20 February 2013

La Creole Orchards
Polk County, Oregon

Water Resources
Feasibility Study

REGISTERED PROFESSIONAL
ENGINEER
19,191

OREGON
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1.0 Introduction

The purpose of this Feasibility Study has been to evaluate options for the on-farm storage and use of groundwater from three points of diversion, and the possibility to reclaim storm drainage resources, for irrigation at La Creole Orchards, just south of Dallas, Oregon, in Polk County (see vicinity map, Fig. 1). La Creole Orchards is a 50-acre farm with the primary crop of truffles. Currently, 2,850 trees for truffle production, 500 fruit trees, and 150 nut trees have been planted over 10 acres.

The Study has confirmed that storing groundwater is an absolute necessity. This is because the orchard's two deep wells and one sump-well are low-yield and would not be able to provide, in real time, all the water needed to irrigate the entire orchard when it reaches maturity. The potential on-farm storage projects are:

a. Storage tanks to hold groundwater pumped from the orchard's two low-yielding wells and sump-well from November 1st to June 30th (supplemented by year-around groundwater pumped under OWRD's "pond maintenance" rules);
b. Storage of groundwater in the sump-well that could be further developed;
c. At a later stage, storage of groundwater in an open pond;
d. A treatment bio-swale to reclaim polluted storm-water runoff discharged on-farm by a drain from a neighboring subdivision along with a reservoir for the reclaimed water.

The study has concluded that storing a minimum of 35,400 gallons is an absolute and <u>immediate necessity</u> to be able to irrigate the 10-acre orchard in 2013 and in subsequent years, until the end of the 2016 season. In order to have adequate water for the maximum number of watering cycles in 2017 and subsequent years, more storage would be required, up to an additional 125,500 gallons. Should the orchard be expanded from the current 10 acres to 20 acres, the total storage capacity needed after 2017 would be as high as 650,000 gallons, which would require open pond storage. The storage projects have thus been forecasted in up to 3 phases.

The construction of a tank with a storage capacity of 35,400 gallons in 2013 would make it possible to:

- Irrigate the entire 10-acre orchard on a 8 to 12-day cycle;
- Irrigate the 10-acre orchard in one day, as opposed to the current week-long process that involves irrigating only a few rows at a time;
- Do this with an affordable, efficient closed storage tank.

The construction, in a second phase, of a larger tank with a storage capacity of 125,500 gallons or more, would offer the same benefits, but also make it possible to:

- Store enough groundwater ahead of the irrigation season that it might <u>not be needed to pump any water from the low-yielding wells in August</u>, when the aquifer is at its lowest;
- Store a relatively large volume of water more efficiently than in an open pond.

Another benefit of storage of groundwater is that it does not need to be pumped at a high-pressure, high-flow rate. Instead, it can be pumped into the storage tank (or open pond) in an open-discharge manner, at flows as low as the estimated recovery rates of the wells and sump-well, thereby reducing the pressure on the aquifer. This pumping can be done with solar-powered pumps, which is a further environmental benefit. La Creole Orchards has used and plans to continue to use 100% solar power for all its on-farm energy needs.

For a more detailed discussion of environmental benefits, see Section 8.0, Environmental Considerations.

2.0 Description of Current Conditions

<u>Existing Orchard</u>

The existing 10-acre orchard has three zones of trees planted. Zone A has a total of 1,650 trees, planted in 2010-2012. Zone B has a total of 850 trees, planted in 2011-2012. Zone C has a total of 1,000 trees planted in 2012-2013. Figure 2 is an aerial photograph of the orchard property showing the existing orchard zones.

<u>Existing Irrigation System</u>

The existing orchard is irrigated by a high efficiency drip irrigation system. All new irrigation will be done with a similar, low water loss system.

<u>Existing Wells</u>

The existing orchard is currently being irrigated by two low-yield wells that were drilled in 2009 and 2010 (Wells POLK 53022 and POLK 53096). The estimated yields of these wells were 1 gpm and 3 gpm, respectively. The wells actually produce a total of approximately 1,000 gallons per day. The pumps are powered by a solar PV system. This, in addition to the wells' lower yields, limits pumping to only 6 to 8 hours per day. Figure 3 shows the solar panel and controls for the two wells.

<u>Existing Sump-well</u>

The third point of diversion is a sump-well that was found on the eastern edge of the property (see Figure 4). This sump-well has been studied as part of this study, in late summer and fall 2012. The sump-well has produced a consistent 1 gpm of recharging flow. The sump-well was flow-tested by pumping down the pond and estimating the recharge rate. This flow appears to be unaffected by the pumping of the other two on-site wells. The hydrostatic pressure of the groundwater is such that it does not overflow the small hole (about 30' in diameter and 7' deep) that was dug to expose the flow. The sump-well appears to be able to produce a total of approximately 1,400 to 1,600 gallons per day. A pump powered by a solar PV system is recommended to be installed near the sump-well to pump groundwater to a storage reservoir.

Existing Water Rights

The Owner has secured groundwater rights from the Oregon Water Resources Department (Permit G-16630) for irrigation on 30 acres that include the 10 acres on which the orchard has been planted. Because storage of groundwater is the recommended solution, an application has been filed with OWRD to obtain a new permit that will replace the current one, in order to include the right to store groundwater for later use (in up to two-connected tanks and in an open pond), and to include all three points of diversion under the new permit.

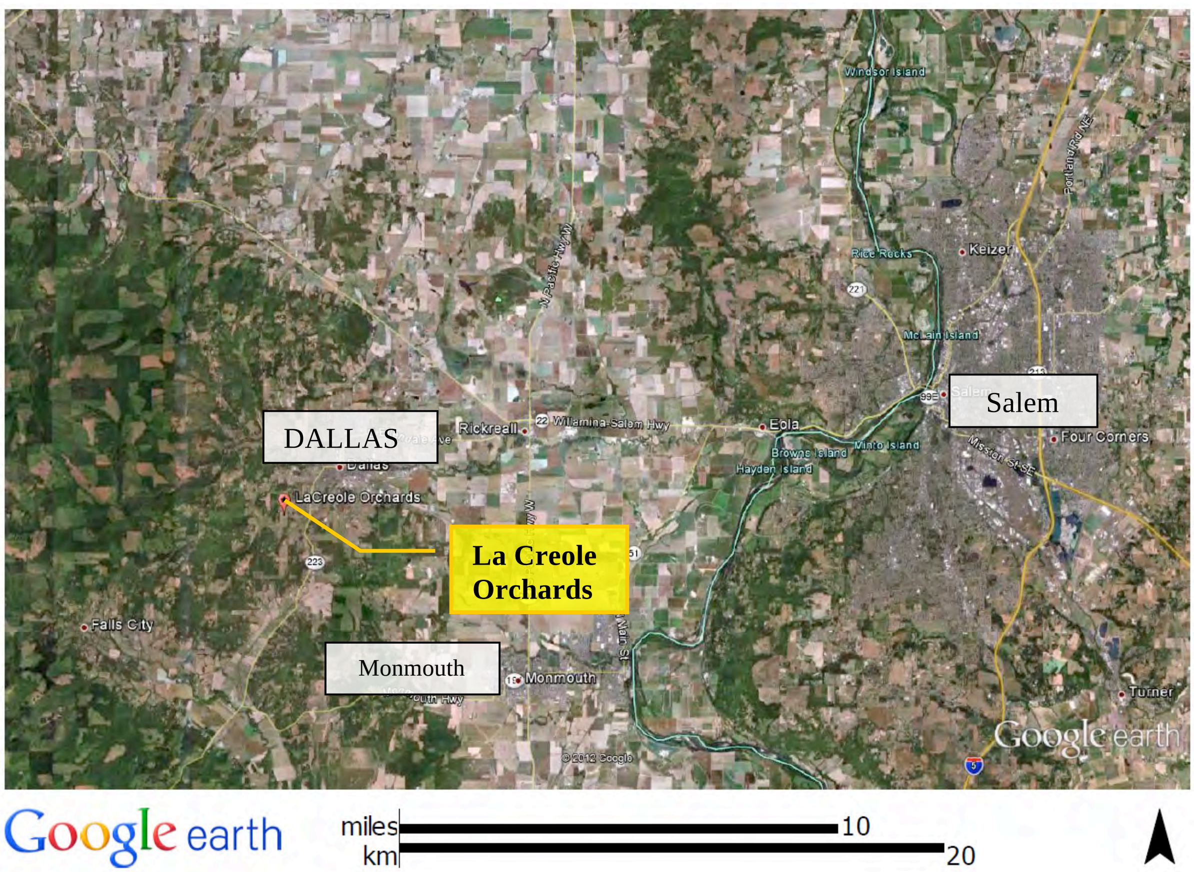


Figure 1 – Project Vicinity Map

Figure 2 – Aerial Photograph Showing Existing Conditions

Figure 3 – Solar PV panels and controls for the two wells (near north-west corner of site)

