DESIGN AND EVALUTATION OF A DRIP IRRIGATION SYSTEM ON APPLE ORCHARDS IN JULIAN, CA

by

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ABSTRACT

This senior project discusses the design and analysis of a drip irrigation design on an apple orchard in Julian, CA. The system will provide the necessary water to the field while achieving high irrigation uniformity and minimizing costs.

The design will be created as to ensure the ease of adding an additional block in the future. The future block is still undeveloped and slopes were assumed to remain constant and follow those of the original field.

The design will use all Netafim products including Netafim Uniram Heavy Wall drip hose. The ranch already has a submersible well pump and filtration system. A filtration system was still designed to meet proper filtration requirements in the future.

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INTRODUCTION

Background

Fawn Hill is a 120-acre, family-owned ranch located in Julian, CA, with currently only 3-acres containing apple orchards. The orchard has been irrigated strictly by rainfall causing a decrease in the population of apple trees in the orchard and apple yield per tree.

Fawn Hill has its own well with a pump and filtration system already installed. The orchard consists of a variety of apple trees including Macintosh, Golden Delicious, Red Delicious and Rome Beauty. The tree spacing is 24-ft between rows and 12-ft between trees.

The owners would like to install an irrigation system that will minimize operating cost and maximize yield. This will require the design of all components to work with their pre-existing pump and filtration system. The system must compensate for varying slopes of 4-8% in the field. All aspects of the field will be considered in order to ensure maximum tree yield and fruit quality while maintaining a high irrigation efficiency.

Figure 1. Fawn Hill Apple Orchard

Justification

With increasing water and energy costs, irrigating orchards has become more expensive and difficult. Through the use of drip irrigation, these costs can be decreased while also making better use of the available irrigation water.

Objectives

The objective of this project is to create a drip irrigation design that can be installed in the future and be able to adapt to a larger field size. The design submitted will maximize the distribution uniformity while maintaining a high irrigation efficiency. A complete cost analysis will be submitted with the design.

LITERATURE REVIEW

The design and use of a drip irrigation system on an existing apple orchard in a semi-Mediterranean environment will save water and increase productivity. For orchards with variable slopes and shapes, drip irrigation systems provide an alternative and more efficient means of irrigating. This search was conducted to explore the advantages of drip irrigating mature apple orchards and to determine the optimal field conditions to maximize fruit quantity and quality.

Crop Water Requirement

An ideal irrigation system will apply the necessary amount of water to maximize tree yield and fruit quality while maintaining a high irrigation efficiency (IE). Irrigation efficiency is a measure of how beneficially the applied irrigation water is being used and can be determined using equation (1) (Burt and Styles, 2011).

$$IE(\%) = \frac{\text{Irrigation Water Beneficially Used}}{\text{Irrigation Water Applied}} * 100 \qquad (1)$$

In order to determine how much water to apply, both the quantity of water required by each crop and the quantity of water lost to the environment must be taken into consideration. Evapotranspiration (ET) is a measure of how much of the applied water the crop is taking up its roots and transpiring through the stomata on its leaves as well as how much of the water is evaporating off the ground (Gong et al. 2007). The ET rates will change depending on the crop and its environment. ET rates can be determined through the use of a reference evapotranspiration (ETo) and a crop coefficient (Kc). Equation (2) shows this calculation (Gong et al. 2007).

$$ETc = ETo * Kc \qquad (2)$$

where,

ETc = crop evapotranspiration
ETo = reference evapotranspiration
Kc = crop coefficient

Reference ETo rates are based on updated weather conditions. With modern technology, weather stations are constantly gathering data and calculating the reference evapotranspiration rates. Both the California Irrigation Management Information System (CIMIS) and the Irrigation Training and Research Center (ITRC) at California Polytechnic State University in San Luis Obispo provide updated reference ETo rates. Irrigation systems are designed to handle the maximum amount of flow, which will be encountered when ETc rates are at their peak during hot and dry years (Burt and Styles, 2011). Table 1 on the following page from the Cal Poly ITRC shows evapotranspiration rates for a dry year (1999) in the San Diego County area (Zone 9) for apple trees with and without a cover crop, which will be considered when determining maximum flow the

system needs to provide. Crop coefficient (Kc) values can be calculated using the data provided and rearranging equation (2).

Table 1. 1999 Zone 9 Dry Year ETo, Apple tree ET and Kc.

		Jan. in.	Feb. in.	Mar. in.	Apr. in.	May in.	Jun. in.	Jul. in.	Aug. in.	Sep. in.	Oct. in.	Nov. in.	Dec. in.	Annual in.
	Precipitation	2.25	1.55	1.91	2.54	0.26	0.53	0	0	0	0	0	0	9.04
	Grass Reference ETo	2.3	2.49	2.9	3.6	4.69	5.61	6.83	6.85	4.81	5.07	2.83	3.2	51.19
Etc	Apple, Pear, Cherry, Plum and Prune	0.65	1.64	2.01	2.77	2.38	4.69	5.86	5.85	4.07	3.52	0	0	33.45
	Apples, Plums, Cherries etc w/covercrop	1.28	2.47	2.82	4.3	4.31	5.21	5.9	5.92	4.13	3.79	1.99	1.63	43.75
Kc	Apple, Pear, Cherry, Plum and Prune	0.28	0.66	0.69	0.77	0.51	0.84	0.86	0.85	0.85	0.69	0.00	0.00	0.65
	Apples, Plums, Cherries etc w/covercrop	0.56	0.99	0.97	1.19	0.92	0.93	0.86	0.86	0.86	0.75	0.70	0.51	0.85

In a study conducted by Girona et al. (2010) over a four-year period, mature apple orchards experienced varying crop coefficients due to changes in canopy size throughout the season. Girona et al. (2010) observed an initial low crop coefficient of 0.2 at bud break that continued to increase until harvest where the crop coefficient reached an average maximum of 0.8, which then dropped down to 0.4 at the end of the irrigation season after fruit harvest.

Systems

There are many options when choosing an irrigation system to water apple orchards. The choice is specific to the site of the orchard and the environment in which the orchard is located. Modern technology and irrigating methods have evolved from flood and sprinkler irrigation to drip and micro irrigation in order to more efficiently use irrigation water.

Although flood irrigating mature apple orchards is more common, a study done by Cetin et al. (2004) on 47 sample apple farms found that through the switch of flood to drip irrigation there would be large yield increases and water savings. Table 2 shows the yield increase through the switch from flood to drip irrigation of two different apple varieties over a ten-year period (Cetin et al. 2004).

Table 2. Effect of drip irrigation on annual yield in t/ha.

