuarios has the functions of: "a) Operation and maintenance of water infrastructure; b) distribution of Water; and c) Collection and administration of the water tariff." (Article 28, Act Nº 29338).[11]

"The Comisiones de Usuarios (Commissions of Users) constitute the Junta de Usuarios and are organized in accordance with the technical criteria of the National Authority." (Article 29, Act Nº 29338).[12]

---

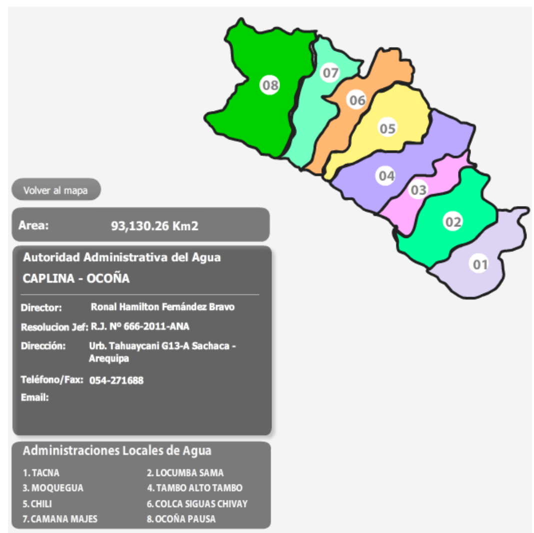
6 Autoridad Nacional del Agua; Ministerio de Agricultura (Lima, Perú, Junio 2009). Ley de Recursos Hídricos - Ley Nº 29338. ® Artículo 14.
7 Autoridad Nacional del Agua; Ministerio de Agricultura (Lima, Perú, Junio 2009). Ley de Recursos Hídricos - Ley Nº 29338. ® Artículo 23.
8 Autoridad Nacional del Agua; Ministerio de Agricultura (Lima, Perú, Junio 2009). Ley de Recursos Hídricos - Ley Nº 29338. ® Artículo 25.
9 Autoridad Nacional del Agua; Ministerio de Agricultura (Lima, Perú, Junio 2009). Ley de Recursos Hídricos - Ley Nº 29338. ® Artículo 26.
10 Autoridad Nacional del Agua; Ministerio de Agricultura (Lima, Perú, Junio 2009). Ley de Recursos Hídricos - Ley Nº 29338. ® Artículo 26.
11 Autoridad Nacional del Agua; Ministerio de Agricultura (Lima, Perú, Junio 2009). Ley de Recursos Hídricos - Ley Nº 29338. ® Artículo 26.
12 Autoridad Nacional del Agua; Ministerio de Agricultura (Lima, Perú, Junio 2009). Ley de Recursos Hídricos - Ley Nº 29338. ® Artículo 26.

The Comisiones de Usuarios are also named as Comisiones de Regantes (Irrigation Commissions) in the irrigation district of La Joya Antigua. The location of different Comités de Regantes of the irrigation district of La Joya Antigua can be differed by the different colours in **Map A2-3**.

"The Comités de Usuarios (Committees of Users) are the minimum level of organization. They integrate with both the Comisiones de Usuarios (Commissions of user) and the the Juntas de Usuarios (Boards of Users)." (Article 26, Act Nº 29338).[13]

"The Comités de Usuarios (User Committees) can be of surface water, of groundwater and of filtration water.
The Comités de Usuarios of surface water are organized at the level of smaller canals , the ones of groundwater are at the level of well, and the ones of filtration water are at the level of the area of surface upwelling." (Article 30, Act Nº 29338).[14]

The administrative structure related to the irrigation district of La Joya Antigua is shown in **Diagram A2-1**.



Map A2-1 Location of AAA Caplina Ocoña within ANA[15] **Map A2-2 Location of ALA Chili within AAA Caplina Ocoña**[16]

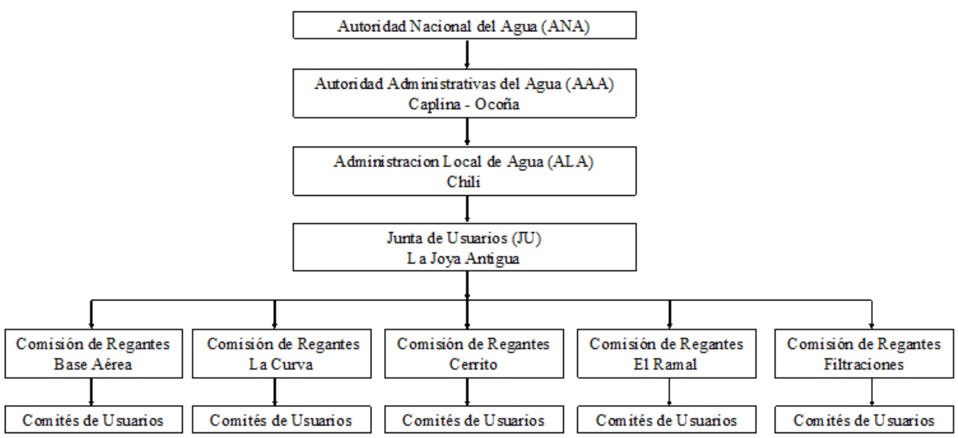
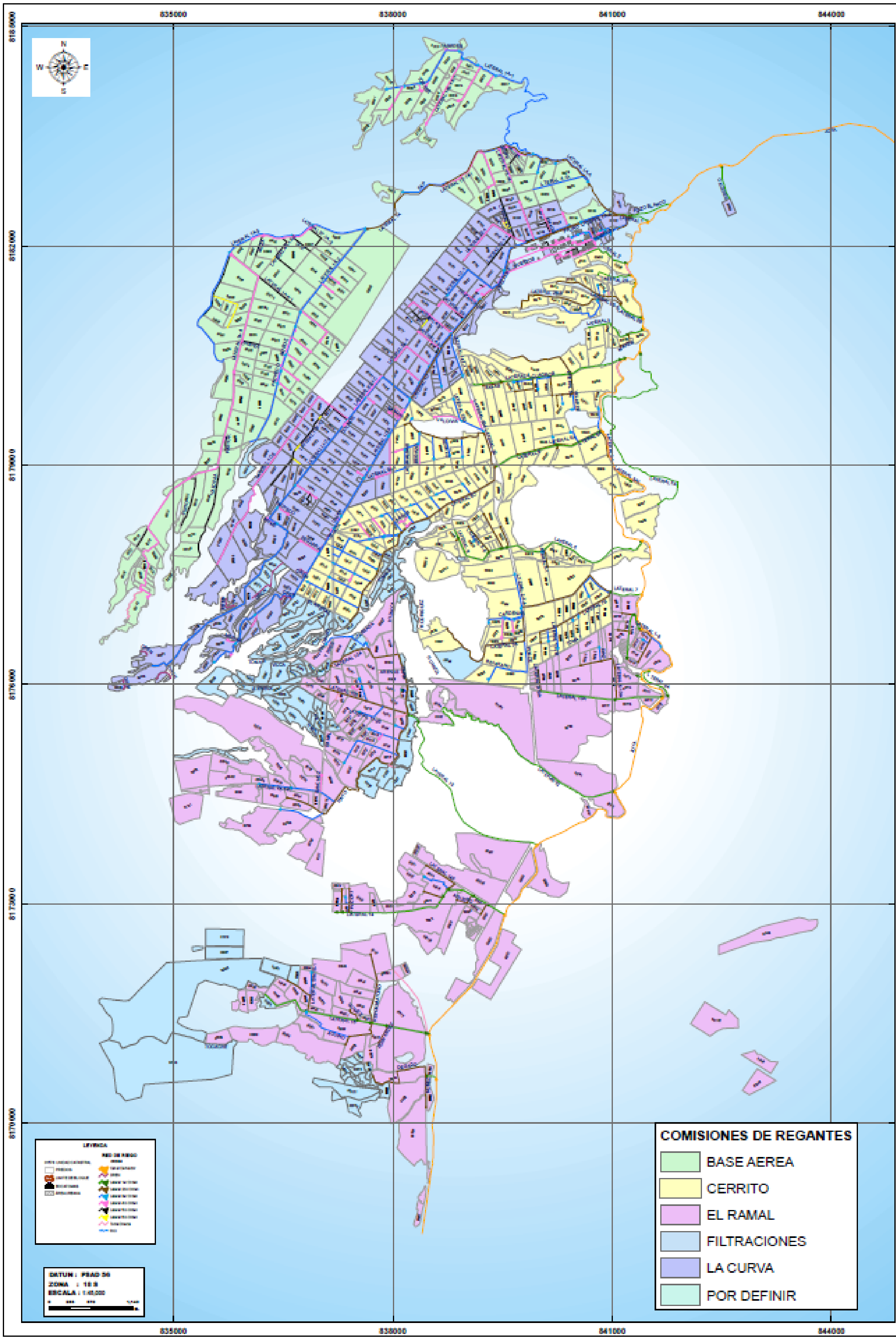


Diagram 1 Structure of the Administrative Organizations Related to the Irrigation District of La Joya Antigua

13 Autoridad Nacional del Agua; Ministerio de Agricultura (Lima, Perú, Junio 2009). Ley de Recursos Hídricos - Ley Nº 29338. ® Artículo 26.
14 Autoridad Nacional del Agua; Ministerio de Agricultura (Lima, Perú, Junio 2009). Ley de Recursos Hídricos - Ley Nº 29338. ® Artículo 26.
15 Official website of Autoridad Nacional del Agua; Ministerio de Agricultura. Peru. Organos Desconcentrados. Available online: http://www.ana.gob.pe/con%C3%B3cenos/organizaci%C3%B3n-y-funciones/estructura-organizacional/organos-desconcentrados.aspx#
16 Official website of Autoridad Nacional del Agua; Ministerio de Agricultura. Peru. Organos Desconcentrados. Available online: http://www.ana.gob.pe/con%C3%B3cenos/organizaci%C3%B3n-y-funciones/estructura-organizacional/organos-desconcentrados.aspx#



Map A2-3 Comisiones de Regantes in the Irrigation District of La Joya Antigua[17]

17 Map from Administración Local de Agua Chili.

Appendix 3 Climate

A3.1 General Climate

The irrigation district of La Joya Antigua is located between the Andes Mountain and the southwestern coastline of Peru. The typical Peruvian coast climate is present in this area. The Humboldt Current which flows along the coastline of Peru together with the rain shadow effect along the (south-) western slope of the Andes Mountain[18,19,20] define the irrigation district of La Joya Antigua (and the Department of Arequipa) a sub-tropical desert climate with very little precipitation.

A3.2 Seasons

Peru is located in the Southern Hemisphere and the period of its four seasons are different with the ones in the Northern Hemisphere. In Peru, spring starts from September 23rd to December 21st with very little or no rainfall; summer starts from December 22nd to March 21st with several extreme and concentrated rainfall; autumn is from March 22nd to June 21st; and winter is from June 22nd to September 22nd. The Agricultural year in Peru starts from August to July in the next year.

Humboldt Current

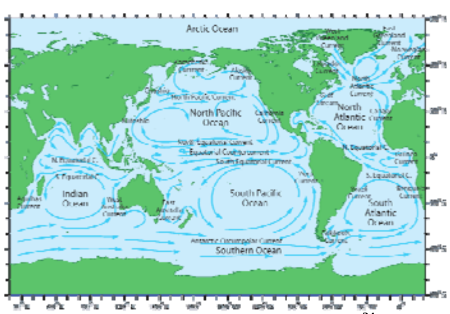
The Humboldt Current is a cold, low-salinity ocean current that flows north-westward along the west coast of South America from the southern tip of Chile to northern Peru. It is an eastern boundary current flowing in the direction of the equator, and can extend 1,000 kilometers offshore.

The Humboldt has a considerable cooling influence on the climate of Chile, Peru and the Ecuador. It is also largely responsible for the aridity that prevails in northern Chile and coastal areas of Peru and southern Ecuador. Marine air is cooled by the current and thus is not conducive to generating precipitation (although clouds and fog are produced).[21] The pattern of the Humboldt Current is shown in **Picture A3-1**.

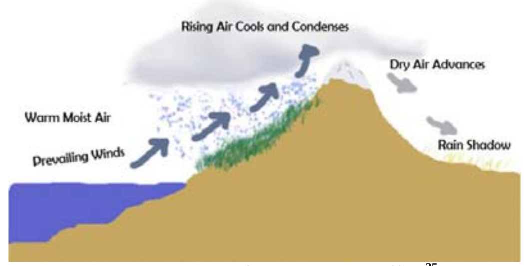
Rain Shadow Effect

A rain shadow is a dry area on the lee side of a mountainous area. The mountains block the passage of rain-producing weather systems, casting a "shadow" of dryness behind them. As shown in **Picture A3-2**, the warm moist air is "pulled" by the prevailing winds over a mountain. Then it condenses and precipitates and the dry air moves forward leaving a rain shadow behind the mountain.[22]

The eastern Andes have a longer and more intense rainy season because of the vicinity of the Amazon. The (south-) western slopes are extremely dry because they lie in the rain-shadow. The annual precipitation ranges from over 1000 mm near the amazon basin to less that 200 mm in the coastal region.[23]



Picture A3-1 Pattern of Humboldt Current[24]



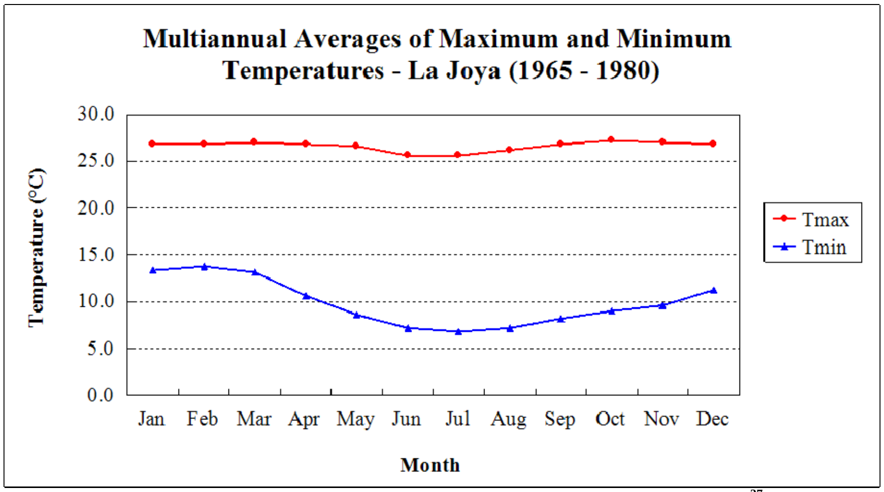
Picture A3-2 Example of Rain Shadow Effect[25]

18 Athahualpa's Weblog. Available online: http://athahualpa.wordpress.com/peru/
19 Leendert van der Sluijs (2004). *Locomotion and energetics of llamas and alpacas under free-ranging conditions*. 1st Edition, 2004. Diss. Göttingen, Cuvillier Verlag, Göttingen, ISBN 3-86537-073-X. Chapter 2.2. P5.
20 Kessler A. and F. Monheim (1968). *Der Wasserhaushalt des Titicacasees nach neueren Meßer-gebnissen*, Erdkunde Bd. 22, 1968.
21 Wikipedia. Humboldt Current. Available online: http://en.wikipedia.org/wiki/Humboldt_Current
22 Wikipedia. Rain shadow. http://en.wikipedia.org/wiki/Rain_shadow
23 Kessler A. and F. Monheim (1968). *Der Wasserhaushalt des Titicacasees nach neueren Meßer-gebnissen*, Erdkunde Bd. 22, 1968.
24 SEOS. *Topics of the Ocean Currents Tutorial. Ocean Currents.* Chapter 2 Wind Driven Surface Currents. http://www.seos-project.eu/modules/oceancurrents/oceancurrents-c00-p01.html
25 Wikipedia. Rain shadow. http://en.wikipedia.org/wiki/Rain_shadow

A3.3 Temperature

According to the report *Inventario de La Infraestructura de Riego y Drenaje y Vías de Comunicación del Junta de Usuarios La Joya Antigua*, the average annual temperature of the irrigation district of La Joya Antigua is 18.3 ºC, with a maximum average monthly temperature of 20.3 º C in February, and a minimum average monthly temperature of 16.6 º C in July and August.[26]

On the official website of Peru Numerical Weather and Climate Prediction Center, the average maximum and minimum temperatures from year 1965 to year 1980 in the District of La Joya are provided. The official temperature data are referred in this study and are listed in **Graph A3-1** and **Table A3-1**.