Figure 4 – Sump-well near east edge of site

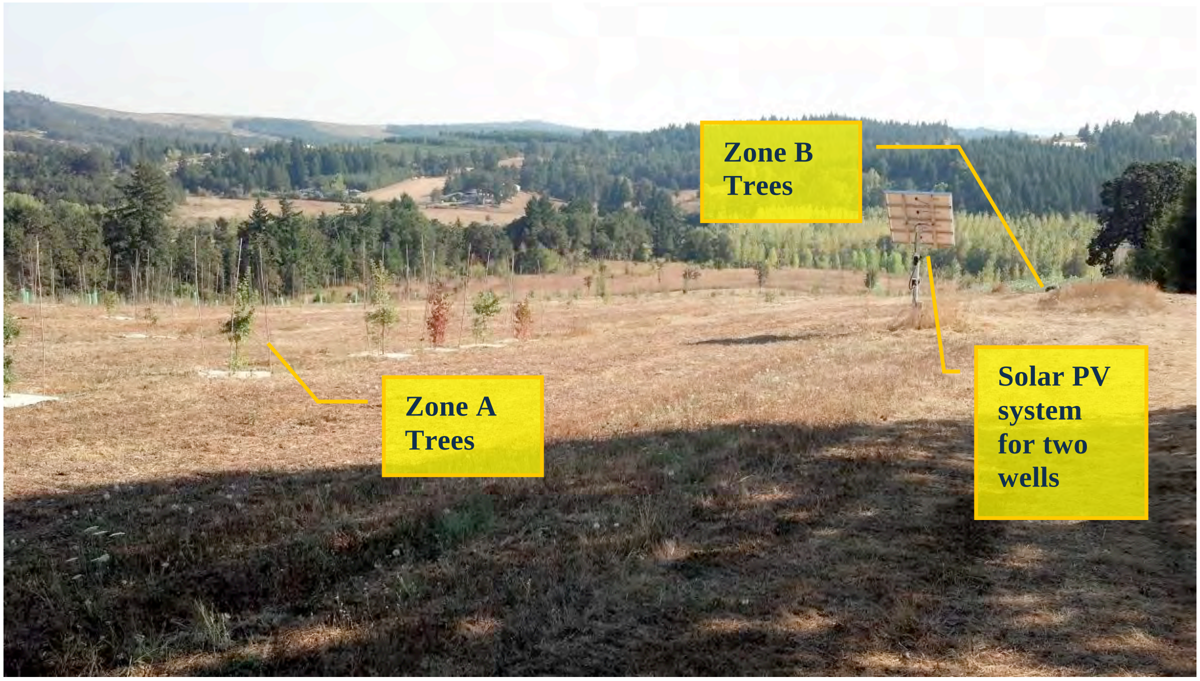


Figure 5 – Existing Orchard (looking SSE from NW corner)

3.0 Evaluation of Future Irrigation Requirements

Calculation of Irrigation Water Needs

The first phase of the orchard has been fully planted (the last trees were planted in winter 2012-2013). The orchard consists of 3,500 trees over 10 acres that will reach maturity by 2019. The orchard could be expanded from its current 10 acres to a full potential of 20 acres in future years.

The irrigation needs of the 10-acre orchard (Zones A, B, and C) will reach 285,000 gallons for the 2019 season (under average weather conditions) or up to 350,000-390,000 gallons under a dry weather scenario (rather extreme weather conditions for the Willamette Valley).

For the orchard to expand from its current 10 acres to a full 20 acres, the water needs of the 20-acre orchard at maturity (sometime after 2020) would increase to 650,000 gallons under average weather conditions or up to 975,000 gallons under a dry weather scenario.

The principles used to estimate the irrigation water needs for the 10-acre orchard are based on data from Owner's extensive research and contacts with dozens of truffle researchers and farmers in France:

1. Application Rates which have been successfully tested in truffle orchards in France: 15 mm per watering (15 L/m^2)
2. Applied to Willamette Valley soils (higher clay), need is only 10 mm: 10 L/m^2 or 3 gal/m^2 or 3 $gal/10ft^2$ (0.3 gal/ft^2), equivalent to 0.4 inches of precipitation
3. Where soils become hard when dry (which is the case at the La Creole Orchards), water every 8 to 10 days
4. Application rate remains constant, but surface to cover grows each season after planting (crucial after 4th season):
    a. First phase: from first season to 4th season, area to cover is less than 6' Ø

   b. Fifth season: 6.5' Ø, sixth season: 7.2' Ø, seventh season: 7.9' Ø, eighth season: 8.5' Ø, after that: 9.2' Ø

5. The number of gallons (per tree per season) will be determined by the area to cover AND by the number of watering cycles:
   a. Average season in the Willamette Valley: first watering around July 8th, last watering in mid-September, or 8 watering cycles over 70-75 days
   b. Dry season (e.g., 2012): first watering July 8th, last watering mid-October, or 11 watering cycles (10 days each) over approximately 90-95 days (driest imaginable season: 105 days).

Below, Table 1 shows the irrigation need by year and orchard zone for the planted 10-acre orchard (Zones A, B, and C). Figure 6 graphs the irrigation needs by year for the planted 10-acre orchard. Both Table 1 and Figure 6 stop in 2019 because in all subsequent years the irrigation need for the 10-acre orchard will remain the same as in 2019.

Table 1 – Irrigation Requirements for the La Creole Orchards

	Year						
Zone	2013	2014	2015	2016	2017	2018	2019
A (gal./watering)	7500	9500	10600	12500	15000	15000	15000
A/average year 8 watering cycles	60000	75000	84800	100000	120000	120000	120000
A/dry year 11 watering cycles	82500	104500	116600	137500	165000	165000	165000
Zone	2013	2014	2015	2016	2017	2018	2019
B (gal./watering)	1800	1800	3600	4800	6000	7200	8400
B/average year 8 watering cycles	14400	14400	28800	38400	48000	57600	67200
B/dry year 11 watering cycles	19800	19800	39600	52800	66000	79200	92400
C (gal./watering)	3000	3000	6000	8000	10000	12000	12000
C/normal year 8 watering cycles	24000	24000	48000	64000	80000	96000	96000
C/dry year 11 watering cycles	33000	33000	66000	88000	110000	132000	132000
Entire orchard per watering cycle	12300	14200	20200	25300	31000	34200	35400
Entire orchard in an average year	98400	113400	161800	202400	248000	273600	283200
Entire orchard in a dry year	135300	156200	222200	278300	341000	376200	389400