	Years	1	2	3	4	5	6	7	8	9	10	Average
Granny Smith												
Annual Yield [t/ha]	Surface Irrigation	17.405	15.516	16.910	15.317	17.508	15.712	17.780	15.646	16.845	15.705	16.4344
	Drip Irrigation	20.815	18.967	19.705	18.910	19.766	18.947	20.745	17.843	19.205	18.869	19.3772
	Yiled Increase	3.410	3.451	2.795	3.593	2.258	3.235	2.965	2.197	2.360	3.164	2.943
Golden Delicious												
Annual Yield [t/ha]	Surface Irrigation	12.490	13.560	12.740	12.935	13.145	12.675	13.400	11.905	12.780	13.080	12.871
	Drip Irrigation	15.950	16.700	14.818	15.040	16.125	15.106	16.700	13.945	14.760	15.217	15.436
	Yield Increase	3.460	3.140	2.078	2.105	2.980	2.431	3.300	2.040	1.980	2.137	2.565

Kücükyumuk et al. (2012) also found that through the use of drip irrigation, they could increase the quality and quantity of apples, while decreasing the amount of applied water and decreasing the evapotranspiration (ET) rate. During flood irrigation, the apple tree is stressed by less frequent irrigation events, resulting in more energy spent on water uptake and less energy spent on growth (Kücükyumuk et al. 2012). Drip irrigation allows for more frequent irrigation events keeping the soil moist, allowing the apple trees to expend more energy on growth and increase fruit yield and quality (Kücükyumuk et al. 2012). Quality is a measure of fruit diameter, length, weight, color, firmness and classification,

which all increased when switching from flood to drip irrigation (Kücükyumuk et al. 2012). The use of drip also allows for simplified chemical injection of pesticides saving up to 90% of the potential crop damage due to insects (Bone et al. 2009).

Field Layout

Not only will the environment affect the orchard, but so will the slope of the land, the tree spacing, and the soil texture and structure. The ideal slope of the field is 4%-8% to allow for the cold air to drain and prevent frost damage to the crop while anything above 8% will be too hard to operate machinery in (Berkette et al. 2007).

An 11-year study done by Robinson (1997) showed that yield per tree is negatively correlated to tree density. The study experimented with in-row spacing from 90cm to 3.66m (3-12ft), and between row spacing of 3m to 6m (10-20ft), creating densities from 449 trees/ha to 3,588 trees/ha (Robinson 1997). Robinson (1997) found that maximum yield could be attained through spacing with a density of 2,200 trees/ac.

Soil composition and structure can be determined through field tests or online resources. The National Resource Conservation Service (NRCS) can be used to obtain a soil survey for specific fields. The University of California at Davis also provides a web soil survey allowing the field to be selected through Google Earth, and providing the soil composition of that field.

Varying soils affect the root system of orchards, while having a well-developed root system is ideal for the growth of the orchard (Gegechkori et al. 2012). Research done by Gegechkori et al. (2012) found that medium loam soils provided for an optimal root system growth. Gegechkori et al. (2012) found that apple trees in heavier soils with more clay content did not have as well of a developed root system than trees in lighter loam soils with a higher sand content, which allows for better drainage.

Distribution Uniformity

Distribution uniformity (DU) is a measure of how evenly applied the irrigation water is to the plants (Burt and Styles, 2011). This is an important consideration while designing a system to ensure that each plant receives its required amount of water. This can be determined by equation (3) (Burt, 2004).

$$DUlq = \frac{\text{Average low quarter depth of water}}{\text{Average depth of water accumulated in all elements}} \qquad (3)$$

This equation determines the DU of the lowest quarter in the field based on the average of the lowest quarter of all values divided by the average depth of the water on the entire field (Burt, 2004). Capra and Scicolone (1998) found that through drip irrigation, a high DU could be achieved up to 0.96. A high distribution uniformity allows for all the trees to receive the water allocated to them.

Irrigation Scheduling

Scheduling irrigation events is specific to the environment, soil, and crop. Ideally, scheduling allows for the least amount of water applied without stressing the crop to the point where it would affect quality or quantity of the fruit produced. Plant water potential is a measure of how much energy the crop uses to uptake water and can be used to determine stress levels in the crop (Burt, 2009). Sokalska et al. (2009) found that in mature apple trees, keeping the soil water potential above -0.03MPa would result in water savings without crop loss. Irrigation events are also scheduled based on the manageable allowable depletion (MAD), which is the percent of available irrigation water the crop is allowed to deplete before the next irrigation event (Burt, 2009). Using a MAD of 50% for mature apple trees results in the highest productivity (Howell and Meron, 2007).

Irrigation intervals must be selected to maintain the stress levels and allowable depletion in the orchard. Furrow irrigating at 20-day intervals did not produce as great of a yield or quality of fruit as drip irrigated trees on four day and seven-day irrigation intervals (Kücükyumuk et al. 2012). Kücükyumuk et al. (2012) found that maximum fruit yield occurred with irrigation intervals of four days a week with drip.

Water Quality

Water quality is an essential part of irrigating crops. Molassiotis et al. found that apple trees exposed to high levels of salts suffered from decreased leaf water content, ultimately damaging the fruit. This high salinity also causes an accumulation of sodium, potassium and chlorine while decreasing the amount of calcium, magnesium, zinc and iron, which are essential for tree growth (Molassiotis et al. 2006). Salinity levels up to 3dS/m will not influence the production of mature apple trees, while levels above 3dS/m will begin to damage the crop (Marler and Zozor, 1996). During early stages of growth, apple trees are less tolerant to salinity, which can stunt plant growth (Grattan and Grieve, 1999). A study done by Grattan and Grieve (1999) found that using irrigation water with high amounts of nitrogen helps plant growth.

System Design

Systems are designed with multiple components to best accommodate specific fields and crops. Pressure compensating emitters are recommended for fields with varying slopes to ensure a high distribution uniformity (Burt and Styles, 2011). Larger emitter holes are a good choice to reduce the chances of plugging which is the single largest cause in drip irrigation uniformity deterioration (Burt and Styles, 2011). Plugging can also be reduced through filtration systems such as sand media filters and disk filters. Drip hose and pipe diameter for mainlines, sub mains, and manifolds are also considered along with their material type to ensure that the pump can overcome the friction losses and distribute water throughout the field (Burt and Styles, 2011).

Economics

Costs vary from system to system. The overall return from installing a drip irrigation system will outweigh the initial investment through water and energy savings. Cetin et al. (2004) found that through the installation of a drip irrigation system, the farm could save on all operating costs including water. The switch to drip irrigation also increased tree yield and fruit quality increasing profits (Cetin et al. 2004). After an initial investment of $1,415 per hectare for a drip irrigation system, Cetin et al. (2004) found average operating costs over a ten-year period to be $126 per hectare. Just as the initial investment and operating cost change from field to field, so does the time it takes to make back the initial investment depending on loans, interests rates and yield. Depending on the season, Cetin et al. (2004) had average earnings of $4,000 to $5,000 an acre.

PROCEDURES AND METHODS

Field Survey

The first step of this design was to survey the land in question and develop a topographic map. In order to do this, a Total Station and surveying rod were used collecting data points at every 20 feet. The Total Station was set up using the Southeast end of the field as a reference point while elevation changes were recorded. Using these data points a topographic map was developed and can be seen in Appendix D.

A soil survey was also conducted to determine the types of soils at different depths. This was done by gathering data in the field, and by using the Natural Resources Conservation Service (NRCS) website. For this design, the NRCS soil survey was used for better accuracy. Figure 2 shows data from the NRCS webpage. The soils on this orchard are Holland stony fine sandy loam with 30 – 60% slopes (NRCS).