Graph A3-1 Maximum and Minimum MonthlyTemperature (1965 - 1980)[27]

Table A3-1 Maximum and Minimum MonthlyTemperature (1965 - 1980)[28]

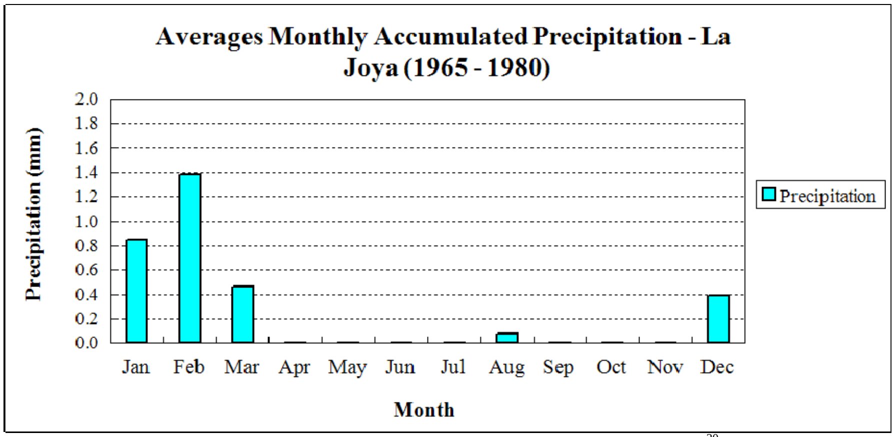
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max. Temperature (° C)	26.8	26.8	27.0	26.8	26.6	25.6	25.6	26.2	26.8	27.2	27.0	26.8
Min. Temperature (° C)	13.3	13.8	13.1	10.6	8.6	7.2	6.8	7.2	8.2	9.0	9.6	11.3

A3.4 Precipitation

According to the report *Plan de Cultivo y Riego 2010-2011 Junta de Usuarios Del Distrito de Riego Chili La Joya Antigua*, the precipitation in the irrigation district of La Joya Antigua is low. The annual precipitation in the irrigation district of La Joya Antigua is around 20 mm concentrating between December and March.[29]

On the official website of Peru Numerical Weather and Climate Prediction Center, the average monthly accumulated precipitation from year 1965 to year 1980 in the District of La Joya are provided. The official precipitation data are referred in this study and are listed in **Graph A3-2** and **Table A3-2**.

26 Junta De Usuarios Del Distrito De Riego Chili La Joya Antigua (2006). Inventario de La Infraestructura de Riego y Drenaje y Vías de Comunicación del Junta de Usuarios La Joya Antigua. Chapter 1.6.2 Clima.
27 Ministerio del Ambiente, Instituto Geofísico del Perú, Investigación en Prevención de Desastres Naturales. Centro de Prediccion Numerica del Tiempo y Clima (CPNTC). La Joya. Available online: http://www.met.igp.gob.pe/clima/HTML/lajoya.html
28 Ministerio del Ambiente, Instituto Geofísico del Perú, Investigación en Prevención de Desastres Naturales. Centro de Prediccion Numerica del Tiempo y Clima (CPNTC). La Joya. Available online: http://www.met.igp.gob.pe/clima/HTML/lajoya.html
29 Junta de Usuarios Del Distrito de Riego Chili La Joya Antigua (2010). *Plan de Cultivo y Riego 2010-2011*. Chapter 2.2 Clima.



Graph A3-2 Monthly Accumulated Precipitation (1965 - 1980)[30]

Table A3-2 Average Monthly Accumulated Precipitation (1965 - 1980)[31]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ave. Precipitation (mm)	0.8	1.4	0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4

A3.5 Humidity

According to the report I*nventario de La Infraestructura de Riego y Drenaje y Vías de Comunicación del Junta de Usuarios La Joya Antigua*,the relative humidity of the irrigation district of La Joya Antigua is low, with a higher average value of 25% between January and April and a lower average value of 18% between July and September.[32]

The meteorological station in the irrigation district of San Isidro which is located in the downstream of the irrigation district of La Joya Antigua had recorded the climate data from October 1965 to May 1972. This meteorological station is located at 71º52' West Longitudes and 16º44' South Latitude and has an elevation of 1255 m.s.n.m. The average monthly relative humidity from the meteorological station are listed in **Table A3-3**.

Table A3-3 Monthly Relative Humidity - San Isidro Meteorological Station (Oct. 1965 - May. 1972)[33]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Relative Humidity	63%	66%	66%	60%	50%	50%	43%	45%	47%	44%	49%	56%

A3.6 Insolation

According to the report *Inventario de La Infraestructura de Riego y Drenaje y Vías de Comunicación del Junta de Usuarios La Joya Antigua*, the annual sun hours in the irrigation district of La Joya Antigua is around 3285 hours, with an average of 9 hours daily.[34]

Due to the lack of the sunshine data in the District of La Joya, the sunshine data of the City of Arequipa are taken as the data in the District of La Joya. The average monthly sunshine hours and the daylight hours in the City of Arequipa are listed in**Table A3-4**.

30 Ministerio del Ambiente, Instituto Geofísico del Perú, Investigación en Prevención de Desastres Naturales. Centro de Prediccion Numerica del Tiempo y Clima (CPNTC). La Joya. Available online: http://www.met.igp.gob.pe/clima/HTML/lajoya.html
31 Ministerio del Ambiente, Instituto Geofísico del Perú, Investigación en Prevención de Desastres Naturales. Centro de Prediccion Numerica del Tiempo y Clima (CPNTC). La Joya. Available online: http://www.met.igp.gob.pe/clima/HTML/lajoya.html
32 Junta De Usuarios Del Distrito De Riego Chili La Joya Antigua (2006). Inventario de La Infraestructura de Riego y Drenaje y Vías de Comunicación del Junta de Usuarios La Joya Antigua. Chapter 1.6.2 Clima.
33 Dr. Edwin C. Olsen III (1974). Assoc. Utah State University. Sprinkler Leaching Program For Very Saline Virgin Desert Soils In The La Joya Irrigation Project Peru. Table 1. Ministerio de Agricultura. Lima, Peru. June 1974. Available online: http://pdf.usaid.gov/pdf_docs/PNAAB252.pdf
34 Junta De Usuarios Del Distrito De Riego Chili La Joya Antigua (2006). Inventario de La Infraestructura de Riego y Drenaje y Vías de Comunicación del Junta de Usuarios La Joya Antigua. Chapter 1.6.2 Clima.

Table A3-4 Monthly Sunshine Hours And Daylight Hours - Arequipa[35]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
Hours of Sunshine	7	7	8	9	9	10	10	10	10	10	10	9	9.08
Hours of Daylight	13	13	12	12	11	11	11	12	12	13	13	13	12.17

A3.7 Evaporation

According to the report *Plan de Cultivo y Riego 2010-2011 Junta de Usuarios Del Distrito de Riego Chili La Joya Antigua*, the annual evaporation in the irrigation district of La Joya Antigua is around 2640 mm, with a daily minimum of 6.2 mm in May and a daily maximum of 8.6 mm in November.[36]

The evaporation data (Pan evaporation) recorded at the meteorological station in the irrigation district of San Isidro from February 1970 to May 1972 are referred in this study and are listed in **Table A3-5**.

Table A3-5 Monthly (Reference) Evaporation - San Isidro Meteorological Station (Oct. 1965 - May. 1972)[37]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Evaporation (mm)	186.0	162.5	170.5	150.0	148.8	114.0	148.8	155.0	159.0	195.3	198.0	182.9

A3.8 Wind

According to the report *Plan de Cultivo y Riego 2010-2011 Junta de Usuarios Del Distrito de Riego Chili La Joya Antigua*, the prevailing wind in the irrigation district of La Joya Antigua is south-west direction. The force of the winds are generally higher in spring and summer.[38]

Due to the lack of the wind speed data in the District of La Joya, the wind speed data of the City of Arequipa are taken. The average monthly wind speed in the City of Arequipa is listed in **Table A3-8**.

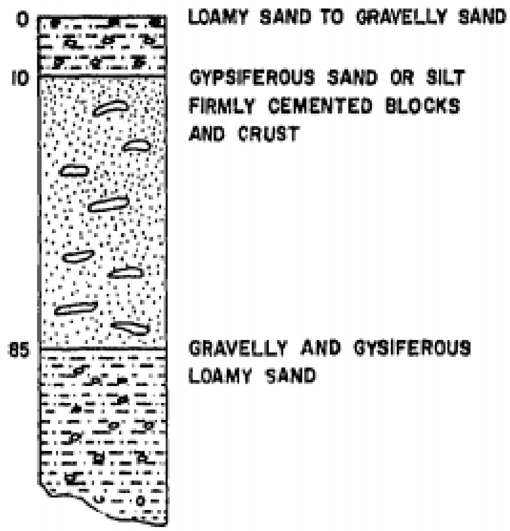
Table A3-8 Monthly Wind Speed - Arequipa[39]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
V (m/s)	2.81	2.64	2.75	2.64	3.00	3.14	3.36	3.22	3.08	3.08	3.14	2.83	2.81

35 World Climate Guide. Arequipa Climate Guide. http://www.worldclimateguide.co.uk/climateguides/peru/arequipa.php?units=metric&style=symbols
36 Junta de Usuarios Del Distrito de Riego Chili La Joya Antigua (2010). *Plan de Cultivo y Riego 2010-2011*. Chapter 2.2 Clima.
37 Dr. Edwin C. Olsen III (1974). Assoc. Utah State University. Sprinkler Leaching Program For Very Saline Virgin Desert Soils In The La Joya Irrigation Project Peru. Table 1. Ministerio de Agricultura. Lima, Peru. June 1974. Available online: http://pdf.usaid.gov/pdf_docs/PNAAB252.pdf
38 Junta de Usuarios Del Distrito de Riego Chili La Joya Antigua (2010). *Plan de Cultivo y Riego 2010-2011*. Chapter 2.2 Clima.
39 Tu Tiempo.net. Historical Weather: Apequipa, Peru. http://www.tutiempo.net/en/Climate/Arequipa/847520.htm

Appendix 4 Type of Soil

According to the report *Plan de Cultivo y Riego 2010-2011 Junta de Usuarios Del Distrito de Riego Chili La Joya Antigua*, the soils in the irrigation district of La Joya Antigua are coarse-textured soils (sand or loamy sand) in the first layer, followed by the stratified-textured horizon with abundant stones and gravels with high permeability. According to the report, the soils in the irrigation district of La Joya Antigua have a great potential for the intensive cultivation.[40] The profiles of soil in the District of La Joya are shown in **Picture A4-1**.



Picture A4-1 Representative Profiles of Soil in the District La Joya[41]

40 Junta de Usuarios Del Distrito de Riego Chili La Joya Antigua (2010). *Plan de Cultivo y Riego 2010-2011*. Chapter 2.3 Recurso Suelo.

41 Dr. Edwin C. Olsen III (1974). Assoc. Utah State University. Sprinkler Leaching Program For Very Saline Virgin Desert Soils In The La Joya Irrigation Project Peru. Table 1. Ministerio de Agricultura. Lima, Peru. June 1974. Available online: http://pdf.usaid.gov/pdf_docs/PNAAB252.pdf

Appendix 5 Cochineal Farming

From **Picture A5-1** to **Picture A5-4**, the photos of cochineal farming in Peru are shown.

Picture A5-1 Cochineal Farming[42]

Picture A5-2 Infestation of Cochineals[43]

Picture A5-3 Cochineal Harvesting

Picture A5-4 Mature Cochineal and the Carminic Acid

42 AnaPeruana.com. (June 27th, 2010). Cochineal Farming in Peru. Available online: http://www.anaperuana.com/2010/06/27/cochineal-farming-in-peru/

43 AnaPeruana.com. (June 27th, 2010). Cochineal Farming in Peru. Available online: http://www.anaperuana.com/2010/06/27/cochineal-farming-in-peru/

Appendix 6 Calculation of the Discharges Assigned by ALA Chili

The discharges assigned to the irrigation district of La Joya Antigua through Canal Madre (the main irrigation canal of the irrigation district La Joya) and the first oder irrigation canals are calculated by multiplying the licensed irrigation area with the irrigation module. The irrigation module is approved by ALA Chili according to the release of the upstream reservoirs and is the same for all the irrigation districts within the regulated system of the Chili-Quilca river basin.[44] The formula for calculating the discharges assigned by ALA Chili is as follows:

$$Q = M * A / 1000$$

In which,

Q = Discharge assigned to the area, m3/s;
M = Irrigation module, l/s/ha;
A = Irrigated area of the irrigation district or the lateral, ha.

In **Table A6-1**, factors that influence the value of the irrigation module and the calculation method of the irrigation module are listed. The calculated irrigation module should only be used as a reference value since many of its influencing factors vary from time to time. In this study, these values are assumed to be constant. The input data for the historical discharge of the Reservoir Aguada Blanca is accessible from the official website[45,46] and are listed in **Table A6-2**.

When comparing the calculated irrigation modules with the historical irrigation modules[47], the calculated irrigation modules give an acceptable inaccuracy around 10% in a normal or a wet year, while an unacceptable inaccuracy of around 20% to 50% inaccuracy in a dry year. Thus, the irrigation modules for a typical dry year are calculated by averaging the historical irrigation modules of the dry years. Since most of the first-hand data were collected during the fieldwork (agricultural year[48] 2010-2011) and the year was reported as a wet year, the agricultural year[49] 2010-2011 was taken as a typical wet year. In **Table A6-3** the historical irrigation modules are listed. The results of the calculated irrigation modules in a wet year and a dry year are listed in **Table A6-4** and **Table A6-5**, respectively.

During the fieldwork, it was noticed that the division structures between Canal Madre and Lateral 1 are proportional weirs and the gates above the Canal Madre are usually fully open. Thus, the discharge in Lateral 1 should indicate the assigned discharge by ALA Chili. Since a canal ruler is present at the beginning of Lateral 1, the calculated assigned discharge in Lateral 1 is brought to the value indicated on the canal ruler and the irrigation module was modified correspondingly. The division structures and the canal ruler at the beginning of Lateral 1 are shown in **Picture A6-1**. With the modified irrigation module, the assigned discharges in a wet year and a dry year can be calculated and are listed in **Table A6-6** and **Table A6-7**, respectively.

Table A6-1 Calculation Method Of Irrigation Modules

Influencing Factors	Unit	Month
① Discharge -- Represa Aguada Blanca	m3/seg	Input -- Discharge Represa Aguada Blanca[25,26]
② Discharge -- Return Waters	m3/seg	2.300
③ Discharge -- Recovery 45%	m3/seg	=(①-②-⑤)*0.45
④ Discharge -- Available Flow	m3/seg	=①+②+③
⑤ Discharge -- Non-agricultural Uses	m3/seg	=0.05+0.15+1.5+1=2.700
⑥ Area -- Agricultural Uses	Ha	=⑦+⑧=15542
⑦ Area -- Chili Regulated	Ha	Input -- 6720.4+(110*0.73) = 6800.700
⑧ Area -- La Joya Regulated	Ha	Input -- 3986.3429+5896-365.45 = 9516.8929
⑨ Irrigation Modules	**l.p.s./Ha**	**=((④-⑤)/⑥*1000)**

Note: The texts with red colour are the required input data.

44 Information provided by the technical manager from Junta de Usuarios La Joya Antigua.
45 Official website AUTODEMA Manejo Sostenible. Movimiento Hídrico Sistema Chili. Available online: http://www.autodema.gob.pe/
46 Official website of Autoridad Nacional del Agua. Sistema de Información de Recursos Hídricos. Available online: http://www.ana.gob.pe:8080/snirh/hidr_caudalmm.aspx
47 Gabriel Riega (2002). Thesis: *Planeamiento de La Cuenca Chili*. Anexos -- Cuadro 40.
48 The agricultural year in the irrigation district of La Joya Antigua starts from August to July in the next year.
49 The agricultural year in the irrigation district of La Joya Antigua starts from August to July in the next year.