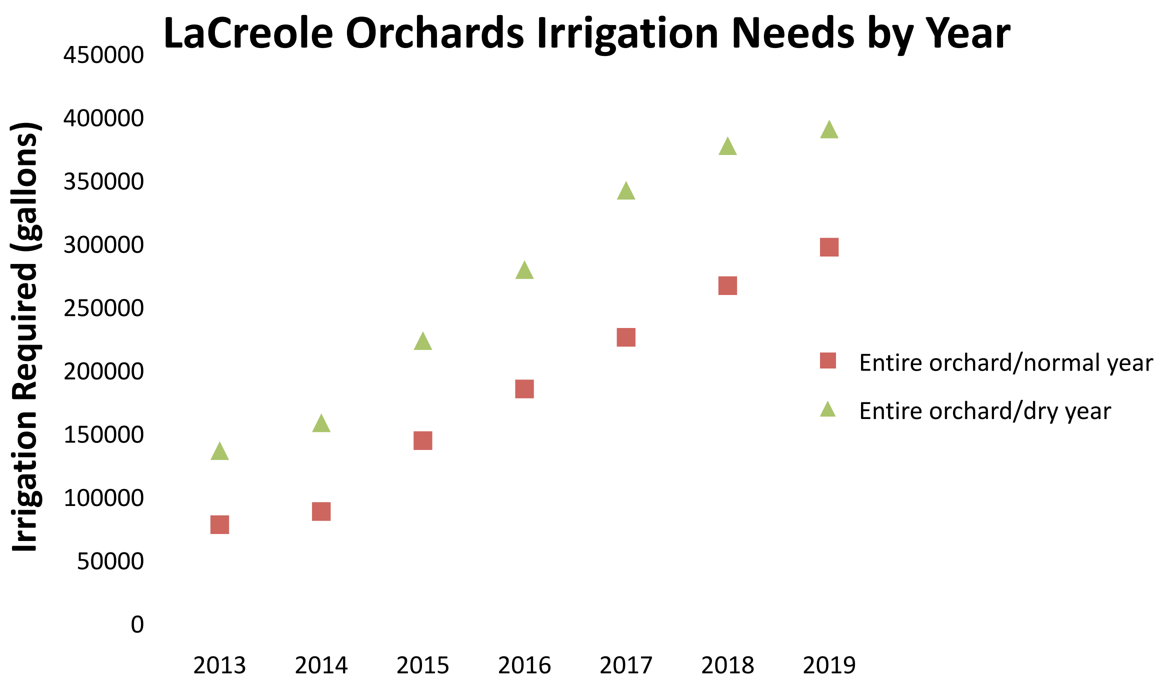


Figure 6 – La Creole Orchards Projected Irrigation Needs (by year)

4.0 Determination of Irrigation Storage Requirements

The wells and sump-well are capable of reliably producing approximately 2,500 gallons per day in July-October. Therefore, the three sources of groundwater can only supply about 225,000-275,000 gallons during the period of the year when irrigation is necessary. To supplement this supply, on-farm storage of groundwater is absolutely necessary.

<u>Water Balance Determination – Tank Storage</u>

For tank storage, the water balance is independent of the effects of evaporation, as tanks are covered by a span-cover that eliminates most evaporation and protects the stored water from the environment.

Different options were considered for storage in tanks. A model was built (as an excel file) to try various options, to see how storage and real-time supply would combine to provide the adequate amount of irrigation water each year (from 2013 to 2019). The best option was retained; it is explained below and it is illustrated in Figures 7a-7g.

Under the best option, the yield from both wells and the sump-well would be utilized starting in 2013. (This would require the installation of a solar-powered pumping station at the sump-well.) The irrigation interval would be 10 days on average, taking into consideration any exceptional precipitation, cloud-cover and temperatures, and soil moisture determined by the feel method using soil samples. It has been calculated that a tank with a capacity of about 35,400 gallons would be sufficient for the 10-acre orchard through 2016. Starting in 2017 a significant addition of storage is needed with a total of about 66,000 gallons needed. The totals needed for 2018 and 2019 are 112,500 gallons and 125,500 gallons, respectively.

This would require a second tank to be installed by the fall of 2016. This additional storage is Phase 2 of the water storage/use improvement projects at La Creole Orchards.

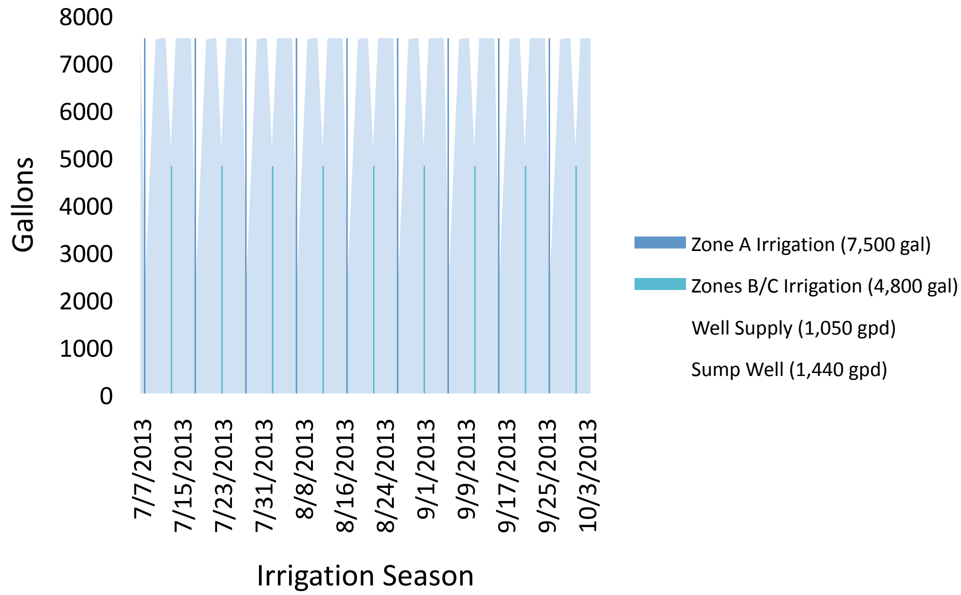


Figure 7a – La Creole Orchards Water Balance for 2013 (2 Zone/10 Day Irrigation)

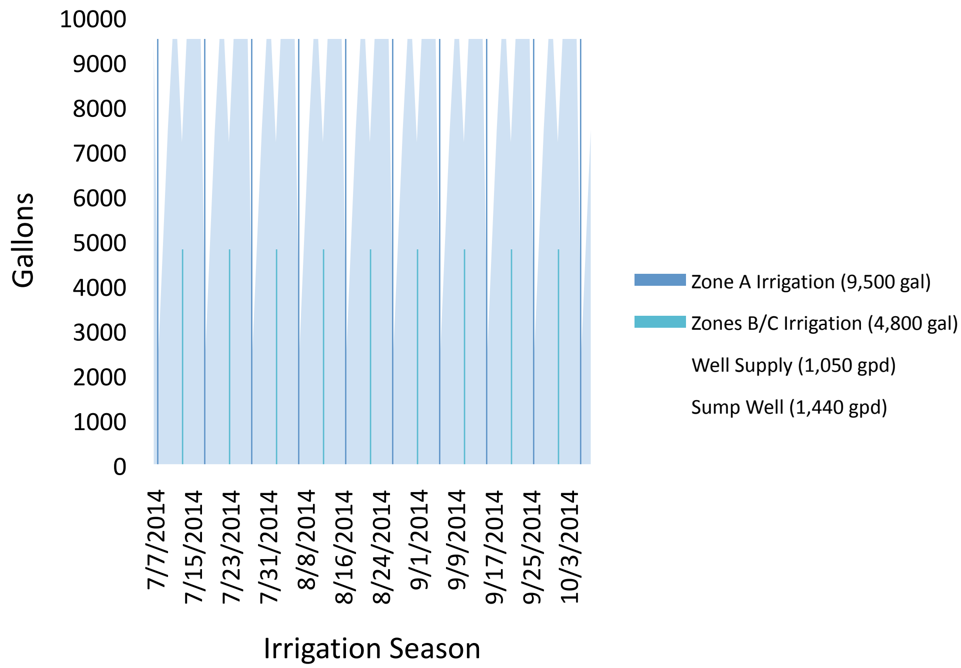


Figure 7b – La Creole Orchards Water Balance for 2014 (2 Zone/10 Day Irrigation)

