Document 525
PRE-IMPLEMENTATION REPORT

CHAPTER: Greater Austin
COUNTRY: Peru
COMMUNITY: Huasta
PROJECT: Agriculture (Irrigation)
TRAVEL DATES: July 1-24, 2013

PREPARED BY

ENGINEERS WITHOUT BORDERS-USA
www.ewb-usa.org

Pre-Implementation Report Part 1 – Administrative Information

1.0 Contact Information

	Name	Email	Phone	Chapter Name or Organization Name
Project Leads				Greater Austin
				Greater Austin
				Greater Austin
President				Greater Austin
				Greater Austin
Mentor #1				Greater Austin
Mentor #2				Texas A&M
Faculty Advisor (if applicable)				
Health and Safety Officer				Greater Austin
Assistant Health and Safety Officer				
Education Lead				Greater Austin
NGO/Community Contact				The Mountain Institute

2.0 Travel History

Dates of Travel	Assessment or Implementation	Description of Trip
8/2/2011 – 8/16/2011	Assessment	Commonwealth
1/1/2012 – 1/14/2012	Assessment	Huasta
7/12/2012 – 7/13/2012	Assessment	Huasta
12/30/2012 – 1/13/2013	Assessment	Huasta

3.0 Travel Team (Should be 8 or fewer):

#	Name	E-mail	Phone	Chapter	Student or Professional
1					Professional
2					Student
3					Student
4					Student
5					Student
6					Student
7					
8					

4.0 Health and Safety

The travel team will follow the site-specific HASP that has been prepared for this implementation trip and has been submitted as a standalone document along with this pre-trip report.

5.0 Monitoring - Identify Projects to be Monitored on this Trip

Instructions: *List the past-implemented projects, by Project Type and Project Discipline (e.g. Water Supply – Source Development), that you plan to schedule time to monitor on this trip. You are encouraged to review the Monitoring section of the 526 Instructions for an understanding of what will be expected in that report on this topic.*

Project Type	Project Discipline(s)	Date of Completion (m/d/y)
Sanitation and Technical Training	Black Water System	TBD

6.0 Budget

Instructions: *Provide total estimated expenses for your trip. Account for in-kind donations in the "Non-Budget Items" section. An in-kind donation is a non-monetary contribution to the project, such as donated labor and materials. Funding that is deposited in a 501(c)3 account (EWB-USA or university account) is not an in-kind donation. EWB-USA must account for all costs associated with a project. Count all costs from the end of the previous trip through the end of the current trip. Please be sure to account for all costs associated with a project without double-counting costs. If you have two separate trip reports that are associated with a single trip in one program, apportion costs between the trips so that you do not double-count the costs.*

For professional service hours, report the hours spent working directly on project work by each professional mentor, calculated at $100/hour. Mentor hours should be counted as follows: 1) For time spent helping prepare students for a trip, count hours spent on any activity that is related to mentoring the chapter. 2) During trips, count 8 hours per day, 7 days per week from the time that you leave home until the time that you return home.

6.1 Project Budget

Project ID: **009122**

Type of Trip: I

Trip type: A= Assessment; **I**= Implementation; **M**= Monitoring & Evaluation	
Trip Expense Category	**Estimated Expenses**
Direct Costs	
Travel	*Budget is for 6 travelers*
Airfare	$7,200
Gas	$200
Rental Vehicle	
Taxis/Drivers	$100
Misc.	$420

Travel Sub-Total	$7,920
Travel Logistics	
Exit Fees/ Visas	
Inoculations	
Insurance	$216
Licenses & Fees	
Medical Exams	
Passport Issuance	
Misc.	
Travel Logistics Sub-Total	$216
Food & Lodging	
Lodging	$300
Food & Beverage (Non-alcoholic)	$900
Misc.	
Food & Lodging Sub-Total	$1,200
Labor	
In-Country logistical support	
Local Skilled labor	$315
Misc.	
Labor Sub-Total	$315
EWB-USA	
Program QA/QC **(1)** See below	$3,675
EWB-USA Sub-Total	$1,225
Project Materials & Equipment (Major Category Summary) add rows if needed	*Itemized materials costs are given in Appendix K*
Conveyance Pipeline	$2,605
Spring Boxes and Break Pressure Tank	$507.50
In-field Irrigation System	$2,916.10
Project Materials & Equipment Sub-Total	$6,343.60
Misc. *(Major Category Summary)*	
Report Preparation	
Advertising & Marketing	
Postage & Delivery	
Misc. Other	
Misc. Sub-Total	$0
TOTAL	$19,669
a. (1) Program QA/QC Assessment = $1,500 Implementation = $3,675 Monitoring = $1,125	
EWB-USA National office use:	
Indirect Costs	
EWB-USA	
Program Infrastructure **(2)** See Below	$1,225

Sub-Total	$1,225
TRIP GRAND TOTAL (Does not include Non-Budget Items)	$20,894
a. (2) Program Infrastructure Assessment = $500 Implementation = $1,225 Monitoring = $375	
Non-Budget Items:	
Additional Contributions to Project Costs	
Community	
Labor	
Materials	
Logistics	
Cash	
Other	
Community Sub-Total	$0
EWB-USA Professional Service In-Kind	
Professional Service Hours	
Hours converted to $ *(1 hour = $100)*	$0
Professional Service In-Kind Sub-Total	$0
TRIP GRAND TOTAL (Includes Non-Budget Items)	$0
Chapter Revenue	
Funds Raised for Project by Source	**Actual Raised to Date**
Source and Amount *(Expand as Needed)*	
Project Balance	$8,893.96
Travel Team Donations	$3,000
Holiday Fundraiser	$5,226
Misc.	
EWB-USA Program QA/QC Subsidy **(3)** See below	$3,900
EWB-USA Program Infrastructure Discount Amount	
Total	$21,019.96
Remaining Funds Needed	**$0**

○ (3) Program QA/QC & Infrastructure Subsidy:
Assessment = $1500
Implementation = $3,900
Monitoring = $1,000

6.2 Donors and Funding

Donor Name	Type (company, foundation, private, in-kind)	Account Kept at EWB-USA?	Amount
Total Amount Raised:			

7.0 Project Discipline(s): Check the specific project discipline(s) addressed in this report. Check all that apply.

Water Supply ____ Source Development ____ Water Storage ____ Water Distribution ____ Water Treatment ____ Water Pump **Sanitation** ____ Latrine ____ Gray Water System ____ Black Water System **Structures** ____ Bridge ____ Building	**Civil Works** ____ Roads ____ Drainage ____ Dams **Energy** ____ Fuel ____ Electricity **Agriculture** ____ Irrigation Pump _X_ Irrigation Line ____ Water Storage ____ Soil Improvement ____ Fish Farm ____ Crop Processing Equipment **Information Systems** ____ Computer Service

8.0 Project Location

Latitude: -10.041267
Longitude: -77.18789

9.0 Project Impact

Number of persons directly affected: ~ 600
Number of persons indirectly affected: ~ 1800

10.0 Professional Mentor/Technical Lead Resume - Please see document *405 - Mentor Qualifications* for Professional Mentor/Technical Lead requirements related to the project area. This can be found in the Sourcebook Downloads on the member pages of the website.

Travelling Mentor – Tim Ager (see Appendix P for resume)
Technical Mentor – Dr. Guy Fipps (resume can be obtained through personal website: http://gfipps.tamu.edu/documents/Fipps%20resume%202-13.pdf)

Pre-Implementation Report Part 2 – Technical Information

1.0 EXECUTIVE SUMMARY

The following pre-implementation report prepared by the Climate Adaptation in Mountain Basins in the Andean Region (CAMBIAR) program within the Greater Austin Chapter of Engineers Without Borders is being submitted to EWB-USA to request approval for the first implementation of the second project in Huasta, Peru – Agriculture (Irrigation), project number 009122. This document provides the background and basis for the trip and outlines the plan and schedule of activities for completing the irrigation project implementation. The report also includes a section on details supporting monitoring activities for the first project (sanitation and technical training) in Huasta.

CAMBIAR is seeking approval from the EWB technical advisory committee (TAC) for the implementation of an irrigation system as outlined in this report. This system will be comprised of spring box structures to capture water from two springs, a conveyance pipeline, a pressure break tank, and an in-field irrigation system consisting of sprinklers on removable risers along with a distribution piping system buried underneath the field.

The objective of the irrigation project in Huasta is to implement an improved irrigation system that will serve as a pilot project to promote water conservation practices for small-scale agriculture within the region. The scope of the project includes the following: (1) develop spring source(s) to provide sufficient water for the irrigation of a community-owned pasture during the dry season; (2) design and install a conveyance system to move water from the spring(s) down to the pasture; (3) install an improved/more efficient (compared to standard practices in the region) irrigation system to water the pasture land; and (4) establish a maintenance and monitoring program for the entire system from the source to the point of use.

This project will be carried out in Huasta, a district located in a tributary of the Pativilca River valley in Ancash, Peru (see Figure A-1 in Appendix A). The population of Huasta is approximately 2,400 people, of whom roughly 1,800 regularly participate in a community land-owners' association known as the *Campesina Community of Huasta*, herein referred to as the "Campesina Community." The Campesina Community collectively owns and manages land in Huasta and distributes the benefits of that land among the entire Campesina Community. The Campesina Community owns the pasture that is to be irrigated through this project; CAMBIAR has engaged in conversations concerning this project with the Campesina Community. In August 2012, CAMBIAR drafted a memorandum of understanding (MOU) and presented it to the Campesina Community through its in-country partner, The Mountain Institute (TMI). An updated MOU was drafted and signed in February of 2013; see Appendix L for a signed copy of the MOU. CAMBIAR has partnered with TMI since the program's inception, and the CAMBIAR program developed through TMI's involvement with conservation projects in the Ancash region. TMI is a non-governmental organization (NGO) with a local office in Huaraz (approximately two hours from Huasta). TMI has invaluable knowledge of local politics and society within the region, since its employees spend much of their time in the field interacting with community leaders to develop sustainable projects.

The CAMBIAR program was initiated in May 2011 with the goal of partnering with several communities located within the Santa, Pativilca, and Fortelaza River basin valleys. In August 2011, CAMBIAR traveled to Ancash, Peru and met with representatives of the Tres Cuencas Commonwealth (Commonwealth), a government-recognized entity made up of 25 communities with the purpose of mitigating water and climate issues. CAMBIAR signed a joint MOU with the Commonwealth and TMI during the August 2011 assessment trip. Immediately following the signing of the MOU, CAMBIAR, TMI, and the Commonwealth discussed several potential projects in various Commonwealth communities and collectively settled on initiating a project in Huasta. CAMBIAR initially began working on an irrigation project in Huasta and explored the possibility of reusing treated wastewater from an existing wastewater treatment plant (WWTP) uphill from the pasture. However, due to the current state of the WWTP facility, CAMBIAR decided to focus on a maintenance and operation program for the WWTP as a stand-alone project. CAMBIAR has been on two assessment trips in January 2012 and July 2012 to support the WWTP project and made initial efforts toward implementing the maintenance and monitoring program in July

2012. Activities planned for maintenance training during the January 2013 assessment trip did not take place, but an adapted (to be straightforward and simple) operations and maintenance manual was given to the municipality along with a maintenance log in which maintenance activities are to be recorded. As a result of the decision to proceed with an irrigation project with the Campesina Community using a water source other than the WWTP, the January 2013 trip to Huasta was dedicated primarily to assessment activities related to the irrigation system for a Community-owned pasture. The July 2013 implementation trip will see the installation of the planned irrigation system, along with community relations and various educational and technical training activities. CAMBIAR will work with members of the Campesina Community to build and install the irrigation system, the design of which is detailed in this document.

A hydraulic model was built using Pipe Flow Expert, a commonly used software package, to carry out the calculations needed for designing the conveyance system. To design the in-field irrigation system, irrigation demand was calculated based on potential evapotranspiration and water requirements for the given crop (alfalfa). These calculations ensure that the water supply from the two springs is sufficient to meet the demand. The irrigation schedule was designed for a 3-day rotation between 3 sections of the field; the schedule was determined based on the soil depth, soil type, and the flow rate of the sprinklers for the selected nozzle sizes. Complete calculations can be found in Section 4.2.

An overview schematic of the irrigation system is shown in Figure 1 in Section 4.1. Drawings of the spring box structures and pressure break tank can be found in Appendix B. Also in Appendix B are drawings of the sprinkler layout, the in-field piping system, and the sprinkler riser design, along with a schematic of the materials to be used to backfill the trenches in which pipe will be buried.

The CAMBIAR team is planning two weeks in Huasta for construction. The Community plans to dig the trenches and lay the conveyance pipeline from the pressure break tank to the field prior to the CAMBIAR team's arrival in the Community so that they can take advantage of moister soil in May just after the rainy season; this work will be supervised by personnel (one environmental engineer and one long-time scientist with extensive local knowledge of Huasta) from TMI, CAMBIAR's NGO partner. Then, during the two-week implementation trip, CAMBIAR team members will direct construction activities with the assistance of Community members who will provide the necessary manual labor. CAMBIAR also plans to hire a skilled mason to supervise the construction of the spring boxes and pressure break tank. Construction activities for each day of the two-week implementation are outlined in Figures 9-12 in Section 6.0.

When the irrigation system is completed, the Campesina Community will assume ownership of the infrastructure. The Board of Directors of the Campesina Community will be responsible for the operations and maintenance of the system. CAMBIAR will conduct a training workshop for Community members that will include instruction in the operations and maintenance tasks required for the system. Maintenance costs are estimated to be between \$142 - \$259 per year, and these costs will be covered by the income that the Campesina Community expects to generate from increased productivity in the Coris field.

Possible further implementation of the project on future trips may include construction of a storage tank to collect water between the source spring(s) and the pasture. The addition of storage will allow for the expansion of the irrigation system to additional fields. The additional fields are currently being watered by flooding from an irrigation canal, but productivity for these fields is hindered because the Campesina Community has limited access to the irrigation canal and cannot optimally water their crops. Future trips will also include follow-up on the operation and maintenance of the system to ensure that it is being handled correctly. CAMBIAR will wait at least one year to observe how the Campesina Community operates and maintains the system before considering expansion of the irrigation system.

2.0 INTRODUCTION

The purpose of this document is to provide a complete description of CAMBIAR's anticipated July 2013 implementation in Huasta, Peru. During this trip, CAMBIAR will implement project number 009122, an agriculture (irrigation) project to irrigate a community-owned pasture. Implementation will include the installation of spring box structures to capture water from two springs, a conveyance pipeline, a pressure break tank, and an in-field irrigation system consisting of sprinklers on removable risers and a distribution piping system buried underneath the field. This is the second project of the program in Huasta; the first project comprises technical training for the operation and maintenance of a wastewater treatment plant. Monitoring of the first project will take place during this implementation trip.

This document provides background information needed to understand the context of the project within the community and of this implementation within the project process. The design of the proposed irrigation system is presented in detail, along with a specific schedule of activities planned to take place during the implementation trip, which include education and training activities. Though the irrigation project is the focus of this document, monitoring of the WWTP project is also discussed herein.

3.0 PROGRAM BACKGROUND

Communities in the mountainous regions of Ancash, Peru, are highly susceptible to the effects of climate change due to their dependence on seasonal snowmelt from Andean glaciers and sensitivity to variations in seasonal rainfall patterns. In recent decades, these sources of fresh water have become less dependable, and many of the rural communities have experienced water shortages during the dry season. The impacts of these shortages have been felt most acutely by farmers and ranchers in the region who have noticed changes in crop yields and struggled to maintain adequate pastureland. Natural heavy metal contamination in several of the region's watersheds compounds water availability issues. The contamination is so concentrated in some areas that stream water is unhealthy for livestock and irrigation use, contributing to the water shortage crisis for these farmers and ranchers.

As a proactive response, several municipal districts have formed the Tres Cuencas Commonwealth (Commonwealth) for the sole purpose of mitigating water issues within the three watersheds (*cuencas*) that feed the region's rivers: the Santa, Fortaleza, and Pativilca (see Figure A-1 in Appendix A for an overview map of the region). In establishing themselves as a nationally recognized entity, the Commonwealth has initiated steps at the local and national levels to address their water concerns. To date, the Commonwealth has gathered leaders from its districts, drafted a document outlining the urgent water needs and goals of the region and held its first meeting as a formal entity. The Ministry of the Economy has approved the Commonwealth's foundational document, ensuring that the Commonwealth is eligible to apply for potential regional public funds. Currently the Commonwealth lacks the financial and technical resources to develop a solution strategy for its members' community-scale water issues. As such, the priority of the CAMBIAR program is to undertake this challenge and help communities in the Commonwealth adapt to climate change, specifically focusing on water-related challenges, through community-driven collaboration and sustainable engineering design solutions.

CAMBIAR has established a partnership with The Mountain Institute[1] (TMI) to provide technical assistance to the Commonwealth and complete small-scale pilot projects that demonstrate successful solutions to the communities' water needs. TMI has worked in Ancash for the last 15 years on USAID-funded projects and currently manages a program working with two communities in the Commonwealth focusing on reforestation through education, ecological conservation, and sustainable development. CAMBIAR is leveraging TMI's knowledge of the region and existing relationships with members of the Commonwealth to effectively plan, implement and monitor pilot projects.

The Commonwealth, TMI and CAMBIAR have selected two communities, Huasta and Canrey Chico, as priority areas. Huasta is located about three hours south of Huaraz by car in the Province of Bolognesi in the District of Huasta and is part of the Pativilca River basin. Canrey Chico is located about 30 minutes from Huaraz in the Province of Recuay in the District of Recuay and lies in the Santa River basin.

Over the duration of the program, it is expected that CAMBIAR will engage in the following:

[1] For more information about The Mountain Institute's projects in Peru see: http://www.mountain.org/andes

- Provide technical assistance needed to help assess and prioritize regional needs;
- Design engineering solutions to meet the communities' water needs;
- Implement small-scale pilot infrastructure;
- Educate citizens on health, sanitation, and conservation.

These goals are oriented to equip Commonwealth residents with the knowledge, means and tools necessary to build resilience to changes in their environment. During the August 2011 program assessment trip, CAMBIAR solidified the aforementioned goals through an umbrella MOU that outlines the responsibilities for each party involved (CAMBIAR, TMI, and the Commonwealth). After careful consideration in the fall of 2011, CAMBIAR selected Huasta as a partner community for the program's first project. Background information about Huasta can be found in the 522 Post-Assessment Report submitted on February 10, 2013. As a result of discussions with the Campesina Community of Huasta, CAMBIAR decided to focus its initial efforts on a water reuse project in Huasta, with a goal of using treated effluent for irrigating a Community-owned pasture. The January 2012 assessment trip was a direct result of this decision.

During the January 2012 assessment trip, the CAMBIAR team evaluated Huasta's WWTP, owned by the Municipality, and performed water quality tests on the influent and effluent to determine the feasibility of using the effluent for irrigating a community-owned pasture; the pasture is owned by the Campesina Community of Huasta, representing approximately 600 families. It became apparent during that assessment trip that the WWTP had not been maintained since it was built in 2006 and was not functioning properly. On the July 2012 follow-up assessment trip, the team met with the newly-hired municipal engineer of Huasta, who visited the WWTP and agreed to take responsibility for the plant as part of his duties within the Municipality. CAMBIAR worked with the engineer to draft a formal list of technical recommendations for rehabilitating the WWTP. CAMBIAR also developed a training program for operations and maintenance workers who will be paid by the Municipality; this program includes training workers to perform water quality tests on the WWTP effluent so that they can continually monitor the functionality of the plant. The role of CAMBIAR is to ensure the sustainability of the WWTP through education of paid workers and dedicated community members.

In order to meet the distinct needs of the Municipality and Campesina Community (i.e. rehabilitating the WWTP and also irrigating the community-owned pasture), CAMBIAR has now separated the WWTP and irrigation projects. CAMBIAR submitted a 501b application for the irrigation project to EWB-USA on September 16, 2012. This document outlines the goals of a new project in Huasta dedicated solely to building a complete irrigation system; this project is a result of several recently discovered springs in Huasta. The selection of local springs as the irrigation water source came from the alternatives analysis (see Appendix M), in which other options were considered and rejected, such as treated WWTP effluent (as discussed above) and water from canals at lower elevations. In the alternatives analysis, various technologies for transporting the water from the source to the field and for applying the water to the field were also considered.

Among the transport options investigated was the possibility of constructing a storage tank to collect water between the source and the field. CAMBIAR decided to postpone construction of a storage tank because the time and effort required to design and construct the tank are beyond the capabilities of the team for the upcoming implementation trip. Addition of storage to the irrigation system is a possibility for the future; it will allow for the expansion of the irrigated area to take advantage of the full flow that the spring sources provide. There will be a small tank installed to break pressure, necessitated by the elevation difference between the source and the field.

The technologies considered for applying irrigation water to the pasture include drip irrigation, porous pipes, flood irrigation, and several types of sprinkler designs. The full details of the alternatives analysis for irrigation systems are discussed in the 523 report in Appendix M. Sprinklers were chosen from these alternatives for several reasons:

- Flood irrigation, which is currently the standard in Huasta, is the least water-efficient alternative, and efficiency is a priority of the Community and this project;

- Drip irrigation, which is in use in Huasta's recently-planted avocado orchard, is not appropriate for irrigating a field of alfalfa, as there are not individual, widely spaced plants to which water must be delivered;
- Sprinkler technology is familiar to the Campesina Community, who already owns sprinklers (though they are not currently in use). In discussions about types of irrigation systems, Community members expressed a preference for sprinklers because they believe that sprinklers can most efficiently water pasture for grazing and will reduce soil erosion. A key part of the decision to use sprinklers is the Community's preference for this type of system;
- Sprinklers are more water-efficient than flood irrigation, and they can be moved to allow for use of the field by grazing cattle without damage to the system. The improved water efficiency will allow for expansion of grazing capacity, which in turn will lead to increased productivity by improving the health and well-being of livestock.

In January 2013, CAMBIAR met with the newly-elected board of directors of the Campesina Community to discuss questions, written by CAMBIAR and irrigation expert Dr. Guy Fipps, regarding the system design and performance metrics. Based on the answers to these questions, CAMBIAR has designed an improved irrigation system to be implemented in July 2013.

During the January meeting, the President of the Campesina Community requested that community members dig the trenches for the system's pipes in May, when the ground is soft after the seasonal rains but before CAMBIAR returns to Huasta; this initiative is seen as an indicator that the Campesina Community is taking ownership of the project, which will contribute significantly to project sustainability. At CAMBIAR's request, the Campesina Community has also agreed to contribute financially to the project at an amount not to exceed 5% of the cost of implementation. As a result of these discussions, a new MOU between CAMBIAR and the Campesina Community was drafted and signed on February 22, 2013.

In addition, a new MOU was signed between CAMBIAR and the Mayor of Huasta regarding each party's role in the WWTP project. The Municipality will take responsibility for hiring maintenance workers for the plant and handling needed repairs; CAMBIAR will train the hired workers and monitor progress. The WWTP project is thus being considered monitoring of a past-implemented project from this point forward.

4.0 FACILITY DESIGN

4.1 Description of the Proposed Facilities

The proposed system will provide the Campesina Community of Huasta with an irrigation system to water the upper portion of a community-owned pasture, Coris, depicted in Figure 1. This pasture is owned and managed by the Campesina Community and has not been irrigated previously as no viable water source had been identified by the community. However, during the wet season the Campesina Community uses this pasture as a grazing area for its livestock. The Campesina Community would like to expand its grazing practices to the dry season to better support their livestock. The Campesina Community plans to cultivate alfalfa in this pasture with the goal of producing 4 cuttings per year; this is equivalent to letting the cattle graze 4 times per year. The alfalfa will be used as fodder for livestock, and cattle will be let onto the field to graze when the crop has reached an adequate height; the exact management of cattle will be determined by the Campesina Community depending on the conditions in the pasture.

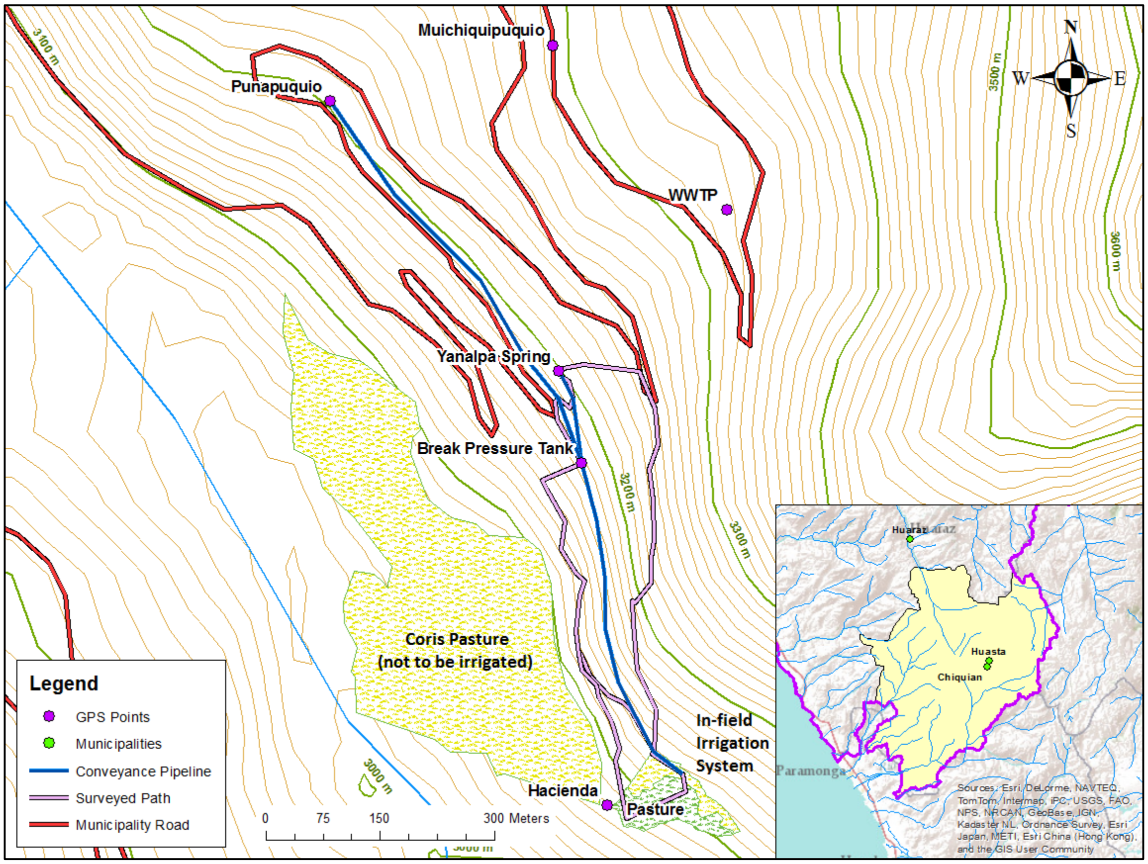

Figure 1. Overview of the Area with System Components

The proposed irrigation system will consist of two small spring boxes to capture water from the Pucapuquio and Yanallpa springs, a conveyance pipeline, a pressure break tank, and an in-field irrigation system. See Figure 1 above for an overview map of the system components. An irrigation schedule will be delivered to the Community along with the irrigation system, as proper use of the irrigation schedule will be the source of much of the water efficiency that the system will provide. Each of the system components is described below.

Spring Box

Based on periodic flow data collected throughout the wet and dry seasons in 2012, it was determined that two nearby springs, Yanallpa and Pucapuquio, combined would sufficiently meet the Community's demand for non-potable irrigation water; supply and demand calculations along with measured flow rates are provided in subsequent sections. Chemical testing of the flow from the springs has shown that the sources contain negligible amounts of biological and chemical hazards (biological and chemical test results can be found in Appendix D). Given this information, it was decided that these two spring sources can be utilized without treatment.

A spring box will be used to protect each spring source from physical contaminants contained in surface runoff. In addition, each spring box will direct the flow from the springs into the conveyance system. The spring box design proposed in this document is in part based on a previous EWB-Greater Austin design used to support the implementation of a potable water distribution system in Panama in 2010[2]. Methods for constructing each spring box have been developed from several sources; however, the construction plan for each spring box will be

[2] The design document can be found here: http://ewbgreateraustin.org/wp-content/uploads/2011/09/525-PreImplentation-Report-20101.pdf

adjusted in the field as necessary to account for topography (Hart, 2003; Jordan, 2008; EWB-Greater Austin, 2010); see Section 6.0 for construction details and Appendix J for photos of the sites where the spring boxes will be constructed.

In order to capture the maximum amount of flow from each spring, the surrounding area will be excavated until the source has been isolated to a single location: the eye of the spring. This excavation also includes digging downward to the confining subsurface layer to ensure that no water from the eye can escape beneath the spring box. Once the eye of each spring has been identified and isolated, the excavated area will be backfilled with clean rocks with an approximate diameter of 3-6 inches. Depending on the conditions of the confining layer beneath each spring, a concrete bed reinforced with rebar may be poured to direct the water beneath the rock backfill to the collection box. This will only be necessary if the confining layer is deemed permeable. CAMBIAR plans to hire a mason or spring box expert to oversee the construction of each spring box (the expert will be local to the area and will be coordinated through TMI).

The spring box itself will be a small poured and formed concrete structure reinforced with rebar. The upstream facing wall will allow spring water to enter the structure through an open area approximately half the height of the spring box. The open area will contain vertical rebar, sleeved in PVC pipe, to prevent rock backfill from entering the spring box; the rebar will also offer structural support for the wall. The downstream facing wall will have three PVC outlet pipes embedded: (1) a clean-out pipe, (2) an outlet pipe and (3) an overflow pipe. The clean-out pipe will enter at an angle through the floor of the spring box and will allow for periodic flushing of sediment during maintenance; when maintenance is not being performed, the clean-out pipe will be capped. The outlet pipe will be connected to a gate valve which will then be connected to the conveyance pipeline. The overflow pipe, located near the top of the spring box, will allow excess water to drain. The overflow pipe will include a mesh screen to prevent insects or animals from entering the spring box. The overflow pipe will drain onto a concrete pad to prevent erosion around the spring box and from there the flow will be directed into an existing stream bed. Detailed design drawings of the spring box can be found in Appendix B.

The spring box will have a concrete lid to keep out contaminants while still providing access for periodic maintenance; accumulated sediment will need to be cleaned routinely. This lid will be slightly mounded to shed water during periods of rainfall. Additionally, the lid will have four rebar handles to facilitate lifting by two people for maintenance. On site, it will be determined whether or not a concrete footing is needed beneath the downstream facing wall of the spring box. Inspections of each site, during previous assessment trips, have led CAMBIAR to believe that the impervious layer underneath the proposed spring box locations is primarily rock. If this is the case, the rock's bearing capacity should be sufficient to support the small and contained structure. If a footing is deemed necessary, concrete will be poured into a dug out area beneath the downstream facing wall of the spring box. The footing will provide extra stability for the structure and prevent water from flowing beneath the spring box.

Actual sizing of the spring box and excavated area will be determined by local conditions, though the proposed design has been created using conservative estimates. Sand and gravel are locally available near the community but will require sifting to achieve the appropriate grain sizes. A diversion ditch behind the excavated area will be dug during construction to minimize surface runoff over the spring box site.

Break Pressure Tank

There is a significant change in elevation between each spring and the pasture to be irrigated, therefore a break pressure tank (BPT) will be constructed to alleviate pressures within the conveyance pipeline while still meeting the pressure requirements for the infield irrigation system. The pressure required for the infield irrigation system is 35 psi; however, pressure reducing valves (PRVs) will be used along the manifold of the irrigation system to regulate the pressures across the field. In order to accommodate these pressure requirements and maintain a maximum pressure of 60 psi within the conveyance system, a BPT will be constructed approximately 39 meters above the pasture. An open field along the survey path shown in Figure 1 is at the appropriate elevation and has been identified as the approximate location of the BPT.

The BPT will be constructed using methods discussed in Thomas Jordan's Handbook of Gravity-Fed Water Systems (Jordan, 2008). The BPT will consist of a small tank approximately 2 ft. x 1.5 ft. x 1.5 ft. in size. The tank will be constructed out of concrete and built to accommodate the necessary valves and components; these components include a gate valve, a PVC overflow line, and 90 degree PVC elbow fittings. The necessary PVC pipe and fittings will be acquired in Peru but it is expected that nominal dimensions will abide by Schedule 40 standards.

The break pressure tank will have a gate valve at the inlet, which will be used to shut off flow during maintenance. An overflow pipe will be installed with a small spill pad to prevent erosion of the soil surrounding the BPT. The BPT will also have a cleanout pipe (normally capped) which will allow sediment to flush out during maintenance.

Conveyance System

The proposed conveyance system will connect both the Pucapuquio and Yanallpa spring boxes with the aforementioned BPT and the in-field irrigation system described in the following section. Expected flow rates, based on routine flow measurements over a period of a year, from the Pucapuquio and Yanallpa springs are 0.69 L/s and 0.24 L/s respectively; max flow rates are 0.83 L/s and 0.28 L/s. The layout of the entire conveyance system can be seen in Figure 1 above; this is a schematic representation of the system. The conveyance system will be constructed along a surveyed path using Schedule 40 PVC pipe and will follow standard specifications (e.g. ASTM D2466, ASTM D2467 etc.) and pipe sizes determined by the accompanying hydraulic model presented in Section 4.2.

Note: *The path from the BPT to the pasture was linearly interpolated based on survey data above and below the anticipated pipe path; the error associated with the topography is subject to the error of the manual survey data collected during the recent assessment trip in January 2013. Although the interpolated survey data depicts a path that increases and decreases in elevation, visual inspection confirms a steady decrease in elevation along the anticipated pipe path. Based on this inspection and the surveyed topography, CAMBIAR does not expect the physical terrain during construction to affect the design of the system. During construction, an experienced professional with extensive knowledge of the system will oversee the installation of the pipe and ensure this assumption is valid. If necessary, air release valves will be installed at high points along the conveyance system. For construction details see Section 6.0.*

The conveyance system will consist of individual main lines from each spring box and will feed into the BPT thus alleviating the need for check valves; the line from Pucapuaqio will be approximately 581 meters long while the line from Yanallpa will be approximately 164 meters long. A single line, of approximate length 508 meters, will be constructed from the BPT to the highest point in the pasture to transport the combined spring flow. The Pucapuquio spring sits at an elevation of 3,208 meters above mean sea level (MSL) while the Yanallpa spring sits at an elevation of 3,204 meters above MSL. The break pressure tank will be built at an elevation of 3,182 meters above MSL, residing approximately 37 meters above the highest point in the pasture; the highest point in the pasture sits at 3,145 meters above MSL. The elevation of the BPT was selected based on the scenarios simulated within the hydraulic model. Survey data collected during the assessment trip in January can be seen in Figure 2 below.

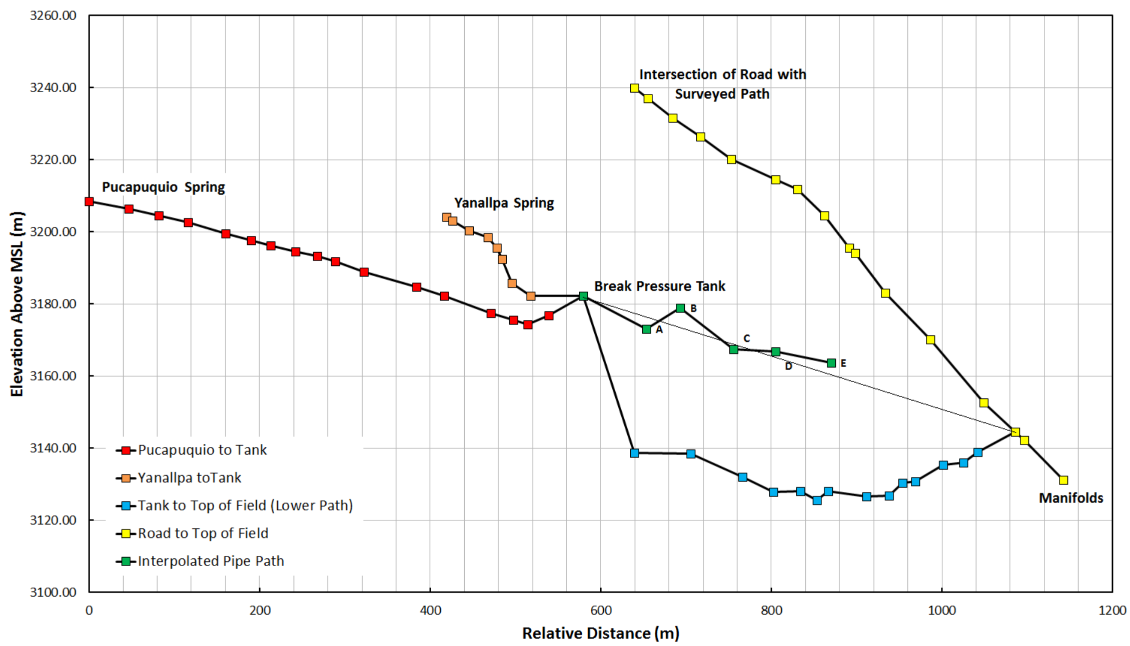

Figure 2. Survey Data Collected in January 2013

Based on the number of structures along the conveyance path (e.g. two spring boxes and one BPT), survey data collected, anticipated pipe geometry (i.e. linear with minimal lateral changes in direction) and measured flows, a limited number of valves and elbow fittings will be used throughout the entirety of the system; gate valves will be used at the outlet of each spring box and the BPT. Although a limited number of elbow fittings are anticipated, these fittings will be used when appropriate to conform to the terrain along the pipe path and the in-line structures. Thrust blocks will be used at the base of the BPT as a precaution; however, it is not expected to affect the design of the system. Because of the minimal lateral changes in direction, thrust blocks will not be utilized along the anticipated pipe path.