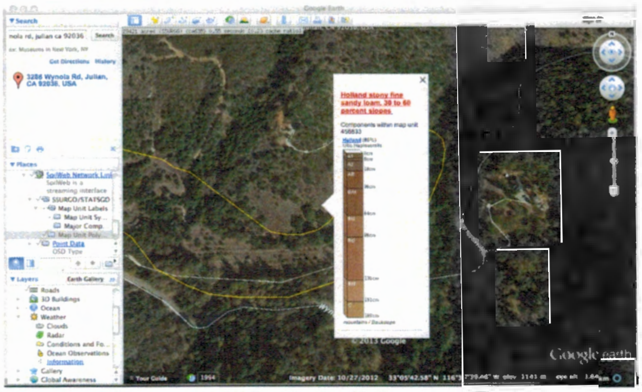

Figure 2. NRCS Soil Survey Data.

Tree Layout

Since this was an already existing apple orchard, the tree layout was set at 10 feet between trees and 15 feet between rows. To ensure the system would be able to adapt to a bigger field, the original field was set up as one block enclosed by roads. Figure 3 shows the original field and the future field.

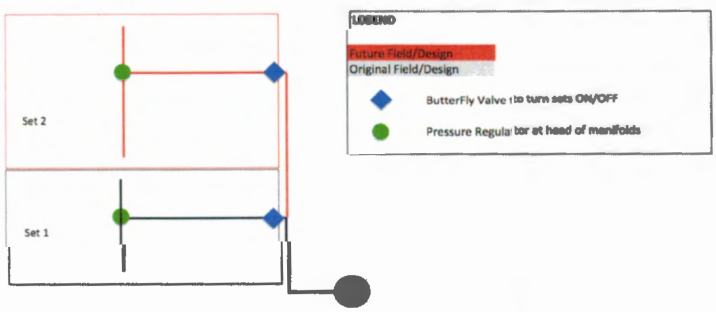

Figure 3. Design Schematic.

Irrigation System Design

Current Situation. The current apple orchard is not irrigated, and four different types of apple variety. The owners would like to minimize the amount of above ground piping. Fawn Hill currently has a smaller, submersible well pump that is pumps out 300 GPM. Figure 4 shows the current layout of the orchard.

Figure 4. Current Orchard Layout.

Distribution Uniformity. The system was designed to meet a set distribution uniformity (DU) requirement. Distribution uniformity (DU) is a measure of how evenly applied the irrigation water is to the plants (Burt and Styles, 2011). A DU of 0.93 was chosen as a target DU.

Wetted Area. Along with DU, the wetted area was also set at the start of the design. Burt and Styles (2011) recommend that a 60% wetted area should be used. This is to compensate for the lateral movement of water through the soil. For a fine sand, the lateral movement for drip will be 1.0-3.0 feet (Burt and Styles 2011). Step (3) in Appendix B shows this calculation.

Evapotranspiration Rates. Once the DU and wetted area are assigned values, the climate was evaluated. The climate and time of the year will have a large impact on the evapotranspiration (ET) rates, which is a major variable in designing an irrigation system. In order to ensure that the system will be able to handle the maximum flow rate, the ET rate for the peak month will be used. Cal Poly's ITRC publishes these values online. From Cal Poly's ITRC for Zone 9 in a dry year, the peak ET will be 5.86 inches in July dictating what the system will be designed to handle.

Flow Rate Requirements. Using the published ET values, the required pump flow rate can be solved for. The peak ET is broken down to inches required per day. The ET, tree spacing, and the hours of operation, are used to calculate the net flow rate. Refer to step (2) of appendix B. Due to pumping costs, the owners would only like to irrigate 20 hours of a day and avoid peak electricity costs which are between 12:00pm and 6:00pm. The system was designed to pump 20 hours a day, 5 days a week. Using the owners preference of Netafim Uniram heavy wall drip hose, a selection table was set up to determine the pressures with the use of different Netafim emitters. The ideal nozzle is

one that is not too small and subject to plugging, but one that is not too large to allow for pressures between 10 to 20 psi to be reached (Burt and Styles 2011). Table 3 shows published data from Netafim.

Table 3. Published engineering factors for Netafim Uniram (from Netafim).

UNIRAM - EMITTER ENGINEERING FACTORS NETAFIM™

ENGINEERING CONSTANT = K
FLOWS @ 10 psi

ENGINEERING EXPONENT = X
BARB LOSS COEFFICIENT = Kd (for different pipe IDs)

[illegible] / Series	Mil	Flow Designation	Flow @ 10 psi (GPH)	[illegible] Low Pressure [illegible]	K (7 psi and above)	X (7 psi and above)	[illegible] at Low Pressure [illegible]	K (Irricad)
All	All	1 LPH	0.26	0.09986	0.2642	0	0.50	1.0000
		1.2 LPH	0.32	0.11983	0.3170	0	0.50	1.2000
		1.6 LPH	0.42	0.15977	0.4227	0	0.50	1.6000
		2 LPH	0.53	0.19972	0.5284	0	0.50	2.0000
		2.3 LPH	0.61	0.22970	0.6077	0	0.50	2.3000
		3.5 LPH	0.92	0.34950	0.9247	0	0.50	3.5000
		3.8 LPH	1.00	0.37946	1.0040	0	0.50	3.8000

[illegible]	[illegible]
540	1.60
570	1.10
620	0.85
690	0.40

Pressure Regulation. Pressure will vary in a system due to varying slopes and pressure losses along pipes and across fittings. This can have an effect on how much flow each emitter is receiving, causing some to have more or less then the required amount; an emitter on the downhill side will have a large flow while the emitter on the uphill side will have little to no flow. When this occurs, it has a huge impact on the distribution uniformity. To eliminate this possibility, pressure regulators can be installed to ensure that none of the emitter will flow until they are all at the required pressure.

Three locations were identified as pressure regulating locations for this design. The emitters will be pressure compensating to ensure equal distribution of water across the field. The head of each manifold will have a pressure regulator to ensure a constant pressure is available for the emitters. This pressure regulator will be designed to maintain a pressure at the emitters nominal flow rate. There will also be a pressure regulator at the head of the sub mains to ensure each manifold receives the required pressure. This can also prevent damage to the system in the occurrence of a pressure surge allowing the water to escape rather then damaging the pipes and system.

Manifold Placement. The manifold needs to be placed in an ideal location where the pumping requirements are minimized, but still achieve the required flow and pressures. For this design, gravity could be used to bring water to the majority of the field. The manifold was placed to minimize the uphill pumping.

Manifold Sizing. The manifold also had to be sized to meet the required flow and pressures. This can be done by hand calculations or ITRC's Drip Hose Hydraulic Program, which was used in this design. The inputs and outputs of the Drip Hose Hydraulics program are shown in Table 4 and 5 on the following page.

Table 4. ITRC's Drip Hose Hydraulics program inputs.

Hose Hydraulic Program Inputs

Average GPH per emitter =	1.81	GPH at	11.69 psi
Emitter discharge exponent =	0.5		
Emitters / Vine = Standard Barb	2		
Slope along hose =	0.7 %		
Distance between emitters = (Extra 1.5% for temperature expansion/contraction)	10.15 ft		121.8 in
Manufacturers cv =	0.025		
Allowable Dulq =	0.96		
Water Temperature =	70 deg F		

Table 5. ITRC's Drip Hose Hydraulics program outputs.