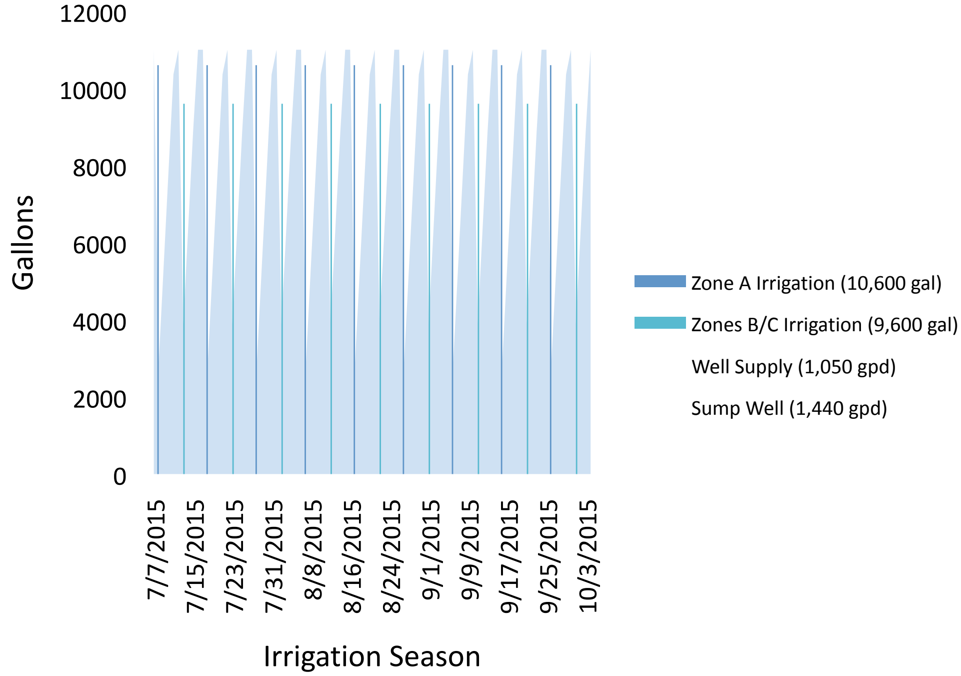


Figure 7c – La Creole Orchards Water Balance for 2015 (2 Zone/10 Day Irrigation)

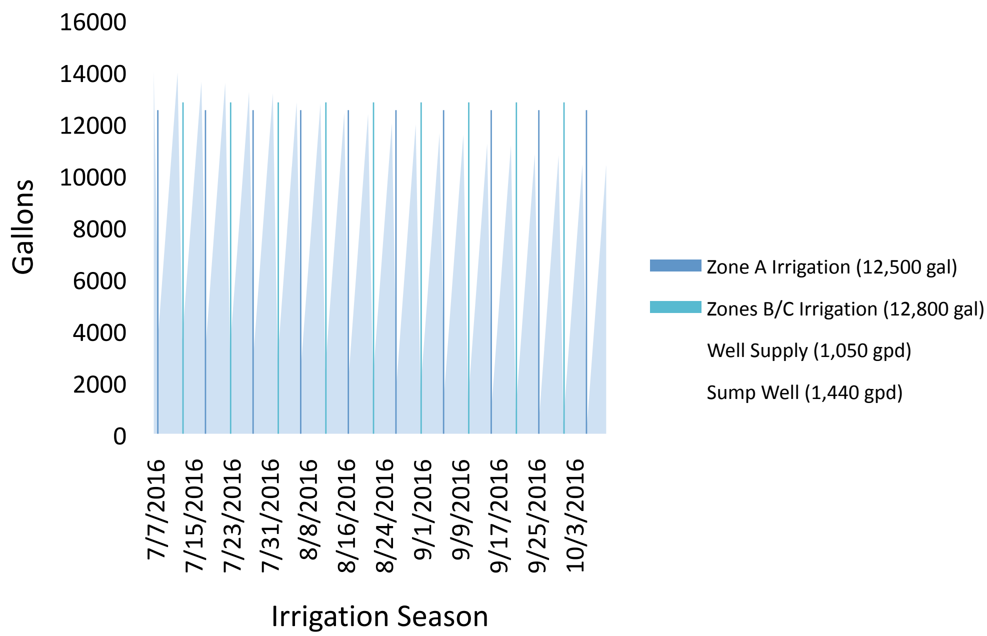


Figure 7d – La Creole Orchards Water Balance for 2016 (2 Zone/10 Day Irrigation)

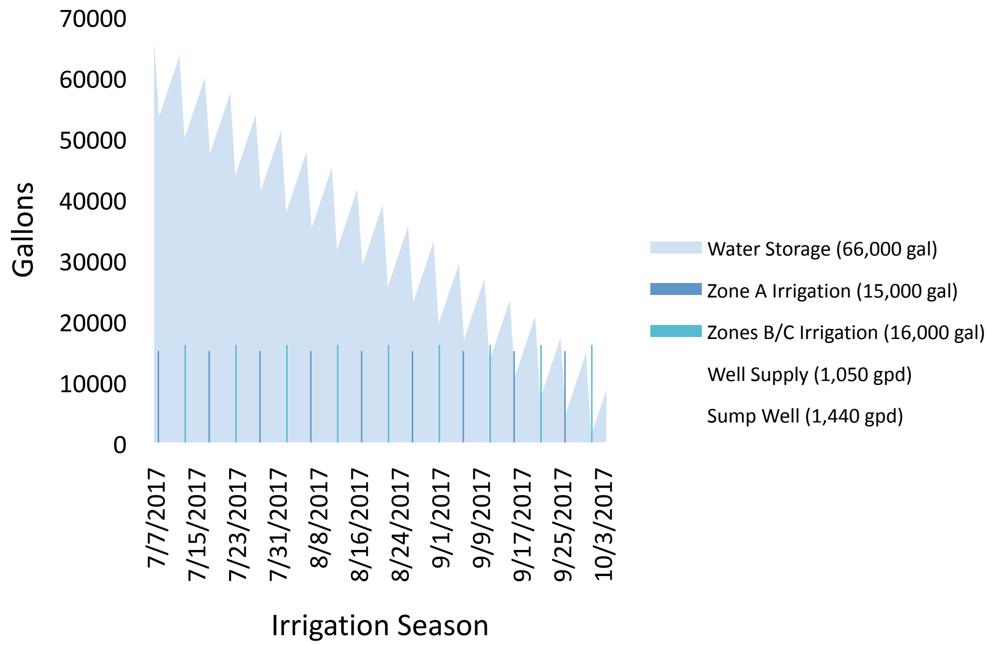


Figure 7e – La Creole Orchards Water Balance for 2017 (2 Zone/10 Day Irrigation) - Min Tank Storage Needed = 66,000 gal