Details of the hydraulic model and associated design calculations can be found in Section 4.2.

In-field Irrigation System

The in-field irrigation system is the means of efficiently distributing water onto the pasture. A solid-set system of impact sprinklers on removable risers will be used to distribute the water to the field; this type of system will present a significant water savings over the flood irrigation systems that have been typically used in the Community. Two springs, the Yanallpa and Pucapuquio springs, will be used to supply irrigation water to the field. The flow from Yanallpa (~ 0.2 L/s) could meet the demand of about half the field, and the flow from Pucapuquio (~ 0.6 L/s) could meet the demand of the entire field. Because there is a minimum flow rate needed to operate impact sprinklers, the combined flow rate from these springs is not large enough to water the entire pasture at once using impact sprinklers unless storage is implemented, thus the pasture will be divided into three irrigation blocks. The next phase of the irrigation project could include installing a storage tank so that a larger portion of the field could be watered at any one time and the system could be expanded. Utilizing both springs, approximately 18 impact sprinklers can be used; this covers approximately 1/3rd of the pasture.

Water samples were taken from both springs, and the results (Appendix D) indicate that the water should be suitable for irrigation. Soil samples at three locations in the field were analyzed to determine that the soil is also acceptable for the irrigation project (see Appendix E).

For this implementation trip, all of the water supplied to the pasture will be taken from the Yanallpa and Pucapuquio springs without any storage. Until a storage tank can be implemented in a future trip, all irrigation scheduling will be temporary and will involve a rotating array of impact sprinklers. The sprinklers will be placed on screw-on risers so they can be moved to different sections of the pasture, and so the sprinkler heads can be removed before cattle graze the pasture.

The total pasture area to be irrigated is approximately 0.64 hectares, or 6,400 square meters, a large portion of which is on a steep slope. The field will be divided into three irrigation blocks: Block I includes the flatter upper portion of the pasture, Block II is the steeply sloped middle portion of the field, and Block III is the lower portion of the field that is relatively flat. The division of the pasture will be done by splitting the upstream conveyance pipeline into three manifold pipelines, one for each irrigation block. The total length of the manifold pipelines will be approximately 235 meters, or 770 feet. The manifold pipelines will all be ½ inch NPS Schedule 40 PVC pipe. Lateral pipes coming off the manifolds will 1” PVC pipe buried underneath the field at a depth of 18 inches. The total length of the laterals coming off the manifolds will be approximately 390 meters, or 1280 feet in total. The pressure for each lateral will be regulated by a PRV so that each sprinkler has the pressure needed to produce the design flow rate. The laterals will be placed along the contours of the field to ensure that the sprinklers connected to each lateral have approximately the same inlet pressure. Each sprinkler station will be connected to a lateral pipe with ½ inch PVC pipe. The total length of ½ inch PVC pipe is approximately 250 meters, or 820 feet.

Each sprinkler station will consist of a concrete base with a threaded connection that can be connected to a riser made of galvanized steel pipe with an impact sprinkler on top. The connection at the concrete base will be capped when not in use. A detailed drawing of the sprinkler riser design is given in Figure B-8 in the drawing set (Appendix B). There will be 54 sprinkler stations spread throughout the pasture, 18 in each irrigation block. 18 risers with impact sprinklers will be constructed for the first phase of the project, and these risers can be moved between each irrigation block and removed and stored when not in use. The distribution of the sprinklers can be seen in Appendix B in Figure B-6. These sprinklers, risers, and piping (as well as the main line splitter) will be the core of the irrigation system implemented on the pasture. The water requirements for irrigation as well as available water are outlined in the irrigation subsection in Section 4.2.

4.2 Description of Design and Design Calculations

Flow Rates

Summaries of the flow rates measured at the two springs that will be used to supply the irrigation systems are given in Tables 1 and 2. A complete record of the flow measurements made to date at the two springs is given in Appendix C. The average water supply from Yanallpa during the dry season was measured to be 0.238 L/s, and the average dry season flow rate measured at Pucapuquio is 0.689 L/s. Conservative estimates for dry season flow, 0.2 L/s from Yanallpa and 0.6 L/s from Pucapuquio, were used for the irrigation design. Irrigation design was done assuming that a combined flow rate of 0.8 L/s could be reliably obtained.

The hydraulic calculations for the conveyance system were performed for a minimum combined flow rate of 0.231 L/s, a maximum combined flow rate of 1.12 L/s, and an approximate average flow rate (for irrigation design) of 0.8 L/s.

Table 1. Summary of flow rates for Yanallpa

July average	0.238 L/s
January average	0.216 L/s
March average	0.269 L/s
Maximum measured flow rate	0.284 L/s
Minimum measured flow rate	0.188 L/s
Overall average	0.241 L/s
Dry season average	0.238 L/s

Table 2. Summary of flow rates for Pucapuquio

July average	0.665 L/s
August average	0.713 L/s
October average	0.536 L/s
November average	0.426 L/s
January average	0.050 L/s
Maximum measured flow rate	0.833 L/s
Minimum measured flow rate	0.043 L/s
Overall average	0.563 L/s
Dry season average	0.689 L/s

The Yanallpa spring is a true spring and has a relatively constant flow rate year-round. Community members have confirmed that Yanallpa has had regular flow for a number of years, so it can reasonably be relied on as a source of irrigation water. Pucapuquio, however, is likely subsurface runoff from flood irrigation water applied higher up. This inference is based on the observation that relatively high flow rates occur during the dry season, and the flow decreases to almost nothing during the rainy season. Community members have tied this variability in flow to the seasonal use of irrigation water. Because this pattern has been observed by Community members for a number of years and it has been Community practice to use water collected at Pucapuquio for a long time as a watering hole for passing animals, the CAMBIAR team believes that the flow at Pucapuquio can be relied upon to provide irrigation water for Coris in the future. The flow of Pucapuquio will be monitored by Community members in the coming months before the July implementation to determine exactly when the flow increases, and a reasonable flow rate will be confirmed by the CAMBIAR travel team before beginning construction of a spring box structure at Pucapuquio. If the flow does decrease in the future, water storage can easily be added to the system so that the demand at the field can still be met.

Spring Box and Break Pressure Tanks

Structural analysis calculations for the spring box are shown in Appendix O. Lateral and compressive loads on the walls were checked and compared to the compressive strength of concrete. Rebar will be placed within the spring box walls, floor and roof to take on any tensile loads experienced by the structure; it is expected that the loads will be minimal due to the size of the structure thus no calculations were performed. As discussed in the previous section, the spring boxes will be built on rock. Because the bearing capacity of soft rock (a conservative assumption) is approximately 64 psi, limited calculations for determining the overall load on the rock itself were performed. Assuming concrete weighs approximately 145 lbs/ft^3, a conservative estimate for the weight of the spring box is 1,160 lbs. Distributed over the footprint of the structure, the load on the rock is estimated to be 2 psi; this is significantly lower than the bearing capacity indicated above.

The concrete mixture proportions are shown below in Table 2-1 below. These proportions were calculated by weight. If the materials can't be weighed on site, the proportions should be done by volume according to a ratio of 1 part cement: 2 parts sand : 4 parts aggregate : ¾ parts water. This volumetric proportion is suggested in Thomas Jordan's *Handbook of Gravity-Fed Water Systems* (Jordan, 2008). All proportion calculations are assuming the aggregates are in the saturated surface-dry moisture state.

The structural standards used for this design are ACI 318 and the Normative Peruvian Standards when available.

Table 2-1: Concrete mixture proportions for 3,000 psi. compressive strength (Units in lbs. unless specified)

	Normalized Weights	Spring Box	Break Pressure Tank
Volume of concrete	1 ft^3	9.8 ft^3	4.5 ft^3
Coarse Aggregate	79.06	774.79	355.77
Fine Aggregate	69.04	676.60	310.68
Cement	20.08	196.78	90.36
Water	14.22	139.36	63.99
Total Weight	182.40	1787.52	820.80

Two admixtures will be used to increase the structure's durability. The primary durability concerns for the spring box are the corrosion of the steel reinforcement, freeze-thaw damage, and the ability of the concrete base to properly set. To address these concerns, admixtures will be used in the concrete mixture. The base of the spring box will be made of a mix dosed with an accelerating admixture which will serve multiple purposes. It will increase the ability of the concrete to properly set on the impervious layer of soft rock on the site. It will also prevent the concrete from having complications setting in a cold climate. The walls of the structure will be dosed with air entrainment. This will help prevent freeze-thaw complications and ultimately protect the steel reinforcement by preventing large fissure from forming in the walls. These admixtures will be used according to directions that accompany the specific dosing agent.

The overflow pipe has also been designed using the *Handbook of Gravity-Fed Water Systems*. To maintain an adequate maximum flow, if needed, the pipe is designed to be 2 inches in diameter and will be installed with a pitch of 10 cm for every 30 cm of pipe length.

Conveyance System

The proposed conveyance system was modeled using Pipe Flow Expert, a software package routinely used by engineers to design and analyze pipe systems. The conveyance system was modeled by separating the pipe network into three branches: (1) Pucapuquio Spring to the BPT, (2) Yanallpa Spring to the BPT, and (3) BPT to the highest point in the pasture. The layout of the model within Pipe Flow Expert can be seen in Figure 3; the elevations indicated at each node are relative and do not represent absolute elevations. Each branch was modeled based on scenarios representing the anticipated supply and demand conditions throughout the lifetime of the system. Nodes within the model were specified based on terrain conditions along the anticipated pipe path (i.e. abrupt changes in slope etc.) Pressures, velocities and losses were computed at each node and compared to industry standards, specifications and design constraints; based on recommendations made by professional engineers, pressures at fittings will not exceed 60 psi and velocities will not exceed 8 ft/sec. Minor losses were not included in the model as these losses were found to be low relative to the available head in the system. Minor loss calculations for the entire system can be found below in Table 3. Based on the model results, an average velocity of 3.8 ft/sec was used for minor loss calculations; loss coefficients were taken from Houghtalen et al. (2010).

$$h_{L\,minor} = \sum K_L \frac{V^2}{2g}$$

Table 3. Head Losses for Hydraulic System Components

Component	Loss Coefficient	Total Units	Head Loss (m)
Inlet	0.50	1	0.03
Outlet	1.00	2	0.14
45˚ Elbow	0.35	86	2.06
Gate Valve	0.15	3	0.03
		Total Head Loss (m)	2.26
		Total Pressure Loss (psi)	3.21

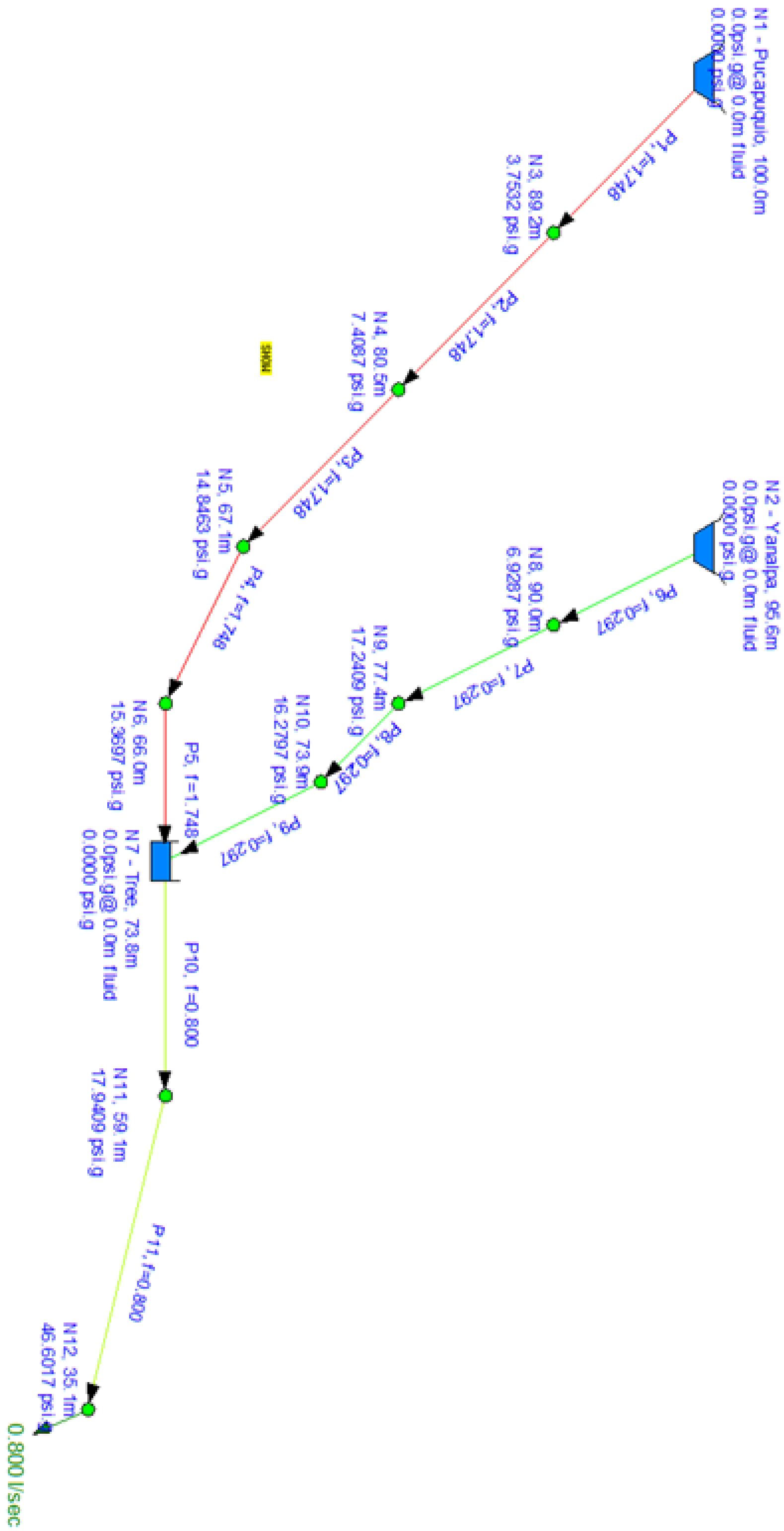

Figure 3. Hydraulic Model from Springs to Pressure Break Tank to Field

The conveyance system upstream of the break pressure tank was modeled using a constant level reservoir as the input to the system to determine the maximum flow rates and associated pressures and losses through the specified pipe. The system was modeled in this way due to variable flow rates associated with each spring source. In order to accommodate the average and maximum flow rates at each spring, 1 inch NPS Schedule 40 PVC pipe will be used for the Pucapuquio to BPT branch and ½ inch NPS Schedule 40 PVC pipe will be used for the Yanallpa to BPT branch; 1 inch NPS Schedule 40 PVC pipe will be used along section P6 to accommodate major head losses within the Yanallpa to BPT branch.

Table 4. Pipe Specifications: P1-P5

Section	Pipe Spec.	Length (m)	Flow (L/s)	Velocity (ft/sec)
P1	1-1/2" PVC (ANSI) Sch. 40	176.00	1.75	4.37
P2	1-1/2" PVC (ANSI) Sch. 40	132.60	1.75	4.37
P3	1-1/2" PVC (ANSI) Sch. 40	174.80	1.75	4.37
P4	1-1/2" PVC (ANSI) Sch. 40	16.86	1.75	4.37
P5	1-1/2" PVC (ANSI) Sch. 40	65.12	1.75	4.37

Table 5. Pipe Specifications: P6-P9

Section	Pipe Spec.	Length (m)	Flow (L/s)	Velocity (ft/sec)
P6	1" PVC (ANSI) Sch. 40	48.36	0.30	1.75
P7	0.500" PVC (ANSI) Sch. 40	28.14	0.30	4.96
P8	0.500" PVC (ANSI) Sch. 40	22.22	0.30	4.96
P9	0.500" PVC (ANSI) Sch. 40	61.30	0.30	4.96

The associated pressures and hydraulic grade lines (HGLs) for the branches upstream of the BPT can be found in the tables and charts below.

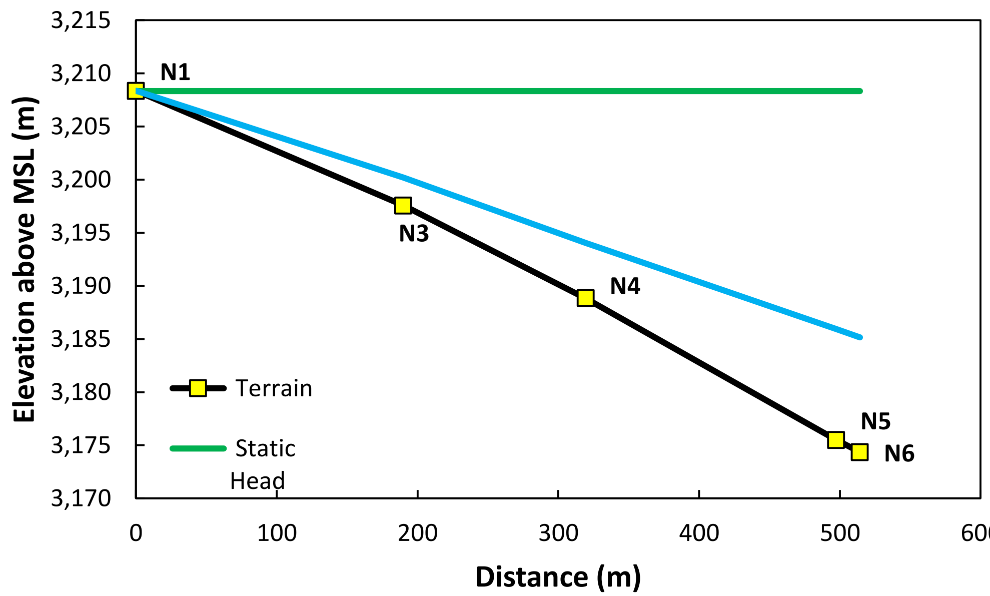

Figure 4. Hydraulic Grade: Pucapuquio to the Pressure Break Tank

Table 6. Pressure and Hydraulic Grade: Pucapuquio to the Pressure Break Tank

Node	Distance (m)	Elevation (m)	Pressure (psi)	Static Head (m)	HGL (m)
N1	0	3,208	0.00	3,208	3,208
N3	190	3,198	3.75	3,208	3,200
N4	319	3,189	7.41	3,208	3,194
N5	497	3,176	14.85	3,208	3,186
N6	514	3,174	15.37	3,208	3,185

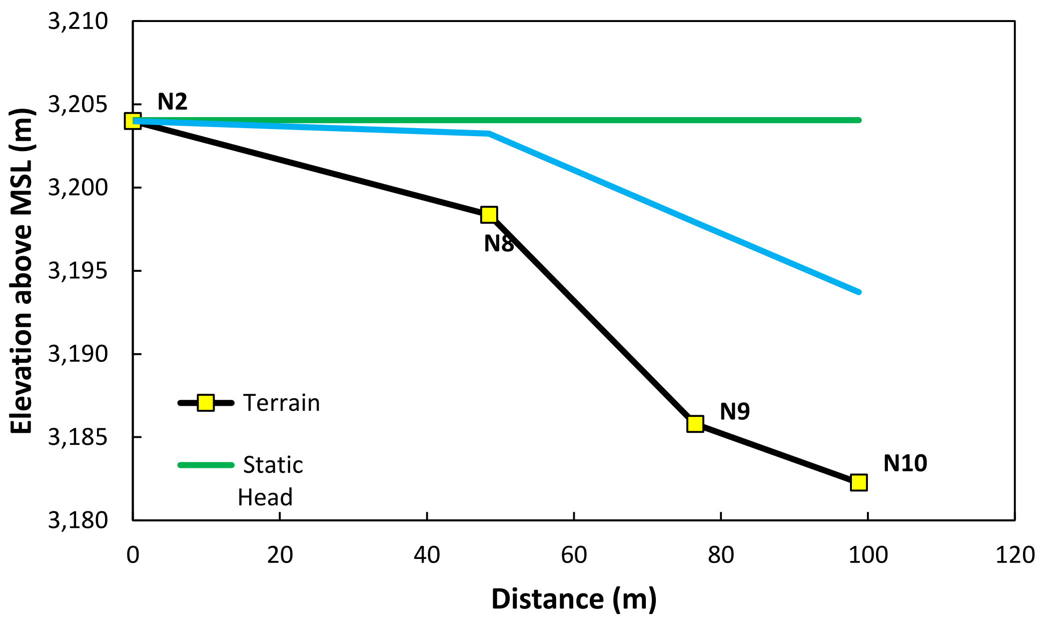

Figure 5. Hydraulic Grade: Yanallpa to the Pressure Break Tank

Table 7. Pressure and Hydraulic Grade: Yanallpa to the Pressure Break Tank

Node	Distance (m)	Elevation (m)	Pressure (psi)	Static Head (m)	HGL (m)
N2	0	3,204	0.00	3,204	3,204
N8	48	3,198	6.93	3,204	3,203
N9	77	3,186	17.24	3,204	3,198
N10	99	3,182	16.28	3,204	3,194

The static pressure along each branch at the inlet of the BPT is approximately 37.3 psi and 31.3 psi, coming from the Pucapuquio and Yanallpa springs respectively. These pressures are well below the recommended 60 psi constraint. A sample calculation for the Pucapuquio to BPT branch can be found below.

$$\frac{P_1}{\gamma} + \frac{{V_1}^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{{V_2}^2}{2g} + Z_2$$

$$Z_1 = \frac{P_2}{\gamma} + Z_2$$

$$P_2 = \gamma(Z_1 - Z_2)$$

$$P_2 = 9{,}800\ \frac{kN}{m^3}(3{,}208\ m - 3{,}182\ m)$$

$$P_2 = 254{,}800\ pascals$$

$$\boldsymbol{P_2 = 37.3\ psi}$$

The branch downstream of the BPT was modeled using the irrigation demand of the pasture. As indicated in the description of the irrigation system, the pasture will be split into three irrigation blocks, each with 18 sprinklers. Based on the design of the irrigation system, each sprinkler will demand 0.042 L/s. Assuming all 18 sprinklers in a given irrigation block are operated simultaneously, as recommended by the design of the system, the irrigation demand will be 0.756 L/s. As a conservative estimate, a flow rate of 0.8 L/s was used in the model. In order to transport the design flow to the field, 1 ½ inch NPS Schedule 40 PVC pipe will be used.

Table 8. Pipe Specifications: P10-P11

Section	Pipe Spec.	Length (m)	Flow (L/s)	Velocity (ft/sec)
P10: N7-N11	1-1/2" PVC (ANSI) Sch. 40	176.50	0.80	2.00
P11: N11-N12	1-1/2" PVC (ANSI) Sch. 40	330.15	0.80	2.00

The associated pressures and hydraulic grade line (HGLs) for the branch downstream of the BPT can be found in the table and chart below.

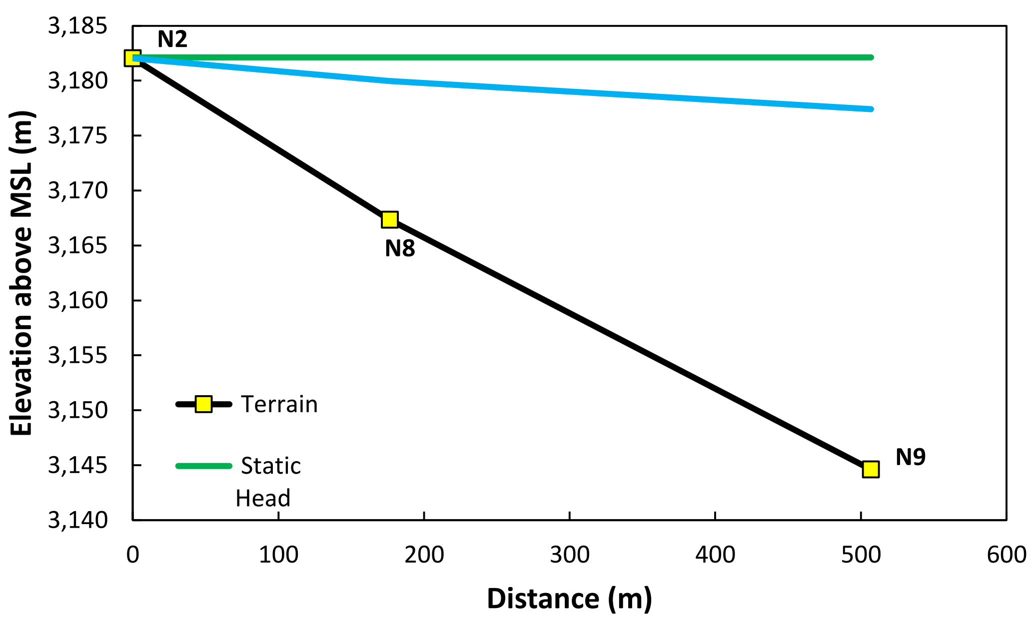

Figure 6. Hydraulic Grade: Pressure Break Tank to Top of Field

Table 9. Pressure and Hydraulic Grade: Pressure Break Tank to Top of Field

Node	Distance (m)	Elevation (m)	Pressure (psi)	Static Head (m)	HGL (m)
N7	0	3,182	0.00	3,182	3,182
N11	176	3,167	17.94	3,182	3,180
N12	507	3,145	46.60	3,182	3,177

The static head for the branch below the BPT is approximately 55 psi; below the 60 psi constraint.

In-field Irrigation System

Calculations for Irrigation Scheduling and Demand

The irrigation scheduling and demand were calculated by considering the evapotranspiration (*ET*) from the crop in question as well as rainfall, available soil moisture, and the amount of water the soil can hold. The data values used in the calculations can be found in Tables 10 and 11.

The data given in Table 10 were provided by a local irrigation specialist, Juan Sevilla. The *ET* value for July given here is actually higher than the values measured during the 2012 July assessment trip (5.03 mm/day for the local table value compared to a maximum measured pan evaporation value of 3.81 mm/day taken during the 2012 July assessment trip), so the calculated demand is likely a conservative estimate.

The potential evapotranspiration (ET_o) represents the water requirement for a typical crop, and this is adjusted using a crop scaling factor to account for the time of year and the actual crop in question.

The effective rainfall (P_e) is the amount of rainfall that is absorbed by the soil and has been calculated from the Renfro equation. An explanation of the Renfro equation is outlined in Appendix I.

K_c in Table 10 represents the crop factor, which is 0.85 for alfalfa (FAO, 1998). The scaled *ET* (ET_c, in mm/month) for alfalfa includes this crop "scaling" factor, which is simply the ET_o for each month multiplied by 0.85. The irrigation requirement (*IR*) for alfalfa for each month is the effective rainfall subtracted from the scaled ET_c for alfalfa:

$$IR = ET_o\left(K_c\right) - P_e$$

The total demand (*D*), taking into account the efficiency of the irrigation method (ε), can be expressed as:

$$D = \frac{IR}{\varepsilon}$$

The final irrigation requirement in mm/month is seen at the bottom of Table 10. This irrigation requirement can then be used to determine the volumetric water requirement for the field.

Table 10. Irrigation Demand Calculation Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o (mm/day)	2.25	2.72	2.59	3.05	3.72	2.93	5.05	4.03	4.31	3.63	3.6	3.84
ET_o (mm/month)	69.75	76.16	80.29	91.5	115.32	87.9	156.55	124.93	129.3	112.53	108	119.04
Total rain, P (mm/month)	36	69	54	33	2	0	0	0	9	33	42	39
Effective rainfall, P_e (mm/month)	13	41.75	30.5	11.5	0	0	0	0	0	11.5	16	14.5
K_c alfalfa	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
ET_c alfalfa (mm/day)	1.91	2.31	2.2	2.59	3.16	2.49	4.29	3.43	3.66	3.09	3.06	3.26
ET_c alfalfa (mm/month)	59.29	64.74	68.25	77.78	98.02	74.72	133.07	106.19	109.91	95.65	91.8	101.18
IR alfalfa (mm/month)	46.29	22.99	37.75	66.28	98.02	74.72	133.07	106.19	109.91	84.15	75.8	86.68
Demand (mm/month)	66.13	32.84	53.92	94.68	140.03	106.74	190.1	151.7	157.01	120.22	108.29	123.83
Demand (mm/day)	2.13	1.17	1.74	3.16	4.52	3.56	6.13	4.89	5.23	3.88	3.61	3.99

The most taxing month will be July, which is in the middle of Huasta's dry season. The design of the irrigation system was done with this *IR* (190.1 mm/month). By designing for the maximum water requirement, all of the water needs during other months can be met. The total water requirement (*WR*) for a given time period (*t*) can be calculated by considering the daily demand (*D*) and the area of the field (*A*):

$$WR = D \times A \times t$$

The daily water requirement for the entire field is therefore:

$$WR = \frac{6.13mm}{day} * 0.64\ hectares ** 1\ day = 39232\ L$$

The maximum time between irrigation applications for a given section of the field is calculated according to the method outlined in Chapter 2 of the NRCS irrigation guide (NRCS, 1993), using information about the soil of the pasture. The basic soil properties of the Coris field are given in Table 11. The soil type was determined by Dr. Guy Fipps during the January 2013 assessment trip, and the information on the soil depth was provided by the board of directors of the Campesina Community. The available water content (*AWC*) was taken from Table 2-2 of the NRCS Irrigation Guide, assuming that the amount of rocks present in the soil is approximately 30% of the soil volume (Fipps, 2013) and taking the mid-range value. The AWC value in Table 2-2 is per unit depth of soil, so the total *AWC* was determined by multiplying the *AWC* by the soil depth. The most restrictive soil depth (30 cm) was used to ensure that all of the field would be adequately watered. The flatter portions of the field that contain deeper soil may require less water.

Table 11. Soil Properties in Coris field

Soil Type	Silty loam
Soil Depth, flat areas	40-50 cm
Soil Depth, upper sloped region	30-35 cm
AWC	0.14 in/in
Total *AWC* for soil depth of 30 cm (11.81 in)	1.652 in

The Management Allowable Depletion (*MAD*) of moisture for alfalfa is 50% of the *AWC* (NRCS, Table 3-3). The *MAD* for alfalfa in the Coris field can therefore be expressed as:

$$MAD(\text{in}) = 0.50(1.652\ \text{in}) = 0.826\ \text{in}$$

The irrigation frequency (*IF*), which is the maximum amount of time that can elapse between water applications, is the *MAD* divided by the crop ET rate:

$$IF(\text{days}) = \frac{MAD(\text{in})}{ET_{crop}\left(\text{in}/\text{day}\right)}$$

The minimum *IF* will be when the *ET* rate is the highest. This occurs in July when the ET_c of alfalfa is 4.29 mm/day or 0.169 in/day. The minimum irrigation frequency is therefore:

$$IF = \frac{0.862\ \text{in}}{0.169\ \text{in}/\text{day}} = 4.89\ \text{days}$$

Calculations for Sprinkler System

The impact sprinkler setup was designed using a conservative estimate of 0.8 L/s for the combined flow rates from the two springs. For the entire pasture to be covered, fifty-four ½" impact sprinklers, each requiring a 0.66 gpm flowrate, will be used, which converts to a flow rate of 2.25 L/s that is needed to operate all 54 sprinklers. Therefore, without water storage, the entire field cannot be watered at one time: it will be split into three irrigation blocks with a three-day rotation in the watering schedule where one irrigation block will be watered each day. RainBird 14VH sprinklers were chosen because they can be operated at low flow rates, allowing the field to be divided into fewer irrigation blocks. The specifications for the sprinkler system are summarized in Table 12.

The RainBird 14VH is a ½" full circle brass impact sprinkler with a trajectory angle of 23˚. The operating specifications for this particular sprinkler are given in Appendix F. The sprinklers will be operating at a pressure of 35 psi. With a 1/16" nozzle size, the sprinklers will have a 30 ft. radius of throw and a flow rate of 0.66 gpm. The pressure at the sprinklers will be controlled by a pressure regulator in each lateral pipe: the 35 psi Seninger PMR-MF Medium Flow Pressure Regulator (specs are given in Appendix G). As long as the inflow to the pressure regulator is between 35 and 100 psi, the pressure leaving the pressure regulator will be within the acceptable range of 34-37 psi. Given a 30 ft. radius of throw, 54 sprinklers are required to cover the entire field with head-to-head coverage. The sprinkler layout is shown in Figure B-6 in the set of drawings in Appendix B. The system will necessarily need to be field-fit, and the primary things to take into account when implementing the in-field irrigation system are the elevation of each sprinkler base and the sprinkler spacing. The laterals should be placed along the contours of the field as much as possible, and the variation in pressure at each sprinkler base should be no more than $\pm$10%. The variation in pressure should be no more than $\pm$3.5 psi, implying that elevation of each sprinkler base should be within ~2.5 m of the average elevation of the lateral pipeline. Because of the uneven layout of the field, complete head-to-head coverage is not always possible, but to ensure an even precipitation rate, the maximum distance between sprinkler heads is 60% of the diameter of throw.

To ensure that the sprinklers will have sufficient flow to operate, the field will be divided into 3 sections of equal area. For 1/3rd of the pasture to be watered, a flow rate of 0.749 L/s is needed. The combined flow from Yanallpa and Pucapuquio springs should be sufficient to water 1/3rd of the field. The time to water 1/3rd of the pasture would be approximately 5 hours per day, as calculated below. This is the primary basis for our temporary pasture irrigation solution until we implement a storage tank.

$$Flow\ rate = 0.749\frac{L}{s}; Water\ need\ for \frac{1}{3} of\ the\ field \sim \frac{39232\ L}{4} = 13077.3\ L;$$

$$\frac{13077.3\ L}{0.749\frac{L}{s}} = 17449.7\ seconds = \ 4.85\ hours$$

The daily demand can be met by watering each section of the field for 5 hours a day or alternately, a three-day rotation can be put in place where three times the daily demand for each section can be applied every fourth day. Each section of the field would then be watered for one 14.5-hour period every three days. That way, the sprinklers can run overnight (eg. from 5 PM to 7:30 AM) when evaporative losses will be lower, and the system can be turned off in the morning.

Each day, a designated Community member will set up the sprinklers on 1/3rd of the field (designated sections appear on the map in Figure B-6) on risers in designated positions on the pasture and begin irrigating. The irrigation will be stopped after 14.5 hours and risers rotated to another 1/3rd of the field. Once the alfalfa is fully grown (approximately 3-4 feet tall), all sprinklers should be removed before opening the pasture to grazing cattle.

Table 12. Specifications of Sprinkler System

Total Number of Sprinklers	54
# Sprinklers per section	18
Nozzle Size	1/16”
Operating Pressure	35 psi
Radius of Throw	30 ft.
Flow Rate (per sprinkler)	0.66 gpm
Watering Time (to meet daily demand)	4.85 hours

To determine precipitation rate, Rain Bird reference tables and appendices were used (Appendix H).

1. The maximum root depth is determined by the depth of the topsoil; a value of 30 cm (minimum soil depth in Table 11) will be used.
2. The field is divided into three irrigation blocks, so three times the daily IR will be applied for each watering (each block will be watered every three days). Therefore, the gross amount of moisture to be applied per watering is approximately 12.9 mm per watering.
3. From *Gross Amount of Moisture* (Table 4), using a hot climate with 70% efficiency in watering, 18.4 mm should be applied per watering.
4. Precipitation rate is determined by dividing gross moisture by number of hours per set. For the pasture, each rotation is a 24-hour period. This means that the required precipitation rate is 0.03 inches/hour or 0.7625 mm/hour.
5. Using 0.66 gpm flow rate for each sprinkler and approximately 30 feet X 30 feet spacing for the sprinkler array (see Figure B-6). Table 8 in the RainBird reference tables in Appendix H does not have a suitable value for the precipitation rate, as the lowest precipitation rate for 30 X 30 sprinklers is 0.11 in/hr for a flow rate of 1 gpm per sprinkler. However, extrapolating the data from the 30 X 30 row for a 0.03 inches/hour flow rate gives a 0.273 gpm sprinkler. Since the design is planned for a flow rate of 0.66 gpm, a lower value from the chart means that our flowrate and spacing is suitable to the pasture.