ITRC Hose Placement Program Outputs:

Hose ID (in)	Uphill L (ft)	Downhill L (ft)	Inlet P (psi)	Dulq
0.54	240	360	117.4	0.97
0.57	222	378	117.2	0.97
0.69	120	480	116.8	0.97

Mainline/Sub main Sizing. The main line needs to be large enough to minimize friction losses but small enough to keep the necessary pressure required. In order to determine this, the allowable friction loss is calculated. Then each segment of the mainline is evaluated and the friction loss is calculated and compared to the allowable pressure loss. If the friction loss is too great, the diameter of the mainline is increased. It is also important to ensure that the velocities in the pipes stay below 5 ft/sec. Figure 5 below shows how the mainline is broken into segments "A" and "B," and the sub-main as segment "C." Table 6 below shows how each segment is evaluated.

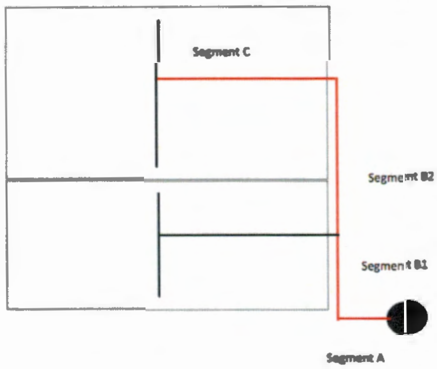

Figure 5. System layout with labeled segments of mainline and sub-main.

Table 6. Critical values for each segment of mainline and sub-main.

Point	Point P (psi)	Manifold Inlet P (psi)	u/s Seg Q (GPM)	Pipe ID (in)	C Value	Segment Length (ft)	Segment Hf (ft)	Segment Hf (psi)	Change in Elevation (psi)	Change in P (psi)	Velocity (ft/s)
			0								
d/s Segment	156.7	156.7	141.5929374	8.205	150	324	0.10808853	0.04679157	-0.981818182	0.93502661	0.82438751
d/s Segment	155.8	155.8	141.5929374	8.205	150	219	0.07172541	0.03104880	2.047619048	2.016569085	0.82438751
d/s Segment	153.8	153.8	141.5929374	8.205	150	[illegible]	0.02168443	0.0093872	0.619047619	0.609660421	0.82438751
d/s Segment	153.2	153.2	141.5929374	8.205	150	[illegible]	0.0200164	0.00866511	-0.181818182	-0.173153076	0.82438751
u/s Segment	[illegible]	[illegible]									

Air Vents. Air Vents are a critical part of the design which help prevent damage to the system. The two basic types of air vents are continuous acting air vents, and double acting air vents. When pumps are shut on/off, they create a suction in the pipe system. This can severely damage the system. Small air vents can be used at the head of drip hoses to minimize soil back-siphonage into emitters (Burt and Styles 2011). For this design, the slopes are minimal and air vents will not be installed at the head of the drip hose lines.

The filtration system is also susceptible to these damages. By installing a continuous acting air vent at the end of the inlets to the filters, a double acting air vent at the downstream end of the cleaned water and at the downstream end of the flush discharge, damages to the filtration system can be avoided (Burt and Styles 2011). This is shown by Figure 6 below, from Burt and Styles (2011).

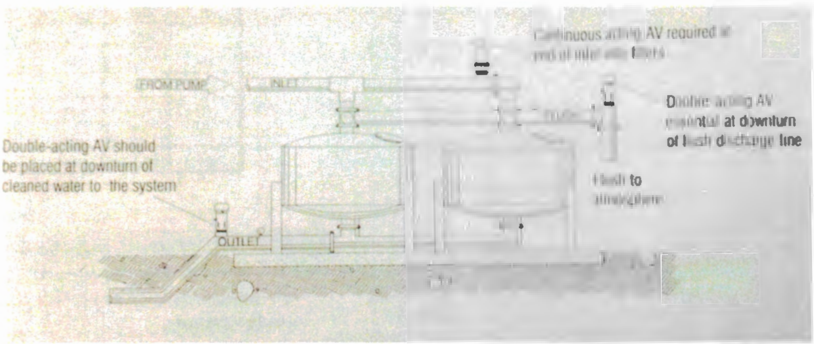

Figure 6. Air vent placement for filtration system (Burt and Styles 2011).

There will also be air vents at the pump location to protect both the pump and the entire system. By placing a double acting air vent followed by a check valve right at the pump discharge, and a continuous acting air vent at a distance of 11 times the pipe diameter, damages to the pump and the system can be avoided (Burt and Styles 2011). Figure 7 below (Burt and Styles 2011) shows the ideal placement of air vents at the pump location.

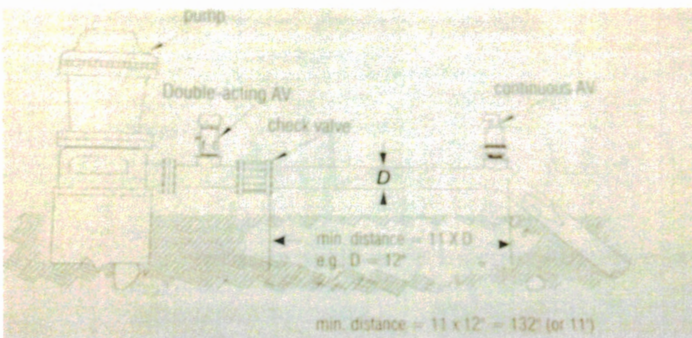

Figure 7. Air vent placement at pump location (Burt and Styles 2011).

Filtration. Emitters are subject to plugging due to improper filtration of irrigation water. To avoid this, a filtration system will be designed to filter out particles 1/10 the size of the emitter diameter. This was used along with the system flow rate to determine the size, the amount, and the mesh of the filters.

RESULTS

One design was submitted to the owner for approval. The design submitted is one that is able to adapt easily to a larger field by tapping in another sub-main and mainline on a T-Valve. Each sub-main will have a butterfly valve so the fields can be irrigated in different blocks.

They will use pressure compensating emitters in order to ensure the design DU of 0.93. The field will be irrigated for 20 hours a day, 5 days a week in order to minimize pumping costs. Pressure regulators will be installed at the heads of the manifolds and sub-mains to protect the system and ensure equal pressure to the manifolds.

Technical Specifications

Crop: Apple Variety
Total Planted Acres Original Design: 1.79 ac
Future Total Planted Acres: 4.13 ac
Spacing between Trees: 10 ft
Spacing between Rows: 15 ft

Irrigation System:
Netafim Uniram Heavy Wall Drip Hose System
Design Emitter Nominal Flow: 0.92 GPH at 10 psi
Design Hose Diameter: 0.54 in
Wetted Diameter: 63.6 ft^2
Original Design Number of Sets: 1
Future Design Number of Sets: 2
Pump TDH: 124.9 psi
Filtration Future Design: 3-30 in #8 Crushed Granite Media Filters
Design DU: 0.93
Hose DU: 0.97

DISCUSSION

This design was created for the already existing apple orchard at Fawn Hill Ranch. Multiple designs were considered for this orchard. After a rough initial design and a second completed design, a third was submitted to meet the owner's requirements. The design was created so that the owner can develop more land and tap into the existing system without having to consider a new design. Many aspects of this design were set by constraints given by the ranch owner.

The field survey proved to be a simple task due to prior knowledge on the subject. This was then easily transferred to a hand-drawn topographic map. The soil survey completed in the field yielded results matching those provided by the NRCS. The NRCS published data is more thorough and in depth, proving to be a better choice for the design.