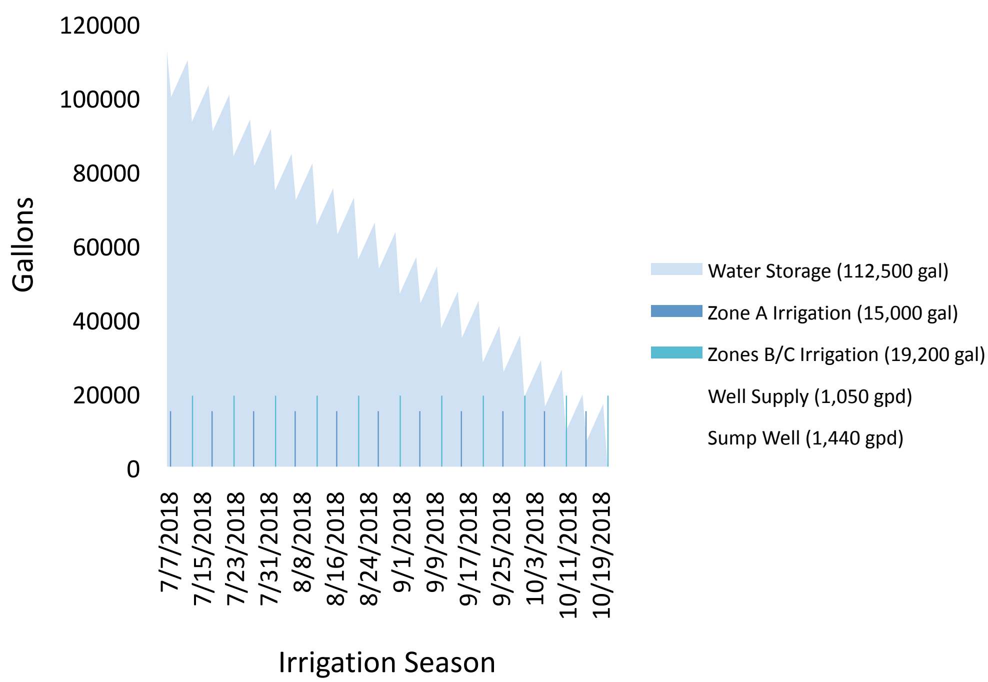


Figure 7f – La Creole Orchards Water Balance for 2018 (2 Zone/10 Day Irrigation) - Min Tank Storage Needed = 112,500 gal

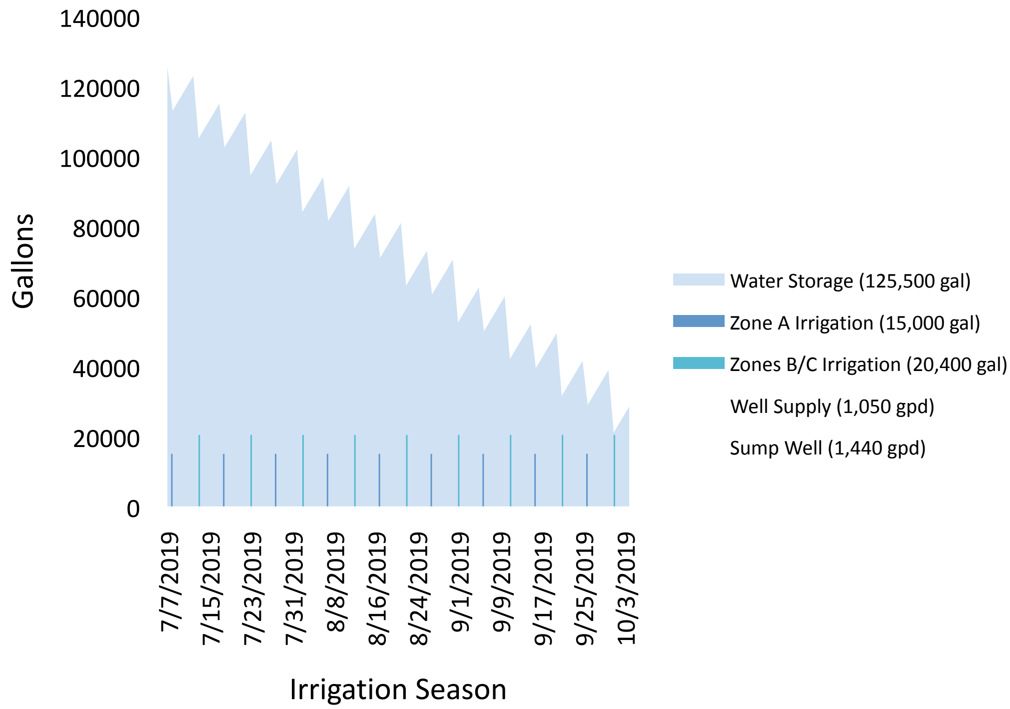


Figure 7g – La Creole Orchards Water Balance for 2019 (2 Zone/10 Day Irrigation) - Min Tank Storage Needed = 125,500 gal

An alternative to the second tank (to be installed in Phase 2 by fall of 2016) would be the expansion of the sump-well hole, to effectively store 125,500 or more gallons of groundwater in the sump-well. However, there are risks posed by the extension of the sump-well (see Section 5.0 below).

This storage capacity would become insufficient only if the orchard is expanded past its current planted 10 acres, toward its full potential of 20 acres, in which case open pond storage would be needed. The pond might be needed in Phase 2, or in a more distant Phase 3.

Water Balance Determination – Pond Storage

Pond storage would be needed if the orchard were to be expanded from the current, already planted 10 acres to a full 20 acres. Effectively, this expansion would create the second 10 acre half of the orchard, including approximately 3,500 new trees. For open pond storage, it is necessary to consider the effect of evaporation and precipitation on the pond itself. This will alter the total amount of storage needed, particularly considering the fact that the bulk of the evaporation occurs during the irrigation season.

For the water balance determination for open ponds, the following assumptions were made:

1. Evaporation Losses were based on a 550,000-gallon storage pond with 12-foot water depth (resulting in 21,500 SF of surface area at max depth).
2. Pan Evaporation for Oregon State University in Corvallis, OR was used. Average Pan Evaporation was increased by 20% for dry-year conditions.
3. Precipitation for Salem, OR was used. Precipitation was decreased by 40% for dry-year conditions. Please note that precipitation assumptions were not significant factors in the water balance determination due to limited precipitation during the irrigation season.

The resulting water balance for an open top pond indicates that a pond with a capacity between 550,000 and 650,000 gallons would be required to meet irrigation needs for the expansion of the orchard. Figure 8 shows the water balance for 2020, which represents the maximum maturity date plus one year for this second half of the orchard. The water balance for 550,000 gallons goes to 29,070 gallons in the middle of October. This should be enough water remaining in the bottom of the pond to prevent the liner from lifting due to wind forces. A pond with a capacity of 650,000 gallons would offer more margin for error (particularly with dry-year assumptions in mind).