Table A6-2 Historical Discharge from Reservoir Aguada Blanca from 1971 to 1995 (l/s/ha)[50]

Year / Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1971	--	--	8.38	7.97	7.77	8.47	7.69	7.85	7.14	7.18	7.09	6.57
1972	7.68	8.59	8.56	8.69	7.72	7.43	8.45	7.99	7.8	8.46	8.42	8.45
1973	8.88	35.28	42.69	12.39	10.11	8.73	8.54	8.83	8.72	8.98	9.53	8.84
1974	19.55	21.39	23.79	11.55	11.98	11.42	13.31	13.19	12.33	12.09	12.11	12.87
1975	13.79	30.9	29.77	13.95	13.09	12.93	13.35	13.39	13.42	13.43	13.07	13.2
1976	14.77	16.5	16.57	10.42	9.74	10.53	9.77	8.86	10.32	9.39	9.34	9.84
1977	8.54	6.96	33.2	9.5	8.41	8.54	8.75	8.91	9.64	10.41	10.79	11.28
1978	10.86	14.98	9.21	8.65	8.71	8.24	8.72	8.41	8.33	8.87	9.18	9.30
1979	9.36	9.03	8.39	7.99	8.3	8.16	8.16	7.97	8.49	8.35	8.74	8.87
1980	8.90	8.75	7.83	7.16	6.36	5.41	5.18	5.34	4.36	4.70	5.54	5.92
1981	6.09	28.2	24.28	10.94	10.26	10.34	10.24	10.25	10.68	11.29	11.38	11.12
1982	12.49	11.72	9.08	9.05	8.19	7.94	8.18	8.42	8.49	8.8	10.08	9.74
1983	9.37	8.09	7.87	6.18	4.04	3.71	3.72	3.74	3.75	4.66	4.98	4.97
1984	5.84	47.15	36.59	17.56	11.24	10.6	10.41	10.86	11.88	12.01	12.95	13.53
1985	12.71	33.13	35.45	34.51	13.84	13.66	13.32	12.08	12.1	13.04	13.24	13.31
1986	26.78	47.94	63.01	24.34	13.55	12.28	12.3	12.44	13.16	13.41	14.11	13.95
1987	27.00	18.34	13.13	10.52	9.45	8.24	8.26	10.08	10.16	9.84	10.49	10.43
1988	10.54	20.3	11.25	16.85	9.23	9.38	9.22	10.03	10.6	10.52	7.53	5.19
1989	10.18	9.39	9.22	12.11	8.91	8.75	8.58	8.91	10.05	10.14	10.11	10.3
1990	9.84	8.31	6.00	4.54	3.89	3.96	4.08	4.14	4.26	4.23	4.38	6.58
1991	9.09	8.81	29.59	10.37	9.80	8.94	8.27	9.29	9.14	9.3	9.85	10.25
1992	8.49	5.84	4.37	3.86	4.23	3.82	4.14	4.21	4.14	4.19	3.9	3.85
1993	7.68	12.56	14.35	8.22	8.28	7.80	8.24	8.21	8.12	8.63	9.53	9.98
1994	19.27	88.19	14.48	11.78	10.68	11.35	11.85	11.41	12.03	12.4	13.2	12.9
1995	11.36	8.9	10.68	10.21	9.67	9.49	9.21	9.21	8.67	9.1	8.92	8.71
1996	5.21	10.19	11.71	10.77	7.12	7.18	7.27	7.99	8.44	8.84	9.32	9.61
1997	9.74	13.71	17.26	12.05	11.11	9.38	6.89	7.67	8.49	8.88	9.2	9.55
1998	10.18	15.46	13.47	12.05	10.75	8.71	8.62	8.62	10.12	10.64	11.12	11.12
1999	10.59	16.8	23.24	20.97	13.18	10.12	10.11	11.47	12.11	12.31	13.12	13.11
2000	16.18	17.53	18.65	16.1	11.67	10.62	10.62	10.84	11.55	12.29	13.12	13.12
2001	16.18	61.93	89.41	34.56	20.02	15.15	15.17	15.3	13.26	11.14	11.19	11.14
2002	7.92	16.42	68.74	27.44	10.48	10.21	9.98	9.39	10.19	10.64	11.9	12.24
2003	12.23	12.31	15.35	18.47	10.98	10.18	10.31	10.53	11.31	12.31	12.15	12.09
2009	9.67	7.69	13.03	9.01	9.00	8.60	7.78	8.01	8.84	9.20	9.21	9.20
2010	8.46	9.13	10.74	11.10	10.66	10.05	10.00	10.91	11.01	11.78	11.87	12.01
2011	11.87	14.92	18.86	20.12	13.32	12.97	13.04	13.00	12.72	13.95	13.69	14.12

Note: The dark blue colour represents a wet year and the orange colour represents a dry year.

50 Gabriel Riega (2002). Thesis: *Planeamiento de La Cuenca Chili*. Anexos -- Cuadro 40.

Table A6-3 Historical Irrigation Modules in the Chili Regulated System from 1971 to 1995 (l/s/ha)[51]

Year / Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1971	1.30	2.17	1.46	0.92	0.91	0.97	0.88	0.89	0.82	0.81	0.76	0.62
1972	0.81	1.98	3.74	1.73	0.95	1.01	1.18	1.12	0.99	1.04	1.02	1.04
1973	1.81	3.49	3.41	1.62	1.15	0.97	0.88	0.95	0.71	0.74	0.74	0.74
1974	1.46	1.80	2.00	0.95	0.99	0.94	1.10	1.09	1.02	1.00	1.00	1.07
1975	1.14	2.61	2.52	1.16	1.08	1.07	1.11	1.11	1.11	1.11	1.08	1.09
1976	1.23	1.38	1.38	0.86	0.82	0.86	0.80	0.72	0.85	0.77	0.76	0.81
1977	0.69	0.56	2.81	0.78	0.68	0.69	0.71	0.73	0.79	0.85	0.89	0.93
1978	0.89	1.25	0.75	0.70	0.71	0.67	0.71	0.68	0.68	0.72	0.75	0.76
1979	0.76	0.74	0.68	0.65	0.67	0.66	0.66	0.64	0.69	0.68	0.71	0.72
1980	0.72	0.71	0.63	0.57	0.52	0.47	0.45	0.46	0.40	0.42	0.47	0.50
1981	0.51	2.38	2.05	0.90	0.84	0.85	0.84	0.84	0.88	0.93	0.94	0.92
1982	1.02	0.96	0.73	0.73	0.66	0.63	0.66	0.68	0.68	0.71	0.82	0.79
1983	0.76	0.65	0.63	0.51	0.38	0.36	0.36	0.36	0.36	0.42	0.44	0.44
1984	0.49	3.96	3.07	1.45	0.92	0.86	0.84	0.88	0.97	0.98	1.06	1.11
1985	1.04	2.77	2.97	2.89	1.14	1.12	1.09	0.99	0.99	1.07	1.08	1.09
1986	2.23	4.03	5.31	2.03	1.11	1.00	1.00	1.02	1.08	1.10	1.16	1.14
1987	2.25	1.52	1.08	0.85	0.76	0.66	0.66	0.82	0.82	0.8	0.85	0.85
1988	0.86	1.68	0.92	1.39	0.74	0.76	0.74	0.81	0.86	0.85	0.6	0.45
1989	0.82	0.76	0.74	0.99	0.72	0.73	0.69	0.71	0.81	0.81	0.82	0.84
1990	0.8	0.67	0.50	0.41	0.37	0.38	0.38	0.39	0.39	0.39	0.40	0.53
1991	0.73	0.71	2.47	0.84	0.79	0.72	0.66	0.75	0.74	0.75	0.8	0.83
1992	0.68	0.49	0.40	0.37	0.39	0.37	0.39	0.39	0.39	0.39	0.37	0.37
1993	0.61	1.03	1.18	0.66	0.66	0.62	0.66	0.66	0.65	0.69	0.77	0.81
1994	1.79	7.30	1.18	0.96	0.87	0.92	0.97	0.93	0.98	1.01	1.08	1.06
1995	0.91	0.70	0.86	0.82	0.77	0.76	0.73	0.73	0.69	0.72	0.71	0.69

Note: The dark blue colour represents a wet year and the orange colour represents a dry year.

Table A6-4 (Calculated) Monthly Irrigation Modules of the Studied Year/ Wet Year (Aug 2010-Jul 2011)

Year 2010					Year 2011						
Aug	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
0.807	0.816	0.884	0.892	0.904	0.892	1.163	1.513	1.625	1.021	0.990	0.996

Table A6-5 (Calculated) Monthly Irrigation Modules of a Dry Year

Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
0.400	0.385	0.405	0.420	0.460	0.740	0.630	0.540	0.465	0.415	0.395	0.395

51 Gabriel Riega (2002). Thesis: *Planeamiento de La Cuenca Chili*. Anexos -- Cuadro 40.

Table A6-6 (Calculated) Monthly Assigned Discharge in a Wet Year

Canal Name	Irrigated Area (ha)	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
	Irrigation Modules	0.807	0.816	0.884	0.892	0.904	0.892	1.163	0.852	0.865	1.186	0.990	0.996
La Joya (Canal Madre)	9516.89	7.68	7.76	8.41	8.49	8.61	8.49	11.07	8.11	8.23	11.29	9.42	9.48
Lateral 1	1618.83	1.31	1.32	1.43	1.44	1.46	1.44	1.88	1.38*	1.40*	1.92*	1.60	1.61
Lateral 6	84.57	0.07	0.07	0.07	0.08	0.08	0.08	0.10	0.07	0.07	0.10	0.08	0.08
Lateral 15	135.58	0.11	0.11	0.12	0.12	0.12	0.12	0.16	0.12	0.12	0.16	0.13	0.14
Lateral 16	61.56	0.05	0.05	0.05	0.05	0.06	0.05	0.07	0.05	0.05	0.07	0.06	0.06
La Joya Antigua	3620.89	2.92	2.95	3.20	3.23	3.27	3.23	4.21	3.09	3.13	4.29	3.58	3.61
La Joya Nueva	5896.00	4.76	4.81	5.21	5.26	5.33	5.26	6.86	5.02	5.10	6.99	5.84	5.87

Note: The sign '*****' represents the discharge indicated on the canal ruler.

Table A6-7 (Calculated) Monthly Assigned Discharge in a Dry Year

Canal Name	Irrigated Area (ha)	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
	Irrigation Modules	0.400	0.385	0.405	0.420	0.460	0.740	0.630	0.540	0.465	0.415	0.395	0.395
La Joya (Canal Madre)	9516.89	3.81	3.66	3.85	4.00	4.38	7.04	6.00	5.14	4.43	3.95	3.76	3.76
Lateral 1	1618.83	0.65	0.62	0.66	0.68	0.74	1.20	1.02	0.87	0.75	0.67	0.64	0.64
Lateral 6	84.57	0.03	0.03	0.03	0.04	0.04	0.06	0.05	0.05	0.04	0.04	0.03	0.03
Lateral 15	135.58	0.05	0.05	0.05	0.06	0.06	0.10	0.09	0.07	0.06	0.06	0.05	0.05
Lateral 16	61.56	0.02	0.02	0.02	0.03	0.03	0.05	0.04	0.03	0.03	0.03	0.02	0.02
La Joya Antigua	3620.89	1.45	1.39	1.47	1.52	1.67	2.68	2.28	1.96	1.68	1.50	1.43	1.43
La Joya Nueva	5896	2.36	2.27	2.39	2.48	2.71	4.36	3.71	3.18	2.74	2.45	2.33	2.33

Picture A6-1 Division Structures and Canal Ruler at the Beginning Of Lateral 1

Appendix 7 Field Measurement

A7.1 Discharge Measurement

The discharge measurement was performed using Float Method. This method was chosen due to the lack of time and facilities.

The formula for calculating the discharge from field measurement is:

$$Q = V * A$$

In which,

Q = Discharge in the canal, m3/s;
V = Average flow velocity, m/s;
A = Wetted cross section of the canal, m2.

A7.2 Velocity Measurement

The velocity measurement is done by measuring the time that a float needs to pass a certain distance. During the fieldwork, a fixed distance of 10 meters was applied along a straight and uniform section in each measurement. Marks (stones, branches, rulers, etc) at the beginning and the end of the section were made. Two types of floats were used for the measurement -- short branches and a 1.5 liter plastic bottle filled with 50% of water. The short branches were mainly used for the middle and small sized irrigation canals; while the plastic bottle was used for the big sized irrigation canals. The water filled in the plastic bottle has the purpose of avoiding the unexpected external influences (such as wind and rapid flow) to the float. A rope of 50 meters long was tied to the plastic bottle to drag the bottle back after each measurement to protect the irrigation system and the environment.

At least two people (A and B for short) are required for this measurement. A stands at the beginning of the section and throws a float at least 5 meters upstream in the middle of the canal. When the float enters the beginning of the section, A shouts out immediately to inform the B who stands at the end of the section. At the same time, B starts the stopwatch and keeps tracing the float. When the float passes the end of the section, B stops the stopwatch immediately and takes down the time. This is repeated 4 to 5 times for each measured section of the irrigation canal and the average values were taken for calculation.

Some exceptions were made considering the conditions of the weather and the irrigation canals:

1) When the irrigation canal encounters frequent winding or dimension change, a straight section less than 10 meters was applied.

2) If the float deviated from the middle line of the irrigation canal or the float was obviously influenced by wind, the measurement became invalid and another round needed to be performed.

The flow velocity can be calculated by the following formula:

$$V_s = L / t'$$

In which,

V_s = Flow velocity, m/s;
L = Distance of the measuring section, m;
t' = The reasonable average travel time of the float, s.

The flow velocity calculated above is the surface flow velocity. Because water flows faster at surface than subsurface, a reduction factor is needed to estimate the average flow velocity in the canal. For most of the irrigation canals, this reduction factor is about 0.75[52]. The average flow velocity is calculated as follows:

$$\boxed{V = 0.75 * V_s}$$

In which,

V = Average flow velocity, m/s.
0.75 = Reduction factor.
V_s = (Surface) Flow velocity, m/s.

A7.3 Dimension Measurement

The dimension measurement was done using one tape ruler and two scaled sticks. The method of this measurement is illustrated in **Picture A7-1**.

The wetted cross section can be calculated using following formulae:

$$\boxed{A = (b + B) * h / 2} \quad \text{For a trapezoidal cross section}$$

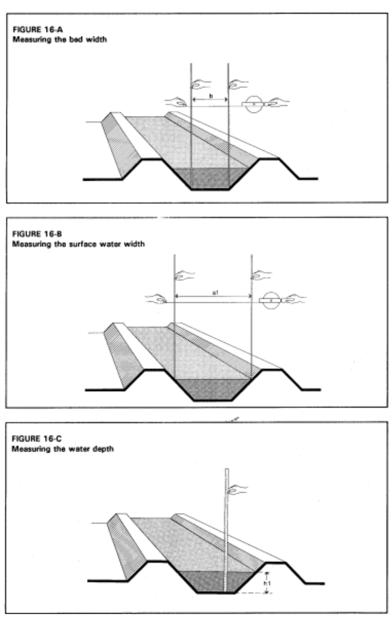
or

$$\boxed{A = b * h} \quad \text{For a rectangular cross section}$$

In which,

A = Average area of the wetted cross section, m2;
b = Average bed width of the canal, m;
B = Average surface width of the flow, m;
h = Average flow depth, m.

The tools that were used for the discharge measurement are shown in **Picture A7-2**. The dimension and discharge data collected from the field measurement are listed in **Table A7-1**.



Picture A7-1 Dimension Measurement[53]

Picture A7-2 Tools for Field Measurement

52 FAO (Rome, October 1992). *Irrigation Water Management -- Training manual no. 7. Canals.* Provisional Edition. Chapter 3 Discharge. P10. Available online: ftp://ftp.fao.org/agl/aglw/fwm/Manual7.pdf
53 FAO (Rome, October 1992). *Irrigation Water Management -- Training manual no. 7. Canals.* Provisional Edition. Chapter 3 Discharge. P10. Available online: ftp://ftp.fao.org/agl/aglw/fwm/Manual7.pdf

Table A7-1 Data Collected from Field Measurement

Canal Name	Canal Shape	Width Canal Surface	Width Canal Bottom	Width Water Surface	Depth Flow	Depth Canal	Discharge	Remarks	Time & Date
		(m)	(m)	(m)	(m)	(m)	(m3/s)		
Canal Madre (Main Canal)	Rectangular	8.91	8.91	8.91	1.10	1.30	10.50	On Average	May 24th 7:00am
							11.11	Canal Ruler	
Lateral 1	Rectangular	2.00	2.00	2.00	Could not measure	0.66	1.40	Canal Ruler	April 25th 11:15am
Lateral 1A	Trapezoidal	2.09	0.53	1.72	0.74	0.97	0.98	Float Method -- Plastic Bottle	April 25th 2:50pm
Lateral 1C	Trapezoidal	2.36	1.70	2.03	0.13	0.26	0.52	Float Method -- Plastic Bottle	April 25th 3:55pm
Lateral 1A-A	Trapezoidal	0.87	0.41	No Water	No Water	0.59	0.00	No Water	April 25th 11:15am
Lateral 1A-2	Trapezoidal	1.70	0.63	1.07	0.19	0.46	0.27	Float Method -- Branches	April 26th 10:00am
Lateral 1A-4	Trapezoidal	2.24	1.19	1.667	0.25	0.55	0.46	Float Method -- Plastic Bottle	April 25th 5:00pm
Lateral 1A-4 Midstream	Trapezoidal	1.92	0.97	1.57 (Water Mark)	0.39 (Water Mark)	0.56	0.00	No Water	May 28th 5:34pm
Lateral 1A-4 Downstream	Trapezoidal	1.54	0.73	1.22 (Water Mark)	0.38 (Water Mark)	0.53	0.00	No Water	May 28th 5:34pm
Lateral 6	Trapezoidal	1.07	0.58	0.88	0.35	0.58	0.16	Float Method -- Branches	April 26th 12:00pm
							0.13	Float Method -- Plastic Bottle	
							0.21	Canal Ruler	
							0.18	Control Gate	April 29th 6:00pm
Lateral 6-1	Trapezoidal	1.08	0.87	0.97	0.32	0.65	0.19	Float Method -- Branches	
Lateral 15	Trapezoidal	1.72	0.95	1.13	0.08	0.36	0.23	Float Method -- Branches	April 29th 4:50pm
							0.23	Control Gate	
FERNANDEZ	Trapezoidal	0.59	0.57	No Water	No Water	0.74	0.00	No Water	
REFORMATO -RIO	Trapezoidal	0.74	0.56	No Water	No Water	0.76	0.00	No Water	
Lateral 2-15	Trapezoidal	1.30	0.68	No Water	No Water	0.73	0.00	No Water	
Lateral S/N-15	Trapezoidal	0.85	0.70	No Water	No	0.60	0.00	No Water	
Lateral S/N-15-1	Rectangular	0.50	0.50	No Water	No	0.34	0.00	No Water	
Lateral S/N-15 after Lateral S/N-15-1	Trapezoidal	0.46	0.43	No Water	No Water	0.36	0.00	No Water	
Discharge to a downstream farm	Trapezoidal	1.68	0.9	1.68	0.48	0.48	0.27	Float Method -- Branches	
Lateral 16	Trapezoidal	1.02	0.43	0.64	0.24	0.67	0.12	Float Method -- Branches	April 26th 3:45pm
Discharge to upstream Farm 00904	Rectangular	1.10	1.10	1.10	0.32	0.67	0.11	Float Method -- Branches	

Note: 'No Water' indicates that there was no water in the irrigation canal during the field measurement.