The design is a long process influenced by many factors. It is important to set as many factors as possible at the start of the design process to help minimize confusion. If one variable is wrongly defined, it can completely change the design.

All components of this design are Netafim products. Technical information and costs for their products can be found on their website.

RECOMMENDATIONS

Before this design is installed, consider completely re-designing the orchard itself. Removing all trees will allow for the field to be re-leveled, including the expanded portion of the field, and also allow for the trees to be planted at a closer spacing maximizing yield. However doing this will stop all apple production until trees reach full maturity.

Also consider having the well ground water mapped. Then install a larger submersible pump in order to allow for the system to be expanded and have the required flow for the new systems.

If these recommendations are followed and a larger field is in question, consider adding a variable flow device (VFD) and installing a supervisory control and data acquisition (SCADA) unit to allow for the system to be monitored and controlled wirelessly (This is due to the owners frequent traveling and leaving the orchard un-supervised). The VFD will also allow for different flows if another crop is chosen to be irrigated in the future.

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APPENDIX A

HOW PROJECT MEETS REQUIREMENTS FOR THE BRAE MAJOR

Major Design Experience

The BRAE senior project must incorporate a major design experience. Design is the process of devising a system, component, or process to meet specific needs. The design process typically includes the following fundamental elements. This project addresses these issues as follows.

Establishing of Objectives and Criteria

The objectives of this project are to provide a drip irrigation system with a mximum distribution uniformity for the existing apple orchard at Fawn Hill Ranch. These objectives were reached.

Synthesis and Analysis

The project will incorporate analysis for maximizing the properties use and options, be a user friendly irrigation system, and be able to adapt to a larger field in the future.

Construction, Testing and Evaluation

The drip irrigation system was designed to be installed on apple orchards at Fawn hill Ranch. This design may be installed in the future

Incorporation of Applicable Engineering Standards

The project will utilize ASABE Standards along with NRCS guidelines regulating drip irrigation systems.

Capstone Design Experience

The engineering design project must be based on the knowledge and skills acquired in earlier coursework. This project incorporates knowledge/skills from these key courses.

BRAE 151 AutoCAD
BRAE 236 Principles of Irrigation
BRAE 239 Engineering Surveying
BRAE 312 Hydraulics/Fluid Mechanics
BRAE 331 Irrigation Theory
BRAE 414 Irrigation Engineering
BRAE 532 Pumps and Wells
SS121 Soil Science
ENG 149 Technical Writing

Design Parameters and Constraints

This project addresses a significant number of categories of constraints listed below.

Physical. The field has an original size of 1.79 ac and was designed to handle a future field size of 4.13 ac.

Economic. The system was designed with selected components that will minimize costs while providing the necessary requirements.

Environmental. The system will have a high irrigation efficiency minimizing water loss.

Sustainability. The drip system is expected to last at least 15-20 years while still maintaining a high distribution uniformity.

Manufacturability. The design will incorporate readily available parts.

Health and Safety. The design will take into account the safety of the public. Pressure relief valves will be installed to protect the components from exceeding the maximum pressure ratings.

Ethical. N/A

Social. N/A

Political. N/A

Aesthetic. N/A

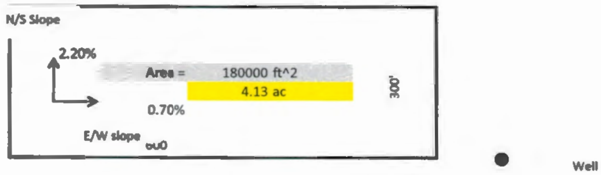
APPENDIX B

DESIGN CALCULATIONS

Design Specs:

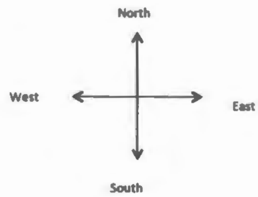
Crop Information

Apples	Crop Type	
6.9	Peak Crop ET Rate (in/31 days)	*(from ITRC data)*
43.8	Annual ET (in/year)	*(from ITRC data)*
10	Tree Spacing (ft)	
15	Row Spacing (ft)	



Field Information

Snady Loam	Soil Type
2.2	South/North Slope (%)
0.7	East/West Slope (%)
130	N/S field Length (ft) at East end.
600	E/W filed length (ft)



Turnout Information

3	Pressure at turnout (psi)
500	Max Available Flow from pump (GPM)

System Information

0.025	Manufacturer CV
0.93	Required system DU
1	Emitters per tree

Design:

1) Determine Peak Etc

Peak ET = 6.9 in/31 days
0.22 in/day

2) Estimate GPH/tree

Net GPM= [(inches/day)(Tree area)]/[(Hours/day)*96.3]
In/day = 0.22
Tree area= 150
Hours/day = 14.3

Net GPM = 0.02 per tree
Net GPH = 1.45 per tree

Gross GPH = Net GPH/Future DU
Net GPH = 1.45
Future DU = 0.8

Gross GPH = 1.81 per tree

3) Estimate number of emitters per tree

Sandy Loam Soil => water needs to infiltrate additional 4.5 ft
Design for wetted Area = 60%

Diameter = 9 ft

One Emitter/Tree = 63.6 ft^2

% Wetted Volume = Wetted Area / Tree Spacing

% Wetted Volume = 42.41 % (Does not meet requirements)

Two Emitter/Tree = 127.2 ft^2

% Wetted Area = 84.8 % Meets Requirement

The grower wants 2 emitters per tree to achieve 60% wetted area.

4) Select microsprayer and number of sets

From Netafim Urinam HeavyWall Drip Line:

Dripper Flow (GPH)	Exponent (x)	Constant (K)	CV
0.26	0.5	0.2642	0.025
0.32	0.5	0.317	0.025
0.42	0.5	0.4227	0.025
0.53	0.5	0.5284	0.025
0.61	0.5	0.6077	0.025
0.92	0.5	0.9247	0.025
1	0.5	1.004	0.025

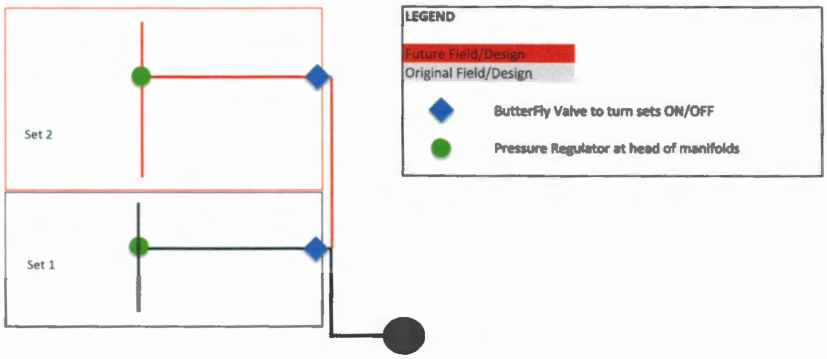
Netafim Chart:

Urinam HeavyWall DripLine:	Inside Diamter (in):	Nominal Flow (GPH) at 10 psi:
540	0.54	0.26, 0.32, .042, 0.53, 0.61, 0.92, 1
570	0.57	0.26, 0.32, .042, 0.53, 0.61, 0.92, 1
820	0.82	0.26, 0.32, .042, 0.53, 0.61, 0.92, 1
690	0.69	0.26, 0.32, .042, 0.53, 0.61, 0.92, 1
820	0.82	0.26, 0.32, .042, 0.53, 0.61, 0.92, 1