Because the field is a pasture and the system must withstand cattle grazing, the piping in the field will consist of laterals of 1 in. PVC pipe buried 1.5 feet from the surface, extending from the manifolds at the perimeter along the contours of the field. ½ in. PVC pipe will be used to connect each riser base to the lateral pipes. The beginning of each lateral pipeline will have its own pressure regulator and shutoff valve. As shown in Figure B-6, most of these valves can be located at the perimeter of the field.

<u>Manifold Pipes</u>

As described above, the manifolds will be used to distribute flow to the lateral pipes. In order to maintain adequate pressures throughout the system (i.e. higher than 35 psi but lower than 60 psi), a PRV will be installed directly upstream of the manifolds. The PRV will regulate the pressure at this point to 35 PSI. The manifold directing flow to the lowest portion of the field will also need a PRV installed due to the significant elevation change between the two points. As with the conveyance system, the manifolds were modeled using Pipe Flow Expert. A layout of the manifold system can be found in Figure 7.

The manifold specifications, pressures and velocities can be seen in Tables 13-18.

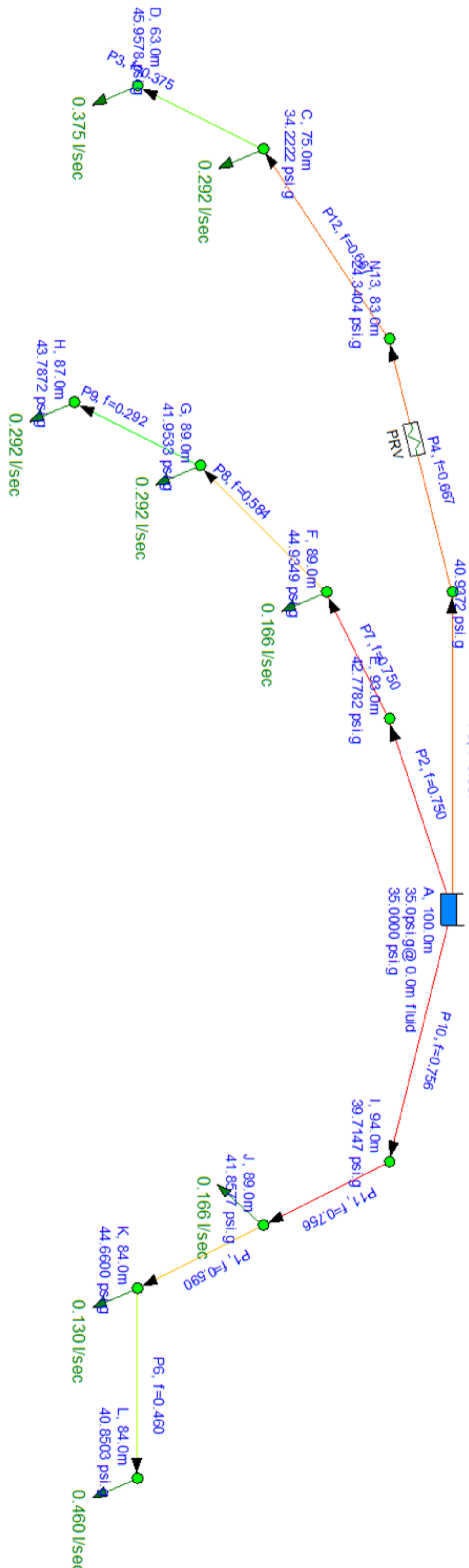

Figure 7. Irrigation Manifold System Layout

Table 13. Pipe Specifications of Manifold System

Section	Pipe Spec.	Length (m)	Flow (L/s)	Velocity (ft./sec.)
P5: A-B	1" PVC (ANSI) Sch. 40	28	0.667	3.925
P4: B-N13	1" PVC (ANSI) Sch. 40	24	0.667	3.925
P12: N13-C	1" PVC (ANSI) Sch. 40	16	0.667	3.925
P3: C-D	1/2" PVC (ANSI) Sch. 40	13	0.375	6.276

Table 14. Pressure and Hydraulic Grade of Manifold System

Node	Elevation (m)	Pressure (psi)	Static Head (m)	HGL (m)
A	3,131	35.00	3,131	3,156
B	3,125	40.94	3,131	3,154
N13	3,114	24.34	3,131	3,131
C	3,106	34.22	3,131	3,130
D	3,094	45.96	3,131	3,127

Table 15. Pipe Specifications of Manifold System

Section	Pipe Spec.	Length (m)	Flow (L/s)	Velocity (ft./sec.)
P2: A-E	1" PVC (ANSI) Sch. 40	19	0.75	4.413
P7: E-F	1" PVC (ANSI) Sch. 40	31	0.75	4.413
P8: F-G	1" PVC (ANSI) Sch. 40	41	0.584	3.436
P9: G-H	1" PVC (ANSI) Sch. 40	47	0.292	1.718

Table 16. Pressure and Hydraulic Grade of Manifold System

Node	Elevation (m)	Pressure (psi)	Static Head (m)	HGL (m)
A	3,131	35.00	3,131	3,156
E	3,124	42.78	3,131	3,154
F	3,120	44.93	3,131	3,152
G	3,120	41.95	3,131	3,150
H	3,118	43.79	3,131	3,149

Table 17. Pipe Specifications of Manifold System

Section	Pipe Spec.	Length (m)	Flow (L/s)	Velocity (ft./sec.)
P10: A-I	1" PVC (ANSI) Sch. 40	33	0.756	4.448
P11: I-J	1" PVC (ANSI) Sch. 40	43	0.756	4.448
P1: J-K	1" PVC (ANSI) Sch. 40	58	0.59	3.472
P6: K-L	1" PVC (ANSI) Sch. 40	80	0.46	2.707

Table 18. Pressure and Hydraulic Grade of Manifold System

Node	Elevation (m)	Pressure (psi)	Static Head (m)	HGL (m)
A	3,131	35.00	3,131	3,156
I	3,125	39.71	3,131	3,153
J	3,120	41.86	3,131	3,150
K	3,115	44.66	3,131	3,147
L	3,115	40.85	3,131	3,144

Lateral Pipes

The lateral pipe system has also been modeled using Pipe Flow Expert to ensure a constant pressure along the length of the pipe. As described above, the lateral pipes will be installed along a constant elevation with a PRV at the manifold junction; the PRV will regulate the pressure to 35 psi in order operate the sprinklers as designed. Figure 8 depicts the schematic layout of the lateral pipe system. The scenario shown in Figure 8 represents the operation of Block C while Block A and B remain shut off; the pressures indicated along Block A and Block B represent the static pressures in the system and are below 60 psi. One can see that the pressures along the laterals in Block C remain relatively constant. Table 19 shows the results of one of the simulated runs.

Table 19. Pressure and Hydraulic Grade for Simulation of Lateral Pipes

Node	Elevation (m)	Pressure (psi)	Static Head (m)	HGL (m)
L	3,115	40.85	3,115	3,144
N55	3,115	35.54	3,115	3,140
N56	3,115	35.54	3,115	3,140
N57	3,115	35.54	3,115	3,140
N58	3,115	35.54	3,115	3,140
N59	3,115	35.54	3,115	3,140
N60	3,115	35.54	3,115	3,140
N61	3,115	35.54	3,115	3,140
N62	3,115	35.54	3,115	3,140
N63	3,115	35.54	3,115	3,140
N64	3,115	35.54	3,115	3,140
N65	3,115	35.54	3,115	3,140

Table 19 only shows one of the laterals along Block C however the results for every lateral in the pasture were checked and determined to be similar to the results shown above and thus were not included in the report.

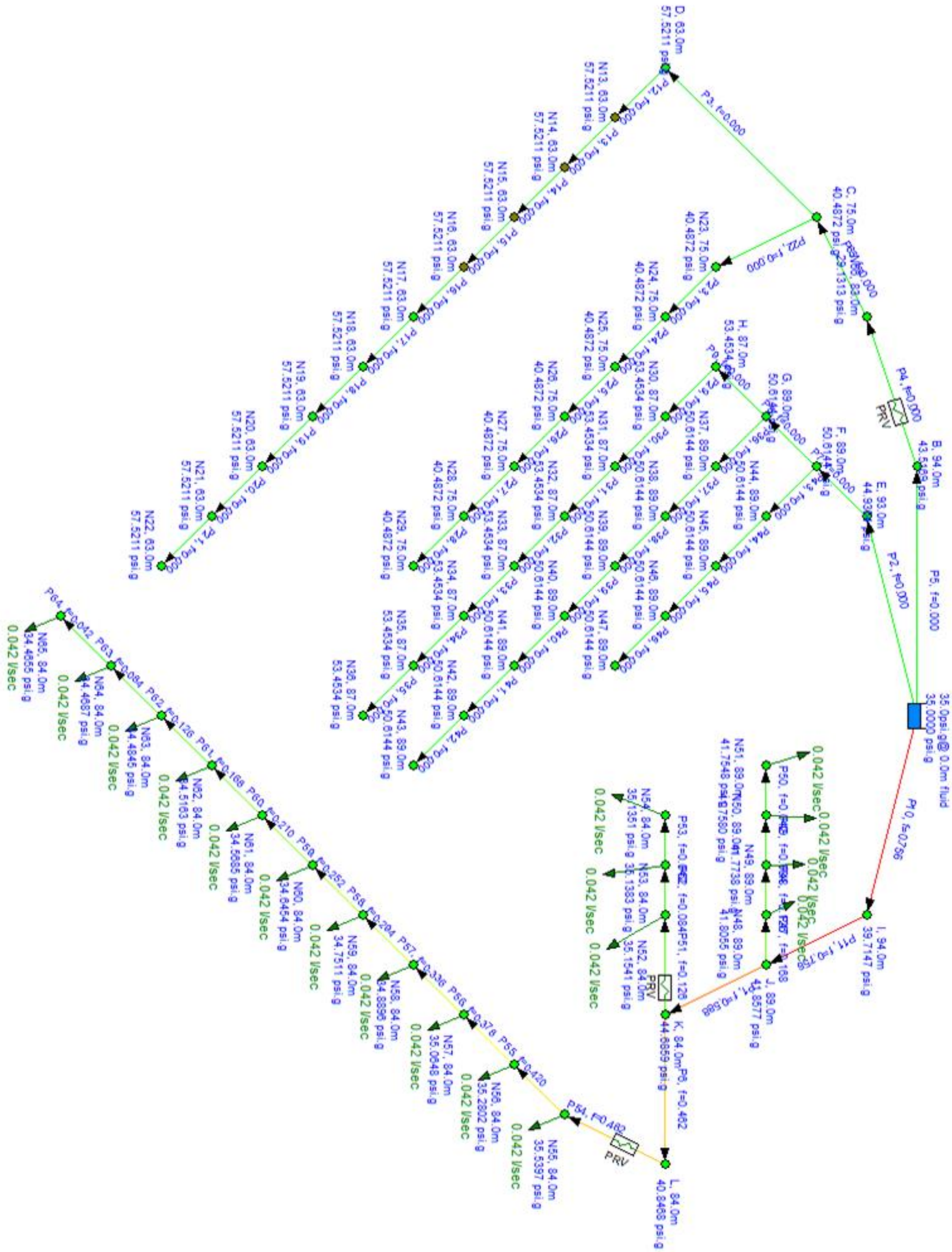

Figure 8. Schematic Layout of Lateral Piping System

4.3 Drawings

The set of drawings for the irrigation system is attached in Appendix B. An overview schematic of the system is given in Figure B-1 as well as drawings of the springs boxes, pressure break tank, conveyance pipeline, in-field irrigation system, and riser design.

4.4 Names and Qualifications of Designers

Name	Student or Professional	Qualifications	Work Done
Irrigation			
Clinton Peterson	Student	Senior level mechanical engineering undergraduate	Irrigation demand and precipitation rate calculations
Craig Dolder	Student	PhD student in mechanical engineering	Irrigation riser design
Rachel Chisolm	Student	PhD student in civil engineering	Irrigation design and scheduling calculations, in-field irrigation layout
Dr. Guy Fipps	Professional	Agricultural engineering professor and irrigation expert	Consultation and review of irrigation design and calculations
Hydraulics			
Fernando Salas	Student	PhD student in civil engineering	Modeled conveyance and irrigation system in Pipe Flow Exper
Elliott Gall	Student	PhD student in civil engineering	Modeled conveyance and irrigation system in Pipe Flow Expert
Valentina Prigiobbe	Professional	Post-doc in civil engineering	Modeled conveyance and irrigation system in Matlab; checked calculations
Juergen Walther	Student	PhD student in Physics	Modeled conveyance and irrigation system in Matlab; checked calculations
Maximilian Guenther	Student	PhD student in Physics	Modeled conveyance and irrigation system in Matlab; checked calculations
Daniel Schoenfelder			
Spring Box and Break Pressure Tank			
Drake Builta	Student	Civil engineering undergraduate student	Technical lead; designed spring boxes and break

			pressure tank
Tim Ager	Professional	Professional and Traveling mentor; has experience constructing spring boxes and tanks	Consultant; oversaw design activities
Evan Reschreiter	Student	Civil engineering undergraduate student	Reviewed spring box and break pressure tank designs; performed design calculations
Aasiyah Baig	Student	Civil engineering undergraduate student	Reviewed spring box and break pressure tank designs; designed concrete mix

4.5 524 Preliminary Design Report Comments

N/A

5.0 PROJECT OWNERSHIP

The spring box, conveyance, and irrigation system will be owned by the Campensina Community of Huasta. The Campesina Community collectively owns the land that the system is built on, and will continue to manage the land with the implemented system. The Community Assembly has approved the location of this project, indicating that all land needed for construction and pipeline is available and will not have property rights conflicts. The President of the Campesina Community has verbally committed to organizing members of the community for constructing the system, financing 5% of the system, learning the technical components of the system, operating the irrigation schedule as designed for optimal crop performance, and paying for the maintenance of the system. The board of directors is expected to appoint several point people to oversee and manage the maintenance of the system.

6.0 CONSTRUCTION PLAN

The construction of the system will be supervised by members of the CAMBIAR travel team and TMI; the Community has agreed to provide the unskilled labor for the project. Although CAMBIAR will primarily play a supervisory role, providing oversight and direction in the construction process, it is likely that team members will also participate in the physical labor required for construction alongside Community members. Materials procurement will be done by TMI and project leads Laura Read and Rachel Chisolm, who will be in Huaraz prior to the implementation trip. A mason with experience constructing spring boxes will be hired to oversee the construction of the two spring boxes and BPT. Because the Community has requested to dig the trenches for the conveyance pipeline between the BPT and the field before the July implementation, the staking and laying of the pipeline will be supervised by experienced personnel from TMI. TMI employees supervising the work of laying the conveyance pipeline will include: Laura Trejo, environmental engineer; Doris Chavez, who will work primarily in Community organization; and Juancito Sanchez, agricultural expert. The Campesina Community's board of directors will organize the labor contribution of Community members and ensure that an adequate number of workers will be present each day. An irrigation expert, Juan Sevilla, will go to Huasta in June to consult about the implementation of the irrigation system; if he is available, he will also be present to oversee the construction of the in-field irrigation system in July.

Details of the construction process for each of the system components is outlined below, with a breakdown of the construction tasks by day in Figures 9-12. The CAMBIAR team has planned 14 days in the Community. Construction of all system components is expected to take 10 days or fewer so that there are 4 extra days built into the schedule to allow for flexibility in the case of unforeseen setbacks or delays. After the complete system has been constructed, each of the system components (i.e. valves, sprinkler heads, etc.) will be tested to ensure that everything is in working order. The bill of materials, broken down for each of the system components, is given in Tables K-1 – K3 in Appendix K. The total estimated cost for each portion of the system is summarized in Table 20.

Table 20: Estimated Cost of Irrigation System

	Cost (US $)
Spring Boxes and BPT	$822.5
Conveyance Pipeline	$2605.00
In-field Irrigation System	$2916.10
Total	**$6343.60**

In-field Irrigation System

The project construction will be done by members of the Campesina Community with the guidance and help of the CAMBIAR team. The timeline for each step of the irrigation construction plan can be seen in Figure 9 along with an estimated number of workers needed for each task. The whole irrigation project is estimated to take approximately 10 days to complete. This is using a conservative estimate of time and number of workers required for each task. This leaves 4 days of extra time in case the project goes over schedule. For safety reasons as well as construction quality and time, it is recommended to use the number of workers specified in Figure 9 for each task.

According to the schedule outlined in Figure 9, the surveying of the irrigation pipeline should be done on the first day, including marking the spots on the field for the sprinkler risers as well as the pipelines according to the map of the field (refer to Figure B-7 for sprinkler and pipeline locations).

The digging of the irrigation pipeline should take place over 2 days, digging trenches deep and wide enough for the PVC pipe to sit 18” below the surface of the soil (Stryker, 2001). This is the most labor-intensive step, and the process of laying the in-field piping will go more quickly if more workers are available. It is possible that the piping for the whole field be laid in a single day if enough people are digging trenches.

The pressure regulators and pipe splitters can be placed as soon as the space is available for each device. This will coincide with irrigation pipe placement. As soon as the irrigation trenches are finished, the PVC pipe should be cut to length and angled joints placed as needed so that the pipe will fit inside the trenches (refer to the map in Figure B-7 for locations). Thrust blocks will be used to stabilize the pipeline wherever 90˚ joints are used.

The mixing of concrete can be completed when holes have been dug for the sprinkler riser footings, each 2’ deep and 6” in diameter, and irrigation-to-riser coupling has occurred. The irrigation-to-riser pipe coupling as well as all irrigation galvanized steel couplings should be done with Teflon tape to prevent leakage. The ½” galvanized steel pipe should be connected to the risers in the following fashion:
½” galvanized steel pipe in the base should have NPT male threading on the end that will connect to the riser. Using Teflon tape and a wrench, the ½” galvanized steel pipe should be connected to a 1/2” galvanized steel-to-PVC steel coupling. The coupling should then be connected to the ½” PVC T-joint. All connections should be made using Teflon tape, except the coupling connecting the riser to the base, which can be connected and disconnected without the use of Teflon tape and should not leak when joined together. This is the critical component of the riser: care should be taken that it not be damaged, and that it rise just above the top of the concrete casing. When risers are not in place, the galvanized steel connection in the base should be capped.

The rest of the riser construction should be done using the following connections: impact sprinkler to female/female coupling to ½" 3-foot long galvanized pipe to coupling. All NPT threads (everything except the coupling) should be done using Teflon tape to prevent leakage.

Once all irrigation pipes, pressure reduction valves, splitters, and risers are in place, the project should be completed and trenches backfilled with soil.

Conveyance System

The path of the pipeline presents several challenges, as the mountainous terrain and accompanying conditions change repeatedly over the 0.75 km distance. Community members have expressed a preference for clearing the path for the main conveyance pipeline and trenching prior to the planned implementation in July because the ground will be softer and easier to dig immediately after the conclusion of the rainy season in May. Prior to arrival of the travel team, community members will remove vegetation along the pipeline path, dig the trenches and lay the pipeline between the pressure break tank and the field. This work will be done with the supervision of experienced personnel from CAMBIAR's NGO partner TMI. Upon arrival of the implementation team, the exact route of the pipeline will be marked, and the ends of the pipeline will be capped so that the valves can be installed and the pipeline can be connected to the pressure break tank and the in-field irrigation system once those components are complete.

The pipeline will be trenched to a depth of 0.5 m for protection from human traffic, animal traffic, and UV damage. The path for the conveyance pipeline will be staked with the supervision of TMI employees. The path should have a relatively constant grade and gradually decreasing elevation to eliminate the need for air release valves and cleanout valves. A survey will be done as the path is staked to ensure that the pipeline elevation is constantly decreasing and that there are no abrupt changes in elevation.

The laying of the pipeline will be done with the supervision of someone from TMI or the CAMBIAR team, and the pipe connections will be cleaned and primed before applying PVC glue to ensure a good seal. Although CAMBIAR does not anticipate any 90˚ bends in the conveyance pipeline, if these should occur, thrust blocks will be installed to prevent excess movement that could cause joints to loosen. There are a number of 90˚ bends in the in-field piping system, and thrust blocks will be placed at each of those joints to prevent movement. The thrust blocks will consist of a piece of poured concrete with a surface area of 0.125 ft^2.

Due to the difficulty in accurately estimating the number and type of each obstacle or condition along the pipeline prior to final pipeline marking, the design and materials list accounts for a varying number of bends and joints. Figure 11 presents a preliminary labor time estimate for each day of construction. It should be noted that allowances for trenching and exposed conditions are assumed. An estimate of the timing and number of workers required for the trenching and laying of the pipeline that will be done by the Campesina Community before the CAMBIAR team arrives is presented in Figure 12.

Shutoff valves will be located at the outlet of each structure as well as the inlet pipes for the BPT. Shutoff valves will also be installed in each of the manifolds. All valves should be tested before they are installed to ensure that they are functioning properly. Valve boxes will be constructed using wood and nails at the location of each valve to protect the valves and allow for easy access. The valve boxes will consist of four sides of wood, cut to fit around the pipe, and a wooden lid on hinges. The proposed design for the valve boxes can be seen in Figure B-5 in the set of drawings in Appendix B.

Spring Boxes and BPT

Bringing construction materials to the site will take 5 to 7 hours. There is about 2,100 lbs. of material that needs to be brought to each spring box construction site, which will require at least 6 people per spring box. A truck will be used to bring materials as close to the site as possible. If available, wheelbarrows can provide extra help in this process.

Excavating the spring box site and cleaning it will take about one day's work. The site must be prepared by digging into the soil to reach the impervious layer near the eye of the spring. This process could be done while materials are brought to the site. This job could use 4 to 8 people.

Locating the eye of the spring is unpredictable by nature, so it's difficult to give a time estimate. Two or three workers should dig towards the flow of the spring and locate the eye (a single point from which the flow appears to come). Meanwhile, flow from the spring should be diverted from the construction site with the use of a drainage basin that surrounds the perimeter of the work area. This should be done early in the excavation process to minimize moisture conditions at the site.

Formwork for each spring box base will take about 4 hours to construct with 3 to 4 people. The spring box base and walls will be cast in one piece to avoid cold joints and to decrease the construction time. The formwork will likely include a large box for the base and the outer faces of the structure. A smaller box will support the inside faces of the structure and will be placed shortly after the base is poured. The inner box must be held in place to prevent buoyant forces from displacing it vertically. Rebar reinforcement and pipework should be placed before pouring of the concrete.

Mixing and pouring each spring box base is more labor intensive and will require three or four teams of three people mixing, with another two or three people supervising. This will probably take about an hour or two but will need to be done precisely. The accelerating agent will be mixed into the water before the water is added to the concrete mixture.

Mixing and pouring of the spring box walls will require five or six teams of three people mixing with another two or three people supervising. This will probably take about an hour or two but will need to be done as soon as possible after the base is poured. Instead of using an accelerating admixture, air entrainment will be used for the wall sections.

Formwork, mixing, and pouring for the roof slab will take around three hours with two groups of three people mixing and another two completing the formwork and rebar placement.

Formwork for the break pressure tank will take around two hours with three to four people. Pipework should be placed before the concrete is poured.

Mixing and pouring of the break pressure tank will take two hours with two teams of three mixers and one person supervising. The overflow, cleanout, inlet, and outlet valves should be installed at this time as well as a spill pad.

Concrete curing: twenty-four hours after the concrete is poured, the formwork should be removed and the concrete wetted. The concrete should be wetted twice a day for seven days afterwards (more often if it is drying out quickly).

Day 1: Begin clearing and leveling site for break pressure tank (BPT) and making formwork for BPT.

Day 2: Finish formwork and pipe placement for BPT. Pour walls of BPT.

Day 3: After 24 hours, remove formwork for BPT walls and allow to cure for 7 days. Move all materials necessary for formwork and excavation to Yanallpa site. Begin digging and cleaning the area while diverting flow into drainage ditch.

Day 4: Finish excavation and locate the eye of Yanallpa. Begin outer formwork for the base of the spring box. Make sure that all materials required for mixing and pouring concrete are on site. Begin moving materials to Pucapuquio.

Day 5: Finish the outer formwork for Yanallpa spring box. Install the cleanout pipe and rebar reinforcement of the base before mixing and pouring concrete into the outer formwork. Place the inner formwork into the structure. Place the outlet, overflow, and cleanout pipes in the formwork before pouring the walls. Mix and pour the wall sections. Pour the spillpad. Place formwork for the roof slab before mixing and pouring it. Allow the concrete to cure for at least 24 hours before removing the formwork and watering with damp burlap if available.

Day 6: Excavate and clean Pucapuquio while diverting water flow and constructing the diversion ditch. Locate the eye of Pucapuquio. Remove the formwork from the Yanallpa spring box once 24 hours have passed and move the forms to Pucapuquio. Make sure that all materials required for mixing and pouring concrete are on site.

Day 7: Place the outer formwork for Pucapuquio spring box. Place the rebar and cleanout pipe. Mix and pour the base section. Place the inner formwork and install the outlet, overflow, and cleanout pipes in the formwork before pouring the walls. Mix and pour the wall sections. Place formwork for the roof slab and spillpad before mixing concrete and pouring them. Allow the concrete to cure for at least 24 hours before removing the formwork and watering with damp burlap if available.

Day 8: Clean the break pressure tank site and dig to a hard layer of rock. Excavate the immediately surrounding area while constructing the formwork. Install the inlet, outlet, cleanout, and overflow pipes before mixing and pouring concrete into the formwork. Allow the concrete to cure for 24 hours before removing the formwork and watering.

Day 9: Pour base of BPT.

Day 10: 24 hours after pouring base of BPT, formwork should be removed and valves and connections to conveyance system can be installed.

Milestone	Workers needed	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Surveying/marking irrigation pipeline	3	X													
Marking sprinkler locations	3	X													
Digging irrigation pipeline	10		X	X											
Pressure regulator/pipe splitter placement	2			X											
Irrigation pipe placement	5				X										
Concrete mixing/filling	3				X										
Sprinkler riser construction/placement	2					X									
Concrete curing	0					X	X	X	X	X	X	X	X	X	X
Pipe cutting/pipe joining	2						X	X	X						
Pasture backfilling	10									X	X				

Figure 9 – Projected irrigation project construction timeline

Task	Workers needed	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Transfer materials	Lots		X BPT		X Yan.	X Yan.		X Puc.	X Puc.	X BPT					
Yanallpa- excavation and cleaning, diversion ditch	3?			X	X										
Yanallpa- formwork	2?				X	X									
Yanallpa- pipe and rebar placement	2?					X									
Yanallpa- concrete mixing and pour	5?					X									
Pucapuquio- excavation, diversion ditch	5?						X	X							
Pucapuquio- formwork, pipe and rebar placement	2							X	X						
Pucapuquio- concrete mixing and pour	5?								X						
BPT- excavate foundation	?	X													
BPT- formwork, pipe placement	2?		X												
BPT- concrete mixing and pour walls	5?		X												
BPT- concrete mixing and pour base										X					

Figure 10 – Projected <u>Structures</u> project construction timeline

Milestone	Workers needed	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Mark line from springs to BPT	3	X													
Trench springs to BPT	20?			X	X	X									
Lay pipe from springs to BPT	5?						X	X							
Backfill- springs to BPT	20?							X							
Install valves and connections to BPT and spring boxes	5?										X				

Figure 11 – Projected conveyance pipeline project construction timeline

Milestone	Workers needed	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Mark line from BPT to field	3, TMI	X													
Trench BPT to field	20?		X	X	X	X	X	X							
Lay pipe from BPT to field, cap ends of pipe	5?								X						
Backfill- BPT to field	20?								X	X					

Figure 12 – Projected conveyance pipeline project construction timeline in May prior to implementation trip

7.0 SUSTAINABILITY

7.1 Background

This implementation will be the first step in providing irrigation water to a community-owned pasture for improved cattle grazing land. The sustainability issues associated with this project relate primarily to long-term operation and maintenance of the system. The ownership of the system is clearly defined; irrigation of this land is a high priority for the Campesina Community, so problems with ownership are not anticipated. Similarly, the community members recognize the value of the system that will be installed and were involved in the selection of the technology (they put forward the suggestion of sprinklers), so problems with acceptance of the technology are not expected. However, understanding of the system will be important for successful ongoing operation and maintenance.

CAMBIAR is taking a three-pronged approach to addressing this sustainability issue. First, members of the Campesina Community will be involved in the construction of the system, which will contribute to their understanding of the system. They will participate in the entire implementation process, which will give them a good understanding of the components of the physical system and how those components are assembled. Second, specific members of the Campesina Community will be designated (by the Community) as responsible for operation and maintenance of the system; these people will be given copies of an operations and maintenance manual and they will receive direct training in how to perform these activities, both through discussion of the manual and through demonstrations and hands-on lessons. Finally, all citizens of Huasta will be invited to participate in educational workshops, during which some of the activities will address methods of irrigation. (See Section 7.3 for further discussion of educational plans.)

7.2 Operation and Maintenance

Community members will directly participate in all phases of construction, and through that process they should gain a good understanding of how the system works and how to install parts of the system. After construction is completed, CAMBIAR will hold a workshop that all Community members will be required to attend. During this workshop, CAMBIAR team members will explain how the system works and go through the steps required for system maintenance. The maintenance steps required for each of the system components are outlined below:

<u>Spring Box and BPT</u>
Check the structures periodically for build up of debris (eg. sand and leaves) and clean out as necessary. A clean-out drain will be installed at the bottom of each structure, and this pipe should be flushed whenever cleaning is performed.

<u>Conveyance Pipeline</u>
The community maintenance team will need to walk the pipeline every three months to check for leaks. Leaks can be detected by identifying places where the surrounding soil is wet or where the vegetation is unusually green. When leaks are detected, the source of the leak should be located and the damaged portion of pipe replaced.

<u>Irrigation</u>
Major problems with the irrigation system (such as clogged sprinkler heads) will most likely be detected during system operations. The sprinklers should be checked periodically to ensure that the proper radius of throw and precipitation rates are being achieved. The sprinkler system is designed to have mostly head-to-head coverage, so if the reach of one sprinkler does not approach the neighboring sprinkler bases, there is most likely a clog in the sprinkler head. Clogs can be fixed by removing the sprinkler head and back-flushing with water. The precipitation rate will be measured by placing a rain gauge in the field and ensuring that the proper amount of

water (as outlined in the irrigation scheduling calculations in Section 4.2) is being applied to the field.

The Board of Directors of the Campesina Community will be responsible for coordinating and overseeing operations and maintenance of the system. The Campesina Community has estimated that increased productivity from irrigating the Coris field could bring in $630 (US $) per year of additional income, and a portion of this income will be used to cover the cost of maintaining the system. The primary maintenance costs associated with the irrigation system are the costs of replacing valves, portions of the pipeline that break and replacement parts for the sprinkler heads. Significant maintenance costs associated with the concrete structures are not anticipated. The NRCS irrigation guide estimates operation and maintenance costs for the lifetime of sprinklers based on the percentage of total project cost. The guide states that handmove and portable sprinklers have a lifetime of 15+ years and require an annual contribution of 2-6% of the total cost to maintain. Valves for the system last for 10-25 years and require a yearly 3% contribution of total project cost. The NRCS handbook also estimates that buried PVC has a lifetime of 25 years and needs about 1% of the project cost for annual maintenance.

Table 21: Annual Maintenance Cost Breakdown

Component	Estimated Annual O&M Cost
Removable/portable sprinkler	$58.32 - $174.96
PVC piping (conveyance)	$26.05
Valves	$58.32
Other	
Total	~ $142 - $259

7.3 Education

The educational/training goals during this trip are twofold:

1. Train community maintenance team and Huasta residents that will be involved in operating and maintaining the irrigation system;

2. Hold capacity-building workshops for the general public (adults and children).

Technical Training

Members of the community will be partipicating in the construction of the irrigation system, which will help them to understand the system and its functionality more thoroughly than could be conveyed simply through training sessions. This participation is considered an important part of the education and training process; there will also be more formalized training sessions on how to operate and maintain the system.

For the training on the operations and maintenance of the irrigation system, CAMBIAR will provide an Operations and Maintenance (O&M) Manual, written by the CAMBIAR team, and maintenance logs for recording all maintenance activity. The travel team will also work with all individuals who will be involved in operating and maintaining the system to explain and demonstrate the tasks necessary for regular maintenance, including keeping work logs.

The O&M Manual will be written in a straightforward format with language that is easy to understand, augmented with illustrations deemed necessary for clarity. The content of the O&M Manual will include:

- Descriptions of each portion of the irrigation system
- Operational procedures for the sprinklers and risers, which are the only portions of the system that should be actively involved in operations
- Preventative and correctional maintenance procedures
- Instructions for tests related to maintenance and monitoring
- Supplemental instructions, as necessary

Copies of the O&M Manual will be given to all individuals participating in the training process as well as to the board of directors of the Campesina Community.

The maintenance logs will be provided for workers to log each maintenance task once it has been completed. This will allow for monitoring of the maintenance program. Maintenance logs will be periodically reviewed so that gaps in maintenance can then be addressed. These documents will be written in English and translated to Spanish.

To complete the technical training process, CAMBIAR travelers (if a trip is taken in January 2014), TMI staff, or other skilled volunteers will visit the operations and maintenance workers about six months after the July 2013 training sessions. During this follow-up, the operations and maintenance workers will be observed to identify potential problems in how they execute tasks, volunteers will clarify misunderstandings and correct errors, and workers will have an opportunity to ask questions that may have arisen in the course of the first season that the system is in use.

Capacity Building

In addition to technical training sessions for the operation and maintenance of the irrigation system, CAMBIAR will hold workshops to which all residents of Huasta will be invited. These workshops will build on the workshops held during previous trips. The subject matter in these workshops will include discussions on different types of irrigation and how they work, and why sprinklers are more conservative than flood irrigation. In addition, the workshops will discuss hygiene issues that were pinpointed as potential problem areas by the activities in the July 2012 workshops.

Workshops specifically for the children of Huasta will be held at the school, which will be in session while the CAMBIAR team is in Huasta. These workshops will include age-appropriate activities to teach about hygiene, climate, and the water cycle.

To supplement the workshop activities held during the implementation trip, the CAMBIAR team will create and distribute materials to reinforce learning after the workshops are over. These will most likely be posters and calendars that can hang on walls and remind Huasta residents on a regular basis of what was discussed in the workshops.

8.0 MONITORING

8.1 Monitoring plan for current project

Several instruments will be installed to enable CAMBIAR and the Campesina Community to monitor the irrigation system for improvements and changes, and allow for a flexible management plan that can adapt to the Community's evolving needs. A flow meter will be installed above the irrigated field to measure the instantaneous flow during irrigation as well as the total amount of water used. Both of these numbers will be recorded on a weekly basis by a designated member of the Campesina Community. Additionally, soil moisture sensors will be placed in the field and read on a weekly basis to help continuously refine the irrigation scheduling for efficient water management. Community members will be trained on how to read the sensors and interpret the output data. Finally, alfalfa production levels will be measured and compared with the community's goal of four cuttings per year. This last metric will be the most difficult to quantify.

Since cattle are allowed to graze on the field rather than manually cutting the alfalfa, the height and density of the crop will be approximated by the community prior to allowing the cattle to graze. However, this metric is also crucial for evaluating system performance and gained yields due to the installation of the irrigation system.

The team plans to train several members of the Community on the data collection equipment and proper practices. Initially, the data will be recorded into a log, kept in the hacienda located near the field. In the future, the team hopes to pilot an SMS-based data collection system that will manage the data electronically.

In summary, the three metrics that CAMBIAR will use to assess the performance of the irrigation system are:

- Flow rate
- Soil moisture
- Crop yield

8.2 Monitoring of past-implemented projects

As stated in previous reports, the objectives of the sanitation project were to provide to the Municipality:

1. A list of general recommendations for the rehabilitation, maintenance and monitoring of the WWTP,
2. Technical training of community members assigned to operate and maintain the WWTP,
3. Assessment of the WWTP and its operational status,
4. General workshops to educate and raise awareness in the community about the importance of health and sanitation.