Comparisons between the calculated assigned discharges, discharges from the field measurement, and the discharges indicated on the canal rulers/control gates are shown in **Table A7-2**. As can be seen from the Table, the discharges measured in Lateral 6 and Lateral 15 are in the same order of magnitude as the discharges indicated on the canal rulers/control gates, which indicates the field measurement is more or less accurate. However, the measured discharges are twice as big as the assigned discharges. This was further confirmed with one of the engineers from ALA Chili--when ALA Chili received complaints from the downstream irrigation district of La Joya Nueva, engineers were sent to check the discharges that were taken by the laterals in the irrigation district of La Joya Antigua. Most of the time, a double amount of the allowable assigned discharges was found in the laterals in the irrigation district of La Joya Antigua. There are several reasons that ALA Chili could not enforce their power to control the amount of irrigation water taken by the irrigation district of La Joya Antigua: 1) ALA Chili does not have enough money to pay for a person to permanently control the amount of irrigation water that was taken by each lateral; 2) The local farmers do not know technically that they are taking too much water but instead, they always think they do not have enough water -- when engineers from ALA Chili tried to regulate the discharges taken by the laterals, the farmers resisted by force. Thus, more irrigation water was taken by the irrigation district of La Joya Antigua, while leaving the downstream irrigation district La Joya Nueva a lack of irrigation water. In coping with this situation, the irrigation district of La Joya Nueva is 'forced' to use the irrigation water more efficiently and is seeking money from ALA Chili to build their own irrigation canal directly from the water source.

Based on the facts above, the discharges in the laterals from Lateral 2 to Lateral 16 are assumed twice as much as the calculated assigned discharges; and the discharge in Canal Madre is enlarged correspondingly as well. Exception is made in Lateral 1, the discharge of which is already large compared to other laterals. Since the flow capacity in Canal Madre is 12.5 m^3/s, the discharge in the Canal Madre that is larger than 12.5 m^3/s after the enlargement is brought back to 12.5 m^3/s. The monthly discharges in Canal Madre after enlargement are listed in **Table A7-3** and **Table A7-4**.

Table A7-2 Comparison between Discharges Assigned by ALA Chili and Discharges From Field Measurement

Laterals	Assigned Discharge (l/s)	Field Measurement -- Float Method (l/s)	Canal Ruler/ Control Gate (l/s)	Time & Date
Lateral 1	1400	--	1400 (Canal Ruler)	April 25 11:15am
Lateral 6	73	156 (Branches) 134 (Bottle)	210 (Canal Ruler)	April 26 12:00pm
Lateral 15	117	226 (Branches)	225 (Control Gate)	April 29 4:50pm
Lateral 16	53	117 (Branches)	--	April 26 3:4pm

Table A7-3 (Enlarged) Monthly Discharge in Canal Madre in a Wet Year

Canal Name	Irrigated Area (ha)	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
	Irrigation Modules	0.807	0.816	0.884	0.892	0.904	0.892	1.163	0.852	0.865	1.186	0.990	0.996
La Joya (Canal Madre)	9516.89	9.293	9.398	10.184	10.278	10.418	10.28	**12.5***	9.814	9.964	**12.5***	11.40	11.473

Note: The sign '*' indicates that the discharge equals to the flow capacity of Canal Madre.

Table A7-4 (Enlarged) Monthly Discharge in Canal Madre in a Dry Year

Canal Name	Irrigated Area (ha)	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
	Irrigation Modules	0.400	0.385	0.405	0.420	0.460	0.740	0.630	0.540	0.465	0.415	0.395	0.395
La Joya (Canal Madre)	9516.89	4.608	4.435	4.665	4.838	5.299	8.524	7.257	6.220	5.356	4.780	4.550	4.550

Appendix 8 Simulation of Discharge -- SOBEK Model

Although discharge measurement was performed, not all the irrigation canals could be measured due to the unaccessibility to certain irrigation canals and the lack of time. For such irrigation canals, SOBEK model is used to simulate the flow in the canal.

To set up SOBEK model, some necessary assumptions were made:

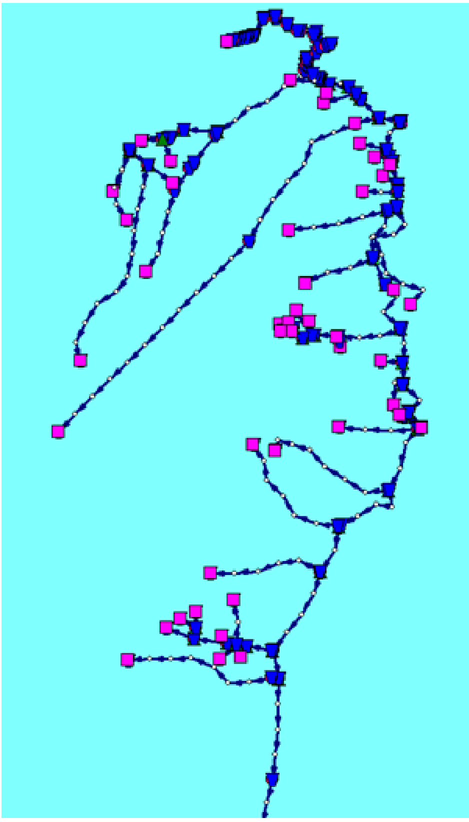
1) When Canal Madre meets its flow capacity, all the first and second order irrigation canals meet their capacity as well;

2) Gates along the same irrigation canals were assumed to have the same dimensions;

3) Bed levels of the downstream irrigation canals are connected with the bed levels of the upstream canals.

4) To prevent the influence of variable annual precipitation on the flows, the precipitation is set to be zero in the model.

For canal information that was not available, a report containing the studies on the irrigation canals of the irrigation district of La Joya Antigua was used.[54] The layout of the SOBEK model for the irrigation district of La Joya Antigua is show in **Picture A8-1**.



Picture A8-1 SOBEK Model - irrigation district of La Joya Antigua

Based on the monthly discharges in Canal Madre, the discharges in the irrigation canals that deliver irrigation water to the studied farms are simulated using SOBEK model and the results are listed in **Table A8-1** and **Table A8-2**.

54 Junta De Usuarios Del Distrito De Riego Chili La Joya Antigua (2006). Inventario de La Infraestructura de Riego y Drenaje y Vías de Comunicación del Junta de Usuarios La Joya Antigua.

Table A8-1 Discharges Simulated Using SOBEK Model in a Wet Year

Canal Name / Month	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Canal Madre	9.293	9.398	10.184	10.278	10.418	10.280	12.500	9.814	9.964	12.500	11.400	11.473
Lateral 1	1.322	1.344	1.506	1.526	1.555	1.526	1.993	1.431	1.460	1.993	1.760	1.776
Lateral 1A	0.778	0.790	0.880	0.891	0.907	0.891	1.149	0.838	0.855	1.149	1.021	1.029
Lateral 1C	0.544	0.553	0.626	0.635	0.648	0.635	0.844	0.592	0.605	0.844	0.739	0.746
Lateral 1C-1	0.128	0.130	0.147	0.149	0.152	0.149	0.199	0.139	0.142	0.199	0.174	0.176
Lateral 1A-A	0.145	0.147	0.161	0.162	0.165	0.162	0.200	0.154	0.157	0.200	0.182	0.183
Lateral 1A-2	0.162	0.165	0.188	0.191	0.195	0.191	0.271	0.178	0.182	0.271	0.229	0.231
Lateral 1A-4	0.300	0.305	0.347	0.353	0.360	0.353	0.462	0.328	0.335	0.462	0.410	0.413
Lateral 6	0.151	0.197	0.144	0.146	0.201	0.167	0.168	0.136	0.138	0.150	0.151	0.153
Lateral 15	0.242	0.315	0.231	0.235	0.322	0.268	0.270	0.219	0.221	0.240	0.242	0.245
Lateral 16	0.110	0.143	0.105	0.106	0.146	0.122	0.123	0.099	0.100	0.109	0.110	0.111
La Joya Antigua Total	5.018	6.542	4.791	4.864	6.669	5.565	5.601	4.537	4.588	4.971	5.017	5.085
La Joya Nueva Total	5.262	6.859	5.023	5.100	6.993	5.835	5.873	4.757	4.810	5.213	5.261	5.332

Table A8-2 Discharges Simulated Using SOBEK Model in a Dry Year

Canal Name / Month	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Canal Madre	4.608	4.435	4.665	4.838	5.299	8.524	7.257	6.220	5.356	4.780	4.550	4.550
Lateral 1	0.411	0.380	0.421	0.452	0.536	1.165	0.912	0.710	0.547	0.441	0.400	0.400
Lateral 1A	0.266	0.248	0.272	0.289	0.338	0.691	0.549	0.436	0.344	0.283	0.260	0.260
Lateral 1C	0.145	0.132	0.149	0.162	0.199	0.474	0.362	0.274	0.203	0.158	0.141	0.141
Lateral 1C-1	0.034	0.031	0.035	0.038	0.047	0.112	0.085	0.064	0.048	0.037	0.033	0.033
Lateral 1A-A	0.057	0.054	0.059	0.062	0.071	0.131	0.108	0.089	0.072	0.061	0.056	0.056
Lateral 1A-2	0.040	0.036	0.041	0.045	0.056	0.141	0.106	0.079	0.057	0.044	0.039	0.039
Lateral 1A-4	0.074	0.067	0.076	0.083	0.103	0.259	0.195	0.145	0.106	0.081	0.071	0.071
Lateral 6	0.125	0.107	0.091	0.079	0.07	0.067	0.067	0.068	0.065	0.069	0.071	0.078
Lateral 15	0.201	0.171	0.146	0.126	0.113	0.107	0.107	0.108	0.104	0.11	0.114	0.125
Lateral 16	0.091	0.078	0.066	0.057	0.051	0.049	0.049	0.049	0.047	0.05	0.052	0.057
La Joya Antigua Total	4.161	3.542	3.036	2.615	2.334	2.221	2.221	2.249	2.165	2.277	2.362	2.587
La Joya Nueva Total	4.363	3.714	3.184	2.742	2.447	2.329	2.329	2.358	2.27	2.388	2.476	2.712

Appendix 9 Interview Questions to the Local Farmers

- Basic Information:

1. What is your name?
2. What is your gender?
3. In which year are you born?
4. What is your level of education?
5. Did you have education at an Agricultural School?
6. What other activities do you attend besides being a farmer?
7. For how long are you a farmer?
8. What are you daily activities (is it necessary to be the total day at your land) ?
9. Do you live close to your land?

- Information about Farms:

10. Which farm(s) belong to you?
11. Is it located upstream/midstream/downstream of the irrigation sector?
12. Are you satisfied with the location of your parcel?
13. How many hectares is your farm?
14. How many hectares do you irrigate when there is sufficient water?
15. How many hectares do you irrigate when there is insufficient water
16. How did you gain your land? (heritage, bought, etc)
17. Do you have workers, yes, how many?
18. How much do you pay your workers?
19. What type soil is your farm?
20. How deep is the surface soil?
21. What crops/fruits do you grow on your farm?
22. When is this crop seeded/planted? When is this crop harvest?
23. Why are you growing these crops (selling price, experience)?
24. Is there information about the yield of your land?
25. Is the yield better or worse than before? Why?
26. Are the yields of the crops used for yourself or for sell? What's the percentage for selling?
27. Are the yields or selling price provides enough to live?
28. What are the selling prices of your crops?

- Water Availability:

29. How often do you irrigate?
30. How many hours do you irrigate each time?
31. What is the average discharge to your land?
32. Who calculates your water demand?
33. Is your water demand stated in laws?
34. Are you satified with the quantity water delivered? How much water do you want?
35. When you get water, is it necessary to check if nobody else is using the water. Do you think it is a job for the Comisión de Regantes?
36. How do you check if someone else is using your water?
37. Do you have information about the amount of water your neighbours use, and do you check this? If yes, how do you check this?
38. Do you have wells / reservoirs / dripping irrigation for your farm?
39. Who constructs/pays for the reservoirs/wells?
40. How often are the canals cleaned, do you also clean the canals?
41. Who are responsible for the maintenance of the canal?
42. When you look at the irrigation system do you think the irrigation system can be better? Why? And how?
43. Did you vote for the board of the Comisión de Regantas?
44. How is the irrigation water charged? By per volume? Or by per hectare?
45. How much do you pay for the irrigation water? Are you agree with this amount?
46. Are there problems with destruction or stealing crops, and if so, what do you do against it?

- In Case of Water Shortage:

47. In which months of the year is there insufficient water?
48. In which months of the year is there severe water shortage (too little water)?
49. Did you ever suffer from a dry year? Which year is it?

- Farmers' Reaction to the Water Shortage:

50. What do you think about the water shortage?
51. What do you think is the cause of the water shortage?
52. What are the losses to your crops/fruits?
53. Do you sell the irrigation water assigned to you to other farmers? How much?
54. Do you think the local irrigation authority performs their duty well?
55. Can you ask for more water if there is not enough water for your farm?
56. Can you get extra water easily or is it very difficult?
57. Is there any people get water secretly from the main canal?
58. Are there officers supervising the abstraction of water from the main irrigation canal during the irrigation turn to ensure the water rights for every farmer?
59. Are the irrigation canals maintained from time to time?

- Deficit Irrigation:

60. What methods do you take to cope with/prevent the water shortage?
61. Are these methods based on experience or science?
62. Are you willing to change the types of crops/fruits if they demand less irrigation water? If yes, which ones? If not, why?
63. Do you know the word "Deficit Irrigation"?
64. Do you apply or have any appliance/facilities of the deficit irrigation?
65. Do you get support from authorities? (Technical, Financial?)
66. When there is not enough water, do you give up some crops? What are the crops that are given up?
67. When there is severe water shortage (too little water), do you focus on specific crops and give up the others? What are crops that are focused and what are the crops that are given up?
68. What achievement can you get by doing so? And what are the losses after the achievement?
69. In case the farmer applies the deficit irrigation, what achievement can you get? And what are the losses after the achievement?
70. Can I have your telephone/ mobile phone number for further contact?