Selection Table:

# of Sets	GPH/Emitter	Pressures 0.26	0.32	0.42	0.53	0.61	0.92	1
1	1.81	46.78	32.49	18.27	11.69	8.84	3.82	3.24
2	3.61	187.11	129.97	73.10	46.78	35.37	15.27	12.96
3	5.42	421.00	292.44	164.47	105.25	79.57	34.37	29.15
4	7.23	748.45	519.89	292.39	187.11	141.46	61.10	51.83
5	9.03	1169.45	812.32	456.86	292.36	221.04	95.47	80.98
6	10.84	1684.00	1169.74	657.88	421.00	318.30	137.47	116.61
7	12.65	2292.12	1592.15	895.44	573.03	433.24	187.11	158.72
8	14.46	2993.79	2079.54	1169.56	748.45	565.86	244.39	207.31
9	16.26	3789.01	2631.92	1480.22	947.25	716.16	309.31	262.38
10	18.07	4677.79	3249.28	1827.43	1169.45	884.15	381.86	323.92

*2 sets. is chosen because the pressure requirment falls in the 12-20 psi range and the 0.92 nozzle is large enough to prevent some plugging



5) Determine DU low quarter for pressure regulators

(Qmin/Qaverage) = (Pmin/Paverage)^x

0.97 = Du low quarter for the pressure regulators

6) Acceptable Design DU for single hose

Minimum acceptable DU low quarter for a single hose = (Desired Dulq system / Dulq pressure regulators)

Acceptable Design DU for single hose = 0.96

7) Determine the optimum location for the manifold

Average Hose Length = 600 ft (not including snaking)

Hose Hydraulic Program Inputs

Average GPH per emitter =	3.61	GPH at	15.27	psi
Emitter discharge exponent =	0.5			
Emitters / Vine = Standard Barb	2			
Slope along hose =	0.7	%		
Distance between emitters = (Extra 1.5% for temperature expansion/contraction)	10.15	ft	121.8	in
Manufacturers cv =	0.025			
Allowable Dulq =	0.96			
Water Temperature =	70	deg F		

ITRC Hose Placement Program Outputs: (Both blocks will be the same)

Hose ID (in)	Uphill L (ft)	Downhill L (ft)	Inlet P (psi)	Dulq
0.54	276	324	156.7	0.97
0.57	276	324	156.1	0.97
0.69	240	360	154.8	0.97

Since all three hoses have the same DU, the 0.54 diameter hose will be the least exonsive and is chosen for this design.

8) Determine the Allowable manifold Change in P

Allowable Change in P = 2*(Pave - Pave*((Dusystem/Duhose)^(1/x)))

Pave =	15.27 psi
DU system =	0.93
DU hose =	0.97
Allowable Change in P =	2.47 psi

9) Sizing the Critical Manifold

Point	Point P	Emitters per Row	Point Q (GPM)	u/s Segment Q	Pipe ID (in)	C Value	Segment Length (ft)	Segment Hf (ft)	Segment Hf (psi)	Change in Elevation (psi)	Change in Pressure (psi)
				0							
1	156.7	120	9.438454678	9.438454678	2.193	146	15	0.02155546	0.00933137	-0.0454545	-0.0361232
2	156.663877	120	9.436278884	18.87473356	2.193	146	15	0.07779868	0.03367908	-0.0454545	-0.0117755
3	156.652101	120	9.435569616	28.31030318	2.193	146	15	0.16483225	0.07135595	-0.0454545	0.02590141
4	156.678003	120	9.437129727	37.7474329	2.193	146	15	0.28082543	0.12156945	-0.0454545	0.07611491
5	156.754118	120	9.441714328	47.18914723	2.193	146	15	0.42461620	0.18381654	-0.0454545	0.13836199
6	156.89248	120	9.450048236	56.63919547	2.193	146	15	0.59540675	0.25775184	-0.0454545	0.2122973
7	157.104777	120	9.462835463	66.10203093	2.193	146	15	0.79264504	0.34313638	-0.0454545	0.29768184
8	157.402459	120	9.480765626	75.58279656	2.193	146	15	1.01596851	0.43981321	-0.0454545	0.39435866
9	157.796817	120	9.504518889	85.08731545	2.193	146	15	1.26517494	0.54769478	-0.0454545	0.50224024
10	158.299058	120	9.534770144	94.62208559	2.193	146	15	1.54020693	0.66675625	-0.0454545	0.6213017
11	158.920359	120	9.572192786	104.1942784	2.193	146	7.5	0.92057205	0.39851604	-0.0227273	0.37578877
Inlet P =	158.920359 psi										

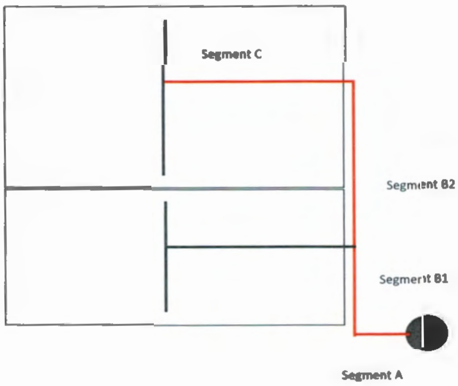
Pmax =	158.920359
Pmin =	156.652101
Change in P =	2.26825804
P average =	157.260368

Sizing the Manifold For Set 1

Point	Point P	Emitters per Row	Point Q (GPM)	u/s Segment Q	Pipe ID (in)	C Value	Segment Length (ft)	Segment Hf (ft)	Segment Hf (psi)	Change in Elevation (psi)	Change in Pressure (psi)
				0							
1	156.7	120	9.438454678	9.438454678	2.193	146	15	0.02155546	0.00933137	-0.0454545	-0.0361232
2	156.663877	120	9.436278884	18.87473356	2.193	146	15	0.07779868	0.03367908	-0.0454545	-0.0117755
3	156.652101	120	9.435569616	28.31030318	2.193	146	15	0.16483225	0.07135595	-0.0454545	0.02590141
4	156.678003	120	9.437129727	37.7474329	2.193	146	15	0.28082543	0.12156945	-0.0454545	0.07611491
5	156.754118	120	9.441714328	47.18914723	2.193	146	15	0.42461620	0.18381654	-0.0454545	0.13836199
6	156.89248	120	9.450048236	56.63919547	2.193	146	15	0.59540675	0.25775184	-0.0454545	0.2122973
7	157.104777	120	9.462835463	66.10203093	2.193	146	15	0.79264504	0.34313638	-0.0454545	0.29768184
8	157.402459	120	9.480765626	75.58279656	2.193	146	15	1.01596851	0.43981321	-0.0454545	0.39435866
9	157.796817	120	9.504518889	85.08731545	2.193	146	7.5	0.63258747	0.27384739	-0.0227273	0.25112012
Inlet P =	157.796817 psi										

Pmax =	157.796817
Pmin =	156.652101
Change in P =	1.1447161
P average =	156.960515