CAMBIAR will continue to monitor the success of this project by measuring both quantitative and qualitative metrics for each goal stated above. CAMBIAR drafted a set of general recommendations for the WWTP and gave them to the Municipality; they can be found in the post-assessment report for Assessment III. The recommendations touch on both infrastructure improvements and operation and maintenance of the WWTP.

In order to judge the success of each recommended infrastructure improvement, the following questions will be asked:

1. *Has the task been completed? If yes, is it serving its function?*

If not,

2. *Have steps been initiated towards completing this task?*
3. *Who is in charge of this task?*
4. *Is there a financial plan for completing this task?*
5. *Have any materials needed to complete this task been acquired?*

As soon as each of the infrastructure improvements has been completed, CAMBIAR will consider this part of the project successful. The success of the operation and maintenance recommendations and the accompanying technical training will be qualitatively measured as these tasks vary in the manner in which they are executed.

In January 2013, CAMBIAR signed an MOU with the mayor concerning WWTP maintenance and presented the Municipality with an operation and maintenance manual and a maintenance log in which technicians can record the maintenance tasks they perform (i.e. the dates on which they perform each task, other notes and observations). The CAMBIAR team was not able to lead the WWTP training workshop because of some organizational difficulties with the Municipality, but the team plans to continue working with the Municipality to improve the operation and maintenance of the WWTP and hopes to conduct a formal training workshop for the WWTP in the summer of 2013. When the planned workshop did not occur in January, the WWTP maintenance log and the operations and maintenance manual were left with the mayor's secretary to deliver. Laura Read plans to follow up with the mayor over the next few months to determine whether the materials have been delivered, and whether the new worker has read the operation manual. From this point, the team will decide how to move forward with this part of the project during the anticipated July implementation trip. Despite CAMBIAR's not having been able to conduct a formal training workshop, significant improvements in the operation of the WWTP have been observed as a result of informal conversations with those responsible for the WWTP maintenance.

Once the WWTP has been rehabilitated and regular operation and maintenance procedures have been put in place, CAMBIAR will monitor the performance of the plant by repeatedly taking water quality measurements at the effluent of the facility; this data will be compared to the baseline data already collected to provide a quantitative metric for success. Because the WWTP is still not fully functioning, the monitoring of the performance of the WWTP through water quality measurements has not yet been initiated.

8.2.1 Functionality Status Supporting Information

Improvements in the operation of the WWTP are noted below in Section 8.2.2. As of Assessment IV in January 2013, the functionality of the WWTP has improved, and on that trip the CAMBIAR team observed the decant, flowing from all three septic tanks, was clear. The septic tanks were, however, still being ventilated with the lids propped open, so it is likely that biological activity in the septic tanks is not being optimized. Water quality tests of the WWTP effluent were not performed because the needed repairs to the WWTP infrastructure have not yet been initiated.

8.2.2 Periodic Maintenance Supporting Information

During Assessment IV, the team visited the WWTP and found that the headworks was clear and water was passing through. It appeared that the intake structure is being cleaned regularly (the CAMBIAR team did not observe any clogs during the trip). Septic tanks were full and the decant was coming off, which is a change from before, when the tanks were being emptied frequently. This has given the sludge a chance to build up and promote biological activity. Several operation concerns still exist: the lids to the septic tanks were propped open and there was a foul odor due to the free ventilation. Also, the sludge continues to be disposed of on the ground next to the drying bed and this has been a persistent problem since the team noted the problem in July 2012. Functionally, the valve to the bypass was still jammed, preventing the water from entering the biological filter.

8.2.3 Demonstration of Knowledge Transfer Supporting Information

As noted above, the CAMBIAR team has seen marked improvements in the operation of the WWTP that are a result of informal conversations with Juvencio, the worker that the Municipality had hired to maintain the WWTP. The changes that the CAMBIAR team has observed are:

- The septic tanks are no longer being emptied on a regular basis. The septic tanks are only emptied when the sludge level reaches a certain point.

- The sludge is being allowed to dry fully in the drying beds before removal.
- The intake structure is being regularly checked for clogs, and the influent is able to flow freely into the WWTP.

9.0 COMMUNITY AGREEMENT/CONTRACT

CAMBIAR has signed Memorandum of Understanding (MOU) documents with in-country partners at various steps in the program. The first MOU was signed with TMI and the Commonwealth in August 2011, and this functions as an umbrella MOU for the program. A benchmark MOU was signed with the Campesina Community of Huasta in August 2012, and a final MOU was signed with the Campesina Community in February 2013.

A copy of the most updated MOU between the Campesina Community and CAMBIAR is attached in Appendix L. This MOU was presented to the Campesina Community on February 5, 2013 and was signed and accepted as final after several changes on February 22, 2013. The CAMBIAR team is encouraged by the president's and secretary's willingness to read through the entire MOU and make changes and comments when needed, and it has been an open conversation regarding implementation plans and the fee structure.

10.0 SITE ASSESSMENT ACTIVITIES

During the implementation trip, assessment activities will be carried out alongside implementation activities to ensure adequate data collection to support the sustainability of the project. Flow rates will be measured at both spring sources to verify sufficient supply. Soil tests will be done at the sites of both spring boxes and the pressure break tank to ensure adequate soil stability to support the structures to be constructed. A site for a storage tank, which may be constructed in the future, will be scouted and soil tests performed at that site as well.

11.0 PROFESSIONAL MENTOR/TECHNICAL LEAD ASSESSMENT

11.1 Professional Mentor/Technical Lead Name (who provided the assessment)

11.2 Professional Mentor/Technical Lead Assessment

The project leads and subgroup leads prepared the various sections of this design and project plan document. Information was gathered from previous assessment reports, firsthand experience from traveling to Peru, as well as from discussions during the weekly Peru Project meetings. These weekly meetings have been a forum to discuss and develop the design and project plan for this upcoming implementation trip. Subgroups were formed for hydraulics, spring box, irrigation, and education with all members of the Peru team contributing to the preliminary design and project plan. The goal of the implementation trip this summer is to construct the irrigation system discussed during numerous meetings with the Campesina Comunidad. Our chapter and the Campesina Comunidad have agreed upon the general form of the irrigation system and with using the springs Yanallpa and Pucapuquio as the irrigation sources. The final details of the irrigation system have been designed over the last three months. Throughout this process, we have been extremely fortunate to have the input of from Texas A&M University. traveled to the project site in January and the project leads have consulted with him as the design has evolved. His extensive experience and expertise in irrigation have been invaluable to the project. I personally have participated in this project for over a year, have been directly involved in the development of this design and project plan, and will continue my involvement up to and throughout this upcoming implementation trip.

11.3 Professional Mentor/Technical Lead Affirmation

I was actively involved in the preparation of this pre-implementation trip report, will continue my involvement, and accept responsibility for the course that this project is taking.

References

FAO Irrigation and Drainage Papers. (1998). *Crop Evapotranspiration.* FAO.

Fipps, G. Personal Communication, 2013, January. (R. Chisolm, Interviewer)

Houghtalen, R.J., Akan, A.O., and Hwang, N.H. (2010). Fundamentals of Hydraulic Engineering Systems (4th ed.). Prentice Hall.

Marchi, E., and Rubatta, A. (1999) Meccanica dei fluidi – principi and applicazioni idrauliche Ed. UTET, Torino, Italy.

Stryker, J. (2013, 4 12). *Irrigation Tutorials*. Retrieved from www.irrigationtutorials.com

United States Department of Agriculture. (1993). *Irrigation Water Requirements: Part 623 National Engineering Handbook.* Washington D.C.: USDA.

Appendix A: Maps

Figure A-1: Regional map of Ancash, Peru.

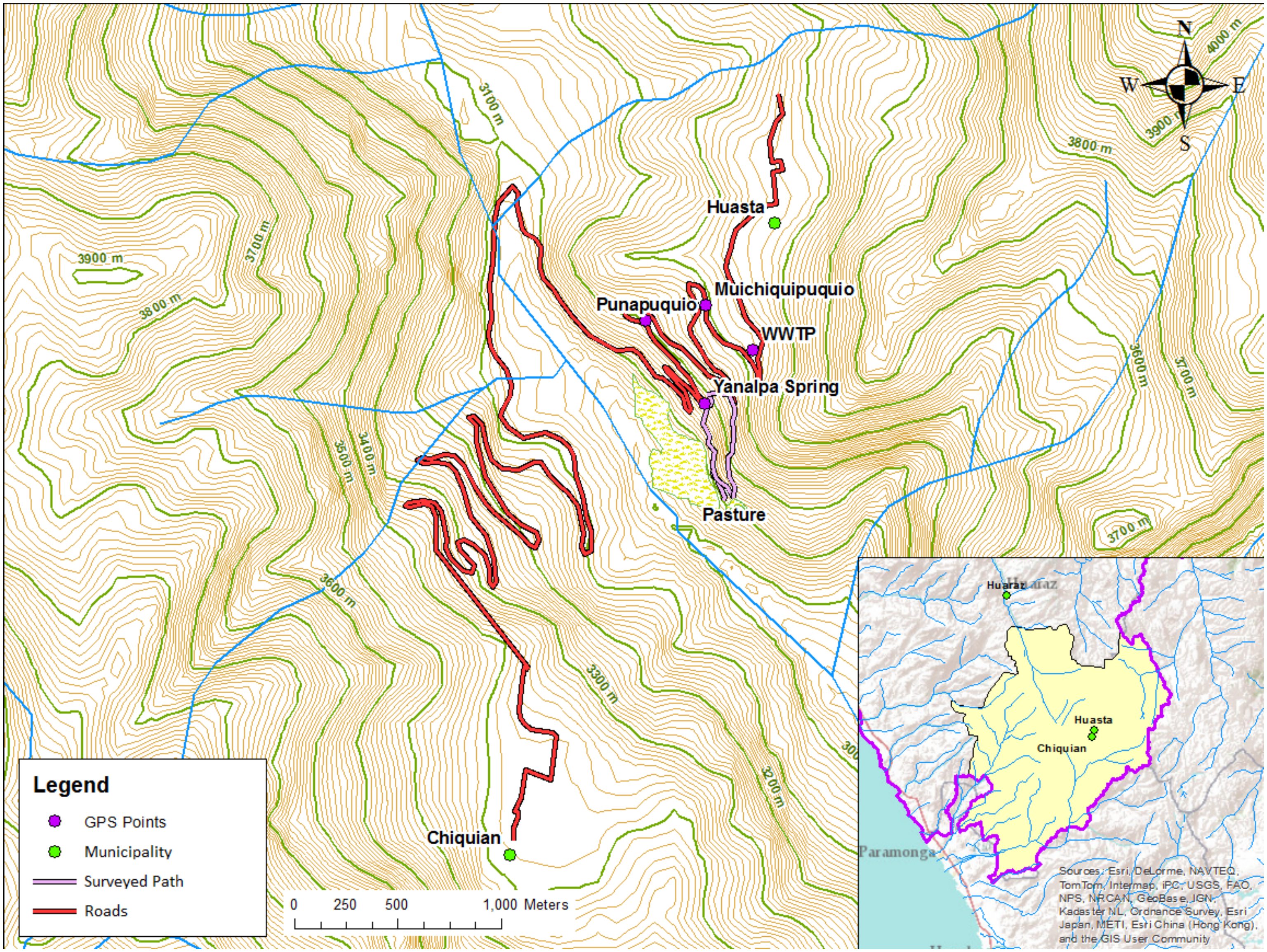

Figure A-2: Road from Chiquian to Huasta.

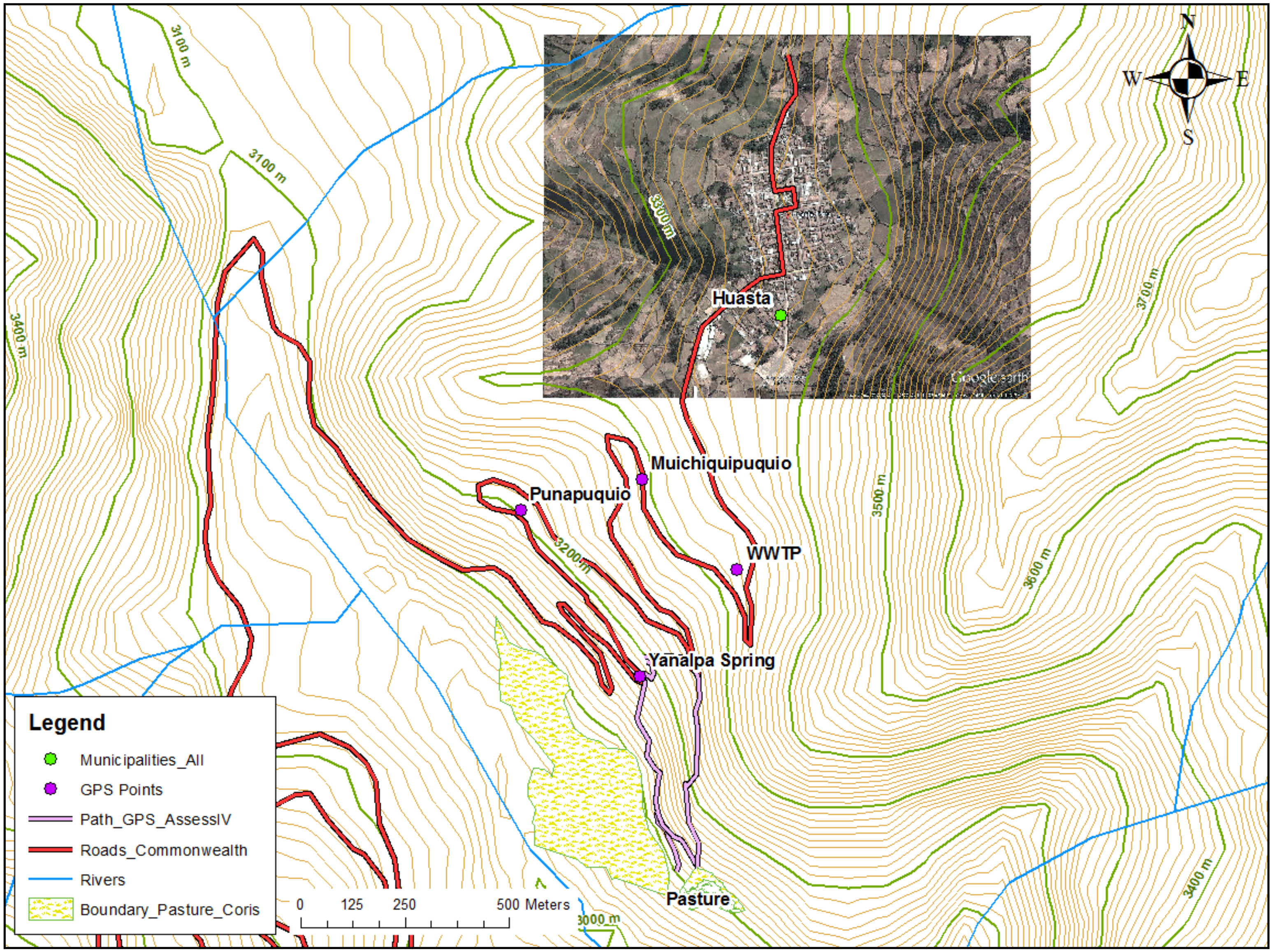

Figure A-3: Map of Huasta area.

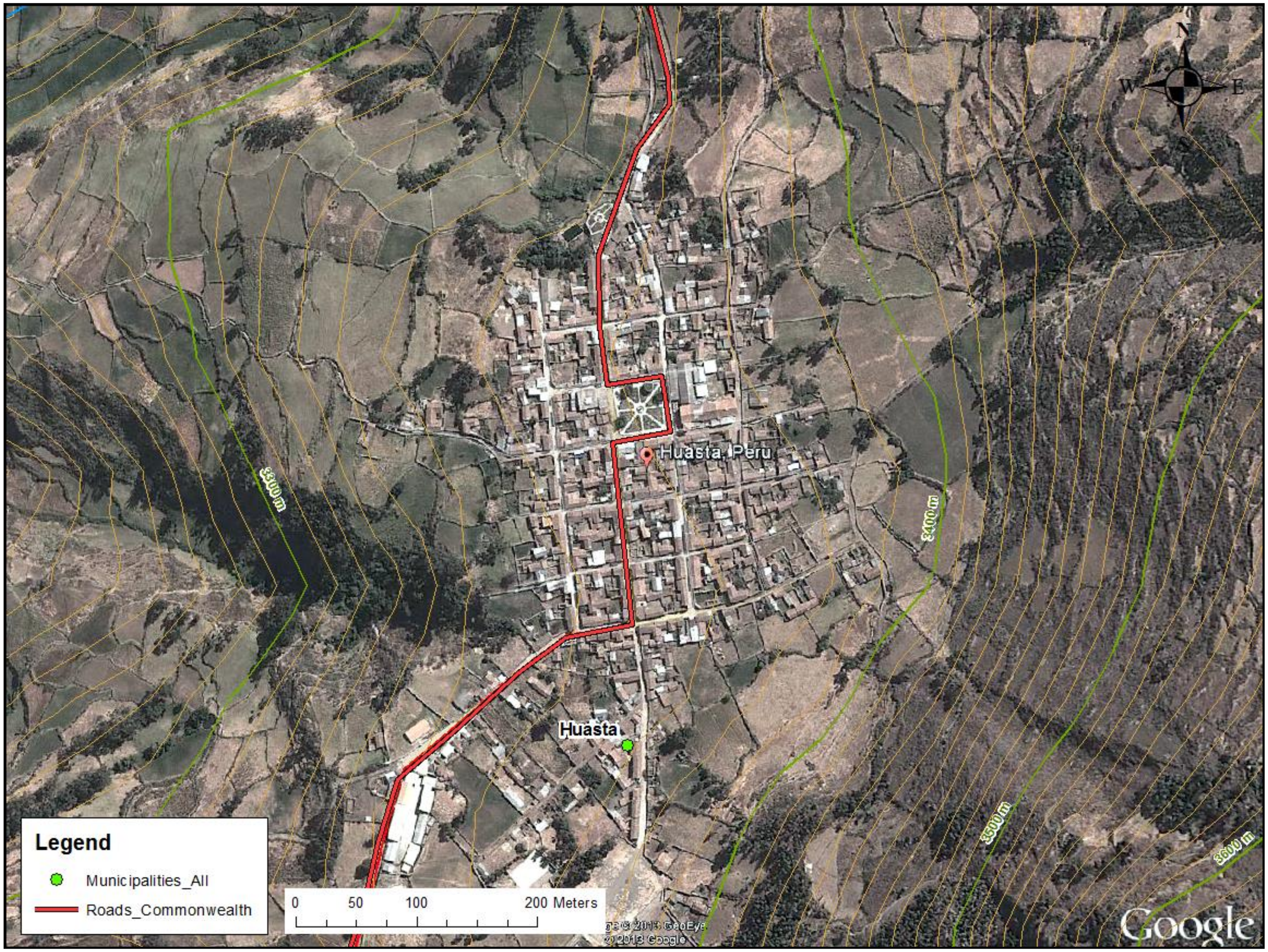

Figure A-4: Aerial image of Huasta.

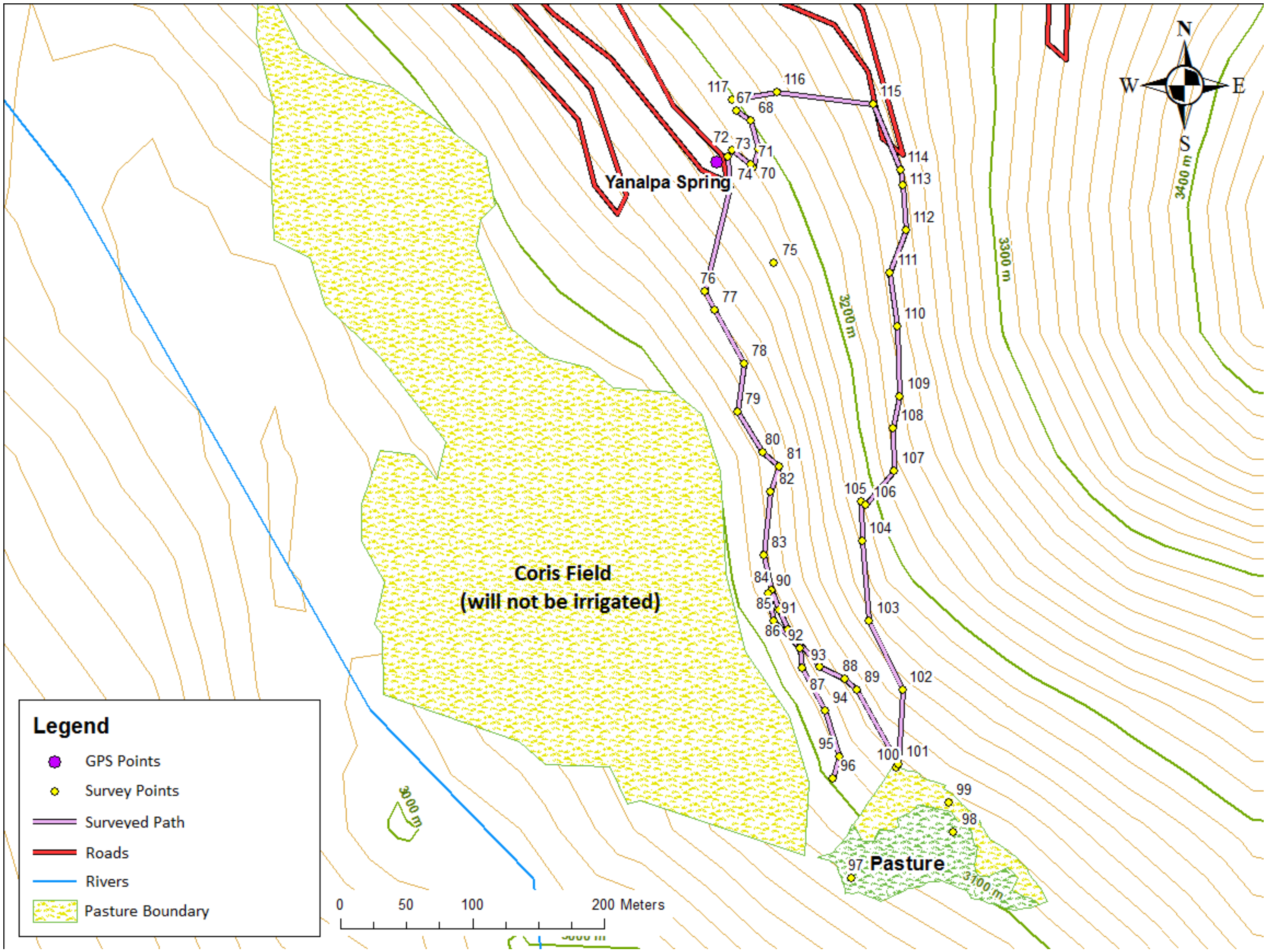

Figure A-5: Surveyed path from Yanallpa Spring to pasture

Appendix B: Drawings

Drawing Set
Engineers Without Borders-USA, Greater Austin Chapter
CAMBIAR Program
Improved Irrigation System-Huasta, Peru

Index of Drawings

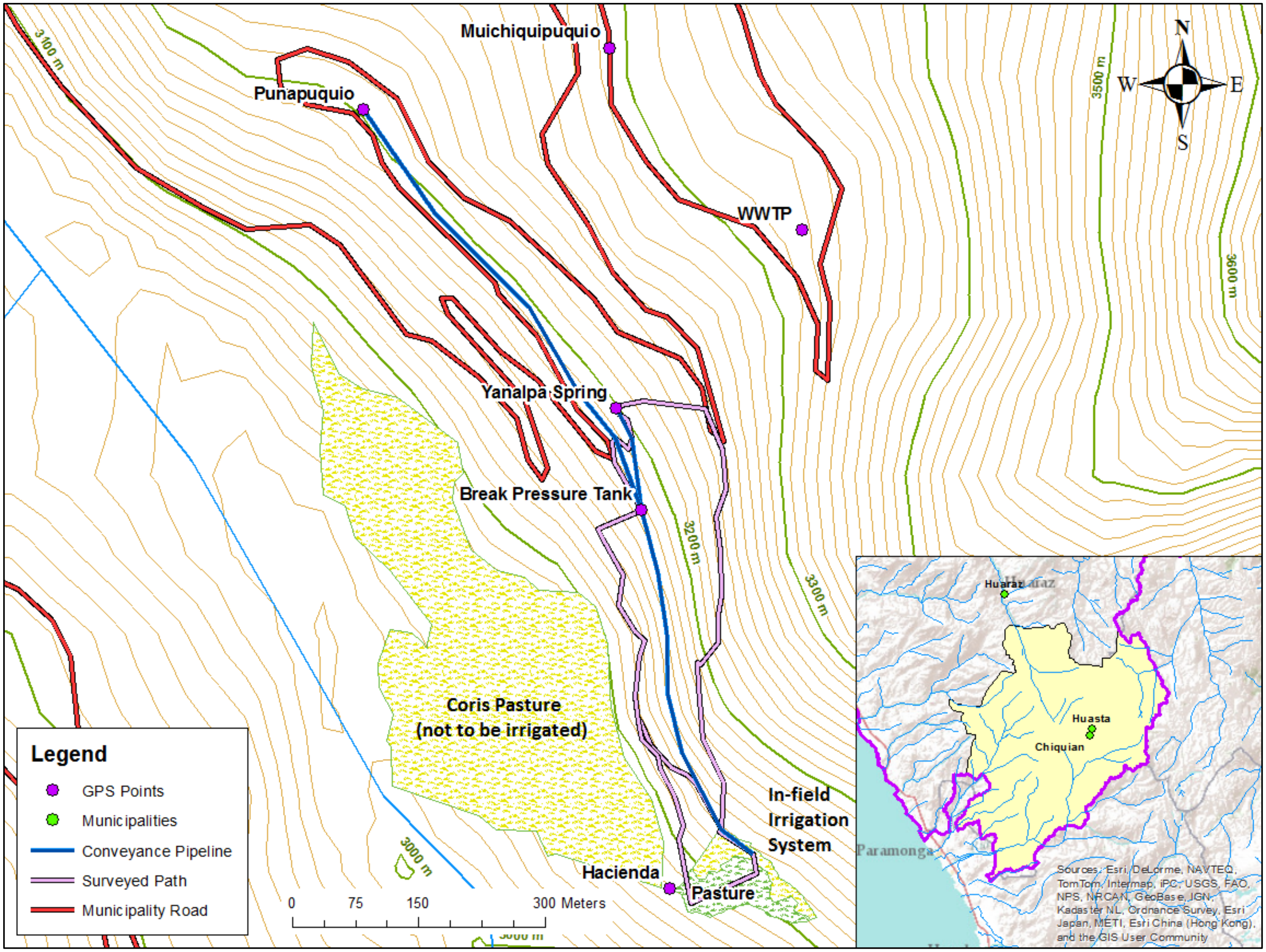

Figure B-1. Overview of the Area with System Components

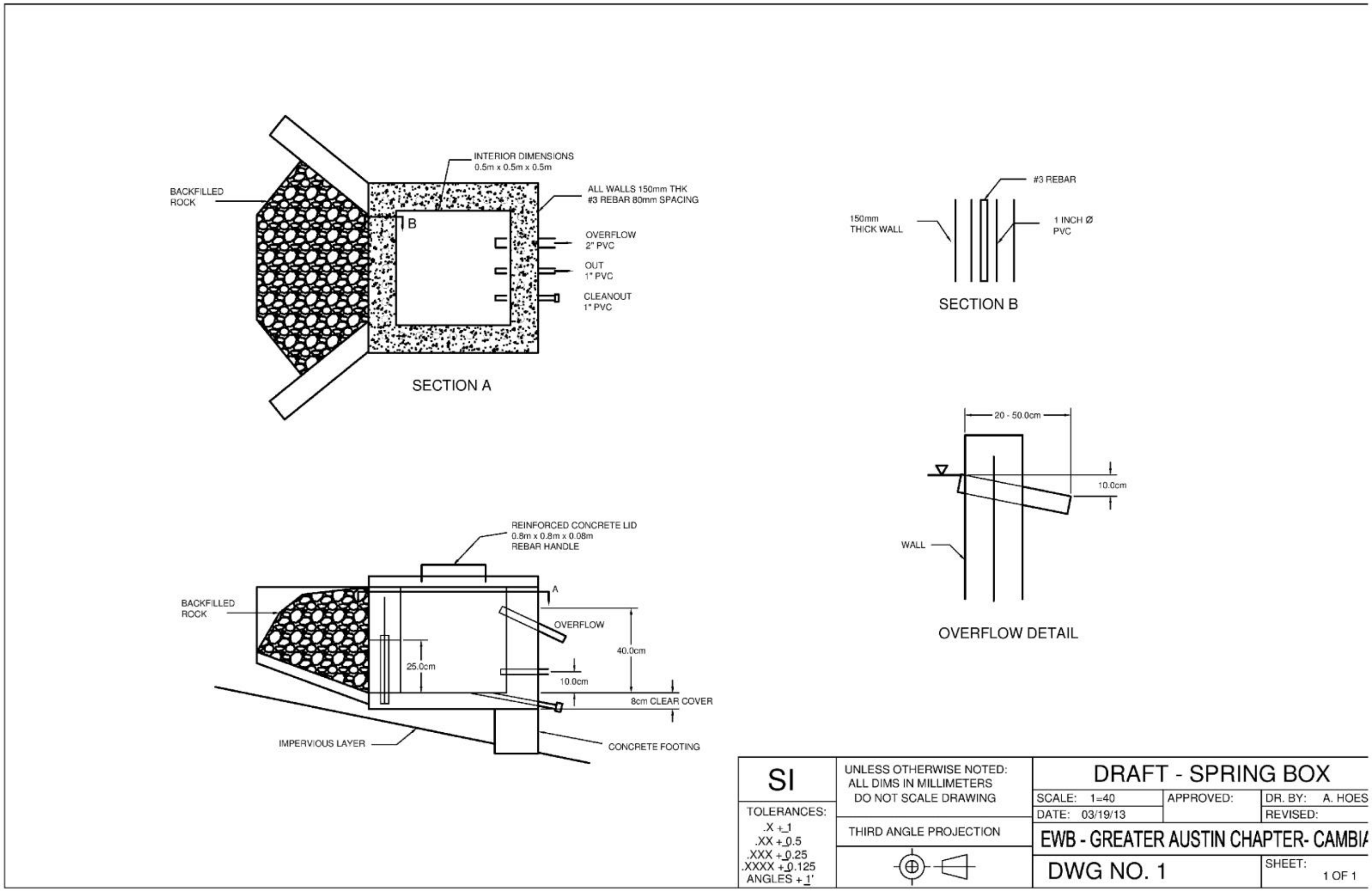

Figure B-2: Spring Box

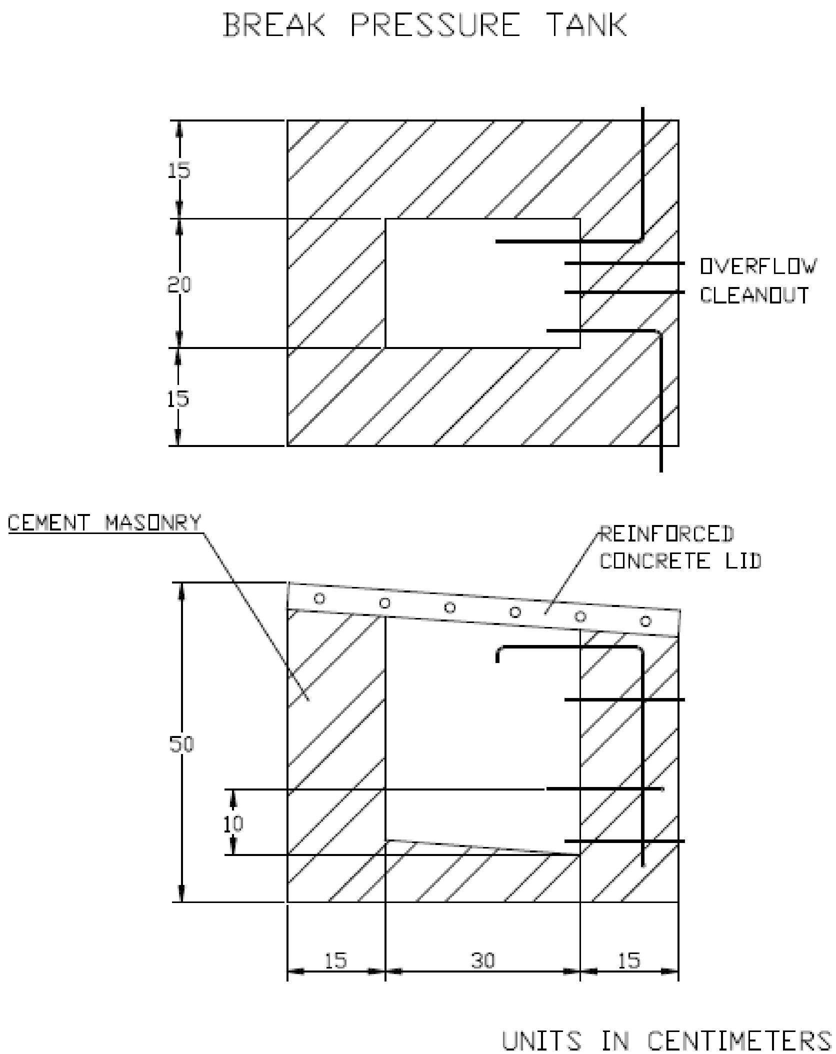

Figure B-3: Break Pressure Tank (All units in cm.)