Appendix 10 Crop and Soil Information

Table A10-1 Crop and Soil Information

Location	Water Source	Soil Type	Soil Depth (m)	Crop Type	Plant Density (Plants/m2)	Effective Rooting Depth[55] (m)	Planting / Harvest Time
L1 Upstream	L 1A-A	Loamy Sand	1 m	Cactus (50%)	6	0.4	January - December
				Garlic (25%)	55.6	0.3	January - July
				Alfalfa (25%)	22.2	1	6 cuts per year. Planted in May 2010, will be replanted in May 2012
L1 Midstream	L 1C-1	Loamy Sand	0.5 m; Assume 1 m	Garpe (100%)	0.8	1	Planted 4 years ago. The harvest is in October and lasts 40 days of harvest.
L1 Midstream	L 1A-2	Loamy Sand	0.5 m; Assume 1 m	Onion (20%)	55.6	0.3	February - late May
				Garlic (40%)	55.6	0.3	January - late June
				Cactus (40%)	6	0.4	Recently planted. The harvest to be in August
L1 Downstream	L 1A-4	Loamy Sand	1.5 m; Assume 1 m	Cactus (99%)	6	0.4	Has been planted for 13 years. The harvest is very 4 months.
				Alfalfa (1%)	22.2	1	Has been planted for one year. Planted in October. Has 12 cuts a year.
L6 Midstream	L 6, L 6-1, L6-1-1	Sandy	1 m	Potato (30%)	4	0.4	February 6th - May Another variety: March 19th - June
				Garlic (10%)	55.6	0.3	February 8th - August.
				Cactus (20%)	6	0.4	Has been planted for 3.5 years. Harvested in February. The harvest is every 4 months.
				Avocado (20%)	0.2	0.5	Planted in 2008. In 2009 was harvested a little because the production takes two years.
				Onion (10%)	55.6	0.3	April - May
				Alfalfa (10%)	22.2	1	(American Variety) Planted in 2010. Two cuts per year.
L15 Upstream	L 15	Loamy Sand	0.5-0.7 m; Assume 1 m	Potato (5/3 ha)	4	0.4	July to September
				Maize (7 ha)	7.5	1	
				Paprika (5/3 ha)	8.3	0.5	Winter - summer
				Leek (4/3 ha)	66.7	0.3	
				Celery (2/3 ha)	16	0.3	
				Alfalfa (the rests)	22.2	1	
L15 Upstream	L 15	Loamy Sand	0.5-0.7 m; Assume 1 m	Maize (5 ha)	7.5	1	
				Garlic (5 ha)	55.6	0.3	
				Oats (the rests)	30.9	1	
				Barley (the rests)	120	1	
L15 Midstream	L 15, GOMEZ	Loamy Sand	1 m	Cactus (80%)	6	0.4	Planted in October, November and December. The 1st harvest is in May.
				Onion (20%)	55.6	0.3	January - April
L15 Midstream	L 15, L 2-15	Sandy	0.3 m; Assume 1 m	Cactus (70%)	6	0.4	Planted in January 2010. The 1st harvest in June.
				Potato (15%)	4	0.4	March 15th - June.
				Maize (5%)	7.5	1	May - September 15.
				Alfalfa (10%)	22.2	1	Planted in June 2010. 7 cuts per year.
L15 Midstream	L 15	Sandy	0.2 m; ; Assume 1 m	Cactus (100%)	6	0.4	Has planted for 8 years. 10% is 8 months old. 4/3 ha harvests every 4 months.
L15 Downstream	L 15, L S/N-15	Clay	7 m	Cactus (98%)	6	0.4	Planted 10 years ago. Replanted every 4 years. Harvested every 4months.
				Alfalfa (2%)	22.2	1	Planted in 2010. Every 1.5 months each cut is made.

55 Richard G. Allen, et al. FAO - Food and Agriculture Organization of the United Nations (Rome, 1998). Crop evapotranspiration - *Guidelines for computing crop water requirements - FAO Irrigation and drainage.* P 56. ISBN 92-5-104219-5. Chapter 8 - ETc under soil water stress conditions. Available online: http://www.fao.org/docrep/X0490E/x0490e0e.htm

L15 Downstream	L 15	Loamy Sand	0.3 m; Assume 1 m	Cactus (100%)	6	0.4	Has been planted about 10 years. The harvest is every 4 months. Replanted when there is no longer cactus springs.
L16 Upstream	L 16	Sandy	0.4 m; Assume 1 m	Alfalfa (50%)	22.2	1	Planted in June 2010. The cut is every 25 days. 9 cuts per year.
				Maize (50%)	7.5	1	Planted in December. Another variety: Planted in July. 4 to 5 months of harvest.

Note: 'cactus' is used as a short name for 'prickly pear cactus'.

Appendix 11 Farmers' Strategies

Table A11-1 Farmers' Strategies Coping with Water Shortage

Location	Water Source	Irrigation Interval (days)	Crop Type	Months of Water Shortage	Satisfied with Water Supply?	Have Reservoir / Well?	Change to Less Water Demanding Crops ?	What To Do When Water Shortage?
L1 Upstream	L 1A-A	3.5	Cactus (50%) Garlic (25%) Alfalfa (25%)	Oct - Dec	No.	No.	Yes. Change all to Cactus.	Only plant Cactus. Give up Garlic and Alfalfa
L1 Midstream	L 1C-1	4	Garpe (100%)	Jul	No. Only enough for 2 ha.	One, 45m*25m* 2.5m	No. Would seek ground water through a well instead.	Irrigated by gravity. Change to drip irrigation 2 months before harvest. By this way irrigation water is enough for 7 ha more. Severe Shortage: Irrigate 7 ha.
L1 Midstream	L 1A-2	4	Onion (20%) Garlic (40%) Cactus (40%)	Oct	Yes.			Only Plant Cactus. Give up Onion and Garlic
L1 Downstream	L 1A-4	4.5	Cactus (99%) Alfalfa (1%)	Oct - Dec	No.	One, 1m*4m*1 m For Garden Use	No.	Increase the distance between furrows and plants.
L6 Midstream	L 6 , L 6-1, L 6-1-1	3.5	Potato (30%) Garlic (10%) Cactus (20%) Avocado (20%) Onion (10%) Alfalfa (10%)	Aug - Oct Severe Shortage: Dec - Jan	No.	One.	Yes only if drip irrigation is applied.	Stop planting 2 ha. Severe Shortage: Change to Cactus and Avocado. Give up Potato, Garlic, Onion and Alfalfa.
L15 Upstream	L 15	3.5	Potato (5/3 ha) Maize (7 ha) Paprika (5/3 ha) Leek (4/3 ha) Celery (2/3 ha) Alfalfa (rests)	Aug - Oct Severe Shortage: Nov	Yes.	Two, 50m*50m* 2m	Yes.	Only plant Forage Crops because it is necessary for cattle. Severe Shortage: Only plant Forage Crops. Give up Traditional Crops.
L15 Upstream	L 15	3.5	Maize (5 ha) Garlic (5 ha) Oats (rests) Barley (rests)	Aug - Oct Severe Shortage: Nov	Yes.			
L15 Midstream	L 15 , GOMEZ	3.5	Cactus (80%) Onion (20%)		No.	One for 5 ha, 150m*4m* 3m	Yes. Stop planting onion.	Only plant Cactus. Give up Onion.
L15 Midstream	L 15 , L 2-15	3.5	Cactus (70%) Potato (15%) Maize (5%) Alfalfa (10%)	Aug - Jan Severe Shortage: Nov	Yes. But during dry period, need 2 more hours for irrigation.	One, 40m*40m* 2m	No. Could change to drip irrigation depending on the economy.	Only Plant Cactus. Severe Shortage: Only plant Cactus.

L15 Midstream	L 15	4	Cactus (100%)	Sep - Oct Severe Shortage: Oct	Yes.	One.	No. Because only hav Cactus planted.	Only plant Cactus. (Had already given up Traditional Crops such as Onion, Potato, Maize and Garlic.)
L15 Downstream	L 15 , L S/N-15	3.5	Cactus (98%) Alfalfa (2%)	May - Sep Severe Shortage: Apr	No. Need water for 1 ha more.	One, 20m*20m* 1.3m	No. Because only has Cactus planted and it does not require much water.	Use groundwater. Stop planting 1/3 ha in order to have enough water.
L15 Downstream	L 15	3.5	Cactus (100%)	Summer, Sep	No. Not enough for 2-3 ha and a land for domestic use (needs water for 4 ha more)	Two, 20m*20m* 2m	No. Because only has Cactus planted.	Only plant Cactus. (Had already given up Garlic, Onion, Potato and Alfalfa more than 10 years ago because of insufficient irrigation water.)
L16 Upstream	L 16	3.5	Alfalfa (50%) Maize (50%)	October - Dec Severe Shortage: Nov	Yes.	One For Cattle Use	Yes.	Only plant Alfalfa and Forage Maize.

Note: 'cactus' is used as a short name for 'prickly pear cactus'.

Appendix 12 Percentage of Readily Available Water (RAW) in the Soil

Deficit irrigation to the crops on the studied farms is simulated using AquaCrop model to see whether it can greatly relieve the crop water demand under water shortage. Deficit irrigation is defined as an optimization strategy '*whereby water supply is reduced below maximum levels and mild stress is allowed with minimal effects on yield. Under conditions of scarce water supply and drought, deficit irrigation can lead to greater economic gains than maximizing yields per unit of water for a given crop.*' [56] (FAO Water Reports 22, 2002) To apply the deficit irrigation, a redistribution of the received irrigation water received is needed, which means the necessity of reservoirs being installed on the farms.

The percentage of Readily Available Water (RAW) in the soil is an important factor deciding crop water demand. RAW is defined as '*the fraction of Total Available Water (TAW, which is the difference between the water content at field capacity and wilting point) that a crop can extract from the root zone without suffering water stress.*'[57] (FAO Paper 56, 1998). In this study, the percentage of RAW for each crop under the present irrigation method is calculated and is called 'present percentage RAW'; to simulate the crop water demand when the deficit irrigation is applied, an optimized percentage of RAW for each crop based on the optimization between crop water demand and crop yield is also calculated and is called 'optimized percentage RAW'.

To calculate the percentage of RAW in the soil, the following steps and formulae are used:

A12.1 Soil Water Depletion in the Root Zone

The evapotranspiration data is important in calculaing the soil water depletion in the root zone. The actual evapotranspiration in the irrigation district of La Joya Antigua can be calculated as follows:

$$ET = K_c * ET_0$$

In which,
ET = Actual evapotranspiration, mm/day;
K_c = Crop coefficient;
ET_0 = Reference evapotranspiration, mm/day.

In this study, the crop coefficient K_c for the mid-stage of each crop type is used to simplify the calculation.

The monthly reference evapotranspiration in the irrigation district of La Joya Antigua are calculated using the FAO ET_0 Calculator and the outputs are listed in **Table A12-1**.

Table A12-1 Reference Evapotranspiration in The irrigation district of La Joya Antigua

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_0 (mm/d)	5.4	5.4	5.2	5.1	5.4	5.2	5.6	5.8	6.2	6.5	6.5	5.9

With the monthly reference evapotranspiration data, the soil water depletion in the root zone within the irrigation interval can be calculated:

$$DPL = ET * T$$

In which,
DPL = Soil water depletion within the irrigation interval, mm;
ET = Actual evapotranspiration, mm/day;
T = Irrigation interval, day.

56 Food And Agriculture Organization of the United Nations (Rome, 2002). *Deficit Irrigation Practices. Water Reports 22.* ISBN: 92-5-104768-5.
57 Richard G. Allen, et al. FAO - Food and Agriculture Organization of the United Nations (Rome, 1998). Crop evapotranspiration - *Guidelines for computing crop water requirements - FAO Irrigation and drainage.* P 56. ISBN 92-5-104219-5. Available online: http://www.fao.org/docrep/X0490E/X0490E00.htm

A12.2 Soil Water Storage in the Root Zone

The total soil water storage can be calculated using the following formula:

$$SWS = AWSC * D_r$$

In which,
SWS = Total soil water storage, mm;
AWSC = Available water storage capacity of the soil, mm water/ m soil;
D_r = Effective rooting depth of the crop, m.

A12.3 Percentage of RAW in the Soil

With the soil water depletion and the total soil water storage in the root zone, the percentage of RAW in the soil within the irrigation interval can be calculated:

$$P = (DPL/SWS *100)\ \%$$

In which,
P = Percentage of root zone depletion, % RAW;
DPL = Soil water depletion within the irrigation interval, mm;
SWS = Total soil water storage, mm.

The percentage of root zone depletion (% RAW) within the irrigation intervals of loamy sand, sandy, and clay soils are listed in **Table A12-2**.

Table A12-2 Average Root Zone Depletion of Crops on The Studied Farms

Crop	Minimum Effective Rooting Depth[58] (m)	$K_{c\ mid}$ [59, 60]	Available Water Storage Capacity of the Soil[61] AWSC (mm water/m soil)			Total Soil Water Storage SWS (mm)			Average Root Zone Depletion (%) RAW - mid season (Note: the number in the brackets indicates irrigation interval)		
			Loamy Sand	Sandy	Clay	Loamy Sand	Sandy	Clay	Loamy Sand	Sandy	Clay
Cactus	0.4	1	100	83	200	40	33.2	80	27 (3.5 d) 31 (4 d) 35 (4.5 d)	60 (3.5 d) 68 (4 d)	25 (3.5 d)
Garlic	0.3	1				30	24.9	60	62 (3.5 d) 71 (4 d)	76 (3.5 d)	-
Alfalfa	1	1.2				100	83	200	24 (3.5 d) 31 (4.5 d)	29 (3.5 d)	12 (3.5 d)
Grape	1	0.85				100	83	200	20 (4 d)	-	-
Onion	0.3	1.05				30	24.9	60	74 (4 d) 65 (3.5 d)	78 (3.5 d)	-
Potato	0.4	1.15				40	33.2	80	61 (3.5 d)	64 (3.5 d)	-
Avocado	0.5	0.85				50	41.5	100	-	41 (3.5 d)	-
Maize	1	1.2				100	83	200	23 (3.5 d)	29 (3.5 d)	-
Paprika	0.5	1.052				50	41.5	100	44 (3.5 d)	-	-
Leek	0.3	1.05				30	24.9	60	71 (3.5 d)	-	-
Celery	0.3	1.05				30	24.9	60	74 (3.5 d)	-	-
Oats	1	1.15				100	83	200	23 (3.5 d)	-	-
Barley	1	1.15				100	83	200	23 (3.5 d)	-	-

Note: 'cactus' is used as a short name for 'prickly pear cactus'.

58 Richard G. Allen, et al. FAO - Food and Agriculture Organization of the United Nations (Rome, 1998). Crop evapotranspiration - *Guidelines for computing crop water requirements - FAO Irrigation and drainage.* P 56. ISBN 92-5-104219-5. Chapter 8 - ETc under soil water stress conditions. Available online: http://www.fao.org/docrep/X0490E/X0490E00.htm
59 FAO Mean Crop Coefficients. Available online: http://texaset.tamu.edu/cropcoe.php
60 Manuel Palada, et al. AVRDC - The World Vegetable Center (Taiwan, 2011). *More Crop Per Drop - Using Simple Drip Irrigation Systems for Small-scale Vegetable Production*. ISBN 92-9058-176-X. CHAPTER 7 - Estimating Crop Water Use. Available online: http://www.avrdc.org/fileadmin/content_images/whatweoffer/crop_mgt/Chapter_7_drip_irrigation_BOOK-7.pdf
61 Janine Nyvall. British Columbia. Ministry of Agriculture, Food and Fisheries (2002). Soil Water Storage Capacity And Available Soil Moisture. *Water Conservation Factsheet*. Available online: http://www.agf.gov.bc.ca/resmgmt/publist/600Series/619000-1.pdf

Appendix 13 Simulation of Crop Water Demand -- AquaCrop Model

In order to simulate the crop water demand on the studied farms under both the present irrigation method and the deficit irrigation, the present percentage RAW and the optimized percentage RAW of each crop are necessary. In **Table A13-1**, the present and optimized percentage RAW on each studied farm are listed.

To have an overview of the crop water demand under the present percentage of RAW, farmers' strategies, under the optimized percentage of RAW, six scenarios are set up for the crops on each studied farm:

Scenario 1: Simulation of the crop water demand under the present percentage RAW.

Scenario 2: Simulation of the crop water demand under the present percentage RAW with the farmer's solution to cope with water shortage.

Scenario 3: Simulation of the crop water demand under the present percentage RAW with the farmer's will of changing crop types (only for the farms that have this information).

For the studied farms that have reservoirs installed for irrigation, the following scenarios are set up:

Scenario 4: Simulation of the crop water demand under the optimized percentage RAW (The biomass or yield reduction of the simulated crop is within 5% compared to the yield under the present percentage RAW. This is applied also to Scenario 5 and Scenario 6.).

Scenario 5: Simulation of the crop water demand under the optimized percentage RAW with the farmer's solution to cope with water shortage.

Scenario 6: Simulation of the crop water demand under the optimized percentage RAW with the farmer's will of changing crop types (only for the farms that have this information).

In order to avoid the influence of the variable annual precipitation on the crop water demand, the precipitation is set to be zero.

During the analyses, the prickly pear cactus becomes a very interesting crop. The first outputs of the AquaCrop modeling indicated that prickly pear cactus would have a high crop water demand resulting in insufficient irrigation water on most of the farms. However, this result contradicts with the farmers statements that the prickly pear cactus requires less irrigation water than the traditional crops. Based on the fact that the farmers usually know the best about what is happening on their farms, a reconsideration on the prickly pear cactus was made. The prickly pear cactus is a type of vegetation that is different from a normal crop. As a C4 crop surviving in the extreme situations in the deserts, the prickly pear cactus stores water in its pads; its stomatas only open in the night. Besides, the prickly pear cactus is extremely tolerant to water stress and is very sensitive to water logging. As mentioned in the Introduction, the prickly pear cactus in the irrigation district of La Joya Antigua is grown as a media for the cochineal farming and the harvest is every 4 months. Thus, a minimum amount of irrigation water that can keep the pads of prickly pear cactus growing is sufficient.

In order to obtain a reasonable crop water demand, the monthly crop water demand of the prickly pear cactus from the report *Plan de Cultivo y Riego 2010-2011 Junta de Usuarios Del Distrito de Riego Chili La Joya Antigua*[62] are used in this study.

A further study on the AquaCrop model for the prickly pear cactus revealed that a crop transpiration coefficient (K_{cb}) of 0.55 and a default value for the soil evaporation coefficient (K_e) may bring the water demand of the prickly pear cactus close to the referred value.

62 Junta de Usuarios Del Distrito de Riego Chili La Joya Antigua (2010). *Plan de Cultivo y Riego 2010-2011*. Anexos -- Table No. 03 Modulos Y Coeficientes De Riego De Los Cultivos.