10) **Sizing the rest of the Critical Path**



Point	Point P (psi)	Manifold Inlet P (psi)	u/s Seg Q (GPM)	Pipe ID (in)	C Value	Segment Length (ft)	Segment Hf (ft)	Segment Hf (psi)	Change in Elevation (psi)	Change in P (psi)	Velocity (ft/s)
			0								
d/s Segment C	158.9	158.9	104.1942784	4.28	149	324	1.47539747	0.6387002	-0.9818182	-0.343118	2.22947864
d/s Segment B2	158.6	158.6	104.1942784	4.28	149	215	0.97904462	0.42382884	-0.6515152	-0.2276863	2.22947864
d/s Segment B1	158.3	158.3	104.1942784	4.28	149	65	0.29599023	0.1281343	-0.1969697	-0.0688354	2.22947864
d/s Segment A	158.3	158.3	104.1942784	4.28	149	60	0.27322175	0.11827782	-0.1818182	-0.0635404	2.22947864
u/s/ Segment A	158.2 psi										

11) **Filtration Requirements**

Max Flow Rate =	104 GPM
Orifice Diameter =	0.05 in
	1.27 mm
Minimum Removed Particle Diameter =	**0.005 in**
	0.127 mm

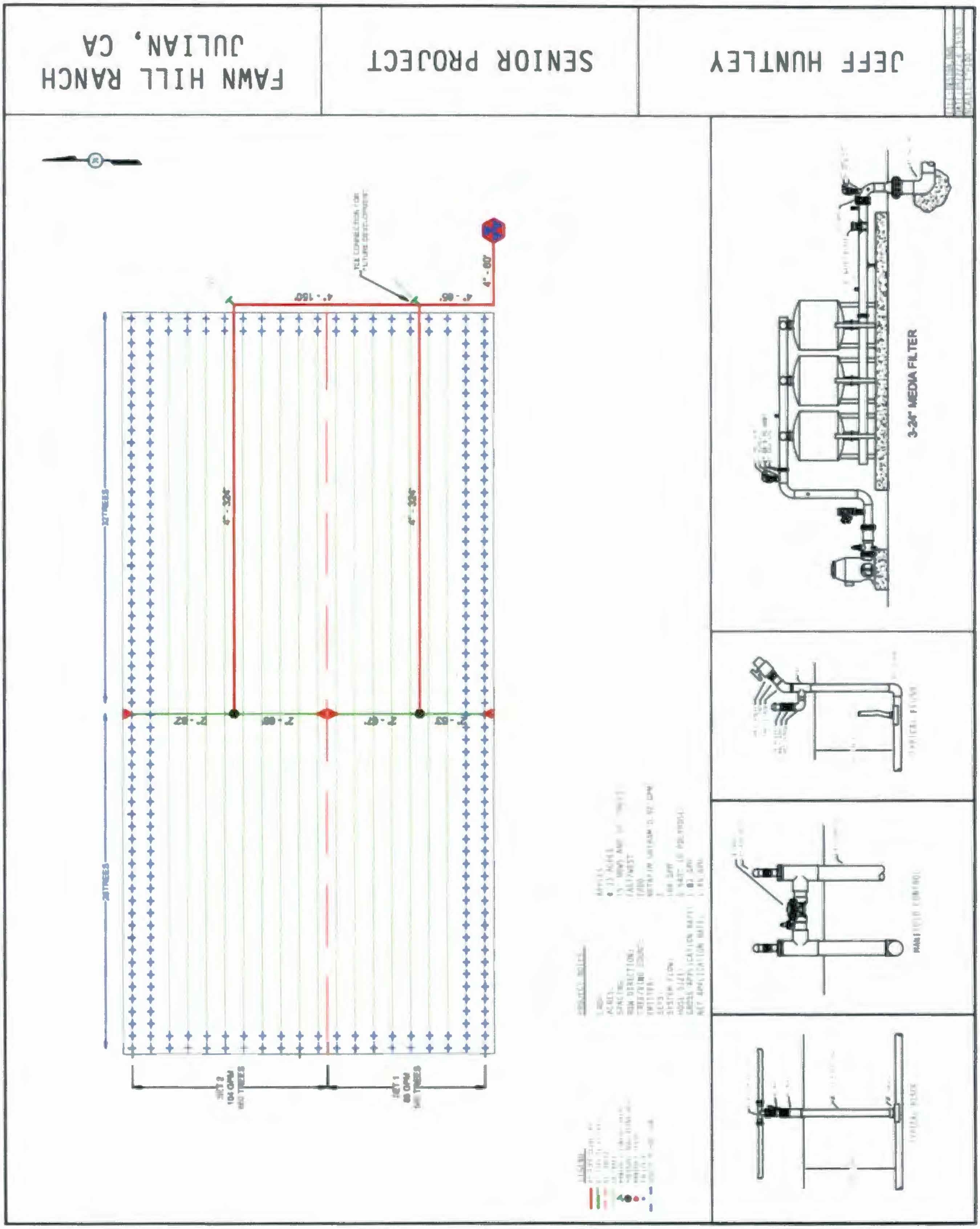
Based on the table above use: 3-24 in #8 Crushed Granite Media Filters

12) Total Dynamic Head required from pump

Pressure at u/s segment A -	115.4 psi
+ Media Filter loss when dirty	7 psi
+ Screen Loss -	0.5 psi
+ Minor Losses -	5 psi
Pump Inlet Pressure -	3 psi
TDH =	**124.9 psi**

APPENDIX C

DESIGN DRAWING


FAWN HILL RANCH
JULIAN, CA
SENIOR PROJECT
JEFF HUNTLEY
3-24" MEDIA FILTER

APPENDIX D

SURVEY DATA

Survey Data

Reference Location at South - East Corner

***Location was given an elevation of 100 ft as a reference and elevation changes were taken from this given.

***Data points were taken every 20 feet in longitude and latitude.

Contour map was developed from data points and drawn by hand.

Longitude Distance	Latitude Distance	Elevation
0	0	100
0	20	100.5
0	40	100.9
0	60	101
0	80	101.5
0	100	101
0	120	101.2
0	140	101
0	160	101.5
0	180	101.8
0	200	102
0	220	102.5
0	240	103
0	260	103.5
0	280	103.4
0	300	103.8
0	320	104
0	340	104.6
0	360	104.2
0	380	104.7
0	400	105
0	420	105
0	440	105.8
0	460	106.2
0	480	106.8
0	500	107.5
0	520	108
0	540	108.6
0	560	109.2
0	580	110
0	600	110.5
Average Elevation =		104.2

Longitude Distance	Latitude Distance	Elevation
0	0	100
20	0	99.2
40	0	98.3
60	0	97.6
80	0	97
100	0	96.2
120	0	94.8
130	0	94
Average Elevation =		97.14

Longitude Distance	Latitude Distance	Elevation
0	0	100
20	20	100
20	40	100
20	60	100.5
20	80	100.8
20	100	100.8
20	120	100.5
20	140	100.8
20	160	101.2
20	180	101.8
20	200	102
20	220	102.3
20	240	102.5
20	260	102.8
20	280	103
20	300	103.2
20	320	103.4
20	340	103.4

Longitude Distance	Latitude Distance	Elevation
0	0	100
40	20	98
40	40	97
40	60	97.5
40	80	97
40	100	96
40	120	96.3
40	140	96
40	160	95.8
40	180	95.6
40	200	95.4
40	220	95
40	240	94
40	260	94.3
40	280	94.6
40	300	94.8
40	320	95
40	340	95.2