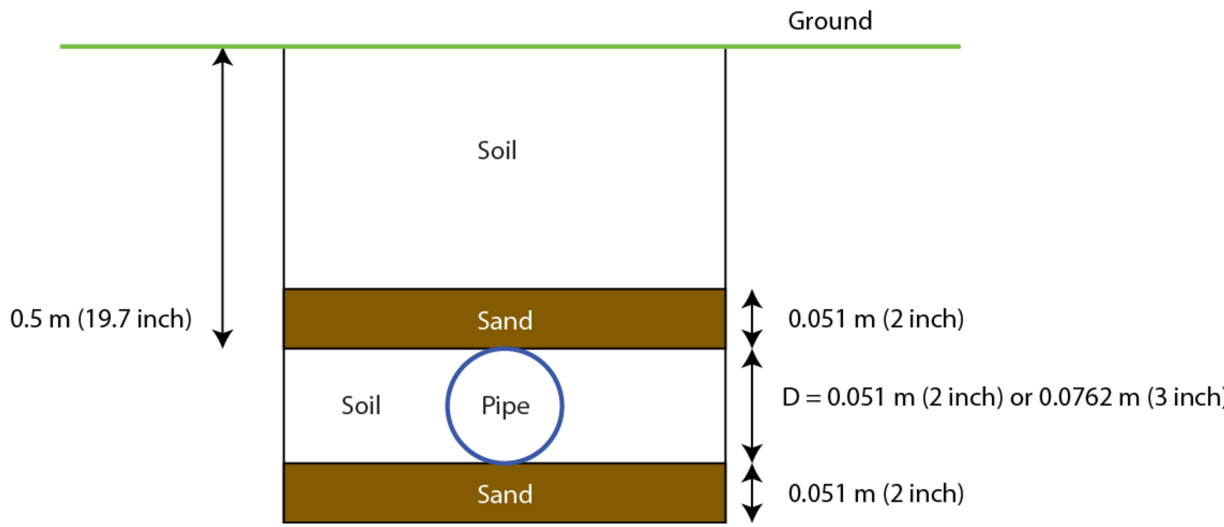

Figure B-4: Schematic of Backfill for Buried Pipes

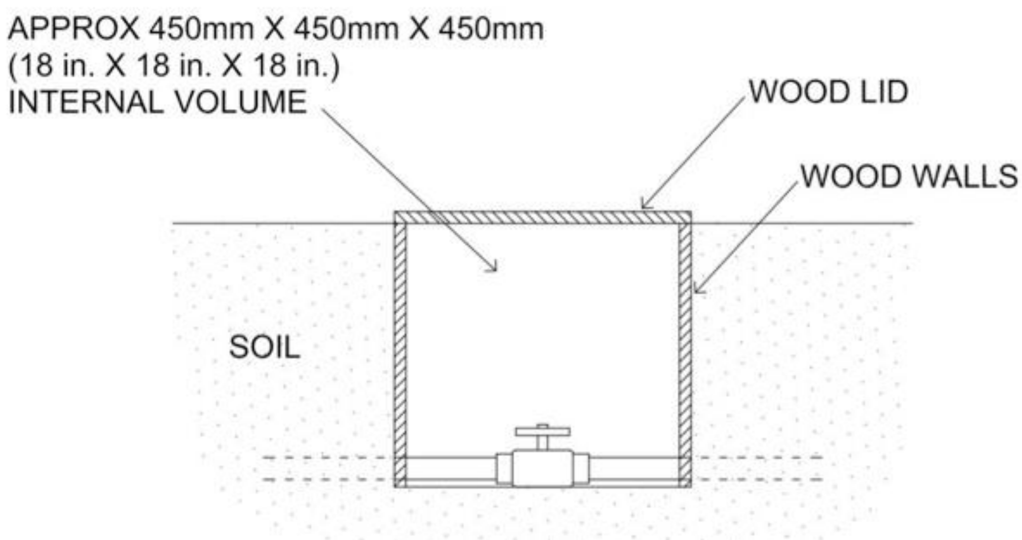

Figure B-5: Valve Box

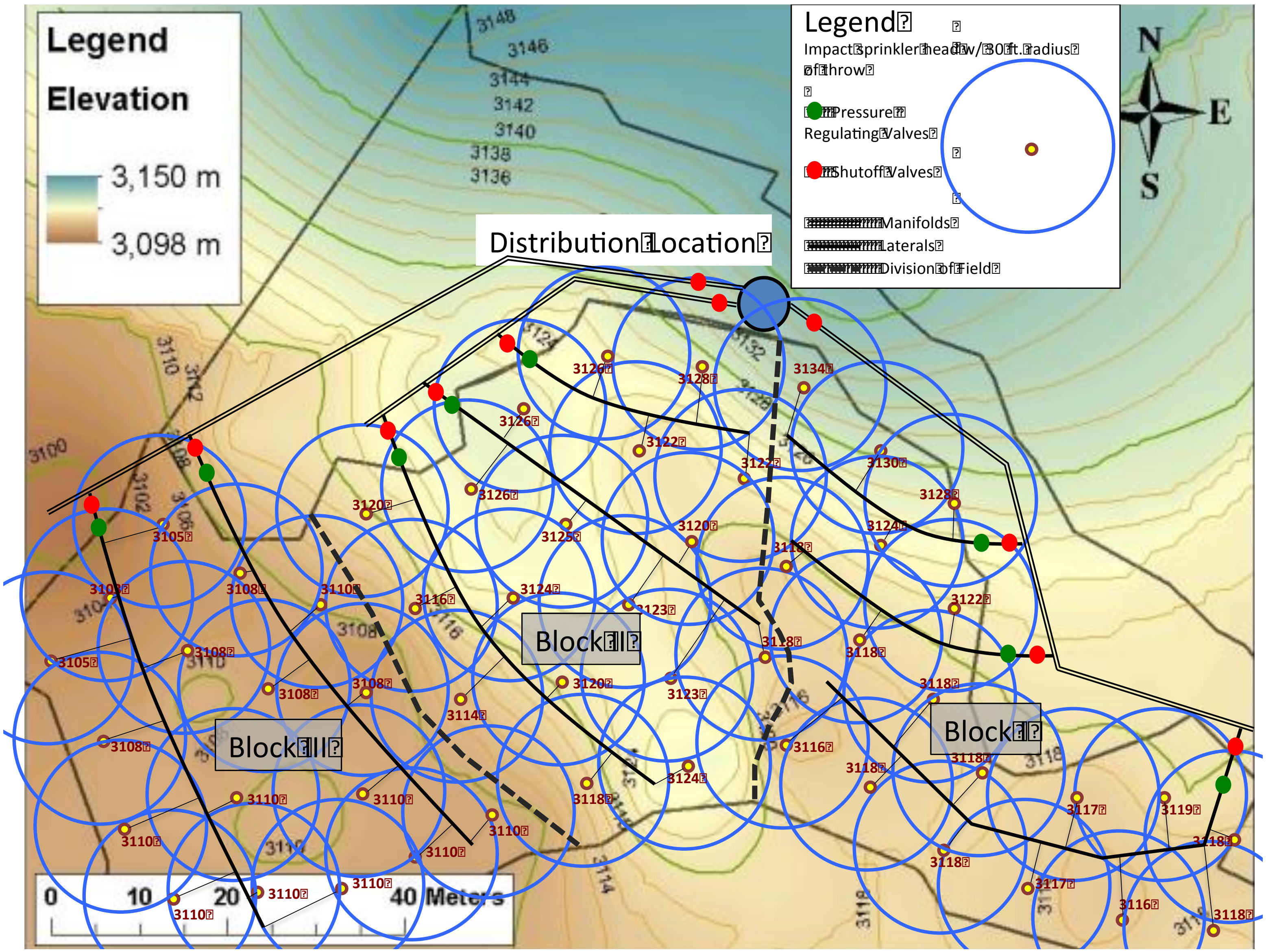

Figure B-6: Diagram of in-field irrigation system

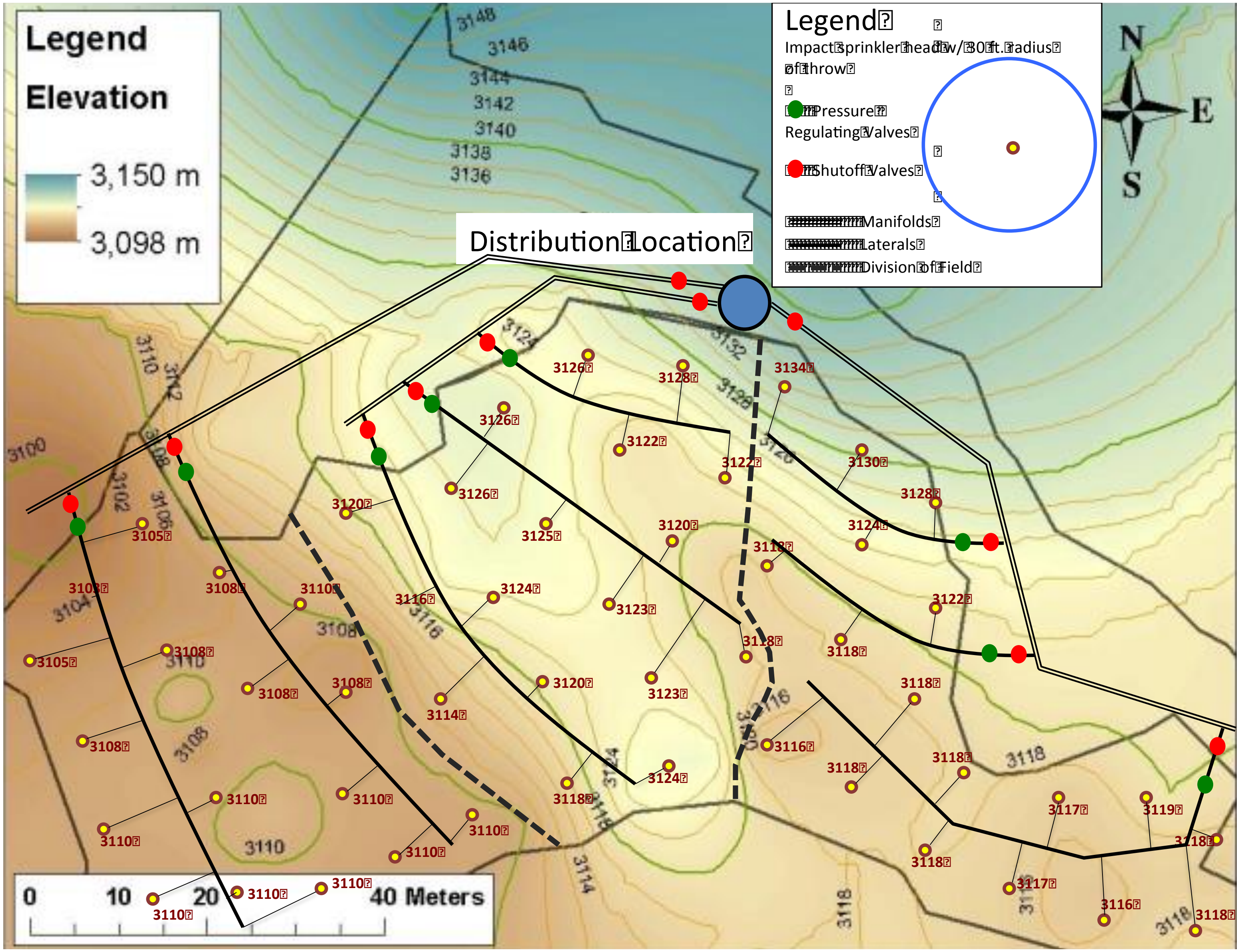

Figure B-7: In-field Piping Network

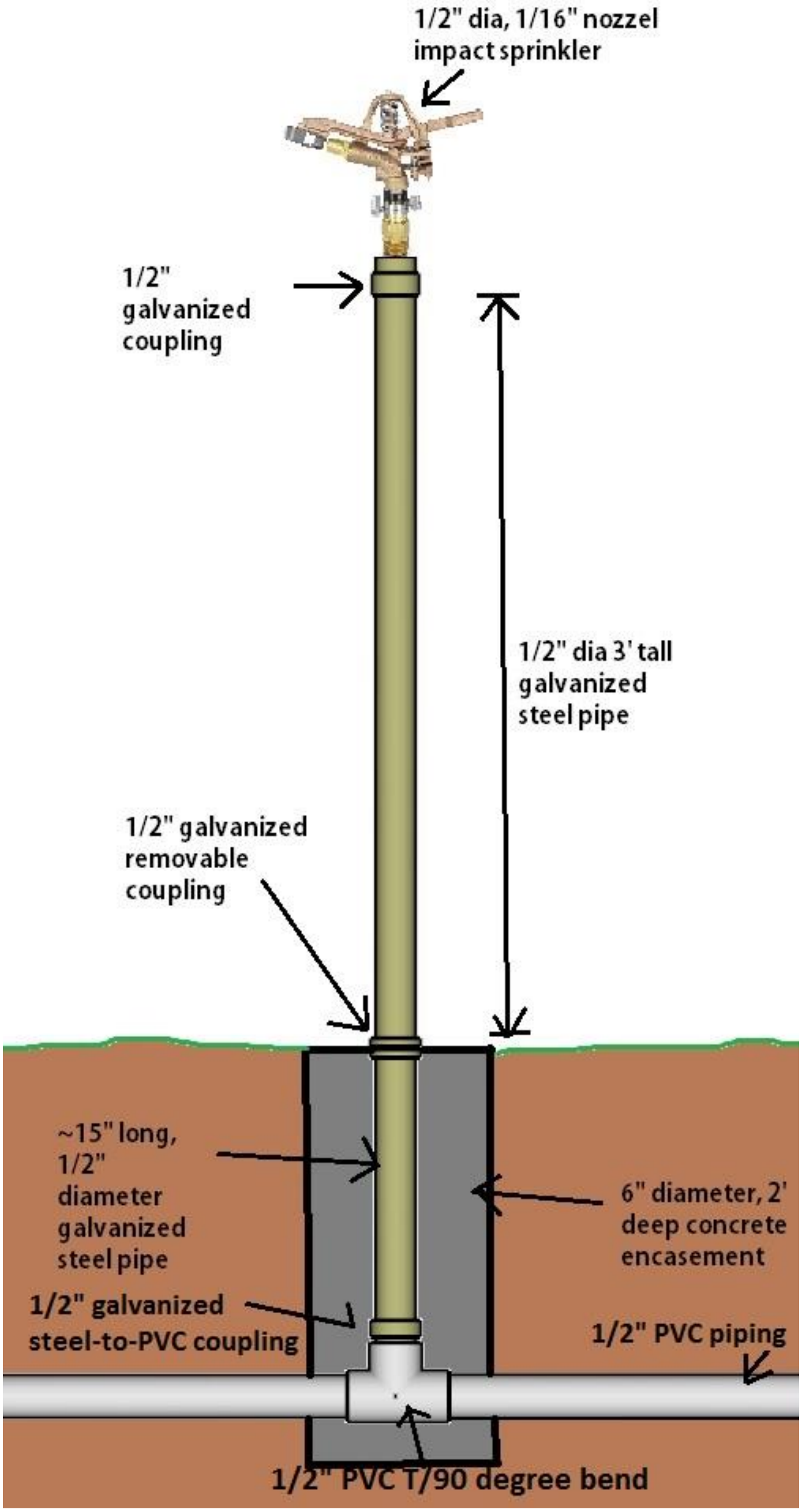

Figure B-8: Sprinkler riser design

Appendix C: Measured Flow Rates of Pucapuquio and Yanallpa Springs

Table C-1: Yanallpa Flow Rate

Date	Flow Rate (L/s)
7/11/12	0.188
	0.241
	0.276
	0.247
1/5/13	0.200
	0.209
	0.222
	0.233
3/3/13	0.254
	0.265
	0.284
	0.274

Table C-2: Pucapuquio Flow Rates

Date	Flow Rate (L/s)
7/9/12	0.672
	0.631
	0.616
7/11/12	0.675
	0.693
	0.706
8/10/12	0.833
	0.769
	0.833
8/ 26/12	0.667
	0.588
	0.588
10/7/12	0.526
	0.556
	0.526
11/3/12	0.455
	0.370
	0.455
1/4/12	0.056
	0.043

Appendix D: Water Test Results

Table D-1: Water quality parameters for the two springs measured during Assessment III

	Nitrate (ppm)	pH	Total Coliform (count/100 mL)	E. Coli (count/100 mL)
Pucapuquio	0	6.8	150	0
Yanallpa	7.86	7.13	920	400

*Agri*LIFE **EXTENSION**
Texas A&M System

Water Analysis Report

Soil, Water and Forage Testing Laboratory
Department of Soil and Crop Sciences
2610 F&B Road, 2478 TAMU
College Station, TX 77843-2478
979-845-4816

Visit our website:
http://soiltesting.tamu.edu

Format based on publication SCS-2002-12

Laboratory #:	22382
Customer Sample ID:	
Date Processed:	1/30/2013
Sample from Huasta, Den County	
Water Source =Other	**Water Use =Irrigation**

Parameter analyzed		Results	Units	Method	V. Limiting	Limiting	Acceptable
Calcium (Ca)		28	ppm	ICP			*****
Magnesium (Mg)		10	ppm	ICP			*****
Sodium (Na)		43	ppm	ICP			*****
Potassium (K)		6	ppm	ICP			*****
Boron (B)		0.01	ppm	ICP			*****
Carbonate (CO_3)		0	ppm	Titr.			*****
Bicarbonate (HCO_3)		83	ppm	Titr.			*****
Sulfate (SO_4-calculated from total S)		31	ppm	ICP			*****
Chloride (Cl-)		69	ppm	Titr.			*****
Nitrate-N (NO_3-N)		9.32	ppm	Cd-red.			*****
Phosphorus (P)	<	0.01	ppm	ICP			*****
pH		7.20		ISE			*****
Conductivity		400	umhos/cm	Cond.			*****
Hardness		6	grains CaCO3/gallon	Calc.			*****
Hardness		109	ppm CaC03	Calc.			*****
Alkalinity		68	ppm CaC03	Calc.			*****
Total Dissolved Salts (TDS)		280	ppm	Calc.			*****
SAR		1.8		Calc.			*****
Iron (Fe)	<	0.01	ppm	ICP			*****
Zinc (Zn)	<	0.01	ppm	ICP			*****
Copper (Cu)	<	0.01	ppm	ICP			*****
Manganese (Mn)	<	0.01	ppm	ICP			*****
Arsenic (As)							
Barium (Ba)							
Nickel (Ni)							
Cadmium (Cd)							
Lead (Pb)							
Chromium (Cr)							
Flouride (F)							
Charge Balance (cation/anion*100)		90		Calc.			

ppm=parts per million=milligrams per liter

N/A, not applicable for this water use

Descriptions of each water parameter, potential use issues and target levels are provided in publication SCS-2002-10, Description of Water Analysis Parameters.

ICP, Inductively coupled plasma; Titr., titration; ISE, ion selective electrode; Cd-red., cadmium reduction; cond., conductivity; calc., calculated

Figure D-1: Water Analysis Report for Yanallpa Spring from Assessment IV

Appendix E: Soil Test Results

TEXAS A&M AGRILIFE EXTENSION

Soil Analysis Report

Soil, Water and Forage Testing Laboratory
Department of Soil and Crop Sciences
2478 TAMU
College Station, TX 77843-2478
979-845-4816 (phone)
979-845-5958 (FAX)
Visit our website: http://soiltesting.tamu.edu

Sample received on: 2/20/2013
Printed on: 2/26/2013
Area Represented: not provided

Outside TX County
Laboratory Number: 378630
Customer Sample ID: #1- Upper Flats Composite Sample
Crop Grown: ALFALFA (NON-IRRIGATED , ANNUALLY)

Analysis	Results	CL*	Units	ExLow VLow Low Mod High VHigh Excess.	Fertilizer Recommended
pH	6.1	(7)	-	Slightly Acid	
Conductivity	140	(-)	umho/cm	None	
Nitrate-N	19	(-)	ppm**		0 lbs N/acre
Phosphorus	19	(60)	ppm		55 lbs P2O5/acre
Potassium	504	(125)	ppm		0 lbs K20/acre
Calcium	1,479	(180)	ppm		0 lbs Ca/acre
Magnesium	207	(50)	ppm		0 lbs Mg/acre
Sulfur	9	(13)	ppm		5 lbs S/acre
Sodium	3	(-)	ppm		
Iron	56.72	(4.25)	ppm		
Zinc	3.92	(0.27)	ppm		0 lbs Zn/acre
Manganese	42.92	(1.00)	ppm		0 lbs Mn/acre
Copper	0.61	(0.16)	ppm		0 lbs Cu/acre
Boron	0.46	(0.60)	ppm		0.5 lbs B/acre
Limestone Requirement					1.00 tons 100ECCE/acre

*CL=Critical level is the point which no additional nutrient (excluding nitrate-N, sodium and conductivity) is recommended. **ppm=mg/kg

Limestone recommendations are based on 100 ECCE liming products. Limestone applications >3 tons/acre should be made >4 months prior to crop establishment to lessen micro-nutrient availability issues.

Sulfur: Available sulfur may be found deeper in soil profile, thus limiting any response to added sulfur.

Boron: Deep rooted perennial crops may not respond due to deeper profile boron.

New online fertilizer calculators have been placed on the laboratory's website to determine appropriate fertilizers to purchase and determine their application rates. http://soiltesting.tamu.edu/webpages/calculator.html

Methods: pH and conductivity 2:1; nitrate-N/Cd-red.; P, K, Ca, Mg, Na, and S/Mehlich 3 by ICP; Fe, Zn, Mn, and Cu/DTPA by ICP; and B/hot water by ICP.

TEXAS A&M AGRILIFE EXTENSION

Soil Analysis Report

Soil, Water and Forage Testing Laboratory
Department of Soil and Crop Sciences
2478 TAMU
College Station, TX 77843-2478
979-845-4816 (phone)
979-845-5958 (FAX)
Visit our website: http://soiltesting.tamu.edu

Sample received on: 2/20/2013
Printed on: 2/26/2013
Area Represented: not provided

Outside TX County
Laboratory Number: 378630
Customer Sample ID: #1- Upper Flats Composite Sample
Crop Grown: ALFALFA (IRRIGATED / 6 TON/A , ANNUALLY)

Analysis	Results	CL*	Units	ExLow VLow Low Med High VHigh Excess.	Fertilizer Recommended
pH	6.1	(7)	-	Slightly Acid	
Conductivity	140	(-)	umho/cm	None	
Nitrate-N	19	(-)	ppm**		0 lbs N/acre
Phosphorus	19	(60)	ppm		85 lbs P2O5/acre
Potassium	504	(125)	ppm		0 lbs K2O/acre
Calcium	1,479	(180)	ppm		0 lbs Ca/acre
Magnesium	207	(50)	ppm		0 lbs Mg/acre
Sulfur	9	(13)	ppm		5 lbs S/acre
Sodium	3	(-)	ppm		
Iron	56.72	(4.25)	ppm		
Zinc	3.92	(0.27)	ppm		0 lbs Zn/acre
Manganese	42.92	(1.00)	ppm		0 lbs Mn/acre
Copper	0.51	(0.16)	ppm		0 lbs Cu/acre
Boron	0.46	(0.60)	ppm		0.5 lbs B/acre
Limestone Requirement					1.00 tons 100ECCE/acre

*CL=Critical level is the point which no additional nutrient (excluding nitrate-N, sodium and conductivity) is recommended. **ppm=mg/kg

Limestone recommendations are based on 100 ECCE liming products. Limestone applications >3 tons/acre should be made >4 months prior to crop establishment to lessen micro-nutrient availability issues.

Sulfur: Available sulfur may be found deeper in soil profile, thus limiting any response to added sulfur.

Boron: Deep rooted perennial crops may not respond due to deeper profile boron.

**New online fertilizer calculators have been placed on the laboratory's website to determine appropriate fertilizers to purchase and determine their application rates.
http://soiltesting.tamu.edu/webpages/calculator.html**

Methods: pH and conductivity/ 2:1; nitrate-N/Cd-red; P, K, Ca, Mg, Na, and S/Mehlich 3 by ICP; Fe, Zn, Mn, and Cu/DTPA by ICP; and B/hot water by ICP.

![TEXAS A&M AGRILIFE EXTENSION]

Soil Analysis Report

Soil, Water and Forage Testing Laboratory
Department of Soil and Crop Sciences
2478 TAMU
College Station, TX 77843-2478
979-845-4816 (phone)
979-845-5958 (FAX)
Visit our website: http://soiltesting.tamu.edu

Sample received on: 2/20/2013
Printed on: 2/26/2013
Area Represented: not provided

Outside TX County
Laboratory Number: 378630
Customer Sample ID: #1- Upper Flats Composite Sample
Crop Grown: ALFALFA (IRRIGATED 8-12 TON/A , ANNUALLY)

Analysis	Results	CL*	Units	ExLow · VLow · Low · Mod · High · VHigh · Excess	Fertilizer Recommended
pH	6.1	(7)	-	Slightly Acid	
Conductivity	140	(-)	umho/cm	None	
Nitrate-N	19	(-)	ppm**		0 lbs N/acre
Phosphorus	19	(60)	ppm		120 lbs P2O5/acre
Potassium	504	(125)	ppm		0 lbs K20/acre
Calcium	1,479	(180)	ppm		0 lbs Ca/acre
Magnesium	207	(50)	ppm		0 lbs Mg/acre
Sulfur	9	(13)	ppm		5 lbs S/acre
Sodium	3	(-)	ppm		
Iron	56.72	(4.25)	ppm		
Zinc	3.92	(0.27)	ppm		0 lbs Zn/acre
Manganese	42.92	(1.00)	ppm		0 lbs Mn/acre
Copper	0.51	(0.16)	ppm		0 lbs Cu/acre
Boron	0.46	(0.80)	ppm		0.5 lbs B/acre
Limestone Requirement					1.00 tons 100ECCE/acre

*CL=Critical level is the point which no additional nutrient (excluding nitrate-N, sodium and conductivity) is recommended. **ppm=mg/kg

Limestone recommendations are based on 100 ECCE liming products. Limestone applications >3 tons/acre should be made >4 months prior to crop establishment to lessen micro-nutrient availability issues.

Sulfur: Available sulfur may be found deeper in soil profile, thus limiting any response to added sulfur.

Boron: Deep rooted perennial crops may not respond due to deeper profile boron.

New online fertilizer calculators have been placed on the laboratory's website to determine appropriate fertilizers to purchase and determine their application rates.
http://soiltesting.tamu.edu/webpages/calculator.html

Methods: pH and conductivity/1:2; nitrate-N/Cd-red; P, K, Ca, Mg, Na, and S/Mehlich 3 by ICP; Fe, Zn, Mn, and Cu/DTPA by ICP, and B/hot water by ICP.

TEXAS A&M AGRILIFE EXTENSION

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Department of Soil and Crop Sciences
2478 TAMU
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979-845-5958 (FAX)
Visit our website: http://soiltesting.tamu.edu

Sample received on: 2/20/2013
Printed on: 2/26/2013
Area Represented: not provided

Outside TX County
Laboratory Number: 378631
Customer Sample ID: #2- Lower Flats Composite Sample
Crop Grown: ALFALFA (NON-IRRIGATED , ANNUALLY)

Analysis	Results	CL*	Units	ExLow VLow Low Mod High VHigh Excess.	Fertilizer Recommended
pH	5.7	(7)	-	Mod. Acid	
Conductivity	209	(-)	umho/cm	None	
Nitrate-N	36	(-)	ppm**		0 lbs N/acre
Phosphorus	42	(60)	ppm		20 lbs P2O5/acre
Potassium	797	(125)	ppm		0 lbs K20/acre
Calcium	1,809	(180)	ppm		0 lbs Ca/acre
Magnesium	255	(50)	ppm		0 lbs Mg/acre
Sulfur	11	(13)	ppm		5 lbs S/acre
Sodium	5	(-)	ppm		
Iron	126.54	(4.25)	ppm		
Zinc	7.67	(0.27)	ppm		0 lbs Zn/acre
Manganese	44.69	(1.00)	ppm		0 lbs Mn/acre
Copper	0.62	(0.16)	ppm		0 lbs Cu/acre
Boron	0.39	(0.60)	ppm		1 lbs B/acre
Limestone Requirement					1.10 tons 100ECCE/acre

*CL=Critical level is the point which no additional nutrient (excluding nitrate-N, sodium and conductivity) is recommended. **ppm=mg/kg

Limestone recommendations are based on 100 ECCE liming products. Limestone applications >3 tons/acre should be made >4 months prior to crop establishment to lessen micro-nutrient availability issues.

Sulfur: Available sulfur may be found deeper in soil profile, thus limiting any response to added sulfur.

Boron: Deep rooted perennial crops may not respond due to deeper profile boron.

New online fertilizer calculators have been placed on the laboratory's website to determine appropriate fertilizers to purchase and determine their application rates.
http://soiltesting.tamu.edu/webpages/calculator.html

Methods: pH and conductivity/ 2:1; nitrate-N/Cd-red.; P, K, Ca, Mg, Na, and S/Mehlich 3 by ICP; Fe, Zn, Mn, and Cu/DTPA by ICP; and B/hot water by ICP.

TEXAS A&M AGRILIFE EXTENSION

Soil Analysis Report

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Visit our website: http://soiltesting.tamu.edu

Sample received on: 2/20/2013
Printed on: 2/26/2013
Area Represented: not provided

Outside TX County
Laboratory Number: 378631
Customer Sample ID: #2- Lower Flats Composite Sample
Crop Grown: ALFALFA (IRRIGATED / 6 TON/A , ANNUALLY)

Analysis	Results	CL*	Units	ExLow / VLow / Low / Mod / High / VHigh / Excess.	Fertilizer Recommended
pH	5.7	(7)		Mod. Acid	
Conductivity	209	(-)	umho/cm	None	
Nitrate-N	36	(-)	ppm**		0 lbs N/acre
Phosphorus	42	(60)	ppm		35 lbs P2O5/acre
Potassium	797	(125)	ppm		0 lbs K2O/acre
Calcium	1,809	(180)	ppm		0 lbs Ca/acre
Magnesium	255	(50)	ppm		0 lbs Mg/acre
Sulfur	11	(13)	ppm		6 lbs S/acre
Sodium	5	(-)	ppm		
Iron	125.54	(4.25)	ppm		
Zinc	7.67	(0.27)	ppm		0 lbs Zn/acre
Manganese	44.69	(1.00)	ppm		0 lbs Mn/acre
Copper	0.62	(0.16)	ppm		0 lbs Cu/acre
Boron	0.39	(0.60)	ppm		1 lbs B/acre
Limestone Requirement					1.10 tons 100ECCE/acre

*CL=Critical level is the point which no additional nutrient (excluding nitrate-N, sodium and conductivity) is recommended. **ppm=mg/kg

Limestone recommendations are based on 100 ECCE liming products. Limestone applications >3 tons/acre should be made >4 months prior to crop establishment to lessen micro-nutrient availability issues.

Sulfur: Available sulfur may be found deeper in soil profile, thus limiting any response to added sulfur.

Boron: Deep rooted perennial crops may not respond due to deeper profile boron.

**New online fertilizer calculators have been placed on the laboratory's website to determine appropriate fertilizers to purchase and determine their application rates.
http://soiltesting.tamu.edu/webpages/calculator.html**

Methods: pH and conductivity 1:2; nitrate-N/Cd-red.; P, K, Ca, Mg, Na, and S/Mehlich 3 by ICP; Fe, Zn, Mn, and Cu/DTPA by ICP; and B/hot water by ICP.

TEXAS A&M AGRILIFE EXTENSION

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979-845-5958 (FAX)
Visit our website: http://soiltesting.tamu.edu

Sample received on: 2/20/2013
Printed on: 2/26/2013
Area Represented: not provided

Outside TX County
Laboratory Number: 378631
Customer Sample ID: #2- Lower Flats Composite Sample
Crop Grown: ALFALFA (IRRIGATED 8-12 TON/A , ANNUALLY)

Analysis	Results	CL*	Units	ExLow VLow Low Med High VHigh Excess.	Fertilizer Recommended
pH	5.7	(7)	-	Mod. Acid	
Conductivity	209	(-)	umho/cm	None	
Nitrate-N	36	(-)	ppm**		0 lbs N/acre
Phosphorus	42	(60)	ppm		50 lbs P2O5/acre
Potassium	797	(125)	ppm		0 lbs K2O/acre
Calcium	1,809	(180)	ppm		0 lbs Ca/acre
Magnesium	255	(50)	ppm		0 lbs Mg/acre
Sulfur	11	(13)	ppm		5 lbs S/acre
Sodium	5	(-)	ppm		
Iron	125.64	(4.25)	ppm		
Zinc	7.67	(0.27)	ppm		0 lbs Zn/acre
Manganese	44.69	(1.00)	ppm		0 lbs Mn/acre
Copper	0.62	(0.16)	ppm		0 lbs Cu/acre
Boron	0.39	(0.60)	ppm		1 lbs B/acre
Limestone Requirement					1.10 tons 100ECCE/acre

*CL=Critical level is the point which no additional nutrient (excluding nitrate-N, sodium and conductivity) is recommended. **ppm=mg/kg

Limestone recommendations are based on 100 ECCE liming products. Limestone applications >3 tons/acre should be made >4 months prior to crop establishment to lessen micro-nutrient availability issues.

Sulfur: Available sulfur may be found deeper in soil profile, thus limiting any response to added sulfur.

Boron: Deep rooted perennial crops may not respond due to deeper profile boron.

**New online fertilizer calculators have been placed on the laboratory's website to determine appropriate fertilizers to purchase and determine their application rates.
http://soiltesting.tamu.edu/webpages/calculator.html**

Methods: pH and conductivity 2:1; nitrate-N Cd-red.; P, K, Ca, Mg, Na, and S Mehlich 3 by ICP; Fe, Zn, Mn, and Cu DTPA by ICP; and B hot water by ICP.

TEXAS A&M AGRILIFE EXTENSION

Soil Analysis Report

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Department of Soil and Crop Sciences
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979-845-4816 (phone)
979-845-5958 (FAX)
Visit our website: http://soiltesting.tamu.edu

Sample received on: 2/20/2013
Printed on: 2/26/2013
Area Represented: not provided

Outside TX County
Laboratory Number: 378632
Customer Sample ID: #3- Terrace Flats Composite Sample
Crop Grown: ALFALFA (NON-IRRIGATED , ANNUALLY)

Analysis	Results	CL*	Units	ExLow VLow Low Med High VHigh Excess.	Fertilizer Recommended
pH	6.2	(7)	-	Slightly Acid	
Conductivity	737	(-)	umho/cm	Slight	
Nitrate-N	212	(-)	ppm**		0 lbs N/acre
Phosphorus	938	(60)	ppm		0 lbs P2O5/acre
Potassium	874	(125)	ppm		0 lbs K2O/acre
Calcium	7,548	(180)	ppm		0 lbs Ca/acre
Magnesium	569	(50)	ppm		0 lbs Mg/acre
Sulfur	54	(13)	ppm		0 lbs S/acre
Sodium	13	(-)	ppm		
Iron	38.00	(4.25)	ppm		
Zinc	34.86	(0.27)	ppm		0 lbs Zn/acre
Manganese	48.83	(1.00)	ppm		0 lbs Mn/acre
Copper	1.27	(0.16)	ppm		0 lbs Cu/acre
Boron	3.84	(0.60)	ppm		0 lbs B/acre
Limestone Requirement					1.80 tons 100ECCE/acre

*CL=Critical level is the point which no additional nutrient (excluding nitrate-N, sodium and conductivity) is recommended. **ppm=mg/kg

Limestone recommendations are based on 100 ECCE liming products. Limestone applications >3 tons/acre should be made >4 months prior to crop establishment to lessen micro-nutrient availability issues.

Phosphorus: Phosphorus is highly elevated, avoid phosphorus containing fertilizers and organics for the next 5 years, retest annually.

New online fertilizer calculators have been placed on the laboratory's website to determine appropriate fertilizers to purchase and determine their application rates.
http://soiltesting.tamu.edu/webpages/calculator.html

Methods: pH and conductivity 1:2.1; nitrate-N/Cd-red ; P, K, Ca, Mg, Na, and S/Mehlich 3 by ICP; Fe, Zn, Mn, and Cu/DTPA by ICP; and B/hot water by ICP.

TEXAS A&M AGRILIFE EXTENSION

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Visit our website: http://soiltesting.tamu.edu

Sample received on: 2/20/2013
Printed on: 2/26/2013
Area Represented: not provided

Outside TX County
Laboratory Number: 378632
Customer Sample ID: #3- Terrace Flats Composite Sample
Crop Grown: ALFALFA (IRRIGATED / 6 TON/A , ANNUALLY)

Analysis	Results	CL*	Units	ExLow VLow Low Med High VHigh Excess.	Fertilizer Recommended
pH	6.2	(7)	-	Slightly Acid	
Conductivity	737	(-)	umhos/cm	Slight	
Nitrate-N	212	(-)	ppm**		0 lbs N/acre
Phosphorus	938	(60)	ppm		0 lbs P2O5/acre
Potassium	874	(125)	ppm		0 lbs K20/acre
Calcium	7,548	(180)	ppm		0 lbs Ca/acre
Magnesium	560	(50)	ppm		0 lbs Mg/acre
Sulfur	64	(13)	ppm		0 lbs S/acre
Sodium	13	(-)	ppm		
Iron	38.00	(4.25)	ppm		
Zinc	34.86	(0.27)	ppm		0 lbs Zn/acre
Manganese	46.83	(1.00)	ppm		0 lbs Mn/acre
Copper	1.27	(0.16)	ppm		0 lbs Cu/acre
Boron	3.84	(0.60)	ppm		0 lbs B/acre
Limestone Requirement					1.80 tons 100ECCE/acre

*CL=Critical level is the point which no additional nutrient (excluding nitrate-N, sodium and conductivity) is recommended. **ppm=mg/kg

Limestone recommendations are based on 100 ECCE liming products. Limestone applications >3 tons/acre should be made >4 months prior to crop establishment to lessen micro-nutrient availability issues.

Phosphorus: Phosphorus is highly elevated, avoid phosphorus containing fertilizers and organics for the next 5 years, retest annually.

New online fertilizer calculators have been placed on the laboratory's website to determine appropriate fertilizers to purchase and determine their application rates. http://soiltesting.tamu.edu/webpages/calculator.html

Methods: pH and conductivity/ 2:1; nitrate-N/Cd-red.; P, K, Ca, Mg, Na, and S/Mehlich 3 by ICP; Fe, Zn, Mn, and Cu/DTPA by ICP; and B/hot water by ICP.

AGRILIFE EXTENSION
TEXAS A&M

Soil Analysis Report

Soil, Water and Forage Testing Laboratory
Department of Soil and Crop Sciences
2478 TAMU
College Station, TX 77843-2478
979-845-4816 (phone)
979-845-5958 (FAX)
Visit our website: http://soiltesting.tamu.edu

Sample received on: 2/20/2013
Printed on: 2/26/2013
Area Represented: not provided

Outside TX County
Laboratory Number: 378632
Customer Sample ID: #3- Terrace Flats Composite Sample
Crop Grown: ALFALFA (IRRIGATED 8-12 TON/A , ANNUALLY)

Analysis	Results	CL*	Units	ExLow VLow Low Mod High VHigh Excess.	Fertilizer Recommended
pH	6.2	(7)	-	Slightly Acid	
Conductivity	737	(-)	umho/cm	Slight	
Nitrate-N	212	(-)	ppm**		0 lbs N/acre
Phosphorus	938	(60)	ppm		0 lbs P2O5/acre
Potassium	874	(125)	ppm		0 lbs K20/acre
Calcium	7,548	(180)	ppm		0 lbs Ca/acre
Magnesium	569	(50)	ppm		0 lbs Mg/acre
Sulfur	54	(13)	ppm		0 lbs S/acre
Sodium	13	(-)	ppm		
Iron	38.00	(4.25)	ppm		
Zinc	34.86	(0.27)	ppm		0 lbs Zn/acre
Manganese	48.83	(1.00)	ppm		0 lbs Mn/acre
Copper	1.27	(0.16)	ppm		0 lbs Cu/acre
Boron	3.84	(0.60)	ppm		0 lbs B/acre
Limestone Requirement					1.80 tons 100ECCE/acre

*CL=Critical level is the point which no additional nutrient (excluding nitrate-N, sodium and conductivity) is recommended. **ppm=mg/kg

Limestone recommendations are based on 100 ECCE liming products. Limestone applications >3 tons/acre should be made >4 months prior to crop establishment to lessen micro-nutrient availability issues.