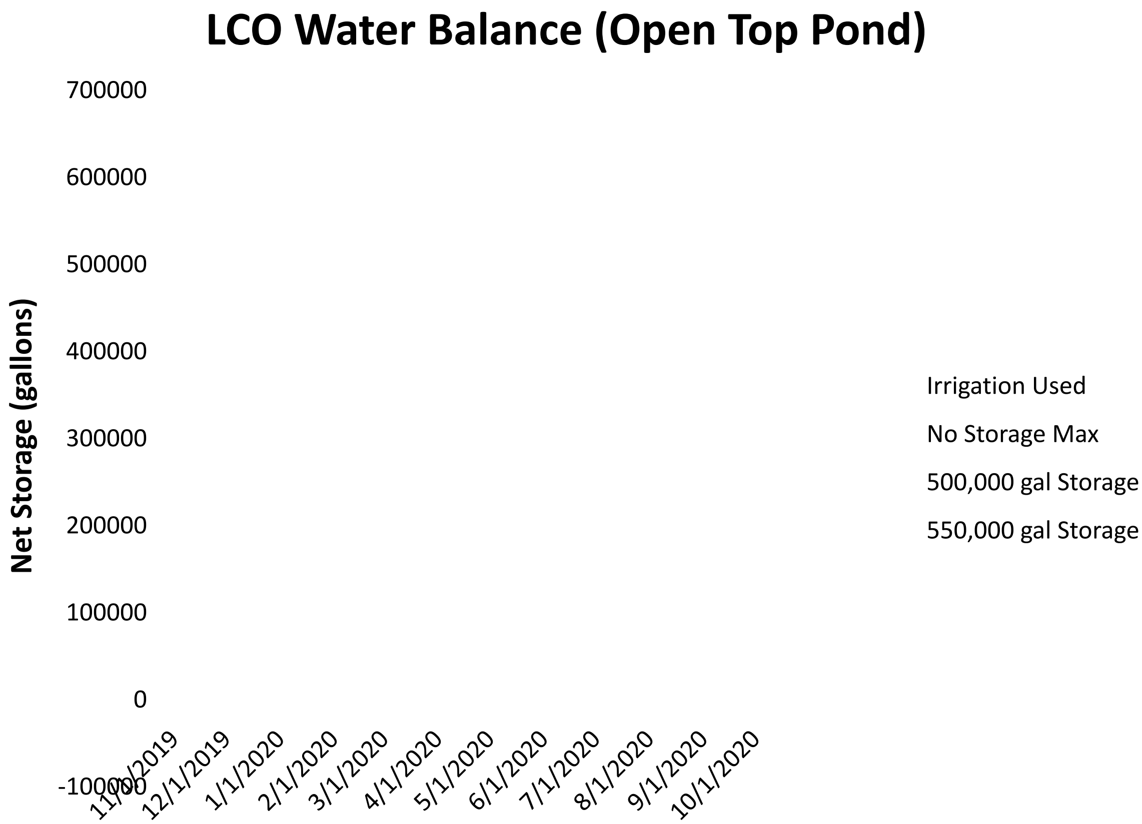


Figure 8 – La Creole Orchards Water Balance for Open Top Pond

5.0 Feasibility of Developing Sump-Well

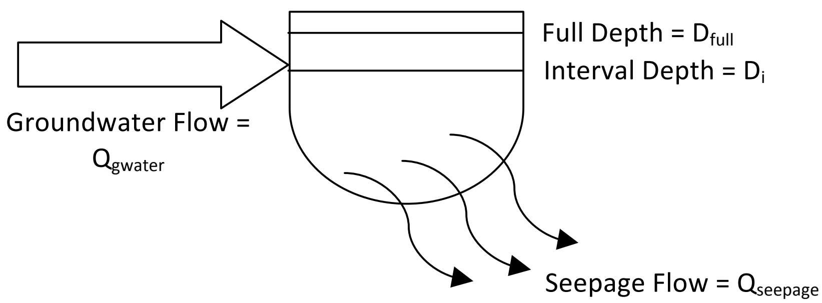
Existing Sump-Well

A sump-well was located near the east property line (see Figure 2 for location and Figures 4 and 9 for photos of the sump-well). It was developed after the Owner explored an area of persistent wetness throughout the year, even at the end of the dry summer months. The Owner exposed the groundwater flow by excavating a 30-foot diameter, 7-foot deep hole, which then filled up with the exposed groundwater. This was done at the end of August, after 50 days without any precipitation. This clearly indicates that this is exposed groundwater. The sump-well hole filled up at a rate of approximately 3 gpm. The sump-well hole has been holding water very well due to the surrounding clay soils and the continuous flow of groundwater.

An attempt to measure the flow rate of the sump-well was made at the end of the summer of 2012 by pumping down the pond and timing the rate of recharge. The measured recharge rate was slightly higher than 1 gpm. It is likely that this rate also includes ground seepage out of the hole (see Figure 10 below for a graphic illustration). Since the sump-well hole does not overflow, the recharge rate reaches 0 gpm. The most likely scenario is that the groundwater flow decreases due to hydrostatic pressure at the same time as the seepage rate increases due to hydrostatic pressure and the rise of the water level into the more porous subsoil region, which contain a lower percentage of clay.

We recommend a solar-powered air diffusion system (an air injection pump capable of fine bubbles) be installed in the sump-well in order to keep the water clean of algae and other organisms that might impact the micro-irrigation system. Adequate filtration is strongly recommended, both before groundwater from the sump-well enters the tank, and downstream from the tank, before it enters the micro-irrigation system.

Figure 9 – Existing Sump-well Near Eastern Edge of Site



Fill Rate = Q_{fill} > 1 gpm

Q_{fill} appears to remain consistent regardless of Interval Depth (D_i)

Therefore:

As, D_i increases, either

Q_{gwater} decreases due to hydrostatic pressure,

OR

$Q_{seepage}$ increases due to hydrostatic pressure and/or change in soil strata

OR

BOTH Q_{gwater} decreases and $Q_{seepage}$ increases (MOST LIKELY SCENARIO)

Figure 10 – Likely Sump-Well Recharge Rate Scenario

Exploration for Additional Sump-Well Location(s)

In addition to the existing sump-well located near the east property line, the Owner explored another persistently wet area that appeared to be approximately up gradient from the current sump-well. The exploration of this potential sump-well was completed with a small excavator by digging small holes until a vein of running groundwater was exposed. This was done in early September 2012, well into the dry season. Once groundwater was located, a larger excavation was completed (see Figure 12 on next page). The excavation for the potential new sump-well was allowed to sit for several days in an attempt to measure the groundwater flow rate. At this location, however, the water level increased to only about 100 gallons at the bottom of the test hole. The flow of the water was insignificant. In addition, the soil appeared to have significantly more silt than optimal for holding water. While it may be possible to develop this sump-well into a water source, it would require a significant capital expenditure, likely including a collection box, infiltration pipes and other infrastructure. The apparent very low flow does not justify this expenditure at this time.

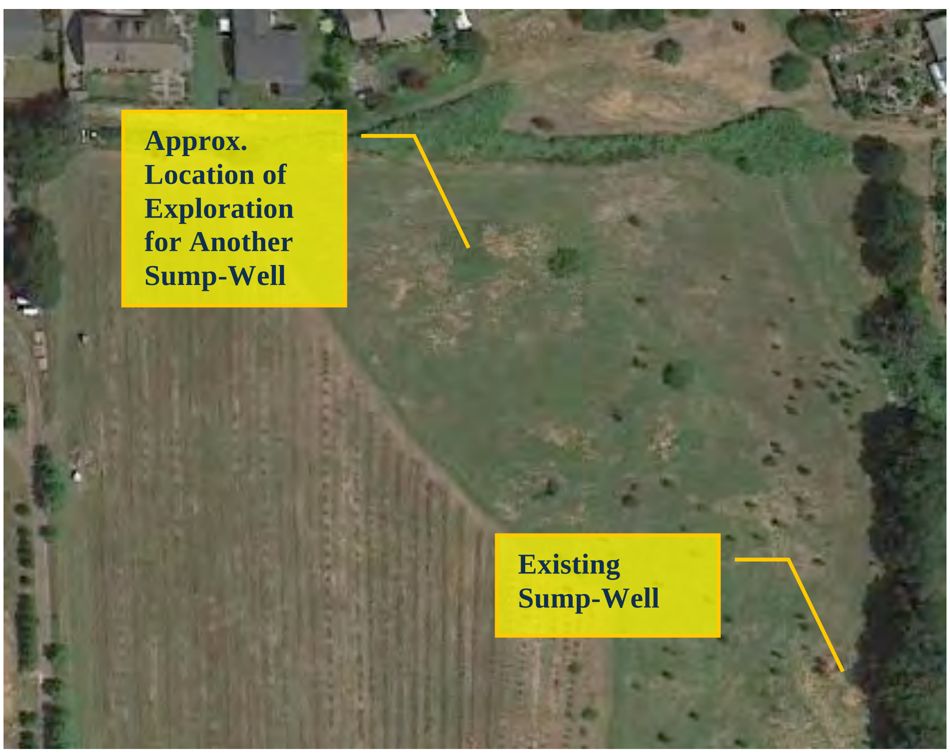


Figure 11 – Location of Additional Sump-Well Exploration Site

Figure 12 – Excavation of Potential Additional Sump-Well Location

Feasibility of Expansion/Development of Existing Sump-Well

The existing sump-well is critical to meet the orchard irrigation needs. This is evident in the water balance analysis presented in Section 4.0. Currently, the existing sump-well has the ability to produce about 1 gpm. The potential does exist for the sump-well to be improved in such a manner that both (a) additional water is made available for irrigation, and (b) additional storage can be economically constructed.