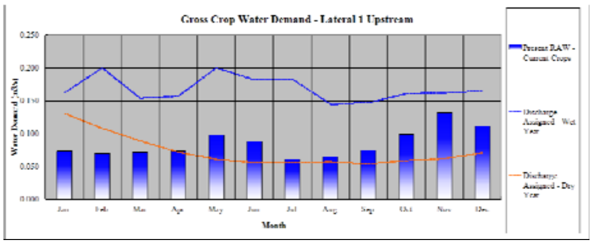
Table A13-1 Present and Optimized Percentage RAW on Each Studied Farm

Location	Water Source	Irrigation Interval (days)	Soil Type	Crop Type	Present Root Zone Depletion (%) RAW - Mid season	Optimized Root Zone Depletion (%) RAW	Yield Reduction (%)
L1 Upstream	L 1A-A	3.5	Loamy Sand	Cactus	-	-	-
				Garlic	62	70	Max. Yield
				Alfalfa	24	75	4 (Biomass)
L1 Midstream	L 1C-1	4	Loamy Sand	Grape	20	85	Max. Yield
L1 Midstream	L 1A-2	4	Loamy Sand	Onion	74	85	4% (Yield)
				Garlic	71	70	Max. Yield
				Cactus	-	-	-
L1 Downstream	L 1A-4	4.5	Loamy Sand	Cactus	-	-	-
				Alfalfa	31	80	3% (Biomass)
L6 Midstream	L 6 , L 6-1, L 6-1-1	3.5	Sandy	Potato	64	75	3.62% (Yield)
				Garlic	76	80	5% (Yield)
				Cactus	-	-	-
				Avocado	41	70	4% (Yield)
				Onion	78	85	4% (Yield)
				Alfalfa	29	70	6% (Biomass)
L15 Upstream	L 15	3.5	Loamy Sand	Potato	61	75	4% (Yield)
				Maize	23	60	5% (Yield)
				Paprika	44	65	Max. Yield
				Leek	71	75	3% (Yield)
				Celery	74	80	4% (Yield)
				Alfalfa	24	75	4% (Biomass)
L15 Upstream	L 15	3.5	Loamy Sand	Maize	23	60	5% (Yield)
				Garlic	62	70	Max. Yield
				Oats	23	70	Max. Yield
				Barley	23	85	Max. Yield
L15 Midstream	L 15 , GOMEZ	3.5	Loamy Sand	Cactus	-	-	-
				Onion	65	85	4% (Yield)
L15 Midstream	L 15 , L 2-15	3.5	Sandy	Cactus	-	-	-
				Potato	64	75	3.65% (Yield)
				Maize	29	60	5% (Yield)
				Alfalfa	29	75	5% (Biomass)
L15 Midstream	L 15	4	Sandy	Cactus	-	-	-
L15 Downstream	L 15 , L S/N-15	3.5	Clay	Cactus	-	-	-
				Alfalfa	12	65	5% (Biomass)
L15 Downstream	L 15	3.5	Loamy Sand	Cactus	-	-	-
L16 Downstream	L 16	3.5	Sandy	Alfalfa	29	80	4% (Biomass)
				Maize	29	60	5% (Yield)

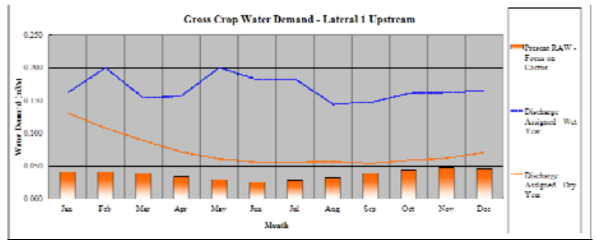
Note: 'cactus' is used as a short name for 'prickly pear cactus'.

Appendix 14 Results and Analysis of Irrigation Water Sufficiency

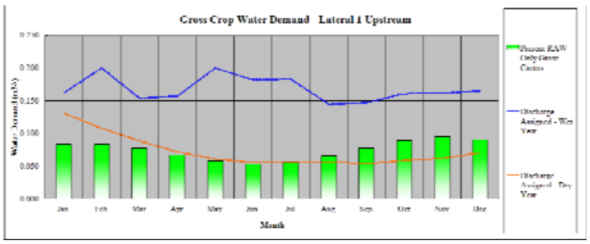
A14.1 Lateral 1 Upstream



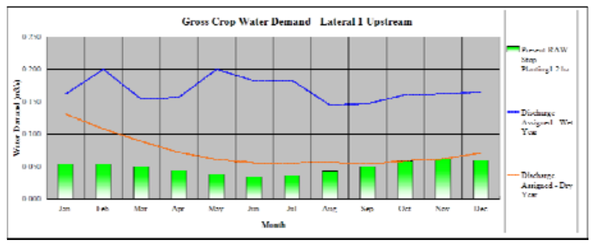
Graph A14-1-1 Crop Water Demand -- Current Crops



Graph A14-1-2 Crop Water Demand -- Focusing on Cactus



Graph A14-1-3 Crop Water Demand -- Grow 100% Cactus

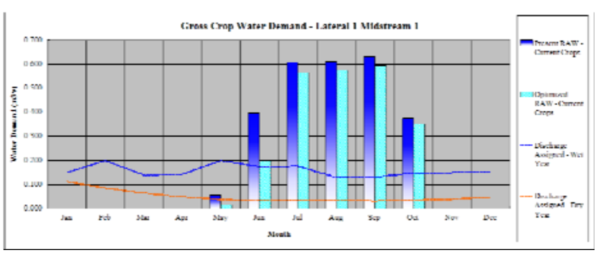


Graph A14-1-4 Crop Water Demand -- Stop Planting 1.2 ha of 100% Cactus

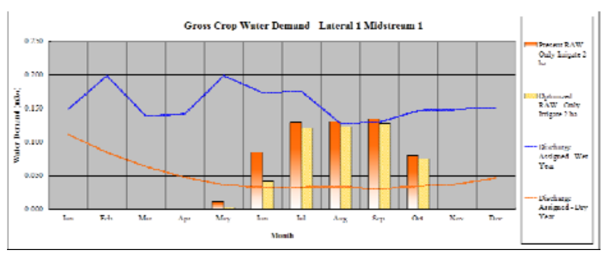
Table A14-1 Basic Information on the Farms along Lateral 1 Upstream

Location	Lateral 1 Upstream	**Water Source**	Lateral 1A-A	**Crop Type & Percentage**	Cactus (50%); Garlic (25%); Alfalfa (25%)	**Soil Type**	Loamy Sand
Farm No.	00133.01; 00133.02	**Capacity**	0.2 m3/s	**Irrigation Interval**	3.5 days	**Soil Depth (Model Input)**	1 m
Licensed Area	(2.24 + 1.2) ha	**Have Reservoir / Well?**	No	**Irrigation time**	2 h 44 min (9840 s)	**Soil Depth (Interview)**	1 m
Total Area	6.78 ha	**Methods Against Water Shortage?**	Only plant Cactus; Give up Alfalfa.	**Change Crop?**	Yes. Change all to Cactus.		

A14.2 Lateral 1 Midstream 1



Graph A14-2-1 Crop Water Demand -- Current Crops

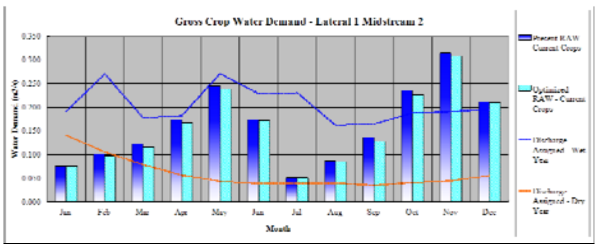


Graph A14-2-2 Crop Water Demand -- Only Irrigate 2 ha

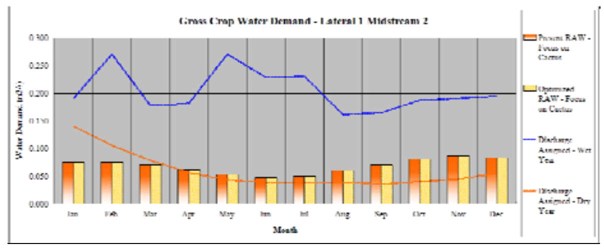
Table A14-2-1 Basic Information on the Farms along Lateral 1 Midstream

Location	Lateral 1 Midstream	**Water Source**	Lateral 1C-1	**Crop Type & Percentage**	Grape (100%)	**Soil Type**	Loamy Sand
Farm No.	00162	**Capacity**	0.2 m3/s	**Irrigation Interval**	4 days	**Soil Depth (Model Input)**	1 m
Licensed Area	9.36 ha	**Have Reservoir / Well?**	Yes. One, 45 m * 25 m *2.5 m.	**Irrigation time**	2 h 20 min (8400 s)	**Soil Depth (Interview)**	0.5 m
Total Area	9.52 ha	**Methods Against Water Shortage?**	Change from gravity irrigation to drip irrigation 2 months before harvest. By this way the water is enough for 7 ha more.	**Change Crop?**	No. Would seek for ground water through a well instead.		

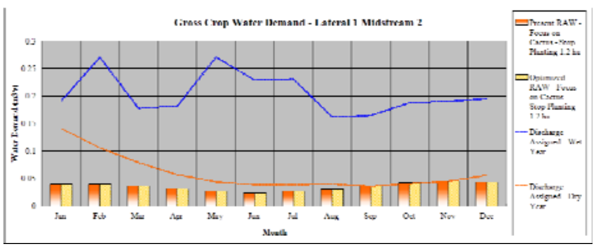
A14.3 Lateral 1 Midstream 2



Graph A14-3-1 Crop Water Demand -- Current Crops



Graph A14-3-2 Crop Water Demand -- Focus on Cactus

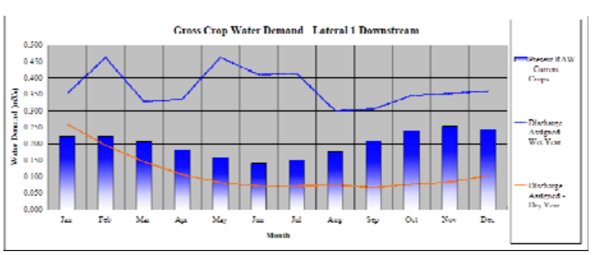


Graph A14-3-3 Crop Water Demand -- Focus on Cactus -- Stop Planting 1.2 ha

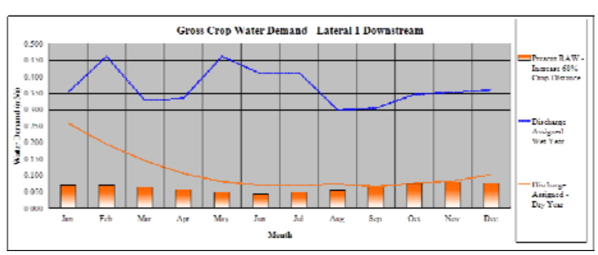
Table A14-3-1 Basic Information on the Farms along Lateral 1 Midstream

Location	Lateral 1 Midstream	**Water Source**	Lateral 1A-2	**Crop Type & Percentage**	Onion (20%); Garlic (40%); Cactus (40%)	**Soil Type**	Loamy Sand
Farm No.	00048	**Capacity**	0.32 m3/s	**Irrigation Interval**	4 days	**Soil Depth (Model Input)**	1 m
Licensed Area	6.27 ha	**Have Reservoir / Well?**	Yes. One, 45 m * 25 m *2.5 m.	**Irrigation time**	2 h 30 min (9000 s)	**Soil Depth (Interview)**	0.5 m
Total Area	6.24 ha	**Methods Against Water Shortage?**	Only plant Cactus; give up Onion and Garlic.	**Change Crop?**	No. Would seek for ground water through a well instead.		

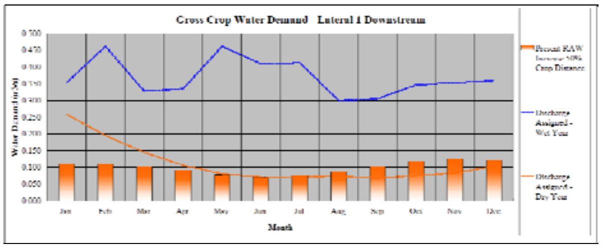
A14.4 Lateral 1 Downstream



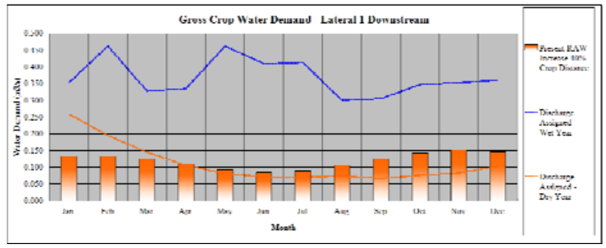
Graph A14-4-1 Crop Water Demand -- Current Crops



Graph A14-4-2 Crop Water Demand -- Increase 68% Crop Distance



Graph A14-4-3 Crop Water Demand -- Increase 50% Crop Distance

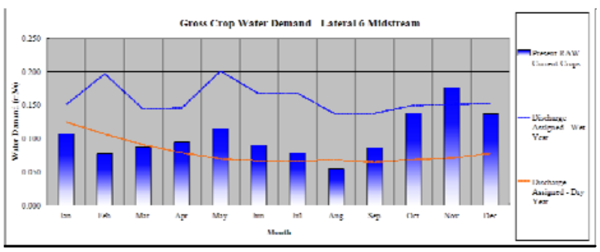


Graph A14-4-4 Crop Water Demand -- Increase 40% Crop Distance

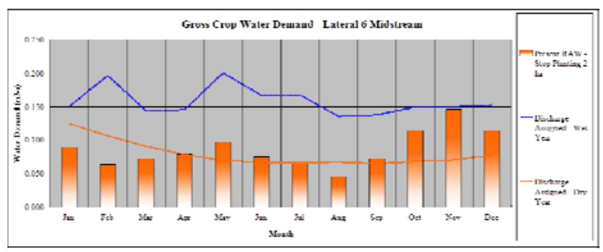
Table A14-4-1 Basic Information on the Farms along Lateral 1 Downstream

Location	Lateral 1 Downstream	**Water Source**	Lateral 1A-4	**Crop Type & Percentage**	Cactus (99%); Alfalfa (1%)	**Soil Type**	Loamy Sand
Farm No.	00118	**Capacity**	0.42 m3/s	**Irrigation Interval**	4.5 days	**Soil Depth (Model Input)**	1 m
Licensed Area	7.04 ha	**Have Reservoir / Well?**	Yes. One. Only for garden. 1m * 4m * 1m.	**Irrigation time**	2 h 43 min (9780 s)	**Soil Depth (Interview)**	1.5 m
Total Area	12.25 ha	**Methods Against Water Shortage?**	Increase distance between furrows and plants	**Change Crop?**	No. Because there is not enough water.		

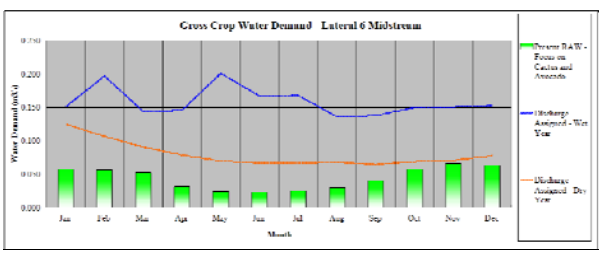
A14.5 Lateral 6 Midstream



Graph A14-5-1 Crop Water Demand -- Current Crops



Graph A14-5-2 Crop Water Demand -- Stop Planting 2 ha

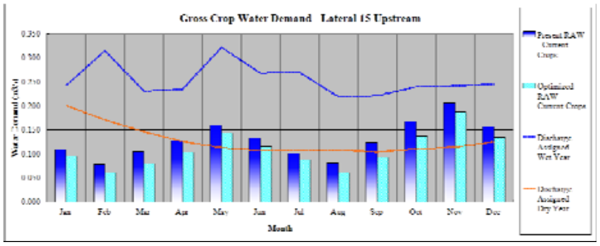


Graph A14-5-3 Crop Water Demand -- Focusing on Cactus and Avocado

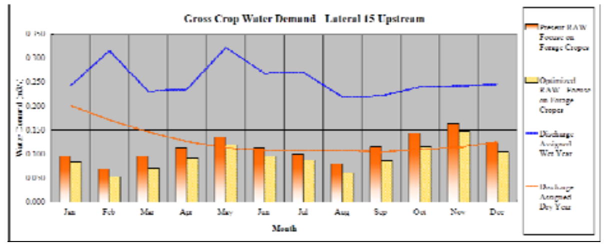
Table A14-5-1 Basic Information on the Farms along Lateral 6 Midstream

Location	Lateral 6 Midstream	**Water Source**	Lateral 6; Lateral 6-1; Lateral 6-1-1	**Crop Type & Percentage**	Potato (30%); Garlic (10%); Cactus (20%); Avocado (20%); Onion (10%); Alfalfa (10%)	**Soil Type**	Sandy
Farm No.	00615; 00618; 00616; 00617; 30006.	**Capacity**	0.28 m3/s	**Irrigation Interval**	3.5 days	**Soil Depth (Model Input)**	1 m
Licensed Area	12 ha	**Have Reservoir / Well?**	Yes. One.	**Irrigation time**	480 min (28800 s)	**Soil Depth (Interview)**	1 m
Total Area		**Methods Against Water Shortage?**	Stop planting 2 ha. Severe Shortage: Change to Cactus and Avocado; give up Potato, Garlic, Onion and Alfalfa.	**Change Crop?**	Yes if the drip irrigation is applied.		