20	360	103.2
20	380	103.2
20	400	103.5
20	420	103.8
20	440	103.6
20	460	103.8
20	480	104
20	500	104.2
20	520	104.6
20	540	104.5
20	560	104.3
20	580	104
20	600	104.2

40	360	95.2
40	380	95.4
40	400	95.8
40	420	96
40	440	96.2
40	460	96.3
40	480	96.8
40	500	97
40	520	98.2
40	540	99.4
40	560	100.2
40	580	102.3
40	600	103

Longitude Distance	Latitude Distance	Elevation
0	0	100
60	20	97.7
60	40	96.7
60	60	97.2
60	80	96.7
60	100	95.7
60	120	96.0
60	140	95.8
60	160	95.6
60	180	95.4
60	200	95.2
60	220	94.8
60	240	93.8
60	260	94.1
60	280	94.4
60	300	94.6
60	320	94.8
60	340	95.0
60	360	94.9
60	380	95.1
60	400	95.5
60	420	95.7
60	440	95.9
60	460	96.0
60	480	96.5
60	500	96.9
60	520	98.1
60	540	99.3
60	560	100.1
60	580	102.2
60	600	102.9

Longitude Distance	Latitude Distance	Elevation
0	0	100.0
80	20	97.6
80	40	96.6
80	60	97.1
80	80	96.6
80	100	95.6
80	120	95.9
80	140	95.7
80	160	95.4
80	180	95.2
80	200	95.0
80	220	94.6
80	240	93.6
80	260	93.9
80	280	94.2
80	300	94.4
80	320	94.6
80	340	94.8
80	360	94.7
80	380	94.9
80	400	95.4
80	420	95.6
80	440	95.8
80	460	95.9
80	480	96.4
80	500	96.7
80	520	97.9
80	540	99.1
80	560	99.9
80	580	102.0
80	600	102.7

Longitude Distance	Latitude Distance	Elevation
0	0	100.0
100	20	97.5
100	40	96.5
100	60	97.0
100	80	96.5
100	100	95.5
100	120	95.8
100	140	95.5
100	160	95.3
100	180	95.1
100	200	94.9

Longitude Distance	Latitude Distance	Elevation
0	0	100
120	20	97.3
120	40	96.3
120	60	96.8
120	80	96.3
120	100	95.3
120	120	95.6
120	140	95.3
120	160	95.1
120	180	94.9
120	200	94.7

100	220	94.5	120	220	94.3
100	240	93.5	120	240	93.4
100	260	93.7	120	260	93.6
100	280	94.0	120	280	93.9
100	300	94.2	120	300	94.1
100	320	94.4	120	320	94.3
100	340	94.6	120	340	94.45
100	360	94.5	120	360	94.35
100	380	94.7	120	380	94.55
100	400	95.3	120	400	95.10
100	420	95.5	120	420	95.30
100	440	95.7	120	440	95.50
100	460	95.8	120	460	95.60
100	480	96.3	120	480	96.10
100	500	96.2	120	500	96.05
100	520	97.4	120	520	97.25
100	540	98.6	120	540	98.1
100	560	99.4	120	560	98.9
100	580	101.5	120	580	101.0
100	600	102.5	120	600	102.0

Longitude Distance	Latitude Distance	Elevation
0	0	100
130	20	97.10
130	40	96.10
130	60	96.60
130	80	96.10
130	100	95.10
130	120	95.40
130	140	95.15
130	160	94.90
130	180	94.70
130	200	94.50
130	220	94.2
130	240	93.3
130	260	93.6
130	280	93.9
130	300	94.1
130	320	94.3
130	340	94.4
130	360	94.3
130	380	94.4
130	400	94.9
130	420	95.1
130	440	95.3
130	460	95.4
130	480	96.00
130	500	95.95
130	520	97.15
130	540	98.00
130	560	98.75
130	580	100.5
130	600	101.5

North South Change in Elevation = 2.2 %

East - West Change in Elevation = 0.7 %

APPENDIX E

SAN DIEGO NRCS SOIL SURVEY

United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

San Diego County Area, California

June 5, 2014

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the

individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map

Map Scale: 1:1,270 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 15, 30, 60, 90

Feet: 0, 50, 100, 200, 300

N

Map projection: Web Mercator   Corner coordinates: WGS84   Edge tics: UTM Zone 11N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: San Diego County Area, California
Survey Area Data: Version 7, Nov 15, 2013

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 2, 2010—Jun 3, 2010

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

San Diego County Area, California (CA638)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
HnG	Holland stony fine sandy loam, 30 to 60 percent slopes	0.6	10.3%
Lu	Loamy alluvial land	5.4	89.7%
Totals for Area of Interest		**6.1**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

San Diego County Area, California

HnG—Holland stony fine sandy loam, 30 to 60 percent slopes

Map Unit Setting

Elevation: 2,000 to 5,000 feet
Mean annual precipitation: 35 inches
Mean annual air temperature: 55 degrees F
Frost-free period: 180 to 230 days

Map Unit Composition

Holland and similar soils: 85 percent
Minor components: 10 percent

Description of Holland

Setting

Landform: Mountains
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Mountainflank
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Residuum weathered from mica schist

Typical profile

H1 - 0 to 10 inches: moderately acid, stony fine sandy loam
H2 - 0 to 10 inches: moderately acid, stony fine sandy loam
H2 - 0 to 10 inches: moderately acid, stony fine sandy loam
H3 - 0 to 10 inches: , stony fine sandy loam

Properties and qualities

Slope: 30 to 60 percent
Depth to restrictive feature: 20 to 40 inches to paralithic bedrock
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 6.2 inches)

Interpretive groups

Farmland classification: Not prime farmland
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: C
Ecological site: LOAMY WEST (R020XD024CA)

Minor Components

Crouch

Percent of map unit: 5 percent

Sheephead

Percent of map unit: 5 percent

Lu—Loamy alluvial land

Map Unit Setting

Elevation: 20 to 3,100 feet
Mean annual precipitation: 8 to 20 inches
Mean annual air temperature: 61 to 64 degrees F
Frost-free period: 230 to 340 days

Map Unit Composition

Loamy alluvial land: 98 percent
Minor components: 2 percent

Description of Loamy Alluvial Land

Setting

Landform: Alluvial fans
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Flat
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Residuum weathered from calcareous sandstone and shale

Typical profile

H1 - 0 to 14 inches: neutral, silt loam
H2 - 0 to 14 inches: neutral, silt loam
H2 - 0 to 14 inches: neutral, silt loam
H2 - 0 to 14 inches: neutral, silt loam
H3 - 0 to 14 inches: neutral, silt loam
H3 - 0 to 14 inches: neutral, silt loam

Properties and qualities

Slope: 0 to 5 percent
Natural drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: About 48 to 72 inches
Frequency of flooding: Rare
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 4.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 5.0
Available water storage in profile: Very high (about 20.8 inches)

Interpretive groups

Farmland classification: Prime farmland if irrigated and drained
Land capability classification (irrigated): 2w
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: C
Ecological site: WET MEADOW (R020XD030CA)

Minor Components

Unnamed

Percent of map unit: 2 percent
Landform: Alluvial fans
Landform position (two-dimensional): Toeslope
Down-slope shape: Linear
Across-slope shape: Convex

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