The following options exist for development of the sump-well:

(a) construction of an advanced spring-box type collection system
(b) expansion of the sump-well hole to allow for additional storage
(c) lining of the hole to prevent water loss due to seepage, and
(d) a combination of any or all of the three options listed above.

<u>Construction of a collection system:</u>

The existing sump-well is largely undeveloped. The groundwater simply fills the excavated hole. There is no effort to maximize the capture of groundwater. To maximize this capture, the owner could construct a spring-box type collection system designed for the capture of a seepage-type spring (see Figure 13). The collection system consists of infiltration galleries extending uphill from the current outlet in a fashion intended to intercept the groundwater as soon as it is encountered. A subsequent cut-off wall is constructed to prevent water from escaping around the collection box. The infiltration galleries are piped to the collection box, where there is an outlet to the storage reservoir. Ideally, the outlet to storage is free flowing at all times so that there is not a build-up of hydrostatic pressure. This pressure build-up can cause the sump-well to plug up with fines or can cause the groundwater to find other drainage routes around the collection box. Table 2 shows a cost estimate for the construction of a collection system for the sump-well.

The primary advantages of this construction type over the current situation are:

1. The infiltration galleries capture the maximum amount of water, so the sump-well yield might be higher than the measured 1 gpm.
2. The constructed cut-off wall would limit the amount of groundwater seeping around the collection box, thereby increasing the yield.
3. Construction of a collection box with a free flowing outlet would allow for the continuous flow of the sump-well, theoretically ensuring a longer life.

The disadvantages of developing the sump-well are:

1. Whether sump-well development would increase flow is unknown. It might well be that the current undeveloped configuration is capturing a majority of the groundwater.
2. There is a slight possibility of disrupting the groundwater flow in the sump-well through construction, especially considering that this flow is of the seepage type.
3. The construction costs for sump-well development would most likely not be offset by reduced needs for storage in tanks, since a significant flow increase is not expected to be realized through the development of the sump-well.

Table 2 – Cost Estimate for Construction of a Sump-Well Collection System

Sump Well Collection System Cost Estimate					
Item No.	**Description**	**Units**	**Quantity**	**Unit Cost**	**Total Cost**
1	Excavation	LS	1	$1,000	$1,000
2	Concrete Collection Box (Manhole Section With Cover)	EA	1	$700	$700
3	Infiltration Trench	LF	100	$25	$2,500
		Construction Total			$4,200
		Contingency (@20%)			$840
		Engineering (@20%)			$840
		Total Project Cost			**$5,880**

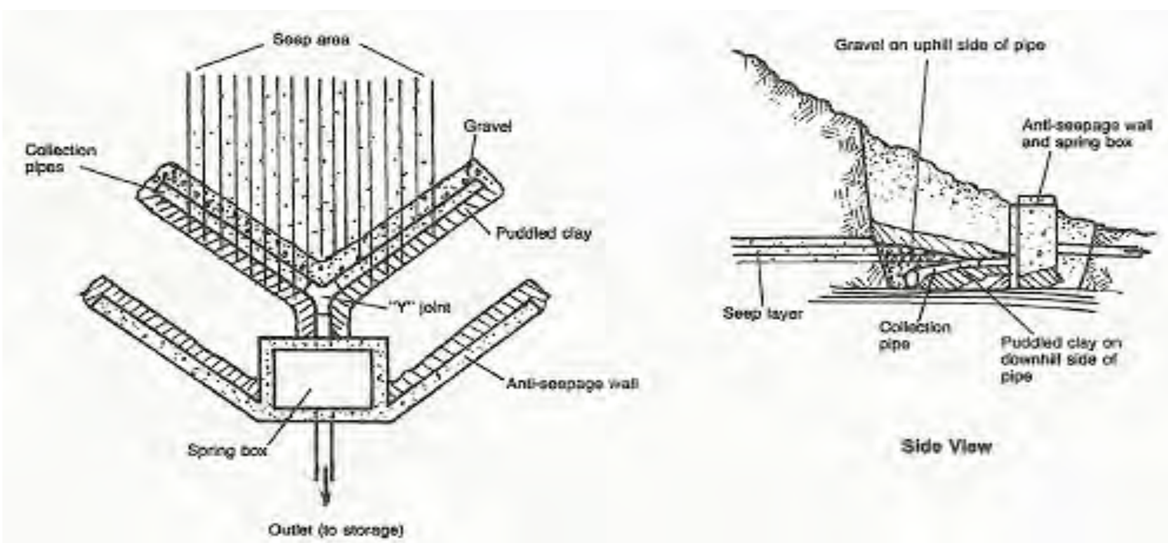


Figure 13 – Typical Spring Development for Seepage Springs

<u>Expansion of the sump-well hole to allow for additional storage:</u>

The Water Balance analysis presented in Section 4.0 illustrated the need for on-farm storage of irrigation water (initially in a tank with a capacity of about 35,400 gallons, and in Phase 2 in two tanks or even in a pond with a capacity of up to 650,000 gallons). It could be possible to expand the existing sump-well hole beyond the existing 30-foot diameter to achieve additional storage in the sump-well hole. The cost of this earthwork is relatively inexpensive and the soil conditions in the immediate vicinity appear to be favorable to holding water.

Care would need to be taken to avoid disturbing the groundwater seepage. There is the potential for intercepting additional seepage; however, this possibility should not be a significant deciding factor, as it is too unknown. In addition, the geography of the site will limit the ability to expand much further eastward. Also, as in the case of the open pond water balance evaluation, the effect of evaporation must be considered. For a sump-well hole with a 2,500 square foot surface area (approximately 130,000 gallons with a 7 foot drawdown), the amount of evaporation in July (highest average month) would average only 387 gallons per day, which is the equivalent of 0.26 gpm of flow. Combined with the initial tank (with a capacity of about 35,400 gallons), a sump-well of this size would eliminate the need for the second tank. Table 3 presents a cost estimate for expanding the volume of the sump-well.

The advantages of expanding the sump-well hole are:

1. The cost for excavation is less than the cost of an above-ground tank.
2. The excavation could be done upstream from the current groundwater flow, in the hope to intercept more groundwater.

The disadvantages of expanding the sump-well are:

1. Additional evaporation loss due to more open-water surface area. This could be mitigated by a floating cover system; however, this would be costly.
2. Limited space available for significant expansion of the sump-well toward the eastern edge of the site.
3. The potential for disturbing the groundwater flow (although there is also the potential to achieve additional seepage flow through expansion).

Table 3 – Cost Estimate for Sump Well Volume Expansion

Sump Well Volume Expansion Cost Estimate					
Item No.	**Description**	**Units**	**Quantity**	**Unit Cost**	**Total Cost**
1	Excavation	CY	950	$4.50	$4,275
2	Clay Liner (Patch)	CY	30	$75	$2,250
		Construction Total			$6,525
		Contingency (@20%)			$1,305
		Engineering (@20%)			$1,305
		Total Project Cost			**$9,135**

<u>Lining sump-well hole to prevent water loss due to seepage:</u>

The possibility of water loss due to seepage from the sump-well is quite likely, especially when the water level is near ground level. At this level, the subsoil contains much more silt than the deeper soils. This can be seen on the sump-well hole cross section.