Phosphorus: Phosphorus is highly elevated, avoid phosphorus containing fertilizers and organics for the next 5 years, retest annually.

New online fertilizer calculators have been placed on the laboratory's website to determine appropriate fertilizers to purchase and determine their application rates.
http://soiltesting.tamu.edu/webpages/calculator.html

Methods: pH and conductivity/ 2:1; nitrate-N/Cd-red.; P, K, Ca, Mg, Na, and S/Mehlich 3 by ICP; Fe, Zn, Mn, and Cu/DTPA by ICP; and B/hot water by ICP.

Appendix F: Product Specs for Rainbird 14VH Sprinklers

RAIN BIRD

14VH

1/2" 13mm Full Circle, Brass, Wedge Drive Impact Sprinkler

BEARING: 1/2" Male NPT, Brass
Trajectory Angle: 23°
Operating Range: 20-60 psi 1.4-4.1 bars
Flow Rate: .56-2.68 GPM 0.14-0.61 m³/h
Radius: 29-38 ft. 9.0-11.70 meters
One 1/8" Female NPT Nozzle Port

Features

- Patented, self-flushing wedge drive
- Durable brass die-cast arm
- Stainless steel springs and fulcrum pin
- Chemically resistant washers
- Two-year warranty

Benefits

- Wedge drive runs on smaller nozzles and lower pressures
- Self-flushing design reduces wear from grit
- Corrosion and grit resistant
- Built to last

U.S. STANDARD DATA | METRIC DATA

PERFORMANCE DATA 14VH

STRAIGHT BORE NOZZLE (SBN-1)*

(Stream Height: 6 ft.)

PSI @ Nozzle	NOZZLE SIZE U.S. STANDARD: 1/16" Rad.	1/16" GPM	51 DRILL Rad.	51 DRILL GPM	5/64" Rad.	5/64" GPM	3/32" Rad.	3/32" GPM	7/64" Rad.	7/64" GPM
20	-	-	29	0.59	30	0.79	33	1.14	34	1.55
25	29	0.56	29	0.65	31	0.88	33	1.27	35	1.73
30	29	0.62	30	0.71	31	0.97	34	1.39	35	1.90
35	30	0.66	30	0.77	32	1.05	34	1.50	36	2.05
40	30	0.72	31	0.83	32	1.12	35	1.61	37	2.19
45	31	0.75	31	0.87	33	1.19	35	1.71	37	2.32
50	31	0.80	32	0.92	34	1.25	36	1.80	38	2.45
55	32	0.84	32	0.96	34	1.31	36	1.89	38	2.57
60	32	0.88	33	1.01	34	1.37	37	1.97	38	2.68

STRAIGHT BORE NOZZLE (SBN-1)*

(Stream Height: 1.8m)

BARS@ Nozzle	NOZZLE SIZE METRIC: 1.59 mm (1/16") Rad. (m)	1.59 mm Flow (lps)	1.59 mm Flow (m³/h)	1.70 mm (51 Drill) Rad. (m)	1.70 mm Flow (lps)	1.70 mm Flow (m³/h)	1.98 mm (5/64") Rad. (m)	1.98 mm Flow (lps)	1.98 mm Flow (m³/h)	2.38 mm (3/32") Rad. ((m)	2.38 mm Flow (lps)	2.38 mm Flow (m³/h)	2.78 mm (7/64") Rad. (m)	2.78 mm Flow (lps)	2.78 mm Flow (m³/h)
1.4	-	-	-	8.8	0.04	0.13	9.3	0.05	0.18	10.1	0.07	0.26	10.4	0.10	0.35
1.5	-	-	-	8.9	0.04	0.14	9.3	0.05	0.19	10.1	0.07	0.27	10.5	0.10	0.37
2.0	9.0	0.04	0.14	9.1	0.04	0.16	9.6	0.06	0.22	10.3	0.09	0.31	10.8	0.12	0.42
2.5	9.2	0.04	0.15	9.3	0.05	0.18	9.8	0.07	0.24	10.6	0.10	0.35	11.0	0.13	0.47
3.0	9.4	0.05	0.17	9.6	0.05	0.19	10.1	0.07	0.27	10.8	0.11	0.38	11.4	0.14	0.52
3.5	9.6	0.05	0.18	9.8	0.06	0.21	10.4	0.08	0.29	11.0	0.11	0.41	11.6	0.16	0.56
4.0	9.8	0.05	0.20	10.0	0.06	0.22	10.5	0.08	0.31	11.2	0.12	0.44	11.7	0.17	0.60
4.1	9.9	0.06	0.20	10.1	0.06	0.23	10.5	0.09	0.31	11.3	0.12	0.45	11.7	0.17	0.61

* Available without Nozzle or Assembled with 5/64" (05) Straight Bore Nozzle.
All other Nozzles must be purchased separately.
See Chart below.

Part Numbers and Ordering Information

Sprinkler Only	
Sprinkler without Nozzle	A01619

Assembled Sprinkler/Nozzle Factory Combination	
Sprinkler with Nozzle SBN-1 5/64"	A0162005

Nozzle Only			XX = Nozzle Size				
		U.S. Standard	1/16"	51 DRILL	5/64"	3/32"	7/64"
		Metric	1.59 mm	1.70mm	1.98 mm	2.38 mm	2.78 mm
Brass Straight Bore Nozzle	SBN-1	105780-XX	04	51	**05**	06	07

Bold nozzle size numbers denote the most common nozzle choices.

source: http://www.rainbird.com/documents/ag/chart_14VH.pdf

Appendix G: Product Specs for Seninger PMR-MF Medium Flow Pressure Regulator

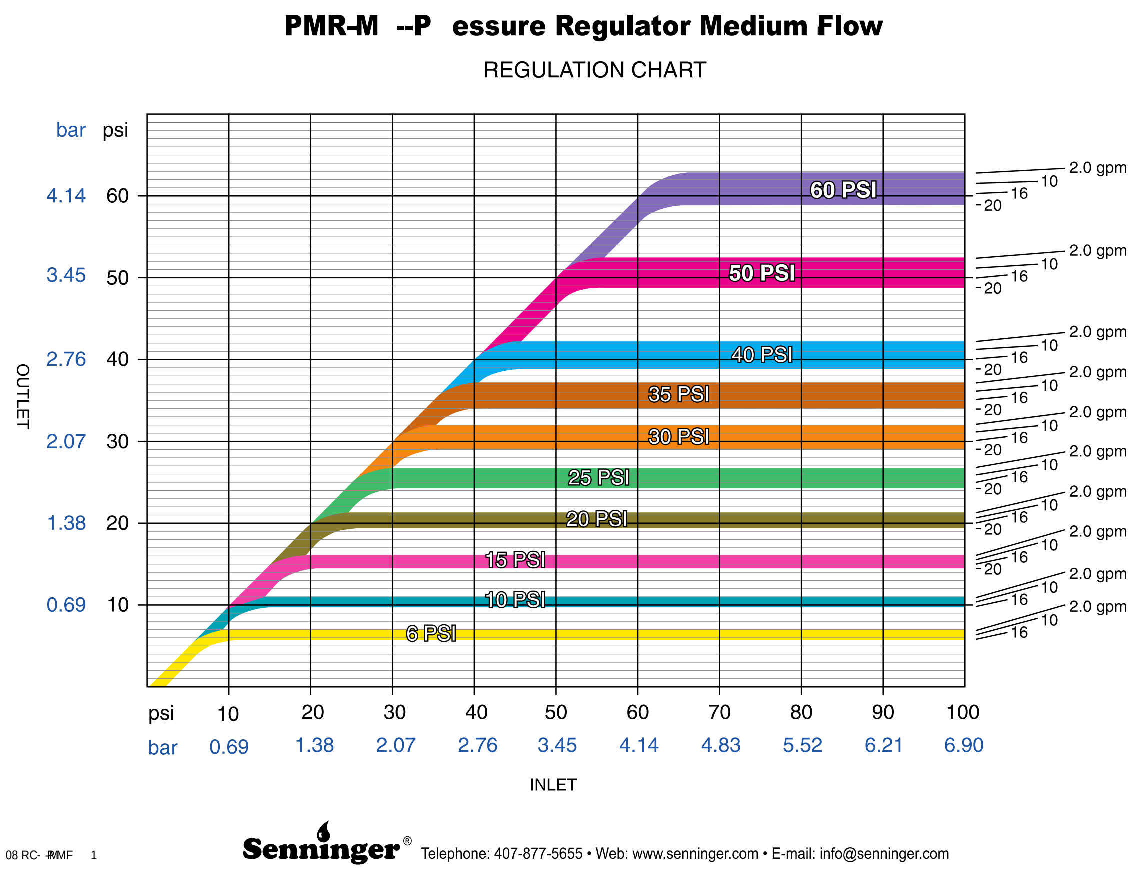

Figure G-1. Pressure Regulator Specification Graph

PMR-MF[Regulators

The medium flow Pressure-Master Regulator® is ideal for installations requiring mid-range flows [2 - 20 gpm] including solid-set, drip or other low-volume irrigation systems as well as center pivot and other mechanical-move irrigation systems.

FEATURES:

- Maintains a constant preset outlet pressure while handling varying inlet pressures
- Very low hysteresis and friction losses
- Maximum flow path resists plugging
- 100% water-tested for accuracy (no adjustments ever needed)
- Two-year warranty on materials, workmanship AND performance
- Can be installed above or below ground.

PMR-MF CMS models are designed specifically for mining applications where pH solutions are less than or equal to 4.0 PMR-MF EFF models (lavender top) are designed specifically for wastewater applications.

PMR-MF - Pressure-Master Regulator® Medium-Flow

Model Number	Preset Oper. Press. psi	[bar]	Maximum Inlet Press. psi	[bar]	Flow Range gpm	[L/hr]	Inlet Sizes	Outlet Sizes
PMR-6 MF	6	0.41	100	6.90	4 - 16	907.2 -3628.8	3/4" F NPT, 1" F NPT, 1"M NPT, 1"F BSP	3/4" F NPT, 1" F NPT, 1"F BSP
PMR-10 MF	10	0.69	120	8.28	4 - 16	907.2 -3628.8	3/4" F NPT, 1" F NPT, 1"M NPT, 1"F BSP	3/4" F NPT, 1" F NPT, 1"F BSP
PMR-12 MF	12	0.83	135	9.31	2-20	453.6-4536.0	3/4" F NPT, 1" FNPT, 1"M NPT, 1"F BSP	3/4" F NPT, 1" F NPT, 1"F BSP
PMR-15 MF	15	1.04	150	10.35	2-20	453.6-4536.0	3/4" F NPT, 1" F NPT, 1"M NPT, 1"F BSP	3/4" F NPT, 1" F NPT, 1"F BSP
PMR-20 MF	20	1.38	150	10.35	2-20	453.6-4536.0	3/4" F NPT, 1" FNPT, 1"M NPT, 1"F BSP	3/4" F NPT, 1" F NPT, 1"F BSP
PMR-25 MF	25	1.73	150	10.35	2-20	453.6-4536.0	3/4" F NPT, 1" F NPT, 1"M NPT, 1"F BSP	3/4" F NPT, 1" F NPT, 1"F BSP
PMR-30 MF	30	2.07	150	10.35	2-20	453.6-4536.0	3/4" F NPT, 1" F NPT, 1"M NPT, 1"F BSP	3/4" F NPT, 1" F NPT, 1"F BSP
PMR-35 MF	35	2.42	150	10.35	2-20	453.6-4536.0	3/4" F NPT, 1" F NPT, 1"M NPT, 1"F BSP	3/4" F NPT, 1" F NPT, 1"F BSP
PMR-40 MF	40	2.76	150	10.35	2-20	453.6-4536.0	3/4" F NPT, 1" F NPT, 1"M NPT, 1"F BSP	3/4" F NPT, 1" F NPT, 1"F BSP
PMR-50 MF	50	3.45	150	10.35	2-20	453.6-4536.0	3/4" F NPT, 1" F NPT, 1"M NPT, 1"F BSP	3/4" F NPT, 1" F NPT, 1"F BSP
PMR-60 MF	60	4.14	150	10.35	2-20	453.6-4536.0	3/4" F NPT, 1" F NPT, 1"M NPT, 1"F BSP	3/4" F NPT, 1" F NPT, 1"F BSP

[1] Regulated pressure is 1/2 psi (0.03 bar) higher with increasing inlet pressure than with decreasing inlet pressure

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Figure G-2. Pressure Regulator Specifications

Appendix H: RainBird Precipitation Rate Tables

RAIN BIRD
Deep roots, high standards.

REFERENCE TABLES
Instructions and Examples

Following is an example of how to use the reference tables when determining crop water requirements and sprinkler spacing.

EXAMPLE PARAMETERS: An alfalfa / lucerne crop is to be irrigated on level ground. The soil is medium type. Climate is hot. For convenience of labor, two eleven-hour sets per day will be used. Normal sprinkler spacing of 30 ft x 50 ft / 9x15 meters will be used. Average wind speed is 4 mph / 6 km/hr.

Use the following steps:

1. From **Plant Feeder Root Depth (TABLE 1)**, alfalfa / lucerne roots are three feet / 90 cm deep.
2. Determine **Soil Type (TABLE 2)**. From **Net Amount of Moisture per Application (TABLE 2)**, three feet / 90 cm depth in medium soil with 50% moisture retained at irrigation means 2.53 inches / 63,3 mm net must be applied per irrigation.
3. From **Peak Moisture (TABLE 3)**, alfalfa / lucerne uses 0.30 inches / 7,5 mm per day in hot climate.
4. Irrigation frequency or interval between irrigation is determined by dividing net moisture applied during irrigation by peak moisture use of the crop per day. For example, the irrigation frequency or interval is 2.53 inches / 63,3 mm net divided by 0.30 inches / 7,5 mm per day peak moisture use or 8.4 days.
5. From **Gross Amount of Moisture (TABLE 4)**, 2.53 inches / 65mm net is 3.57 inches / 92,95 mm gross in a hot climate with 70% irrigation efficiency. Also see additional example **(TABLE 5)** estimating irrigation efficiencies.
6. Precipitation rate in inches / millimeters per hour is determined by dividing gross moisture in inches / millimeters by number of hours per set. For example, the required precipitation rate is determined by dividing 3.57 inches / 92,95 mm by 11 hours per set or 0.32 inches / 8,45 mm per hour.
7. From **Maximum Precipitation Rate (TABLE 6)** for medium soil, maximum rate is from 0.25 to 0.5 inches / 6 to 12 mm per hour. Therefore, precipitation rate of 0.32 inches / 8,45mm per hour in step 6 is satisfactory.
8. Use **Slope Precipitation (TABLE 7)** to reduce precipitation due to slope of ground.
9. From **Table of Precipitation (TABLE 8)** on 30 ft x 50 ft / 9x15 meter spacing with a precipitation rate of 0.32 inches / 8,45 mm per hour, a 5 gpm / 1,08 m^3/hr sprinkler is required.
10. From the **Rain Bird Agriculture Irrigation Equipment Catalog** a 30WH Rain Bird with 5/32 inches / 3,97 mm nozzle discharges 5 gpm / 1,16 m^3/hr at 50 PSI / 3,5 bars with a 90 ft / 13,64 m diameter of throw.
11. From **Maximum Spacing of Sprinklers (TABLE 9)**, 40% of diameter between sprinklers and 65% of diameter between laterals may be used in winds up to 7 mph / 10 km/hr. Diameter of 90 ft / 27,28 m times 40% and 65% give a theoretical spacing of 36 ft x 58.5 ft / 10,9 x 17,7 meters. A spacing of 30 ft x 50 ft / 9x15 meters will give good coverage.

TABLE 1
Plant Feeder Root Depths*

Crop	Feeder Root Depth	
Alfalfa / lucerne	90-180 cm	3-6 ft
Beans	60 cm	2 ft
Beets	60-90 cm	2-3 ft
Berries (cane)	90 cm	3 ft
Cabbage	45-60 cm	1.5-2 ft
Carrots	45-60 cm	1.5-2 ft
Corn	75 cm	2.5 ft
Cotton	120 cm	4 ft
Cucumbers	45-60 cm	1.5-2 ft
Grain	60-75 cm	2-2.5 ft
Grain, Sorghum	75 cm	2.5 ft
Grapes	90-180 cm	3-6 ft
Lettuce	30 cm	1 ft
Melons	75-90 cm	2.5-3 ft
Nuts	90-180 cm	3-6 ft
Onions	45 cm	1.5 ft
Orchard	90-150 cm	3-5 ft
Pasture (grasses only)	45 cm	1.5 ft
Pasture (with clover)	60 cm	2 ft
Peanuts	45 cm	1.5 ft
Peas	75 cm	2.5 ft
Potatoes	60 cm	2 ft
Soy Beans	60 cm	2 ft
Strawberries	30-45 cm	1-1.5 ft
Sweet Potatoes	90 cm	3 ft
Tobacco	75 cm	2.5 ft
Tomatoes	30-60 cm	1-2 ft

* Majority of Feeder Roots

RAIN BIRD NOZZLES
Equivalency Chart

Size in Inches	Size in mm	Order Number
1/16"	1,59	04
5/64"	1,98	05
3/32"	2,38	06
7/64"	2,78	07
1/8"	3,18	08
9/64"	3,57	09
5/32"	3,97	10
11/64"	4,37	11
3/16"	4,76	12
13/64"	5,16	13
7/32"	5,56	14
15/64"	5,95	15
1/4"	6,35	16
17/64"	6,75	17
9/32"	7,14	18
19/64"	7,54	19
5/16"	7,94	20
11/32"	8,73	22
3/8"	9,53	24
13/32"	10,32	26
7/16"	11,11	28
15/32"	11,91	30
1/2"	12,70	32
17/32"	13,49	34
9/16"	14,29	36
5/8"	15,88	40
11/16"	17,46	44

TABLE 2
NET AMOUNT OF MOISTURE PER APPLICATION

		LIGHT SANDY SOIL TYPE						MEDIUM SOIL TYPE						HEAVY SOIL TYPE					
Root Zone Depth	cm	30	45	60	75	90	120	30	45	60	75	90	120	30	45	60	75	90	120
a. Field Capacity	mm	31,0	47,0	62,5	78,0	93,7	125,0	56,0	84,5	112,5	140,5	168,7	225,0	92,0	137,5	183,5	229,0	275,0	367,0
b. Amount held at wilting point (a x %)	Percent	20%	20%	20%	20%	20%	20%	25%	25%	25%	25%	25%	25%	35%	35%	35%	35%	35%	35%
	mm	6,0	9,4	12,5	15,6	18,7	25,0	14,0	21,0	28,0	35,0	42,0	56,0	32,0	48,0	64,0	80,0	96,0	128,5
c. Available moisture for plant use (a - b) = c	mm	25,0	37,6	50,0	62,4	75,0	100,0	42,0	63,5	84,5	105,5	126,7	169,0	60,0	89,5	119,5	149,0	179,0	239,5
Net mm to apply per irrigation with appropriate % of available moisture retained in soil at irrigation (see note below)	67%	8,2	12,4	16,5	20,6	25,0	33,0	14,0	21,0	27,9	34,0	41,9	56,0	19,8	29,6	39,0	49,2	59,1	79,0
	50%	12,5	18,8	25,0	31,2	37,5	50,0	21,0	31,8	42,2	52,8	63,3	84,5	30,0	44,8	59,8	74,5	89,5	119,8
	33%	16,8	25,2	33,5	41,8	50,0	67,0	28,0	42,5	56,6	70,7	84,8	113,0	40,2	60,0	80,0	99,8	119,9	160,5

NOTE: For optimum yield of high-valued, shallow-rooted crops maintain **67%** available moisture. For lower-valued, deeper-rooted crops maintain **50%** available moisture. For low-value, deep-rooted crops maintain **33%** available moisture.

CONTINUED ON NEXT PAGE . . .

RAIN BIRD
Deep roots, high standards.

Reference Tables (continued)

TABLE 3
Peak Moisture Use for Common Irrigated Crops and Optimum Yields*

Crop	COOL Climate			MODERATE Climate			HOT Climate			HIGH DESERT Climate			LOW DESERT Climate		
	mm/day	m^3/hr /hectare	lps /hectare	mm/day	m^3/hr /hectare	lps /hectare	mm/day	m^3/hr /hectare	lps /hectare	mm/day	m^3/hr /hectare	lps /hectare	mm/day	m^3/hr /hectare	lps /hectare
Lucerne (Alfalfa)	5,00	20,52	0,57	6,25	25,92	0,72	7,50	31,32	0,87	8,75	36,36	1,01	11,25	46,80	1,30
Cotton	5,00	20,52	0,57	6,25	25,92	0,72	7,50	31,32	0,87	8,75	36,36	1,01	11,25	46,80	1,30
Pasture	5,00	20,52	0,57	6,25	25,92	0,72	7,50	31,32	0,87	8,75	36,36	1,01	11,25	46,80	1,30
Grain	3,75	15,48	0,43	5,00	20,52	0,57	5,50	22,68	0,63	7,50	31,32	0,87	10,00	41,76	1,16
Potatoes	3,50	14,40	0,40	5,00	20,52	0,57	6,25	25,92	0,72	7,50	31,32	0,87	10,00	41,76	1,16
Beets	5,00	20,52	0,57	6,25	25,92	0,72	7,50	31,32	0,87	8,75	36,36	1,01	11,25	46,80	1,30
Orchards & Groves	5,00	20,52	0,57	6,25	25,92	0,72	7,50	31,32	0,87	8,75	36,36	1,01	11,25	46,80	1,30
Orchards & Groves w/cover	6,25	25,92	0,72	7,00	29,16	0,81	8,75	36,36	1,01	9,50	39,60	1,10	12,00	50,04	1,39

*Continuous flow required per acre at 100% irrigation efficiency. Divide this value by estimated irrigation efficiency (see TABLE 5).

TABLE 4
Gross Amount of Moisture to Apply to Obtain Desired Net in Different Climates[1]

Desired Net Millimeters	COOL Climate Gross mm @ 80% Efficiency	MODERATE Climate Gross mm @ 75% Efficiency	HOT Climate Gross mm @ 70% Efficiency	HIGH DESERT Climate Gross mm @ 65% Efficiency	LOW DESERT Climate Gross mm @ 60% Efficiency
5,00	6,25	6,65	7,15	7,70	8,30
6,00	7,50	7,98	8,58	9,24	9,96
7,00	8,75	9,31	10,01	10,78	11,62
8,00	10,00	10,64	11,44	12,32	13,28
9,00	11,25	11,97	12,87	13,86	14,24
10,00	12,50	13,30	14,30	15,40	16,60
15,00	18,75	19,95	21,45	23,10	24,90
20,00	25,00	26,60	28,60	30,80	33,20
25,00	31,25	33,25	35,75	38,50	41,50
30,00	37,50	39,90	42,90	46,20	49,80
35,00	43,75	46,55	50,05	53,90	58,10
40,00	50,00	53,20	57,20	61,60	66,40
45,00	56,25	59,85	64,35	69,30	74,70
50,00	62,50	66,50	71,50	77,00	83,00
55,00	68,75	73,15	78,65	84,70	91,30
60,00	75,00	79,80	85,80	92,40	99,60
65,00	81,25	86,45	92,95	100,10	107,90
70,00	87,50	93,10	100,10	107,80	116,20
75,00	93,75	99,75	107,25	115,50	124,50
80,00	100,00	106,40	114,40	123,20	132,80
85,00	106,25	113,05	121,55	130,90	141,10
90,00	112,50	119,70	128,70	138,60	149,40
95,00	118,75	126,35	135,85	146,30	157,70
100,00	125,00	133,00	143,00	154,00	166,00
105,00	131,25	139,65	150,15	161,70	174,30
110,00	137,50	146,30	157,30	169,40	182,60

[1] Very low application rate systems can attain 80% efficiency in all climate areas.

TABLE 5
Estimating Irrigation Efficiencies

Desert Climate	65%
Hot Dry Climate	70%
Moderate Climate	75%
Humid or Cool Climate	80%

Example: For a 50mm requirement in a hot-dry climate,

$$\frac{50\text{mm}}{0.70} \times 10 \frac{\text{m}^3\text{/hectare}}{\text{mm applied}} = 714\ \text{m}^3\text{/hectare}$$

Thus: 714 m^3/hectare water applied each irrigation

TABLE 6
Maximum Precipitation Rates to Use on Level Ground

Light sandy soils	18 - 12 mm per hour
Medium textured soils	12 - 6 mm per hour
Heavy textured soils	6 - 2.5 mm per hour

Allowable rates increase with adequate cover and decrease with land slopes and time.

TABLE 7
Slope Precipitation Table

Slope[1]	Precipitation Rate Reduction[2]
0 - 5 % grade	0 %
6 - 8 % grade	20 %
9 - 12 % grade	40 %
13 - 20 % grade	60 %
over 20 % grade	75 %

[1] Grade = drop in 100 meters
[2] Applied to proper soil type precipitation rate

APPENDICES

CONTINUED ON NEXT PAGE . . .

Reference Tables (continued)

TABLE 8*
Table of Precipitation (mm per hour)

Spacing (meters)	Flow from each Full Circle Sprinkler																									
	m3/hr	0,18	0,36	0,56	0,72	0,90	1,08	1,44	1,80	2,16	2,52	2,88	3,24	3,60	3,96	4,32	5,40	6,40	7,20	9,00	10,8	18,0	36,0	72,0	108	216
	lps	0,05	0,10	0,15	0,20	0,25	0,30	0,40	0,50	0,60	0,70	0,80	0,90	1,00	1,10	1,20	1,50	1,80	2,00	2,50	3,00	5,00	10,0	20,0	30,0	60,0
6 x 6		5,00	10,0	15,0	20,0	25,0	30,0	40,0	50,0																	
6 x 9		3,30	6,60	10,0	13,3	16,6	20,0	26,6	33,3	40,0	46,6	53,0														
6 x 12		2,50	5,00	7,50	10,0	12,5	15,0	20,0	25,0	30,0	35,0	40,0	45,0	50,0												
8 x 8		2,80	5,60	8,40	11,2	14,0	16,9	22,5	28,1	33,7	39,4	45,0	50,0													
9 x 9		2,20	4,40	6,60	8,90	11,1	13,3	17,8	22,2	26,6	31,1	35,5	40,0	44,4	48,8	53,3										
9 x 12		1,60	3,30	5,00	6,60	8,30	10,0	13,3	16,6	20,0	23,3	26,6	30,0	33,3	36,6	40,0	50,0	59,2								
9 x 14		1,40	2,80	4,30	5,70	7,10	8,60	11,4	14,3	17,1	20,0	22,8	25,7	28,5	31,4	34,3	42,8	50,8								
9 x 15		1,30	2,70	4,00	5,30	6,60	8,00	10,6	13,3	16,0	18,6	21,3	24,0	26,6	29,4	32,0	40,0	47,4								
9 x 18			2,20	3,30	4,40	5,50	6,60	8,90	11,1	13,3	15,5	17,8	20,0	22,2	24,4	26,6	33,3	39,5	44,4	55,5						
12 x 12			2,50	3,70	5,00	6,20	7,50	10,0	12,5	15,0	17,5	20,0	22,5	25,0	27,5	30,0	37,5	44,4	50,0	62,5						
12 x 15			2,00	3,00	4,00	5,00	6,00	8,00	10,0	12,0	14,0	16,0	18,0	20,0	22,0	24,0	30,0	35,5	40,0	50,0						
12 x 18			1,60	2,50	3,30	4,20	5,00	6,60	8,30	10,0	11,6	13,3	15,0	16,6	18,3	20,0	25,0	29,6	33,3	41,6	50,0					
15 x 15					3,20	4,00	4,80	6,40	8,00	9,60	11,2	12,8	14,4	16,0	17,6	19,2	24,0	28,4	32,0	40,0	48,0					
15 x 18					2,60	3,30	4,00	5,30	6,60	8,00	9,30	10,6	12,0	13,3	14,6	16,0	20,0	23,7	26,6	33,3	40,0					
15 x 21					2,30	2,80	3,40	4,60	5,70	6,80	8,00	9,10	10,3	11,4	12,6	13,7	17,1	20,3	22,8	28,5	34,3					
18 x 18							3,30	4,40	5,50	6,60	7,80	8,90	10,0	11,1	12,2	13,3	16,6	20,0	22,2	27,7	33,3					
18 x 21							2,80	3,80	4,70	5,70	6,60	7,60	8,60	9,50	10,5	11,4	14,3	16,9	19,0	23,8	28,6					
18 x 24							2,50	3,30	4,20	5,00	5,80	6,60	7,50	8,30	9,10	10,0	12,5	14,8	16,6	20,8	25,0					
21 x 21							2,40	3,20	4,10	4,90	5,70	6,50	7,30	8,10	8,90	9,80	12,2	14,5	16,3	20,4	24,5	40,8				
21 x 24								2,80	3,60	4,30	5,00	5,70	6,40	7,10	7,80	8,60	10,7	12,7	14,3	17,8	21,4	35,7				
21 x 27								2,50	3,20	3,80	4,40	5,10	5,70	6,30	7,00	7,60	9,50	11,3	12,7	15,9	19,0	31,7				
24 x 24									3,10	3,70	4,30	5,00	5,60	6,20	6,90	7,50	9,40	11,1	12,5	15,6	18,7	31,2				
24 x 30									2,50	3,00	3,50	4,00	4,50	5,00	5,50	6,00	7,50	8,90	10,0	12,5	15,0	25,0				
28 x 33										2,30	2,70	3,10	3,50	3,90	4,30	4,70	5,80	6,90	7,80	9,70	11,7	19,4	38,9			
30 x 30										2,40	2,80	3,20	3,90	4,00	4,40	4,80	6,00	7,10	8,00	10,0	12,0	20,0	40,0			
30 x 36											2,30	2,60	3,00	3,30	3,60	4,00	5,00	5,90	6,60	8,30	10,0	16,6	33,3			
35 x 41														2,50	2,70	3,00	3,70	4,40	5,00	6,30	7,50	12,5	25,0	50,1		
45 x 45																	2,60	3,20	3,50	4,40	5,30	8,90	17,7	35,5	53,3	
45 x 54																		2,60	2,90	3,70	4,40	7,40	14,8	29,6	44,4	
60 x 60																				2,50	3,00	5,00	10,0	20,0	30,0	60,0
90 x 90																						2,20	4,40	8,80	13,3	26,6
100 x 100																							3,60	7,20	10,8	21,6

TABLE 9
Maximum Spacing of Sprinklers

The maximum spacing of sprinklers is based on the diameter of coverage of the sprinkler used.

Average Wind Speed: Up to 10 km/hr

Spacing
40% between sprinklers
65% between laterals

Average Wind Speed: 10 to 15 km/hr

Spacing
40% between sprinklers
60% between laterals

Average Wind Speed: above 15 km/hr

Spacing
30% between sprinklers
50% between laterals

*Calculation of Flow From Each Full Circle Sprinkler

$$\text{Spacing} \quad x \quad \frac{\text{Precipitation Rate}}{1000} \quad = \quad \text{Flow from each Full Circle Sprinkler}$$

EXAMPLE:

$$9\text{m} \times 15\text{m} \quad x \quad \frac{8{,}45 \text{ m/hr}}{1000} \quad = \quad 1{,}14 \text{ m}^3\text{/hr}$$

Appendix I: Calculations with the Renfro Equation

Source: http://www.fao.org/docrep/X5560E/x5560e03.htm#3. determining effective rainfall from formulae

The Renfro formula can be seen below.

$$P_e = E \cdot P + A$$

P represents the growing season rainfall, ie. the monthly rainfall. *A* is the average irrigation application, and *E* is a coefficient based on the ratio of consumptive use of water (*CU*) to rainfall during the growing season (*P*). The value of *E* for a given *CU/P* ratio can be determined from table I-1 (Chow,1964 – Handbook of Applied Hydrology, Vol. 1). The values for each variable will vary from month to month depending on how much rain has fallen and the monthly irrigation application.

Table I-1

CU/P	***E***	***CU/P***	***E***
0	0	2.4	0.72
0.2	0.10	2.6	0.75
0.4	0.19	2.8	0.77
0.6	0.27	3.0	0.80
0.8	0.35	3.5	0.84
1.0	0.41	4.0	0.88
1.2	0.47	4.5	0.91
1.4	0.52	5.0	0.93
1.6	0.57	6.0	0.96
1.8	0.61	7.0	0.98
2.0	0.65	9.0	0.99
2.2	0.69	/	/

Appendix J: Photos of Project Site

Figure J-1: Pucapuquio Spring (red box indicates location where spring box will be constructed)

Figure J-2: Pucapuquio Spring, Location Where Spring Box Will be Constructed


Figure J-3: Yanallpa Spring


Figure J-4: Eye of Yanallpa Spring


Figure J-5: Yanallpa Spring


Figure J-6: Eye of Yanallpa Spring


Figure J-7: Eye of Yanallpa Spring


Figure J-8: View of Coris Field from Below


Figure J-9: View of Coris Field from Below


Figure J-10: Coris Field from Above During the Rainy Season


Figure J-11: Looking Up from the Bottom of the Pasture (Dry Season)


Figure J-12: Looking Up from the Bottom of the Pasture (Dry Season)

Figure J-13: Looking Down from the Top of the Pasture (Dry Season)

Appendix K: Bill of Materials

Table K-1: Materials and Cost Estimate for Conveyance Pipeline

Item	# Units	Unit Price (US $)	Total Price (US $)
Pipes and Fittings			
1.5 in. PVC pipe (5 m units)	214	10.00	2140.00
1 in. PVC pipe (5 m units)	10	6.00	60.00
1/2 in. PVC pipe (5 m units)	23	4.00	92.00
1.5" 90 deg. Elbow	3	3.00	9.00
1.5" 45 deg. Elbow	72	3.00	216.00
1" 90 deg. Elbow	2	1.00	2.00
1" 45 deg. Elbow	4	1.25	5.00
1/2" 90 deg. Elbow	2	0.50	1.00
1/2" 45 deg. Elbow	8	0.50	4.00
Valves			
1.5" globe valve	3	10.00	30.00
1" globe valve	3	4.00	12.00
1/2" globe valve	2	2.00	4.00
Other			
PVC glue (1/4 gal.)	3	10.00	30.00
		Total	**$2,605.00**

Table K-2: Materials and Cost Estimate for Spring Boxes and Break Pressure Tank

Item	# Units	Unit Cost (US $)	Total Cost (US $)
Labor			
Mason for spring box construction (# days)	7	45.00	315.00
Pipework			
1” PVC Pipe (5 m units)	2	6.67	13.34
2” PVC Pipe (5 m units)	3	12.96	38.88
1" PVC 90 deg. Elbow	5	0.50	2.50
1” to 2” PVC couple	5	2.00	10.00
1” Diameter PVC cap	2	2.00	4.00
1” PVC globe Valve	1	4.00	4.00
Float Valve	1	30.00	30.00
Mesh for overflow pipes (3”x3” Squares)	2	2.00	4.00
Concrete			
Cement US-C150 (42.5 kg bag)	11	8.00	88.00
Coarse Aggregate (per m^3)	1.5	40.00	60.00
Sand (per m^3)	1	25.93	25.93
Air entrainment (per kg- 1 kg per bag of cement)	5	2.50	12.50
#3 Rebar	12	7.04	84.48
Formwork			
Tie wire 26 gauge (1 kg)	1	1.59	1.59
Plywood (1.2m x 2.4m section)	4	24.07	96.28
Wood -- 2 x 4	2	6.00	12.00
Miscellaneous Tools (to be provided by Campesina Community)			
Plastic Tarp	2	10.00	20.00
Burlap			
Shovels			
Pick axe			
hacksaw			
wood saw			
heavy duty buckets			
pliers			
hammer			
nails			
measuring tape			
speed square			
spare saw blade			
trowel			
PVC glue	included in pipeline materials		
Chicken wire			
		Total	**$822.50**

Table K-3: Materials and Cost Estimate for In-field Irrigation System

Item	# Units	Unit Cost (US $)	Total Cost (US $)
Sprinkler Risers			
1/2" NPT conection metal impact sprinkler	20	19.00	380.00
1/2" Galvanized steel NPT union (2 female ends)	20	6.00	120.00
1/2" 3'-long galvinized steel pipe (2 male ends)	20	10.00	200.00
1/2" galvanized steel coupling (removable)	20	2.00	40.00
1/2" galvanized steel 1/2" NPT to 1/2" PVC coupling	20	2.00	40.00
1/2" 18" long galvanized steel pipe (2 male ends)	20	7.00	140.00
PTFE tape (1 roll)	5	1.50	7.50
Irrigation Pipeline			
1 in. PVC pipe (5 m units)	150	6.00	900.00
1/2 in. PVC pipe (5 m units)	85	4.00	340.00
1/2" sch. 40 PVC 90 degree elbow (2 female)	54	1.30	70.20
1/2" to 1" dia. sch. 40 PVC coupling	54	2.00	108.00
1" sch. 40 PVC angle elbow (2 female)	8	1.30	10.40
1" sch. 40 PVC Wye coupling	54	2.00	108.00
1.5" PVC spliter (1 main line split into 3 lines)	1	10.00	10.00
1" pressure regulators	8	40.00	320.00
1.5" sch. 40 PVC T coupling	8	3.00	24.00
1.5" to 1" sch. 40 PVC coupling	8	3.00	24.00
1.5" sch. 40 PVC cap	3	2.00	6.00
1" sch. 40 PVC cap	8	2.00	16.00
1" PVC ball valve	10	4.00	40.00
1.5" sch. 40 PVC angle bracket	4	3.00	12.00
Total Irrigation Project Cost:			**$2,916.10**

Appendix L: Memorandum of Understanding- signed

CAMBIAR

INGENIEROS SIN FRONTERAS-EE.UU
GREATER AUSTIN CHAPTER

Convenio Para el Proyecto de Riego Tecnificado en Huasta, Peru
Memorandum of Understanding: Improved Irrigation Project in Huasta, Peru

Este convenio es entre la Comunidad Campesina de Huasta e Ingenieros sin Fronteras de Greater Austin (EWB-Austin) para el proyecto de riego tecnificado ("el proyecto"). Este proyecto es una parte del programa de Climate Adaptations in Mountain Basins In the Andean Region (CAMBIAR) ("el programa"). El propósito de este acuerdo es establecer un marco de colaboración con este proyecto. Acuerdos adicionales se firmarán con cada etapa del proyecto después de confirmar los detalles más específicos en el proceso de desarrollar el proyecto.