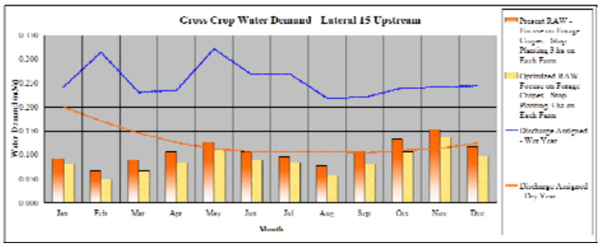
A14.6 Lateral 15 Upstream



Graph A14-6-1 Crop Water Demand -- Current Crops



Graph A14-6-2 Crop Water Demand -- Focus on Forage Crops

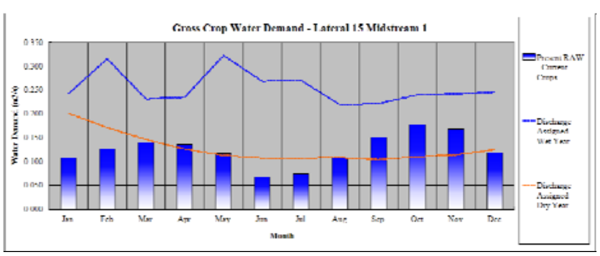


Graph A14-6-3 Crop Water Demand -- Focus on Forage Crops -- Stop Planting 3 ha on Each Farm

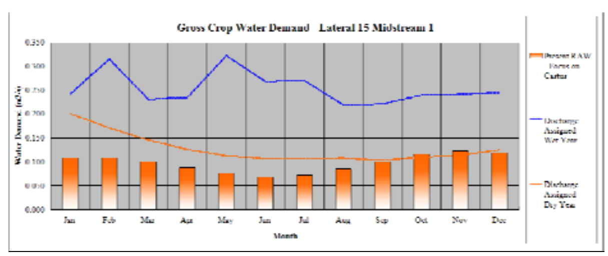
Table A14-6-1 Basic Information on the Farms along Lateral 15 Upstream

Location	Lateral 15 Upstream	**Water Source**	Lateral 15	**Crop Type & Percentage**	Farm 00872: Potato (5/3 ha); Maize (7 ha); Paprika (5/3 ha); Shallot (4/3 ha); Celery (2/3 ha); Alfalfa (rests) Farm 00873: Maize (5 ha); Garlic (5 ha); Oat & Barley (rests);	**Soil Type**	Loamy Sand
Farm No.	00872; 00873	**Capacity**	0.3 m3/s	**Irrigation Interval**	3.5 days	**Soil Depth (Model Input)**	1 m
Licensed Area	(22.67 + 28.33) ha	**Have Reservoir / Well?**	Yes. Two, 50m * 50m * 2m.	**Irrigation time**	34 h 25 min (123900 s)	**Soil Depth (Interview)**	0.5 m - 0.7 m
Total Area	(28.31 + 35.39) ha	**Methods Against Water Shortage?**	Only plant Forage Crops for his cattle; give up traditional crops such as potato and onion.	**Change Crop?**	Yes. But it's not within the region of his work.		

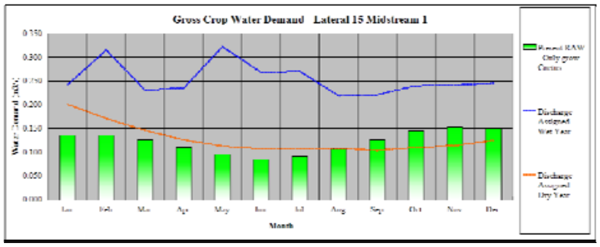
A14.7 Lateral 15 Midstream 1

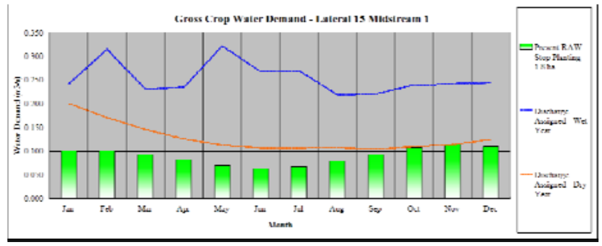


Graph A14-7-1 Crop Water Demand -- Current Crops



Graph A14-7-2 Crop Water Demand -- Focusing on Cactus





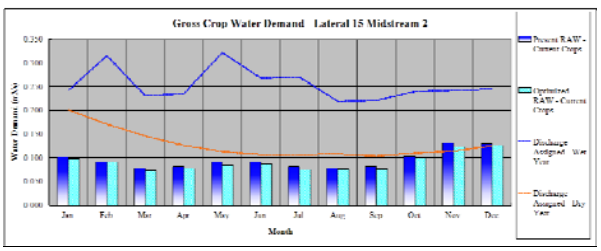
Graph A14-7-3 Crop Water Demand -- Grow 100% Cactus

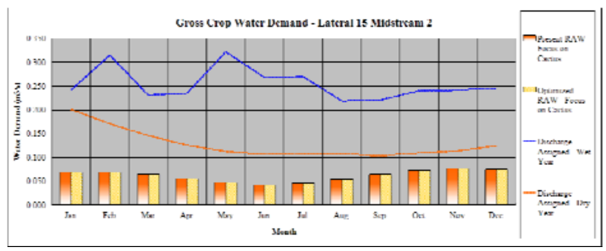
Graph A14-7-4 Crop Water Demand -- Stop Planting 2 ha of 100% Cactus

Table A14-7-1 Basic Information on the Farms along Lateral 15 Midstream

Location	Lateral 15 Midstream	**Water Source**	Lateral 15, GOMEZ	**Crop Type & Percentage**	Cactus (80%); Onion (20%)	**Soil Type**	Loamy Sand
Farm No.	00735; 00849; 2 ha more	**Capacity**	0.3 m3/s	**Irrigation Interval**	3.5 days	**Soil Depth (Model Input)**	1 m
Licensed Area	(2.5 + 2.5) ha	**Have Reservoir / Well?**	Yes. One for 5 ha, 150 m * 4 m * 3 m.	**Irrigation time**	3 h 26 min (12360 s)	**Soil Depth (Interview)**	1 m
Total Area	(6.62 + 6.03 + 2) ha	**Methods Against Water Shortage?**	Only plant Cactus.	**Change Crop?**	Yes. Only plant cactus; give up onion.		

A14.8 Lateral 15 Midstream 2





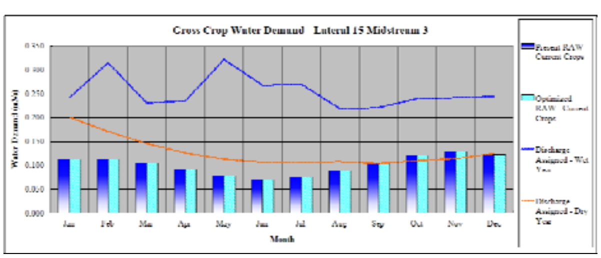
Graph A14-8-1 Crop Water Demand -- Current Crops

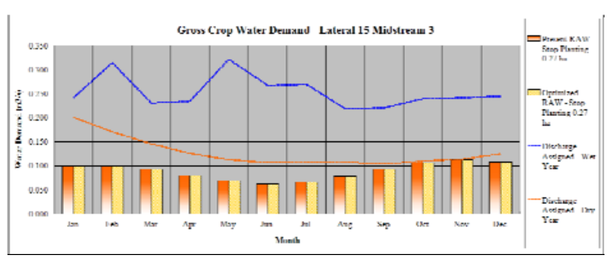
Graph A14-8-2 Crop Water Demand -- Focusing on Cactus

Table A14-8-1 Basic Information on the Farms along Lateral 15 Midstream

Location	Lateral 15 Midstream	**Water Source**	Lateral 15, Lateral 2-15	**Crop Type & Percentage**	Cactus (70%); Potato (15%); Maize (5%); Alfalfa (10%)	**Soil Type**	Sandy
Farm No.	00886.01; 00887	**Capacity**	0.3 m3/s	**Irrigation Interval**	3.5 days	**Soil Depth (Model Input)**	1 m
Licensed Area	(11.15 + 4.35) ha	**Have Reservoir / Well?**	Yes. One, 40 m * 40 m * 2 m.	**Irrigation time**	10 h 30 min (37800 s)	**Soil Depth (Interview)**	0.3 m
Total Area	(20 + 6.44) ha	**Methods Against Water Shortage?**	Only plant Cactus; give up Potato, Maize and Alfalfa.	**Change Crop?**	No. Could change to drip irrigation depending on the economy.		

A14.9 Lateral 15 Midstream 3





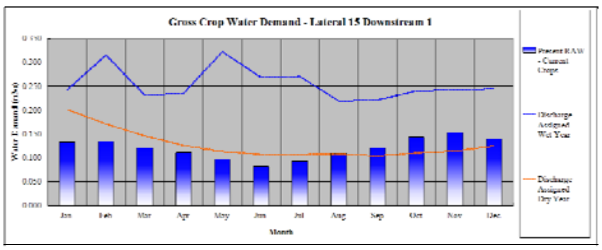
Graph A14-9-1 Crop Water Demand -- Current Crops

Graph A14-9-2 Crop Water Demand -- Stop Planting 0.27 ha

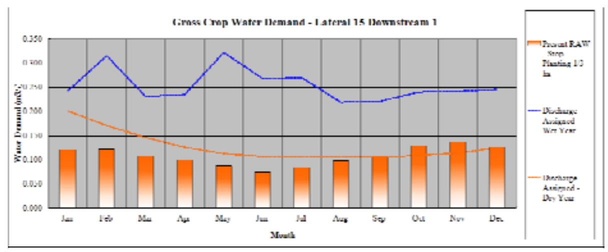
Table A14-9-1 Basic Information on the Farms along Lateral 15 Midstream

Location	Lateral 15 Midstream	**Water Source**	Lateral 15	**Crop Type & Percentage**	Cactus (100%)	**Soil Type**	Sandy
Farm No.	00886.02	**Capacity**	0.3 m3/s	**Irrigation Interval**	4 days	**Soil Depth (Model Input)**	1 m
Licensed Area	2.3241 ha	**Have Reservoir / Well?**	Yes. One.	**Irrigation time**	1 h 34 min (5640 s)	**Soil Depth (Interview)**	0.2 m
Total Area	20 ha	**Methods Against Water Shortage?**	Only has Cactus.	**Change Crop?**	No. Because only has cactus.		

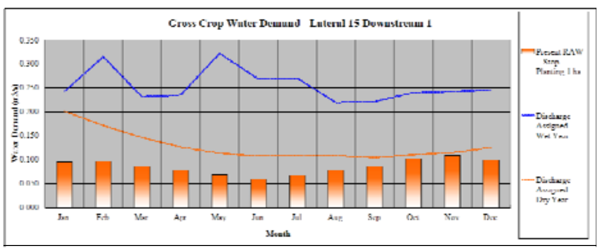
A14.10 Lateral 15 Downstream 1



Graph A14-10-1 Crop Water Demand -- Current Crops



Graph A14-10-2 Crop Water Demand -- Stop Planting 1/3 ha

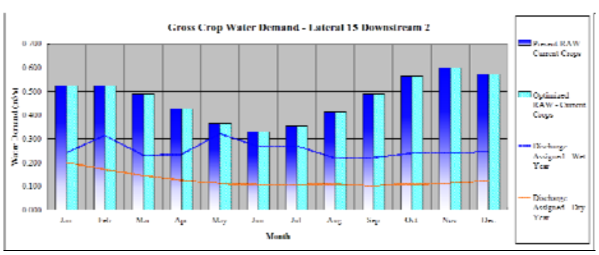


Graph A14-10-3 Crop Water Demand -- Stop Planting 1 ha

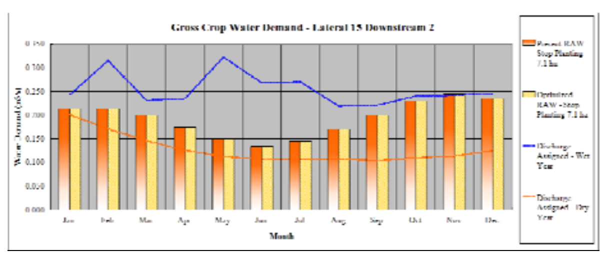
Table A14-10-1 Basic Information on the Farms along Lateral 15 Downstream

Location	Lateral 15 Downstream	**Water Source**	Lateral 15, Lateral S/N-15	**Crop Type & Percentage**	Cactus (98%); Alfalfa (2%)	**Soil Type**	Clay
Farm No.	00858; 00859	**Capacity**	0.3 m3/s	**Irrigation Interval**	3.5 days	**Soil Depth (Model Input)**	7 m
Licensed Area	(1 + 2.5) ha	**Have Reservoir / Well?**	Yes. One, 20 m * 20 m * 1.3 m.	**Irrigation time**	2 h 21 min (8460 s)	**Soil Depth (Interview)**	7 m
Total Area	(1.73 + 5.36) ha	**Methods Against Water Shortage?**	Use groundwater. Stop planting 1/3 ha.	**Change Crop?**	No. Because only has cactus.		

A14.11 Lateral 15 Downstream 2



Graph A14-11-1 Crop Water Demand -- Current Crops

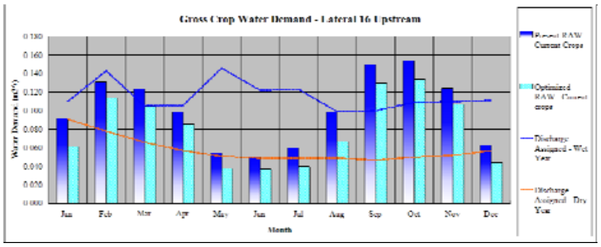


Graph A14-11-2 Crop Water Demand -- Stop Planting 7.1 ha

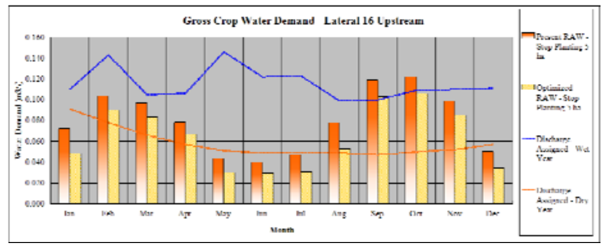
Table A14-11-1 Basic Information on the Farms along Lateral 15 Downstream

Location	Lateral 15 Downstream	Water Source	Lateral 15	Crop Type & Percentage	Cactus (100%)	Soil Type	Loamy Sand
Farm No.	00930	**Capacity**	0.3 m3/s	**Irrigation Interval**	3.5 days	**Soil Depth (Model Input)**	1 m
Licensed Area	2.5 ha	**Have Reservoir / Well?**	Yes. Two, 20 m * 20 m * 2 m.	**Irrigation time**	1 h 40 min (6000 s)	**Soil Depth (Interview)**	0.3 m
Total Area		**Methods Against Water Shortage?**	Only has Cactus.	**Change Crop?**	No. Because only has cactus.		

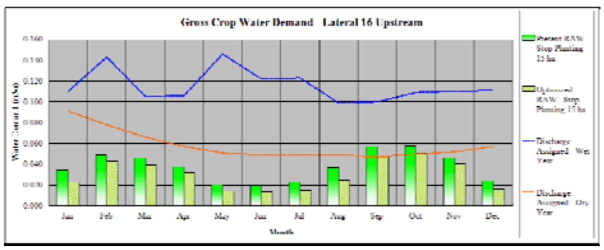
A14.12 Lateral 16 Downstream



Graph A14-12-1 Crop Water Demand -- Current Crops



Graph A14-12-1 Crop Water Demand -- Stop Planting 5 ha



Graph A14-10-1 Crop Water Demand -- Stop Planting 15 ha

Table A14-12-1 Basic Information on the Farms along Lateral 16 Upstream

Location	Lateral 16 Downstream	Water Source	Lateral 16	Crop Type & Percentage	Alfalfa (50%); Maize (50%)	Soil Type	Sandy
Farm No.	00904	**Capacity**	0.2 m3/s	**Irrigation Interval**	3.5 days	**Soil Depth (Model Input)**	1 m
Licensed Area	24 ha	**Have Reservoir / Well?**	Yes. One. Only for cattle.	**Irrigation time**	19 h 40 min (70800 s)	**Soil Depth (Interview)**	0.4 m
Total Area	26.83 ha	**Methods Against Water Shortage?**	Only plant alfalfa and forage maize.	**Change Crop?**	Yes. But didn't say.		

Appendix 15 Summary

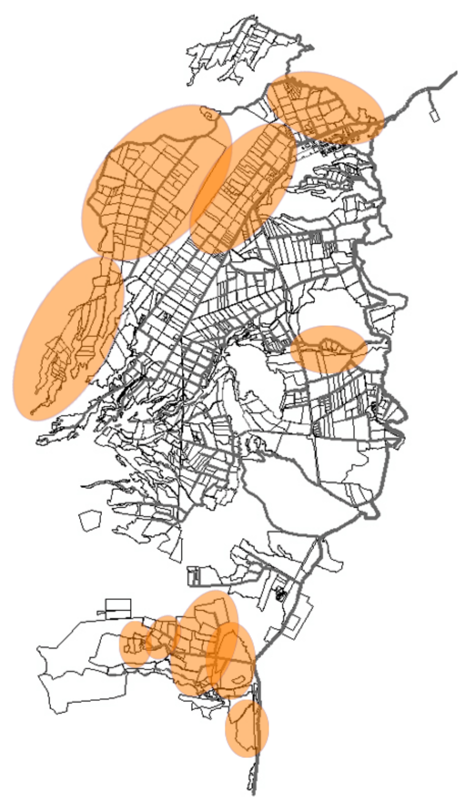
A15.1 Irrigation Water Sufficiency

Comparison between irrigation water availability and crop water demand shows irrigation water sufficiency in the irrigation district of La Joya Antigua. In **Map A15-1** irrigation water sufficiency under the present percentage RAW in a wet year is shown; in **Map A15-2**, irrigation water sufficiency under the present percentage RAW in a dry year is shown. Since the studied farms were selected to represent the farms within the upstream, midstream and downstream region, the irrigation water sufficiency of the studied farms are extended to the upstream, midstream and downstream regions as well.

From **Map A15-1** and **Map A15-2** it can be seen that although farmers on the downstream farms of Lateral 1 and Lateral 15 are not satisfied with the amount of irrigation water assigned to their farms, there is sufficient irrigation water in both of the regions. The reason for this contradiction is the crop types on the farms -- On the downstream farms of Lateral 1 and Lateral 15, more than 98% of the irrigation area of each studied farm is planted with prickly pear cactus. Interviews to the farmers on these farms revealed that half of the interviewed farmers had given up the traditional crops years ago due to the lack of irrigation water; the rest of the farmers confirmed that there is insufficient irrigation water on their farms while the prickly pear cactus has a much lower crop water demand than other crop types. Besides, 100% of the interviewed farmers considered prickly pear cactus as an important economic crop.

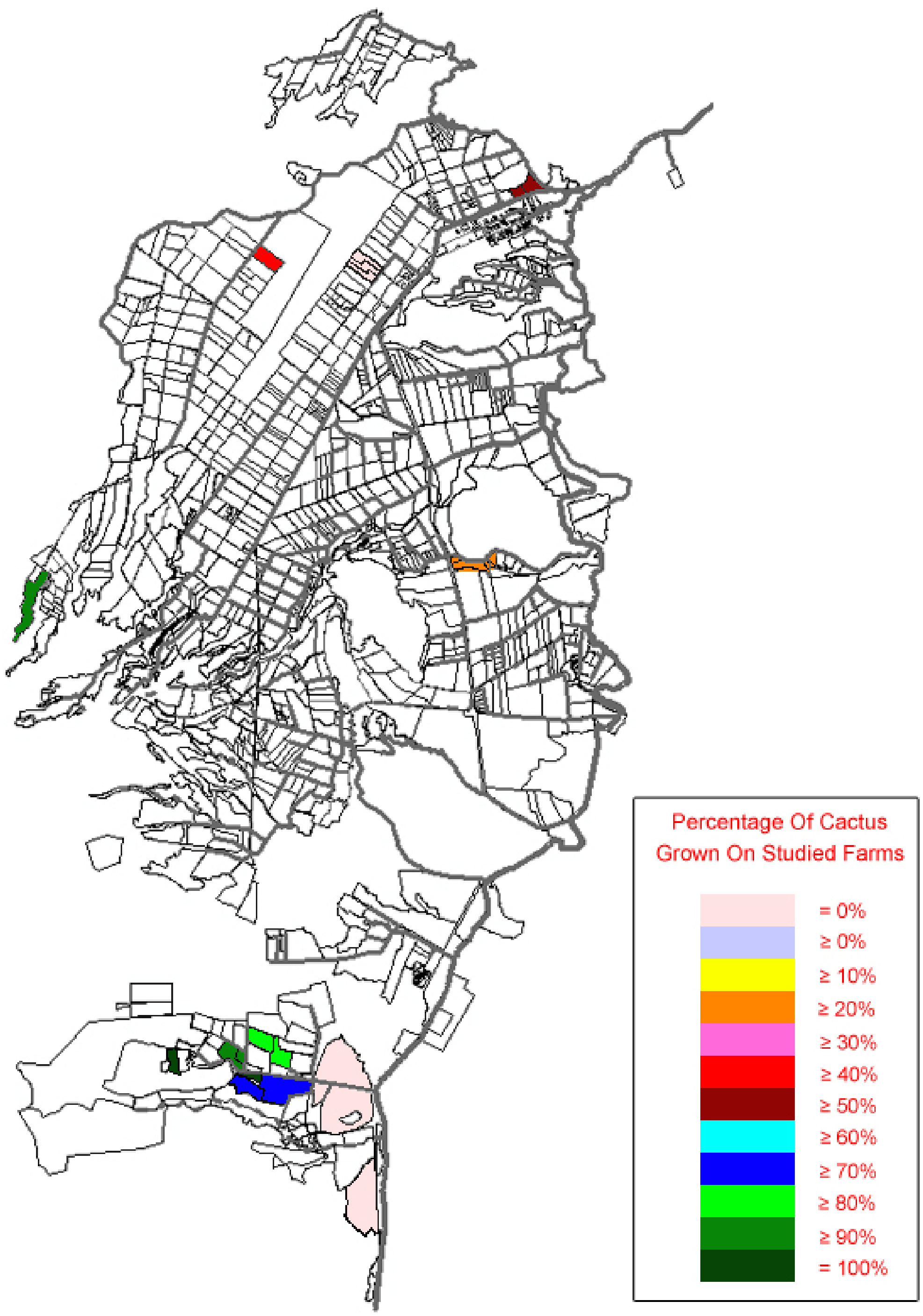
In **Map A15-3**, the percentage of prickly pear cactus that is planted on each farm studied is shown. As can be seen from the map, the percentage of prickly pear cactus increases from upstream to downstream along the studied laterals. For example, along Lateral 15, 0% prickly pear cactus is planted at upstream compared to 100% at downstream. When taking the irrigation water sufficiency into consideration (**Map A15-1**), the percentage of prickly pear cactus corresponds to the irrigation water sufficiency along the studied laterals.

Map A15-1 Irrigation Water Sufficiency - Wet Year



Map A15-2 Irrigation Water Sufficiency - Dry Year

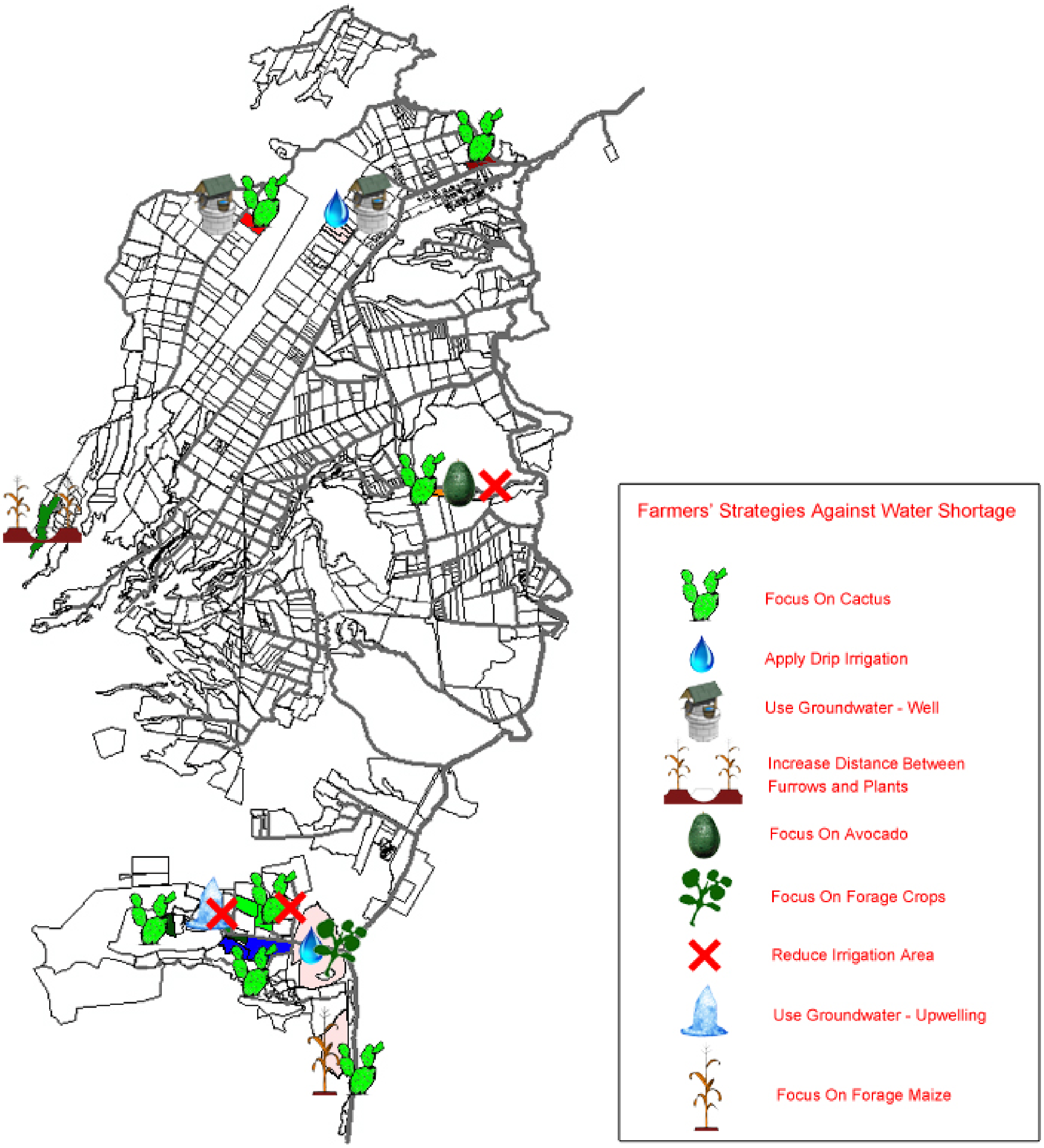
Note: - The dark blue colour represents sufficient irrigation water within the region; while the orange colour represents insufficient irrigation water within the region.
- The downstream farms of Lateral 15 and Lateral 16 have access to the upwelling groundwater.



Map A15-3 Percentage of Prickly Pear Cactus Grown on Each Studied Farm

A15.2 Farmers' Strategies Coping with Water Shortage

In order to cope with water shortage, local farmers have certain strategies according to the irrigation water availability, the locations of their farms, and their economic conditions. Although the farmers' strategies are mainly based on experience, these strategies have contributed to the continuing development of the irrigation district for more than 70 years. In **Map A15-4**, the summarization of the farmers' strategies on each studied farm is shown.



Map A15-4 Summarization of the Farmers' Strategies Coping with Water Shortage

References

1. Athahualpa's Weblog. Available online: http://athahualpa.wordpress.com/peru/
2. Peru Regions And Departments. Peru Maps. Mapsof.net. Available online: http://mapsof.net/map/peru-regions-and-departments#.TwUPcDXOXuN
3. Procesos programados para el año 2006 del de partamento de AREQUIPA . Sistema Electrónico de Contrataciones del Estado.Available online: http://app.seace.gob.pe/mon/ProcesoReporteGrafPb.jsp?tipo_cons=1&dep_codigo=04&tipo_cons_sub=3&anhoentidad=2006&anho_rep=
4. Autoridad Nacional del Agua; Ministerio de Agricultura (Lima, Perú, Junio 2009). Ley de Recursos Hídricos - Ley Nº 29338. ®
5. Official website of Autoridad Nacional del Agua; Ministerio de Agricultura. Peru. Organos Desconcentrados. Available online: http://www.ana.gob.pe/con%C3%B3cenos/organizaci%C3%B3n-y-funciones/estructura-organizacional/organos-desconcentrados.aspx#
6. Leendert van der Sluijs (2004). *Locomotion and energetics of llamas and alpacas under free-ranging conditions*. 1st Edition, 2004. Diss. Göttingen, Cuvillier Verlag, Göttingen, ISBN 3-86537-073-X.
7. Kessler A. and F. Monheim (1968). *Der Wasserhaushalt des Titicacasees nach neueren Meßer-gebnissen*, Erdkunde Bd. 22, 1968.
8. Wikipedia. Humboldt Current. Available online: http://en.wikipedia.org/wiki/Humboldt_Current
9. Wikipedia. Rain shadow. http://en.wikipedia.org/wiki/Rain_shadow
10. SEOS. *Topics of the Ocean Currents Tutorial. Ocean Currents.* Chapter 2 Wind Driven Surface Currents. http://www.seos-project.eu/modules/oceancurrents/oceancurrents-c00-p01.html
11. Junta De Usuarios Del Distrito De Riego Chili La Joya Antigua (2006). Inventario de La Infraestructura de Riego y Drenaje y Vías de Comunicación del Junta de Usuarios La Joya Antigua.
12. Ministerio del Ambiente, Instituto Geofísico del Perú, Investigación en Prevención de Desastres Naturales. Centro de Prediccion Numerica del Tiempo y Clima (CPNTC). La Joya. Available online: http://www.met.igp.gob.pe/clima/HTML/lajoya.html
13. Junta de Usuarios Del Distrito de Riego Chili La Joya Antigua (2010). *Plan de Cultivo y Riego 2010-2011*.
14. Dr. Edwin C. Olsen III (1974). Assoc. Utah State University. Sprinkler Leaching Program For Very Saline Virgin Desert Soils In The La Joya Irrigation Project Peru. Table 1. Ministerio de Agricultura. Lima, Peru. June 1974. Available online: http://pdf.usaid.gov/pdf_docs/PNAAB252.pdf
15. World Climate Guide. Arequipa Climate Guide. Available online: http://www.worldclimateguide.co.uk/climateguides/peru/arequipa.php?units=metric&style=symbols
16. Tu Tiempo.net. Historical Weather: Apequipa, Peru. Available online: http://www.tutiempo.net/en/Climate/Arequipa/847520.htm
17. AnaPeruana.com. (June 27th, 2010). Cochineal Farming in Peru. Available online: http://www.anaperuana.com/2010/06/27/cochineal-farming-in-peru/
18. Official website AUTODEMA Manejo Sostenible. Movimiento Hídrico Sistema Chili. Available online: http://www.autodema.gob.pe/

19. Gabriel Riega (2002). Thesis: *Planeamiento de La Cuenca Chili*. Anexos -- Cuadro 40.

20. FAO (Rome, October 1992). *Irrigation Water Management -- Training manual no. 7. Canals.* Provisional Edition. Chapter 3 Discharge. P10. Available online: ftp://ftp.fao.org/agl/aglw/fwm/Manual7.pdf

21. Richard G. Allen, et al. FAO - Food and Agriculture Organization of the United Nations (Rome, 1998). Crop evapotranspiration - *Guidelines for computing crop water requirements - FAO Irrigation and drainage*. P 56. ISBN 92-5-104219-5. Chapter 8 - ETc under soil water stress conditions. Available online: http://www.fao.org/docrep/X0490E/x0490e0e.htm

22. Food And Agriculture Organization of the United Nations (Rome, 2002). *Deficit Irrigation Practices*. Water Reports 22. ISBN: 92-5-104768-5.

23. FAO Mean Crop Coefficients. Available online: http://texaset.tamu.edu/cropcoe.php

24. Manuel Palada, et al. AVRDC - The World Vegetable Center (Taiwan, 2011). *More Crop Per Drop - Using Simple Drip Irrigation Systems for Small-scale Vegetable Production*. ISBN 92-9058-176-X. CHAPTER 7 - Estimating Crop Water Use. Available online: http://www.avrdc.org/fileadmin/content_images/whatweoffer/crop_mgt/Chapter_7_drip_irrigation_BOOK-7.pdf

25. Janine Nyvall. British Columbia. Ministry of Agriculture, Food and Fisheries (2002). Soil Water Storage Capacity And Available Soil Moisture. *Water Conservation Factsheet*. Available online: http://www.agf.gov.bc.ca/resmgmt/publist/600Series/619000-1.pdf