This agreement is between the Campesina Community of Huasta and Engineers Without Borders-Greater Austin (EWB-Austin) for the improved irrigation project ("the project"). This project is part of the Climate Adaptations in Mountain Basins In the Andean Region (CAMBIAR) program ("the program"). The purpose of this agreement is to establish a framework for collaboration with this project. Additional agreements will be signed with each phase of the project after confirming more specific details in the process of developing the project.

CLÁUSULA PRIMERA: DE LAS PARTES
First Clause: Parties

1.1 Comunidad Campesina de Huasta es un grupo de Campesinos que trabajan y viven en Huasta.

1.1 The Campesina Community of Huasta is a group of Campesinos who work and live in Huasta.

1.2 **Ingenieros Sin Fronteras – E.E.U.U (EWB-USA)** es una organización humanitaria sin fines de lucro establecida para desarrollar programas de apoyo comunitario a nivel mundial a través de asociaciones que diseñan e implementan proyectos de ingeniería sostenible. Los miembros de EWB-USA, que comprenden profesionales y estudiantes de ingeniería y otras disciplinas, trabajan con comunidades y ONG's locales en más de 45 países en vías de desarrollo alrededor del mundo en proyectos de agua, energía renovable, sanitarios, et setera. Los proyectos siempre tienen dos metas (1) cumplir las necesidades de ingeniería de las comunidades con un enfoque de sostenibilidad de largo plazo, y (2) proveer una oportunidad educativa para que los voluntarios ganen una experiencia práctica en ingeniería.

La sede de Austin de EWB-USA (EWB-Austin) es la combinación de profesionales y estudiantes de EWB-USA que está localizado en Austin, Texas, USA.

1.2 ***Engineers Without Borders-USA (EWB-USA)*** *is a nonprofit humanitarian organization established to support community-driven development programs worldwide through partnerships that design and implement sustainable engineering projects. EWB-USA members, comprised of professional and student engineers or other disciplines, work with local communities and NGOs in over 45 developing countries around the world on projects such as water, renewable energy, sanitation and more. The projects always have two objectives (1) to fulfill the engineering needs of the communities with a focus on long-term sustainability, and (2) to provide an educational opportunity so that the volunteers gain practical engineering experience.*

The Greater Austin Chapter of EWB-USA (EWB-AUS) *is a combined professional-student chapter of EWB-USA that is located in Austin, Texas, USA.*

CLÁUSULA SEGUNDA: DE LOS FINES DEL PROYECTO
Second Clause: Objectives of the Project

El propósito de este proyecto es para implementar un sistema de riego tecnificado en el campo comunal de la Comunidad Campesina de Huasta Coris. El objetivo de este proyecto es para ser una pilota mostrando como la tecnología pueda ahorrar agua y ayudar a la gente de la región de Ancash a adaptar a los cambios climáticos y el escasez del agua.

The purpose of this project is to implement an improved irrigation system in the communal pasture of Coris owned by the Campesina Community of Huasta. The objective of this project is to be a pilot project, demonstrating how technology can conserve water and help people of the Ancash Region adapt to climate change and water scarcity.

CLÁUSULA TERCERA: DEL PROYECTO QUE SE PROPONE
Third Clause: The Proposed Project

El agua de ojo de Yanallpa se llevara al campo de Coris por medio de un sistema de tubería. La línea de tubería se evaluó en el viaje en Enero. La Comunidad Campesina e Ingenieros Sin Fronteras acordaron implementar el proyecto en Julio 2013.

The water from the Yanallpa spring will be conveyed to the Coris field by a piping system below the ground. The survey line has been determined from the January assessment trip and the Campesina Community and EWB-AUS have agreed to implement the project in July 2013.

CLÁUSULA CUATRO: DE LAS RESPONSABILIDADES
Fourth Clause: Responsibilities

4.1 Obligaciones Conjuntas
Las obligaciones de ambas partes son:

- Estar abierto en la comunicación y compartir información en cada fase del proyecto
- Trabajan juntos para la implementación dc un piloto de sistema de información para monitorear el clima, hidrológica, calidad del agua, y suelo en Coris
- Ingenieros Sin Fronteras y La Comunidad Campesina de Huasta conversamos y decidimos que la contribución de financiamiento de la Comunidad Campesina no excederá el 5% dc total del costo del proyecto.
- En mediato de Mayo La Comunidad Campesina excavasen e instalan de tubería con las materiales compran de Ingenieros Sin Fronteras. En 1 de Julio se estará instalando todos los materiales de instalación para riego de Coris.

4.1 Joint Obligations
The obligations of both parties are:

- *Be open in communication and share information at each phase of the project*
- *Work together to pilot a data collection system to monitor the climate, hydrology, wáter quality, and soil moisture levels at Coris.*
- *EWB-AUS and the Comunidad Campesina will discuss and agree on a financial contribution from the Comunidad Campesina that will not exceed 5% of the total project budget.*

4.2 Responsabilidades de Ingenieros sin Fronteras (EWB-Austin)
Las responsabilidades de EWB-Austin son:

a) Ingenieros Sin Fronteras colaborará con el liderazgo de la Comunidad Campesina en tomar todas decisiones en cada fase del proyecto.
b) Ingenieros Sin Fronteras proveerá el diseño técnico y operación del sistema según las normas de ingeniería.
c) Ingenieros Sin Fronteras enseñara la Comunidad como mantener la infraestructura implementada y proveerá de manuales (en español) sobre el tema.
d) Ingenieros Sin Fronteras trabajará con la Comunidad para llevar a cabo una evaluación del proyecto seis meses después de la infraestructura se ha completado.
e) Ingenieros Sin Fronteras hace una base de información electrónica para almacenar los datos del clima e hidrológica, y provee fondos para instrumentos al inicio.

4.2 Responsibilities of Engineers Without Borders (EWB-Austin)
The responsibilities of EWB-Austin are:

a) EWB-Austin will work with the leadership of the Comunidad Campesina of Huasta when making decisions in each phase of the project.
b) EWB-Austin will provide the technical design and operation of the system according to engineering standards.
c) EWB-Austin will teach the Comunidad Campesina to maintain the implemented infrastructure and will provide manuals (in Spanish) for doing so.
d) EWB-Austin will work with the Comunidad Campesina to conduct a project evaluation six months after the infrastructure is completed.

e) EWB-Austin will set up a database for storing collected field data and provide initial funding for instrumentation to collect climate, hydrologic, and soil moisture data.

4.3 Responsabilidades de la Comunidad Campesina de Huasta
Las responsabilidades de la Comunidad Campesina son:

a) La Comunidad Campesina proveerá dos contactos quienes serán responsables de la comunicación con EWB-Austin y trabajaran como un comité para supervisar la implementación y recolección de datos.
b) La Comunidad Campesina contribuirá con el trabajo que sea necesario para la pre-implementación, que incluye la excavación de zanjas para las tuberías de agua, asi como la búsqueda de permisos de los residentes de Huasta por donde pasen las tuberías.
c) Los miembros de la Comunidad Campesina se comprometen a tener disponibilidad de tiempo para realizar los trabajos de construcción de la infraestructura del proyecto del 1-15 de Julio aproximadamente. La Comunidad Campesina ayudará a los Ingenieros Sin Fronteras a realizar el plan de trabajo de implementación y asegurar que hay a suficiente personal disponible los días necesarios.
d) Los miembros de la Comunidad Campesina serán responsables de monitorear el caudal de Yanallpa y recolectar datos específicos del clima y otros datos relacionados al proyecto.
e) La Comunidad Campesina proveerá suporte logístico en la organización de alojamiento y otras cosas durante visita EWB-Austin.
f) La Comunidad Campesina entiende que este proyecto forma parte de un programa conjunto entre la Mancomunidad Municipal Tres Cuencas y se compromete a hacer el sitio disponible para otras comunidades en la Mancomunidad que estén interesados en aprender más sobre el proyecto.

4.3 Responsabilities of the Comunidad Campesina of Huasta
Responsabilities of the Campesina Community are:

a) The Comunidad Campesina will provide two contacts who are responsible for communication with EWB-Austin and will serve as the committee for overseeing the implementation and collecting data.
b) The Comunidad Campesina will assist with work that may be required for pre-implementation, including trenching the proposed pipeline and seeking permissions from Huasta residents to locate infrastructure on their property, if necessary.
c) Members of the Comunidad Campesina will be available to work on building the project infrastructure from approximately July 1st to July 15th. The Comunidad Campesina will assist EWB-Austin when making the implementation work plan to ensure that enough people will be available on the necessary days.
d) Members of the Comunidad Campesina will be responsible for monitoring the flow of the Yanallpa and collecting other specified climate and project-related data from the field.
e) The Comunidad Campesina will provide logistic support in organizing sleeping arrangements and other things when EWB-Austin teams visit Huasta.

f) The Comunidad Campesina understands that this project is part of a joint Program that includes the Tres Cuencas Commonwealth and agrees to make the site available to other communities in the Commonwealth that are interested in learning more about the project.

CLÁUSULA CINCO: DURACIÓN Y VIGENCIA
Fifth Clause: Duration and Validity

El presente Convenio entrará en vigencia a partir de la suscripción del mismo hasta que dure el programa o la infraestructura se ha completado. Al siguiente año, EWB-Austin llevará a cabo una revisión y análisis del proyecto. En ese momento este Memorando de Entendimiento podrá ser modificado con una extensión mayor a que ambas partes lo consideren necesario.

En caso de surgir situaciones no previstas o de incumplimiento de las obligaciones asumidas en el presente Convenio, cualquiera de las partes podrá solicitar su resolución, previa notificación escrita a la otra parte con treinta (30) días de anticipación, dentro del cual se procederá a concluir las actividades y dejar un informe completo de lo avanzado hasta la fecha.

This MOU will take effect on its date of execution until the program lasts or the infrastructure of the project is completed. The following year, EWB-Austin will conduct a final review of the project. At that time this MOU may be amended with an extension if the parties deem it necessary.

In the event of unforeseen circumstances or breach of their obligations under this MOU, parties may seek to end the MOU upon written notice to the other parties. With thirty (30) days of written notice of termination parties will conclude their activities and leave a full report on the progress to date.

CLÁUSULA SEIS: DE LA MODIFICACION DEL CONVENIO
Sixth Clause: Modification of the Agreement

Cualquier modificación y/o ampliación del presente Convenio se efectuará por acuerdo de las partes mediante adenda respectiva y por periodos similares.

Any modification and/or extension of this MOU shall be effected by agreement of the parties through addenda.

CLÁUSULA SEITE: DE LA SOLUCION DE CONTROVERSIAS
Seventh Clause: Dispute Resolution

Cualquier asunto no previsto en el presente Convenio o cualquier discrepancia o controversia respecto de su aplicación o interpretación, deberá ser solucionado a través del entendimiento directo entre las partes, sobre la base de las reglas de la buena fe y común intención, designándose para ello representantes por cada una de las partes. Dicha designación deberá ser puesta en conocimiento de la otra parte.

Any matter not provided for in this MOU or any dispute or controversy regarding its application or interpretation shall be settled through direct agreement between the parties, based on the rules of good faith and common intention, by designated representatives of each of the parties. Such designation must be made known to the other party.

CLÁUSULA OCHO: DE LAS DISPOSICIONES FINALES
Eighth Clause: Final Dispensations

Toda controversia sobre la interpretación y aplicación del presente Convenio será solucionada en la ciudad de Huaraz en forma armoniosa por los representantes que designen cada uno de las partes, y en caso contrario se sujetará a lo dispuesto en el Código Civil y demás normas aplicables.

Any dispute concerning the interpretation and application of this MOU shall be settled in the city of Huaraz in a harmonious way by the representatives designated by each of the parties, and otherwise be subject to the provisions of the Civil Code and other applicable rules.

CLAUSULA NUEVE: EJECUCIÓN
Ninth Clause: Execution

Los que abajo subscriben representando a la Comunidad Campesina de Huasta representado por su presidente y a los Ingenieros sin fronteras de la sede de Austin-USA acuerdan respetar las condiciones descritas arriba.

On behalf of, and acting with the Campesina Community of Huasta represented by its president and the Greater Austin Chapter of EWB-USA the under-signed agree to abide by the above conditions.

Ingenieros Sin Fronteras- Greater Austin
CAMBIAR Engineers Without Borders- Greater Austin

Document 523
ALTERNATIVES ANALYSIS REPORT

CHAPTER: Greater Austin
COUNTRY: Peru
COMMUNITY: Huasta
PROJECT: Agriculture (Irrigation)

PREPARED BY

April 14, 2013

ENGINEERS WITHOUT BORDERS-USA
www.ewb-usa.org

Alternatives Analysis Report Part 1 – Administrative Information

1.0 Contact Information

Project Title	Name	Email	Phone	Chapter Name or Organization Name
Project Leads				Greater Austin
				Greater Austin
				Greater Austin
President (student)				Greater Austin
President (professional)				Greater Austin
Mentor #1				Greater Austin
Mentor #2				Texas A&M
Faculty Advisor (if applicable)				
Health and Safety Officer				Greater Austin
Assistant Health and Safety Officer				
Education Lead				Greater Austin
				Greater Austin
NGO/Community Contact				The Mountain Institute (TMI)

2.0 Travel History

Dates of Travel	Assessment or Implementation	Description of Trip
8/2/2011 – 8/16/2011	Assessment	Commonwealth
1/1/2012 – 1/14/2012	Assessment	Huasta
7/12/2012 – 7/13/2012	Assessment	Huasta
12/30/2012 – 1/13/2013	Assessment	Huasta

3.0 Project Discipline(s): Check the specific project discipline(s) addressed in this report. Check all that apply.

Water Supply
____ Source Development
____ Water Storage
____ Water Distribution
____ Water Treatment
____ Water Pump

Sanitation
____ Latrine
____ Gray Water System
____ Black Water System

Structures
____ Bridge
____ Building

Civil Works
____ Roads
____ Drainage
____ Dams

Energy
____ Fuel
____ Electricity
Agriculture
____ Irrigation Pump
__X_ Irrigation Line
____ Water Storage
__X_ Soil Improvement
____ Fish Farm
____ Crop Processing Equipment

Information Systems
_X__ Computer Service

4.0 Project Location

Latitude: S 10.041267
Longitude: W 77.18789

Alternatives Analysis Report Part 2 – Technical Information

1.0 EXECUTIVE SUMMARY

The following alternatives analysis report prepared by the Climate Adaptation in Mountain Basins in the Andean Region (CAMBIAR) program within the Greater Austin Chapter of Engineers Without Borders is being submitted to EWB-USA to supplement the pre-implementation report (document number 525) for the first implementation trip within the second project in Huasta, Peru - Agriculture (Irrigation), project number 009122. This document provides the background and basis for the selection of a source and irrigation design given a set of possible alternatives.

The goal of this project is to pilot a conservation technology and system for irrigating pasturelands in the dry season. The main objective of the irrigation project in Huasta is to implement an improved irrigation system that will promote water conservation practices for small-scale agriculture within the region and the Tres Cuencas Commonwealth. The scope of the project includes the following: (1) develop spring source(s) to provide sufficient water for the irrigation of a community-owned pasture during the dry season; (2) design and install a conveyance system to move water from the spring(s) to the pasture; (3) install an improved, or more efficient irrigation system to water the pasture land; and (4) establish an operation, maintenance and monitoring program for the entire system from the source to the point of use.

This project will be carried out in Huasta, a district located in a tributary of the Pativilca River valley in Ancash, Peru. The population of Huasta is approximately 2,400 people, of which roughly 1,800 regularly participate within a community "land-owner" association known as the *Campesina Community of Huasta* herein referred to as the "Campesina Community". The Campesina Community collectively owns and manages land in Huasta and distributes the benefits of that land among the entire Campesina Community. They own the pasture "Coris" that is to receive the irrigation system through this project. In February 2013, CAMBIAR signed a Memorandum of Understanding detailing the expectations for both groups for the project, and specifically for July implementation. The CAMBIAR team will work through The Mountain Institute (local NGO partner), to coordinate travel logistics and support the project on the ground prior to implementation. The Mountain Institute specializes in community conservation projects, technical education, and capacity building, and has an on-going presence in Huasta primarily through a reforestation project and a medicinal plants project with members of the Campesina Community.

The CAMBIAR program started in August 2011 after one project member spent time in the Ancash region learning of the water and climate change challenges faced by rural communities, and being introduced to The Mountain Institute and the current needs of communities in the region. The CAMBIAR program currently has two open projects in Huasta: a WWTP technical education project and an improved irrigation system project. The team has traveled on four assessment trips related to these two projects and has spent significant time defining the Campesina community's goals and identifying a feasible project.

This document describes the alternatives analysis for two components of the improved irrigation project: (1) source development, and (2) irrigation system design selection. The alternatives for source development have been thoroughly explored on the previous three assessment trips, and include alternative spring sources that were located in the region, effluent from the WWTP, canals that pass near the field, and river sources. In the process for selecting the appropriate irrigation technology, the team researched methods used in the region for irrigating alfalfa and determined that flood irrigation and open channel watering, as is commonly practiced, do not meet the conservation goals of the CAMBIAR program. Other alternatives considered that do serve to improve efficiency are sprinklers of various designs and drip irrigation.

Methodology to evaluate alternatives for both components include assessing both the technical and social feasibility of the proposed plan. For source development, the team conducted two assessment trips (II and III) devoted to exploring potential irrigation sources, while assessment IV followed up on the identified potential sources to confirm their usability. On assessments II and III, the team met with the Campesina

Community board, mapped the region's water sources, and visited all nearby springs as well as canal and river sources, in addition to discussing with the municipality the idea of using WWTP effluent. Alternatives were evaluated and eliminated based on analyzing six months of spring flow data, conversations with the Campesina Community regarding property rights of the water from the various sources, and technological appropriateness (of bringing in large machinery or using a pump). The performance measures of the system are: to irrigate based on the crop's needs during the dry season, to design a system that is resistant to range animals grazing, and one that can be locally maintained and sustained within the means of the community. Alternatives were also evaluated based on their ability to increase conservation and efficiency (sustainability), material availability and cost, and cultural acceptance within the Campesina Community.

Following the four assessment trips, the source of irrigation for the community field was selected as a perennial spring source, Yanallpa, which can serve the water needs of the field using a gravity fed pipeline network. Water from the Yanallpa spring is not allocated to other uses, has adequate water quality for irrigation, meets minimum flow requirements, and is located a reasonable distance from the field. After discussing feasibility and performance measures of the field irrigation system with the community, the irrigation design analysis led to selection of a sprinkler system mounted on temporary metal risers with a corresponding irrigation schedule. The riser-sprinkler system is able to deliver the exact amount of water needed by the crop (promotes conservation), can be easily dismantled during periods of grazing, and has few maintenance parts – all are locally available within the Ancash region.

2.0 INTRODUCTION

The purpose of this document is to provide the background necessary to qualify our design decisions within the context of the CAMBIAR program and the proposed irrigation project in Huasta. The following tables outline the alternatives considered by CAMBIAR for source development (Table 1) and for the irrigation system design (Table 2) in Huasta.

Table 1. Source development alternatives

Source	Description	Conveyance
WWTP	Effluent from Huasta's WWTP located above the pasture	Pipe
Yanallpa	Spring source located above pasture	Pipe
Muichiquipuquio	Spring source located above pasture	Pipe
Pucapuquio	Spring source located above pasture	Pipe
Canal Abajo	Irrigation canal located below the pasture	Pump
Rio Aynin (Pativilca)	Main stem river that passes below Huasta	Pump or pipe

Table 2. Irrigation system design alternatives

Alternative	Description
Stationary Sprinkler	Permanent sprinkler structure installed in the field
Pop up Sprinkler	Temporary sprinkler that can be disabled and removed between irrigation periods
Rotating (movable) sprinkler	Permanent structure that rotates around field
Flood Irrigation	Inundation of irrigation area using canals or pipes
Drip Irrigation	Underground piping system that distributes water through small holes
Porous Pipes	Above ground piping system with evenly spaced holes for watering

3.0 PROGRAM BACKGROUND

Communities in the mountainous regions of Ancash, Peru, are highly susceptible to the effects of climate change due to their dependence on seasonal snowmelt from Andean glaciers and sensitivity to variations in seasonal rainfall patterns. In recent decades, these sources of fresh water have become less dependable, and many of the rural communities have experienced water shortages during the dry season. The impacts of these shortages have been felt most acutely by farmers and ranchers in the region who have noticed changes in crop yields and struggled to maintain adequate pasture land. Natural heavy metal contamination in several of the region's watersheds compound water availability issues for these communities. The contamination is so concentrated in some areas that stream water is unhealthy for livestock and irrigation use, contributing to the water shortage crisis for farmers and ranchers.

As a proactive response, several municipal districts have formed the Tres Cuencas Commonwealth (Commonwealth) for the purpose of mitigating water issues within the three watersheds (*cuencas*) that feed the region's rivers: the Santa, Fortaleza, and Pativilca. In establishing themselves as a nationally recognized entity, the Commonwealth has initiated steps at the local and national levels to address their water concerns. The Ministry of the Economy has approved the Commonwealth's foundational document, ensuring that the Commonwealth is eligible to apply for potential regional public funds, and have recently succeeded in winning two projects from the regional government for grassland and forest management. In general, the Commonwealth lacks the financial and technical resources to develop a solution strategy for their community-scale water issues. As such, the priority of the CAMBIAR program is to undertake this challenge and help communities in the Commonwealth adapt to climate change, specifically focusing on water-related challenges, through community driven collaboration and sustainable engineering design solutions.

CAMBIAR has established a partnership with The Mountain Institute[3] (TMI) to provide technical assistance to the Commonwealth and complete small-scale pilot projects that demonstrate successful solutions to their water needs. TMI has worked in Ancash for the last 15 years on USAID funded projects and currently manages a program working with two communities in the Commonwealth focusing on reforestation through education, ecological conservation, and sustainable development. CAMBIAR is leveraging TMI's knowledge of the region and existing relationships with members of the Commonwealth to effectively plan, implement and monitor pilot projects.
Over the duration of the program, it is expected that CAMBIAR will engage in the following:

- Provide technical assistance needed to help assess and prioritize regional needs
- Design solutions for water projects
- Implement small-scale pilot infrastructure
- Educate citizens on health, sanitation, and conservation.

These goals are oriented to equip Commonwealth residents with the knowledge, means, and tools necessary to build resilience to changes in their environment. During the August 2011 program assessment trip, CAMBIAR solidified the aforementioned goals through an umbrella MOU that outlines the responsibilities for each party involved (EWB Greater Austin, TMI and the Commonwealth). After careful consideration of selecting a first project, in the fall of 2011 CAMBIAR decided to focus its initial efforts on a water reuse project in Huasta. This project has evolved from reuse of WWTP effluent as an irrigation source into a pilot project to test the feasibility of more efficient irrigation technologies on small community fields.

4.0 PROJECT DESCRIPTION

[3] For more information about The Mountain Institute's projects in Peru see: http://www.mountain.org/andes

Huasta is a district and also a municipality comprised of about 600 families, 80% belonging to the Campesina Community (farmer's cooperative) that own and manage the land and its resources. The district of Huasta is located in the Pativilca river basin and is a member of the Tres Cuencas Commonwealth. The Campesina Community of Huasta expressed need to irrigate a pasture ("Coris") that currently lacks access to existing irrigation infrastructure due to both location and the Community's lack of resources to expand irrigation. In the past Coris has not been a priority to irrigate, however recently a shortened and more irregular rainy season has caused the Campesina Community to seek expansion of their pasture area for grazing year-round. This project fits well within the mission of CAMBIAR, to address climate change and water issues through adaptation and conservation.

The Huasta irrigation project was originally planned to use effluent from the town's wastewater treatment plant (WWTP) for irrigating the Coris pasture. After testing the water quality on the influent and effluent and conversing with the municipal authorities, it was clear that the WWTP has not been maintained since it was built in 2006 and is not functioning properly. The third assessment trip in July 2013 was focused on determining the feasibility of continuing to develop the WWTP effluent as the primary source for the project. With the help of Kelly Latham from the National office, CAMBIAR conducted a complete analysis of the technical and social challenges involved with developing the WWTP effluent. After consideration of the risks and responsibilities that accompany the renovation and operation/maintenance of the WWTP, CAMBIAR decided to pursue an alternate irrigation source for Coris. CAMBIAR worked with the municipal engineer to draft a formal list of technical recommendations for rehabilitating the WWTP as well as developed a training program for operations and maintenance workers, both reviewed by the EWB-USA Mountain Technical Advisory Committee (TAC) in May 2012 and presented to the municipality in January 2013. CAMBIAR also intends to train workers paid by the Municipality to perform water quality tests on the WWTP effluent so that they can continually monitor the functionality of the plant. The role of CAMBIAR at this point is to ensure the sustainability of the WWTP through education of paid workers and dedicated community members.

The team has since been exploring alternative sources for irrigating Coris, focusing on testing water quality and flow from local springs. After monitoring flow and water quality for six months, as well as surveying potential paths for conveyance and continuing talks with the Campesina Community, a spring source was identified on the January 2013 assessment trip. At this time, the team also completed a detailed survey of the pipeline path from the selected spring, Yanallpa, and measured "wet season" flow. Dr. Guy Fipps, the project's technical mentor, joined the group to assess the irrigation system design options and provide suggestions for materials and scheduling based on the crop (alfalfa) and the soil type of the field. The team and Campesina Community have outlined the implementation schedule and defined expectations as drafted in the MOU for a July 2013 implementation.

CAMBIAR is submitting a 525 for design of the conveyance system and irrigation design. Activities planned for the implementation consist of: community organization and preparation for construction work, construction of source protection and the field irrigation system, technical maintenance education, a sprinkler operation schedule, and education and technical training for the WWTP system.

5.0 DESCRIPTION OF COMPARISON METHODOLOGY

5.1 Source water selection method

Criteria for assessing the alternative water source options for the irrigation project are summarized in Table 3.

Table 3. Performance measures for spring source alternatives

	Criteria
1.	Reliability of quality
2.	Reliability of quantity

3.	Ability to meet flow needs for irrigation
4.	Accessibility of system for maintenance
5.	Operation and maintenance capability (parts availability)
6.	Operation and maintenance capability (cost)
7.	Operation and maintenance capability (education)
8.	Property rights
9.	Cost of construction
10.	Social (community) acceptability

Each source was evaluated by ranking the criteria from 1 (low) to 5 (high), or N/A where information was not available. The scores were totaled and compared to make the final decision on selecting a spring source. All criteria were weighted the same, as each element contributes to project success and weighting the criteria would introduce a bias. Quantitative data were used for criteria when appropriate (1-3, 6, 9, 10), and for criteria 4, 5, 7, 8 and 10, sources were evaluated based on previous conversations with the Campesina Community and knowledge of common practices in the region. Appendix II provides a complete tabulation of the individual scores.

5.2 Irrigation design evaluation method

Table 4. Performance measures for irrigation design alternatives

Criteria
1. Reliability of product (& warranty if applicable)
2. Resistant to problems with animal grazing
3. Degree of appropriateness for alfalfa
4. Operation and maintenance capability (parts availability)
5. Operation and maintenance capability (cost)
6. Operation and maintenance capability (education)
7. Degree of conservation achieved
8. Cost of construction
9. Social acceptability

Each source was evaluated by ranking the criteria listed in Table 4 from 1 (low) to 5 (high), or N/A where information was not available. The scores were totaled and compared to make the final decision on determining the most optimal irrigation design for the Huasta Community and the technical specifications. All criteria were weighted the same, as each element contributes to project success and weighting the criteria would introduce a bias. Quantitative data were used for criteria when appropriate (1, 5, 7, 8), and for criteria 2-4, 6, and 9, sources were evaluated based on technical expertise of Dr. Fipps on the technical capacity of the products, and on conversations with the Campesina Community regarding knowledge of common practices in the region. Appendix III provides a complete tabulation of the individual scores.

6.0 DESCRIPTION OF ALTERNATIVES

6.1 Source water alternatives

The sources described in Table 1 are further described in this section to provide the context for the team’s selection. Two maps are presented as a reference for scale and feasibility (Figures 1-2). A summary of the average flows from the spring source alternatives and the WWTP are shown in Figure 3.

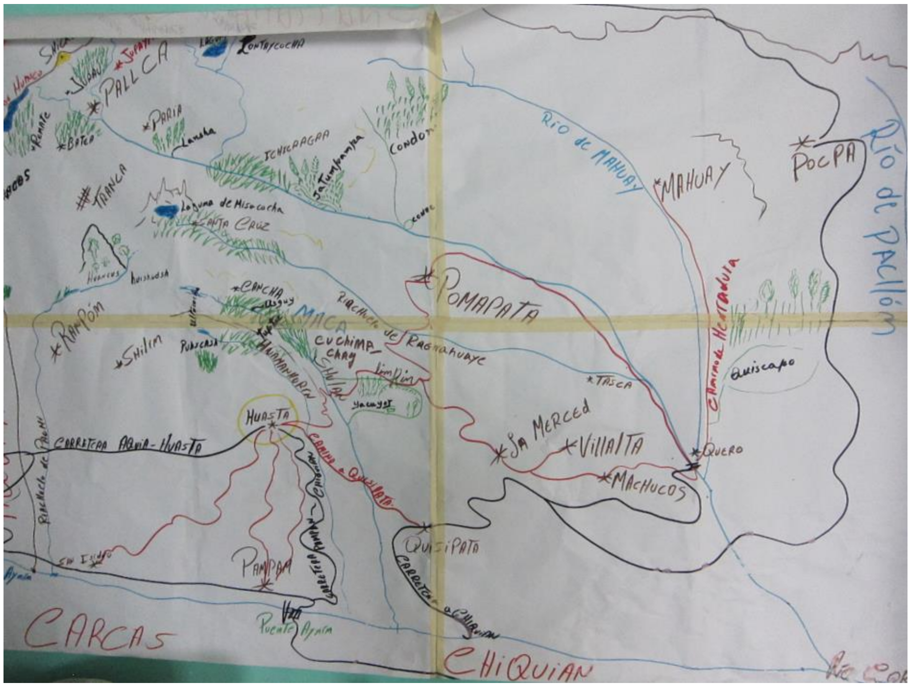


Figure 1. Community drawn map of water sources and landmarks

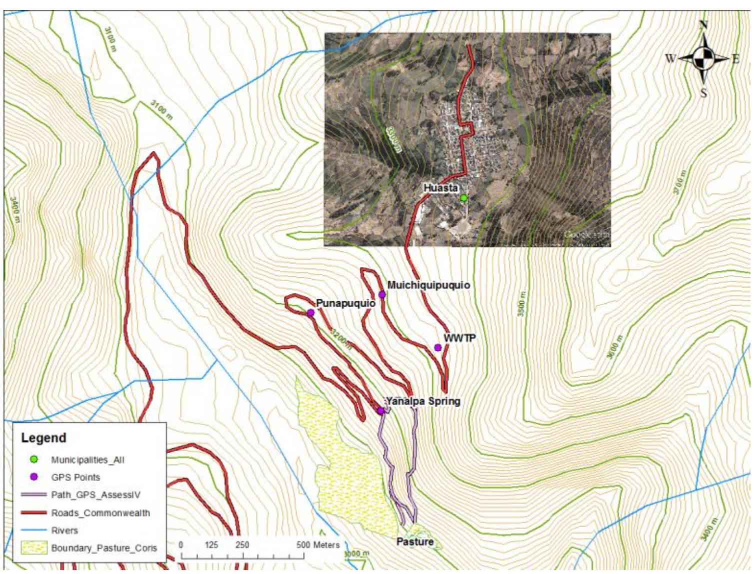


Figure 2. Topographic view of spring sources and WWTP relative to pasture

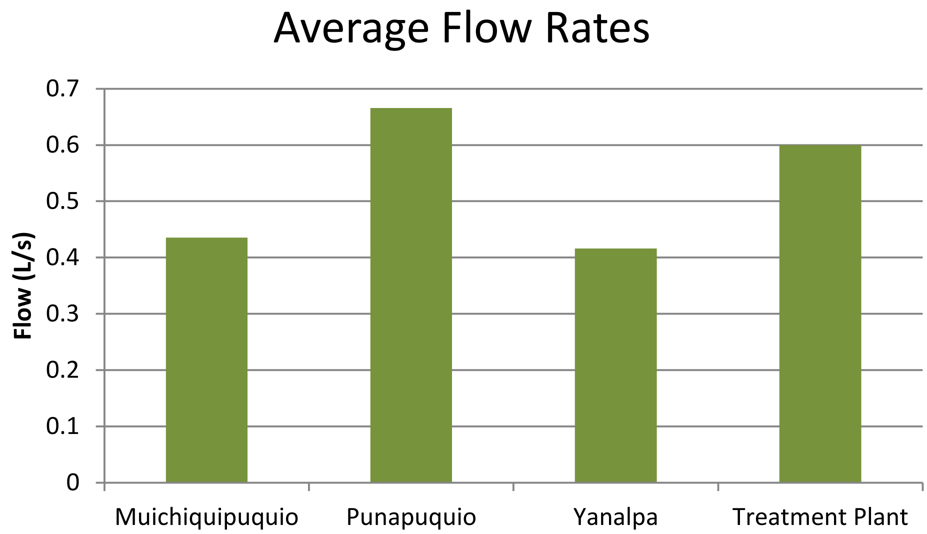


Figure 3. Average measured flow rates from potential source alternatives

6.1.1 WWTP

Description - The general state of the plant is non-functional but the structural state is very sound. The plant is currently being used incorrectly, allowing the sludge to constantly being flushed out into the collection basin and the flow completely bypassing the slow sand filter. Using the effluent for irrigation is not an option unless significant improvements are made to the plant, and it is maintained regularly and correctly.

Advantages – The flow from the WWTP is constant year round as measured over a six month period, and periodically in the wet and dry season. On testing, the water quality meets the minimum requirements for non-consumable irrigation.

Disadvantages- The collection basin and sedimentation tanks need to be flushed. The slow sand filter consists of only one media, gravel (no sand), and is full of weeds, and is currently bypassed due to a broken gate. The greatest obstacle to using WWTP effluent is the unreliability of the quality of water due to a lack of consistent maintenance by the municipal workers (See Appendix I, Table 1 for a summary of effluent quality). This is a serious concern for the long term sustainability of the Coris irrigation project, as the responsibility of the WWTP lies with the municipality, CAMBIAR cannot ensure that the O&M is of sufficient quality in the future.

6.1.2 Pumping water from the irrigation canal

Description - The irrigation canal that runs directly below the pasture is a viable alternative because of its proximity to the field, however, there are problems with the water rights for the canal. The community shares the canal with several other communities, and they only have access to the canal for six days out of the dry season.

CAMBIAR proposed building a reservoir to store the water during the days that they have access to the water in the canal so that the water can be distributed more efficiently throughout the dry season, but the community anticipates that would cause conflict with downstream users of the canal. A drip irrigation project from a nearby avocado farm project currently takes water from the canal at night during the community's access period and stores it in a reservoir for later use. This has already caused conflict with a community downstream because they believe Huasta is taking more than its share of water, and the Community of Huasta does not wish to incite further conflict. Clearly there is a need for education on water use—there is a lack of understanding that building a reservoir is not using more water but storing it and using it more efficiently—but because it involves another community, this is beyond the scope of our project.

Advantages – Proximity to Coris and knowledge of how to operate and maintain an irrigation canal are the two advantages to this system.

Disadvantages – Social acceptability and operation and maintenance are the two major concerns for pursuing this as a source. As described, the community expects conflict with using the irrigation canal and expressed interest in pursuing other options. Pumping water from the canal would require the use of a small pump to reach the upper parts of Coris, a feasible option, but one that complicates the technology and maintenance further than a simple system.

6.1.3 Pumping water from the River Aynín (Pativilca)

Description - The River Aynín runs directly below the community pasture, and the elevation drop from the field to the river is approximately 100 m.

Advantages – The river (theoretically) contains enough water to sufficiently irrigate Coris, but the Campesina Community is not certain as to how much water they may be allocated. Diverting flow from the river in a canal system is a familiar and socially accepted process to the Campesina Community.

Disadvantages - An elevation change of 100 m would require significant pumping power, and we believe that the design would be beyond the capabilities of CAMBIAR. In addition, the River Aynín is prone to flooding during the rainy season, so the infrastructure for the uptake of water from the river would need to be sturdy enough to withstand floodwaters, presenting a significant design challenge. Water rights to this source are also an issue, as downstream communities use the water for agriculture in an unknown capacity.

6.1.4 Piping water from the River Aynín (Pativilca)

The River Aynín is a substantial water source, and the flow is not significantly diminished in the dry season. The irrigation canal that the community uses for the other community-owned fields originates from the River Aynín, so we investigated what would be required to pipe water directly from the river following a similar path as the canal. The distance from the upstream point of the river to the field to be irrigated is substantial (approximately 5 km).

Advantages - Given resolution of property rights issues, this source would provide reliable quantity of water for irrigation. Although unknown, the community has commented that the quality is acceptable, and this could be confirmed upon testing.

Disadvantages - The prohibitive factor to piping water from the Rio Aynin is the canal's path line and distance. Parts of the path are rocky, which would prevent burying the pipe, and the canal passes below the town of Pampan for a significant distance. In this section, the canal passes underground and is covered with concrete. Because houses and other structures have been built on top of the canal, further access to the canal at that point is impossible. It would also be impossible to lay the pipeline around the town because all of the nearby land is privately owned and the community cannot get the rights to pass the pipeline through privately owned land. Any significant circumvention of the town of Pampan would involve scaling an elevation significantly higher than the point of uptake from the river, which would not be feasible with a gravity-fed system.

6.1.5 Spring sources

Description - The Campesina Community has three major springs in the area below the town which are used primarily by ranchers passing their animals through the fields. over the past year, CAMBIAR has collected flow and quality data from each spring to assess the feasibility of using these as irrigation sources. The president of the Campesina Community presented the springs to the monthly Assembly meetings in both January 2012 and July 2012 for approval to develop as part of this project, and no objections were recorded. A map of the springs is shown in Figure 2.

6.1.5.1 Muchiquipuquio

Advantages - The water from Muchiquipuquio is available for development as long as the animal drinking holes are left unaffected. Quality as measured in July 2012 is acceptable in terms of bacteria, nitrates, phosphates and physical parameters (See Appendix I, Table 2 for a summary of quality measurements).

Disadvantages - In the wet season months (as observed in January 2013), there is no measurable flow from Muchiquipuquio, suggesting that the outlet is a secondary spring from an irrigated area above. Though the flow timing lines up well with the irrigation needs of Coris, the reliability is questionable since the primary source is unknown. This causes a long term sustainability issue for using this spring.

6.1.5.2 Pucapuquio

Advantages - This spring has the greatest flow volume compared with the other available springs. It also has minimal bacteria and trace nitrates and phosphate levels that are well below the FAO's recommended maxima.

Disadvantages - The spring only flows in the dry season indicating that it is likely coming from a seasonal source upstream of the outlet. While the timing of the flow lines up well with the watering needs of Coris, the seasonal unreliability and unknown main source is a risk for selecting this spring. See Appendix I, Table 3 for a summary of quality from Pucapuquio.

6.1.5.3 Yanallpa

Advantages - The Yanallpa spring has consistent flow in the wet and dry season and meets the requirements of the FAO for irrigating non-consumable crops. The spring's location is also relatively close and can be piped to the Coris field without a road crossing. The community has approved this spring for the project, as the outlet is on the former president's land and he does not use the flow.

Disadvantages - The flow from Yanallpa is less than the ideal amount for irrigating the 0.66 hectares in Coris. The water contains a slightly higher concentration of nitrates and bacteria compared with the other available springs (See Appendix I, Table 4 for a summary of quality).

6.2 Irrigation system design alternatives

6.2.1 Sprinklers

Both stationary and movable sprinklers are potential alternatives suitable for irrigating the field. The advantages of using a sprinkler system are that water would be evenly distributed and simulate actual rainfall. The sprinklers allow water to cover a certain radius ("of throw") around the sprinkler head ranging from 10 to 60 meters in radius. There are many different kinds of sprinklers that could be utilized, including overhead sprinklers and pop-up sprinklers in addition to the movable (rotating) spray irrigation utilized by farmers across the United States. Sprinklers also offer an opportunity to conserve water as compared with the region's widespread use of flood irrigation for grasses like alfalfa. The major disadvantage of using sprinklers is that they apply a spray of water to the top of the crop, letting water trickle down to the roots, meaning that runoff and evaporation will affect the efficiency of the system, especially on an incline.

Figure 4. Typical irrigation sprinkler

Figure 5. Stationary impact sprinkler head

In the case of stationary sprinklers, the impact sprinkler (shown above in Figure 5) simulates rainfall and has a largeradius of throw range. For these reasons, multiple impact sprinklers are a feasible option for irrigating the 0.64 hectares at Coris. The disadvantage of using impact sprinklers and other above-ground sprinklers is that the sprinklers could possibly be damaged by the cattle that would be grazing on the alfalfa. This potential negative impact can be eliminated by using detachable risers to remove the sprinklers for grazing periods.

Pop-up sprinklers are also an option, as these sprinklers would be buried underground with the piping. However, the buried sprinkler are still susceptible to damage from the hooves of cows and donkeys, especially if they are plastic. A typical pop-up sprinkler head system can be seen in Figure 6.

Figure 6. Pop-up sprinkler head

A potential arrangement of sprinklers can be seen in the below Figure 7:

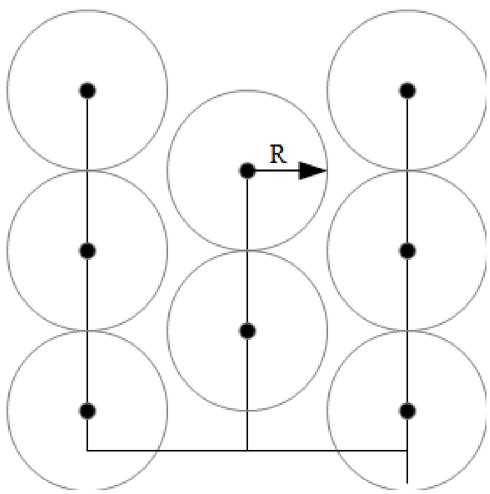


Figure 7. Sprinkler arrangement, showing underground piping for each sprinkler

Another option for sprinkler irrigation is to utilize modern farming methods of rotating sprinklers on wheels. This would require a separate machine to be built, powered, and maintained, and is therefore outside the scope of this project. These types of sprinkler systems are meant to cover a wide flat area, also not applicable for this project. A typical movable (or rotating) sprinkler system can be seen below in Figure 8.


Figure 8. Typical moveable or rotating sprinkler

6.2.2 Flood Irrigation

Flood irrigation is the most obvious form of irrigation and is what the community utilizes currently as the only method of watering in Huasta. The advantages of flood irrigation are that it is easy to operate, minimal technology is necessary, and the community is very familiar with the operation and maintenance of the canal system. The major disadvantage of flood irrigation is that much of the water is completely wasted due to runoff, evaporation, and oversaturation of the field. Other disadvantages include soil damage, lack of conservation, and the cost of constructing a new canal. Specific to Coris, which is on an incline, the soil damage and runoff losses are enhanced. In addition, the community has not identified a source for which to provide a canal/flood irrigation water source, as the selected spring (Yanallpa) would not provide enough flow to flood irrigate without storage. A typical flood irrigation setup can be seen in Figure 9 below.


Figure 9. Typical flood irrigation results

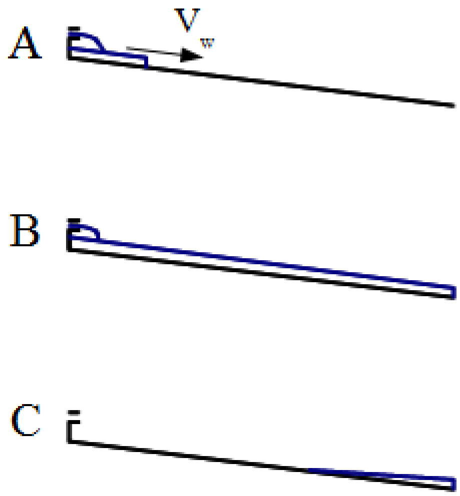


Figure 10. Typical flood irrigation process

Shown in Figure 10 above, the flood irrigation process starts by water flowing across the field at an initial velocity Vw, flooding the entire field. Then, the field is drained. The problem with flood irrigation on an inclined field is that the soil will not become saturated while the field is flooded and instead only the bottom portion of the field will be covered in water for the sufficient time required by the crop.

6.2.3 Drip Irrigation

In drip irrigation systems water flows through a main pipe into smaller distribution lines with special emitters in the sides of the pipes. These emitters let water flow directly to the root of the plants. The main advantage of drip irrigation is that it is very efficient, letting water seep directly to the plant’s roots delivering the exact amount of water needed with minimal exposure to evaporative losses. The system can be valve controlled to prevent oversaturation. The major disadvantages of this system are that it is fragile and prone to failures, including clogs in emitters, pipe breakages or seepages, valve problems, and a high cost of replacement (maintenance). Particular to Coris, selecting drip irrigation is relatively high risk in terms of fragility and effectiveness. Fragility is a major concern due to the frequency of large animal grazing; and drip irrigation systems are not as common with grasses like alfalfa because they do not line up the root of the grass with the emitter like with larger rooted crops. Drip irrigation is also less effective on uneven slopes, as a portion of the water is wasted as runoff. A typical drip irrigation setup can be seen below in Figures 11-12.

Figure 11. Typical drip irrigation

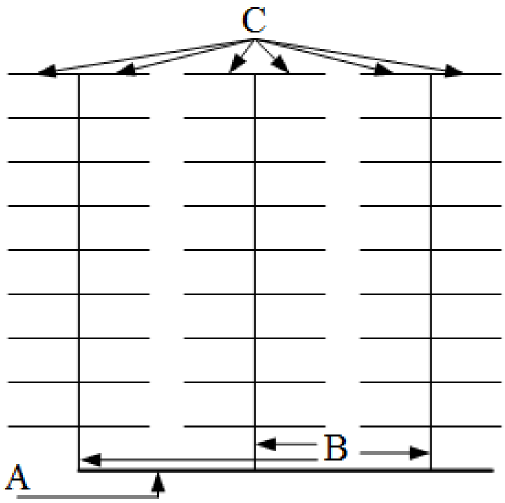


Figure 12. Planned drip irrigation setup

6.2.4 Porous Pipes

Another possible option is to have a series of pipes laid above ground that run the length of the field with holes cut in the side at regular intervals. This would allow the water to leak out of the higher-pressure pipe into the lower-pressure atmosphere. This system is very similar to drip irrigation in terms of setup and its conservation advantages, but less complicated as less maintenance would be necessary. However, more tuning must be necessary for this to be used on uneven slopes. Porous pipe irrigation is also less efficient than drip irrigation as more water is lost due to runoff and evaporation. For Coris, laying an above ground flexible pipe with holes is high risk due to animal grazing, and again this system is usually implemented with larger root crops than for a grass pasture. A typical porous pipe irrigation setup can be seen below in Figure 13, and a possible setup of a porous pipe irrigation system can be seen in Figure 14.

Figure 13. Typical porous pipe irrigation setup

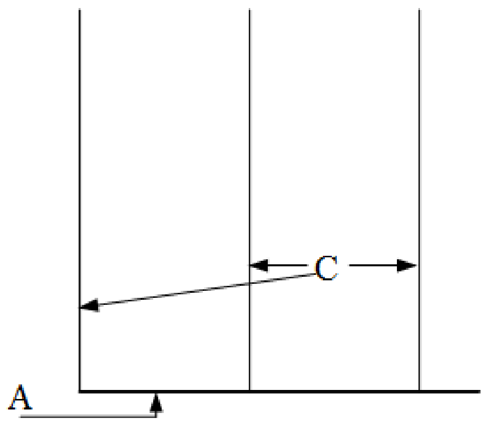


Figure 14. Typical porous pipe irrigation system, showing the main line (A) and secondary lines (C)

7.0 ANALYSIS OF ALTERNATIVES

Appendix II provides detailed scoring of each alternative under the given criteria. The results for the spring source selection are shown in Figure 15, where both Yanallpa and Pucapuquio springs have the highest scores of 3.4 and the two rivers have the lowest scores. Both springs scored high on operation and maintenance capabilities, construction cost, and social acceptability. The rivers scored low on the property rights, parts availability, and accessibility (with quality and quantity both unknown). The canal ranked low for community acceptability and property rights, and high for knowledge of the system and maintenance capability. The WWTP scored high on quantity and community acceptability, but low on operation and maintenance costs and education, and reliability of quality.

The irrigation design methodology suggests stationary sprinklers are the optimal decision with a score of 3.6, and flood irrigation is the second choice with 3.5. See Figure 16 for a summary of the scores and Appendix III for a detailed scoring of each irrigation design alternative. Drip irrigation and porous pipes score the lowest among the alternatives. The stationary sprinklers scored high on product reliability, appropriateness for alfalfa, operation and maintenance and cost, and low on resistance to animal grazing. Flood irrigation scored high on social acceptability, and operation and maintenance parts availability and education, and low on conservation. The rotating and pop-up sprinklers scored mid-range based on their ability to meet the crop needs, but lower scores in the areas of operation and maintenance due to cost and community unfamiliarity (rotating), and reliability of product (pop-up). The drip and porous pipe systems scored low based on cost of construction, maintenance, and expected social acceptability.

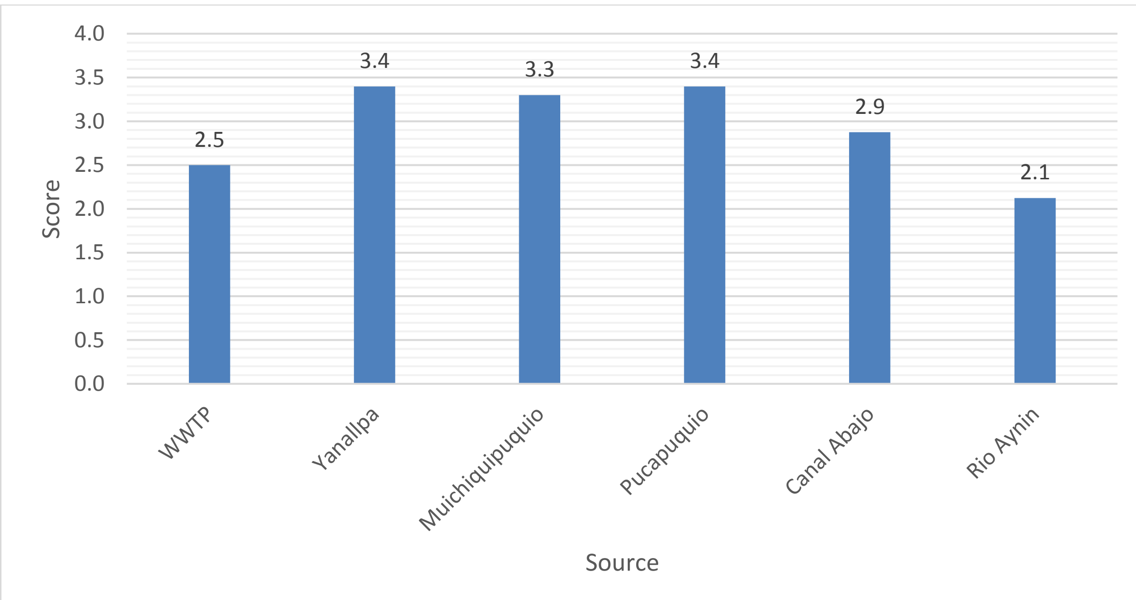


Figure 15. Scoring results of spring source alternatives

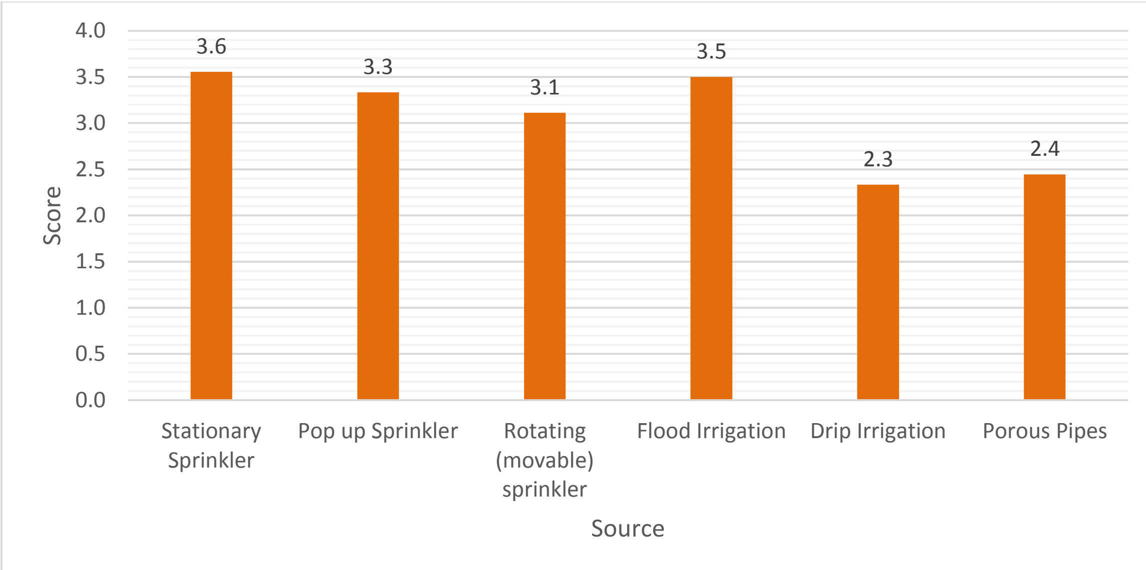


Figure 16. Scoring results of irrigation design alternatives

8.0 DESCRIPTION OF PREFFERED ALTERNATIVE

8.1 Spring source selection

Based on the results presented in section 7.0 and in combination with the Campesina Community's stated preferences, the team will construct a combined system using Yanallpa and Pucapuquio to supply the system. The strength of Pucapuquio's flow will offset Yanallpa's lower flow, while Yanallpa's perennial reliability will supplement the seasonality of Pucapuquio's flow.

The Campesina Community took part in this decision by helping the team eliminate alternatives throughout the process. During meetings with the Board of Directors, issues of property rights, distances, and social acceptability were raised for each proposed source, and eventually, the springs clearly became the best options. After Yanallpa and Pucapuquio were identified, the President presented the selection to the monthly Assembly meeting, where all community members attend and vote/discuss collective decisions, and it was approved.

8.2 Irrigation system design selection

The irrigation system analysis provided in section 7.0 selects a stationary sprinklers as the technology for the design. Based on these results and expertise from the team's technical mentors, the team will implement stationary sprinklers with metal risers. This alleviates the issue of resistance to animal grazing as the sprinklers will be removed from the field prior to grazing. The Campesina Community has experience with sprinklers on risers and will therefore be familiar with these components for operations and maintenance. The Campesina Community was also directly involved in the process for determining the irrigation design of the system. The CAMBIAR team asked the President to identify performance measures for the system and based the decision on how each alternative met these criteria.

9.0 PROFESSIONAL MENTOR/TECHNICAL LEAD ASSESSMENT

CAMBIAR has benefited from the expertise of three professional mentors for the duration of the Huasta irrigation project who have each contributed in aiding the team to select an appropriate system for design. In selecting a spring source, CAMBIAR was fortunate to have travel in July 2013 to evaluate the technical and social feasibility of developing the WWTP effluent as a source for the irrigation project.

The result of this assessment was a list of technical recommendations for the plant, and the decision to pursue alternative sources for the community. the current co-president for the EWB-Greater Austin chapter, traveled with the team in January 2013 to assess the source protection and distribution system, for which he has past experience constructing and supervising. Tim was accompanied by Dr. research professor in agricultural engineering at Texas A&M University, who joined the project as a technical mentor for the irrigation system design. has extensive experience in developing country agriculture systems and was able to help guide the team on the appropriate technology given the location, crop type, soil, and community's performance criteria. Working jointly these three professionals have aided in the decisions to pursue appropriate alternatives and eliminate infeasible ones.

9.1 Professional Mentor/Technical Lead Name (who wrote the assessment)

9.2 Professional Mentor/Technical Lead Assessment

The project leads and subgroup leads prepared the various sections of this design and project plan document. Information was gathered from previous assessment reports, firsthand experience from traveling to Peru, as well as from discussions during the weekly Peru Project meetings. These weekly meetings have been a forum to discuss and develop the design and project plan for this upcoming implementation trip. Subgroups were formed for hydraulics, spring box, irrigation, and education with all members of the Peru team contributing to the preliminary design and project plan. The goal of the implementation trip this summer is to construct the irrigation system discussed during numerous meetings with the Campesina Comunidad. Our chapter and the Campesina Comunidad have agreed upon the general form of the irrigation system and with using the springs Yanallpa and Pucapuquio as the irrigation sources. The final details of the irrigation system have been designed over the last three months. Throughout this process, we have been extremely fortunate to have the input of from Texas A&M University. traveled to the project site in January and the project leads have consulted with him as the design has evolved. His extensive experience and expertise in irrigation have been invaluable to the project. I personally have participated in this project for over a year, have been directly involved in the development of this design and project plan, and will continue my involvement up to and throughout this upcoming implementation trip.

9.3 Professional Mentor/Technical Lead Affirmation

I was actively involved in the preparation of this alternatives report, will continue my involvement, and accept responsibility for the course that this project is taking.

Appendix I: Source Water Quality Summary

Table 1. WWTP Effluent Quality

Constituent	Average
Ammonia (ppm)	3.33
Phosphate (ppm)	29.5
Nitrite (ppm)	0
Nitrate (ppm)	0
Total Chlorine (ppm)	0
Free Chlorine (ppm)	0
Total Hardness (ppm)	237
Total Alkalinity (ppm)	147
pH	7.01
Conductivity (µs/cm)	307
TDS (mg/L)	477
Turbidity (NTU)	179
DO (mg/L)	2.55

Table 2. Muchiquipuquio quality

Constituent	Average
Nitrate	0.5
Nitrite (ppm)	0
Alkalinity	40
pH	6.7
Bacteria- Coliform Count (red)	1
Bacteria- E Coli Count (blue)	0
Hardness (grains CaCo3/gal)	1.5/25

Table 3. Pucapuquio quality

Constituent	Average
Nitrate	0
Nitrite (ppm)	0
Alkalinity	40
pH	6.8
Bacteria- Coliform Count (red)	2
Bacteria- E Coli Count (blue)	0
Hardness (grains CaCo3/gal)	7/120

Table 4. Yanallpa quality

Constituent	Average
Nitrate	10
Nitrite (ppm)	0

Alkalinity	40
pH	7
Bacteria- Coliform Count (red)	21
Bacteria- E Coli Count (blue)	1
Hardness (grains CaCo3/gal)	7/120

Appendix II: Raw ranking scores for spring source alternatives

WWTP Rankings

Criteria	Score
Reliability of quality	1
Reliability of quantity	5
Ability to meet flow needs for irrigation	3
Accessibility of system for maintenance	4
Operation and maintenance capability (parts)	2
Operation and maintenance capability (cost)	1
Operation and maintenance capability (education)	1
Property rights	4
Cost of construction	1
Social (community) acceptability	3
Total	**2.5**

Yanallpa

Criteria	Score
Reliability of quality	3
Reliability of quantity	4
Ability to meet flow needs for irrigation	3
Accessibility of system for maintenance	4
Operation and maintenance capability (parts)	3
Operation and maintenance capability (cost)	3
Operation and maintenance capability (education)	4
Property rights	3
Cost of construction	2
Social (community) acceptability	5
Total	**3.4**

Canal Abajo

Criteria	Score
Reliability of quality	Unknown
Reliability of quantity	Unknown
Ability to meet flow needs for irrigation	1
Accessibility of system for maintenance	4
Operation and maintenance capability (parts)	4
Operation and maintenance capability (cost)	4
Operation and maintenance capability (education)	5
Property rights	1
Cost of construction	3
Social (community) acceptability	1
Total	**2.9**

Muichipuquio

Criteria	Score
Reliability of quality	4
Reliability of quantity	2
Ability to meet flow needs for irrigation	3
Accessibility of system for maintenance	4
Operation and maintenance capability (parts)	3

Operation and maintenance capability (cost)	3
Operation and maintenance capability (education)	4
Property rights	3
Cost of construction	2
Social (community) acceptability	5
Total	**3.3**

Pucapuquio

Criteria	Score
Reliability of quality	4
Reliability of quantity	2
Ability to meet flow needs for irrigation	4
Accessibility of system for maintenance	4
Operation and maintenance capability (parts)	3
Operation and maintenance capability (cost)	3
Operation and maintenance capability (education)	4
Property rights	3
Cost of construction	2
Social (community) acceptability	5
Total	**3.4**

Rio Aynin

Criteria	Score
Reliability of quality	Unknown
Reliability of quantity	3
Ability to meet flow needs for irrigation	2
Accessibility of system for maintenance	2
Operation and maintenance capability (parts)	1
Operation and maintenance capability (cost)	2
Operation and maintenance capability (education)	2
Property rights	1
Cost of construction	4
Social (community) acceptability	Unknown
Total	**2.1**

Appendix III: Raw ranking scores for irrigation design alternatives

Stationary Sprinklers

Criteria	**Score**
Reliability of product (including warranty)	4
Resistant to problems with animal grazing	1
Degree of appropriateness for alfalfa	5
Operation and maintenance capability (parts)	4
Operation and maintenance capability (cost)	3
Operation and maintenance capability (education)	4
Degree of conservation achieved	4
Cost of construction	4
Social acceptability	3

Total	**3.6**

Rotating Sprinklers

Criteria	Score
Reliability of product (including warranty)	4
Resistant to problems with animal grazing	1
Degree of appropriateness for alfalfa	5
Operation and maintenance capability (parts)	3
Operation and maintenance capability (cost)	3
Operation and maintenance capability (education)	3
Degree of conservation achieved	4
Cost of construction	2
Social acceptability	3
Total	**3.1**

Popup Sprinklers

Criteria	Score
Reliability of product (including warranty)	3
Resistant to problems with animal grazing	3
Degree of appropriateness for alfalfa	4
Operation and maintenance capability (parts)	3
Operation and maintenance capability (cost)	3
Operation and maintenance capability (education)	4
Degree of conservation achieved	4
Cost of construction	3
Social acceptability	3
Total	**3.3**

Flood irrigation

Criteria	Score
Reliability of product (including warranty)	N/A
Resistant to problems with animal grazing	4
Degree of appropriateness for alfalfa	4
Operation and maintenance capability (parts)	5
Operation and maintenance capability (cost)	3
Operation and maintenance capability (education)	5
Degree of conservation achieved	1
Cost of construction	2
Social acceptability	4
Total	**3.5**

Drip Irrigation

Criteria	Score
Reliability of product (including warranty)	2
Resistant to problems with animal grazing	3
Degree of appropriateness for alfalfa	2
Operation and maintenance capability (parts)	3
Operation and maintenance capability (cost)	1
Operation and maintenance capability (education)	2
Degree of conservation achieved	5

Cost of construction	1
Social acceptability	2
Total	**2.3**

Porous Pipes

Criteria	Score
Reliability of product (including warranty)	2
Resistant to problems with animal grazing	2
Degree of appropriateness for alfalfa	3
Operation and maintenance capability (parts)	3
Operation and maintenance capability (cost)	1
Operation and maintenance capability (education)	2
Degree of conservation achieved	5
Cost of construction	2
Social acceptability	2
Total	**2.4**

Appendix N: In-Country Contacts

Principal Contacts

EWB-Greater Austin Cell Phone:

The Mountain Institute- Huaraz office:

Contacts in the Municipality of Huasta:

Contacts in the Campesina Community of Huasta:

The Mountain Institute (NGO partner) Contacts:

Hostels

Lima:

Huaraz:

Additional Contacts

Contacts in the Municipality of Huasta:

Contacts in the Campesina Community of Huasta:

TMI Contacts:

Mailing address

Contacts in Lima:

<u>Contacts in Canrey Chico:</u>

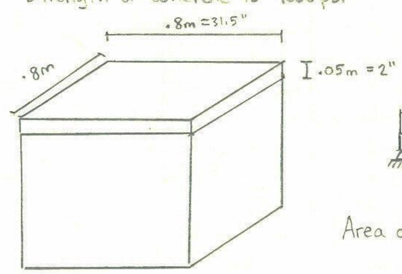
<u>Students for International Development</u>- group of Canadian university students working in Chiquian, Huasta, and other communities on health promotion and microfinance

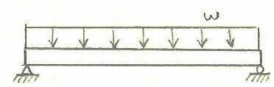
Appendix O: Spring Box Design Calculations

Spring Box Lid Stress Check.

Assumptions

- Critical load of lid occurs when only 2 opposite ends are bearing on the spring box walls
  - This loading scenario can be modeled as a simply supported beam
  - The only load acting on the lid is its self-weight
- Any steel reinforcement will not be considered to be conservative
- Density of concrete is 150 lb/ft³
- Strength of concrete is 4000 psi

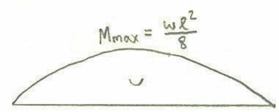




Area of X_{sc} = $63\,in^2$ $\quad 150\,lb/ft^3 = .0868\,lb/in^3$

$w = 63\,in^2 \times .0868\,lb/in^3 = 5.5\,lb/in$

Moment Diagram



$$M_{max} = \frac{w\ell^2}{8} = \frac{(5.5\,lb/in)(31.5")^2}{8} = 682.2\ lb\text{-}in$$

$I = \frac{1}{12}(31.5")(2")^3 = 21\ in^4$ Extreme Fiber Stress : $\sigma = \frac{My}{I}$

y = distance from centroid of section to outside edge = 1"

$$\sigma = \frac{682.2\ lb\text{-}in\ (1")}{21\,in^4} = 32.5\ psi$$ Extreme Fiber Stress in Tension

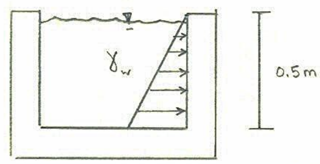
Tensile Strength of Concrete in Flexure $f_r = 7.5\sqrt{f'c} = 7.5\sqrt{4000\ psi}$

$f_r = 474\ psi$

Capacity		Load	
474 psi	>>	32.5 psi	Lid Strength Satisfactory

Spring Box Wall Stress Check

Assumptions
- Critical loading occurs at overflow of entire springbox (overflow pipe clogged)
- Wall response can be idealized as a cantilever beam
- Water load is hydrostatic pressure



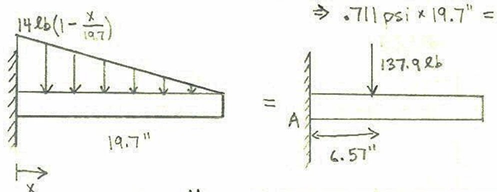
$\gamma_w = 62.4\ lb/ft^3$ $\quad 0.5m = 1.64' = h$

$P = \gamma_w \times h = 62.4\ lb/ft^3 \times 1.64' = 102.34\ lb/ft^2$

$102.34\ \frac{lb}{ft^2} \times \frac{1\ ft^2}{144\ in^2} = .711\ psi$

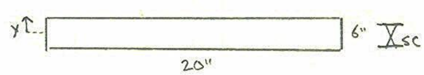
Width of wall (interior dimension) = 0.5m = 1.64' = 19.7"

$\Rightarrow .711\ psi \times 19.7" = \underline{14\ lb/in}$



$M_A = 137.9\ lb \times 6.57" = 905\ lb\text{-}in$

$\sigma = \frac{My}{I}$



$I = \frac{1}{12}(20")(6")^3 = 360\ in^4$ $\quad y = 3"$

$\sigma = \frac{(905\ lb\text{-}in)(3")}{360\ in^4} = \underline{7.54\ psi}$ Extreme Fiber Stress in Tension

Modulus of rupture ACI 318-02 $f_r = 7.5\sqrt{f'c}$

Assume low strength concrete $f'c = 4000\ psi$

$f_r = 7.5\sqrt{4000\ psi} = \underline{474\ psi}$ Flexural Strength of Section

Capacity		Load		
474 psi	>>	7.54 psi	✓	The strength of the wall is satisfactory

Appendix P: Mentor Resumes

- **Harvest Classic Motorcycle Rally** (Luckenbach, TX), 2003 - present
  Co-founder, Volunteer Coordinator

  Annual family-friendly European and vintage motorcycle rally to benefit Candlelighters Childhood Cancer Foundation, a human services program of Any Baby Can. Member of team that produces and runs all aspects of the event: registration, merchandise, sponsorships, silent auction, raffle, bike show, food and entertainment. Attracts over 2,500 attendees annually with proceeds of over $300,000 in nine years.

- **Habitat for Humanity** (Tosagua, Ecuador), 2006
  Volunteer

  Nonprofit dedicated to building simple, decent, and affordable houses for low-income families around the world. Intensive construction project including slab pouring, brick-laying, and concrete masonry.

- **MedAid: The U.S. Latin American Medical Aid Foundation** (Havana, Cuba), 2001
  Volunteer

  Traveled to Cuba (under license from the U.S. Department of the Treasury) with Texas-based humanitarian aid group. Hand-delivered donated medical supplies to clinics and hospitals. Toured healthcare facilities throughout Havana, meeting with doctors and nurses to assess future needs.

SKILLS

- **Software:**

  Unigraphics, Inventor, SolidWorks, HP Solid Designer, AutoCAD, Boothroyd-Dewhurst DFMA cost estimator, Microsoft Office Suite.

- **Engineering:**

  Design for manufacturability, geometric dimensioning and tolerancing (GD&T), engineering change orders, supplier problem sheets, workmanship standards, QA standards, cleanroom protocol.

- **Construction:**

  Slab prep: site leveling, digging footings, rebar placement, form construction. Slab pouring and finishing. Masonry: mixing mortar and laying up both CMU and rock veneer walls. Framing, roofing, electrical, plumbing, insulation, flooring, dry wall, painting.

- **Other:**

  Intermediate Spanish speaker, First Aid/CPR certification, travel experience to over 30 countries on 5 continents.

EDUCATION

- **M.S., Mechanical Engineering**, The University of Texas at Austin
  Emphasis in Mechanical Systems and Robotics with Mathematics Minor
- **B.S., Mechanical Engineering**, The University of Texas at Austin