To prevent seepage from the sump-well hole, it is possible to line it with a material such as bentonite clay. This clay can be fairly expensive and this should only be considered if it is felt that water loss through seepage is significant. It is possible to line the upper section of the walls to limit leakage at higher levels.

An accurate cost estimate for lining the existing hole is not possible, as it is not known how much bentonite would be needed. Bentonite by the dump truck can be delivered for approximately $65/CY. The typical minimum order would be 10 to 20 CY.

The advantages of lining the sump-well hole are:

1. Lining would ensure that seepage losses are kept to a minimum.
2. It is possible to spot seal the walls with bentonite clay, such as at the upper section, where the seepage may be more significant due to more porous soil conditions.
3. The cost of lining the small sump-well hole with bentonite is relatively low.

The disadvantages of lining the sump-well hole are:

1. The cost/benefit ratio of lining may not be significant, as the current net recharge of the sump-well is sufficient to supply significant irrigation water to the orchard.
2. The existing seepage rate of the sump-well may not be significant enough to justify lining. There is no apparent evidence of moist areas down gradient of the sump-well.

Recommendations:

It is recommended that the owner consider the benefits vs. cost of further development of the sump-well in conjunction with a small expansion of the sump-well hole (for storage). This expansion should be limited so as to limit the effect of evaporation on the overall water supply and to avoid any disruption to the groundwater flow. Sump-well hole lining should be considered as a spot fix only as needed.

6.0 Feasibility of Treatment and Storage of City Storm Drainage

One of the initial options considered by the Owner was capture, treatment and storage of the suburban runoff from a storm drain that outlets south of the Bridlewood subdivision, just 2 feet north of the orchard site (see location on Figure 2). This storm system drains an approximate total of 14 acres of single-family residential development. While this is not a significant area from which to draw storm water, storage facilities downstream from a treatment area might provide a small quantity of usable water.

Table 4 below lists the primary pollutants found in urban runoff. Of most concern for La Creole Orchards would be the potential for fuels, oils and grease, volatile organic compounds (pesticides and herbicides), heavy metals, bacteria, and generally any pollutant with fungicide properties. The typical treatment regime for storm water would be the installation of a combination of bio-swales and oil-water separation devices. When properly maintained, these treatment devices perform adequately for the removal of significant levels of pollutants. However, these technologies are designed to lessen the impact of these pollutants rather than eliminate them. Some level of pollutant would certainly reach the truffle crop and this would be very harmful to this sensitive crop.

<u>Recommendation:</u>

Provided that adequate treatment could be achieved, significant storage would still need to be provided since the runoff events occur outside of the irrigation season. Due to the availability of adequate water (supplemented with storage) from the wells and sump-well, coupled with the high risk of contamination to the truffle crop, pursuing treatment and storage of the city storm drainage is <u>not recommended</u>.

Table 4 – Major Pollutants Found in Suburban Storm Water (Minton, 2005).

Source	Major Pollutants
Atmospheric deposition	Ammonia, fine particles, metals, nitrate, pesticides, petroleum products, phosphorus, toxic organics
Public infrastructure	Bacteria, metals, nitrogen, organics, petroleum products, phosphorus
Pavement and pavement maintenance	Materials from abraded or degraded pavement, petroleum derivates from asphalt, temperature modification
Pavement deicing	Chlorides, coarse sediments, cyanide, organics from acetate deicers, sulfates
Transportation vehicles	Brake drum and tire wear; fuels; fine particles; metals, especially cadmium, chromium, copper, lead, and zinc; petroleum products such as oil, grease, and PAH
Residential activities	Bacteria, herbicides, landscaping debris, nitrogen, paint, pesticides, petroleum products, phosphorus, vehicle maintenance fluids, wood preservation, zinc
Building exteriors	Chipped and eroded paints, corrosion of surfaces accelerated by acid rain, galvanized metals, other metals
Site development	Cement, concrete, high pH, organics, paint, particulate matter, petroleum products, phosphorus
Residential and roadside landscape maintenance	Dissolved organics from soil amendments, herbicides, humic organics, nitrogen, pesticides, phosphorus; personal and commercial debris discarded to roadways and parking lots such as cans, food, paper, plastics; leaves and yard debris
Urban wildlife and pets	Bacteria, nitrogen, phosphorus

7.0 Storage Project Cost and Non-cost Considerations

For the following project considerations the following assumptions are made:

1. The solar-powered wells will continue to supply 1,050 gallons/day of slowly pumped groundwater to be stored and used as irrigation water.
2. The existing sump-well will be able to provide 1 gpm (1,440 gallons/day) of groundwater to be stored and used as irrigation water.
3. New groundwater use rights will be secured for the use of the sump-well.
4. New groundwater storage and use of stored water rights will be secured for the storage facilities (tanks and ponds) for the period from November 1 to June 30, and for "pond maintenance" for the rest of the year.
5. The location of the storage tank(s) will be in the NW corner of the property, which is at the highest elevation on the site. This location limits the impact on the existing orchard.[1]

Tank Storage Project Considerations

The water balance conducted in Section 4.0 indicates the immediate need for a covered tank with a capacity of at least 35,400 gallons to get through 2016, with additional tank storage required in subsequent years. For purposes of cost estimation and further discussion, the Phase 1 tank has a capacity of 35,400 gallons, and the Phase 2 tank holds 125,500 gallons.

The Owner is proposing to use field-erected tanks with internal flexible membranes (a blanket and a liner) and an anti-algae span cover that significantly reduces evaporation. The tanks are manufactured by Dutch company BUWATEC, a world leader in water storage solutions (see Figures 15 and 16).

[1] While the location of the storage tank at the highest elevation on the site could provide driving pressure for the micro-irrigation system, the use of a 2 hp booster pump is recommended because it makes the system more efficient. It also allows the installation of good filtration (120 mesh) downstream from the storage tank, before water enters the micro-irrigation system.

The BUWATEC tanks are assembled from galvanized steel panels. When constructed with shorter sidewalls, which is the case here, these tanks can be erected on a compacted sand base and do not require a ring wall. Therefore, site preparation and assembly of the tank are very simple. The installation of the blanket and liner are equally straightforward. A four-person crew can accomplish most of the tasks. Cost estimates for the tanks are presented in Tables 5 and 6.

The layout presented in Figure 14 shows two tanks, as they would appear in Phase 2: the initial tank with a capacity of 35,400 gallons and the second tank with a capacity of up to 125,500 gallons.

Table 5 – Cost Estimate for 35,400-gallon Tank

One BUWATEC Tank With Capacity Of 35,400-gallon					
Item No.	**Description**	**Units**	**Quantity**	**Unit Cost**	**Total Cost**
1	Site Preparation	LS	1	$1,000	$1,000
2	35,400-gallon BUWATEC Tank	EA	1	$5,200	$5,200
3	Tank Construction	HRS	100	$12	$1,200
4	Plumbing, etc.	LS	1	$1,600	$1,600
		Construction Total			$9,000
		Contingency (@20%)			$1,800
		Engineering (@10%)			$900
		Total Project Cost			**$11,700**

Table 6 – Cost Estimate for 125,500-gallon Tank

One BUWATEC Tank With Capacity of 111,200-gallon					
Item No.	**Description**	**Units**	**Quantity**	**Unit Cost**	**Total Cost**
1	Site Preparation	LS	1	$2,000	$2,000
2	125,500-gallon BUWATEC Tank	EA	1	$15,000	$15,000
3	Tank Construction	HRS	240	$12	$2,880
4	Plumbing, etc.	LS	1	$1,600	$1,600
		Construction Total			$21,480
		Contingency (@20%)			$4,300
		Engineering (@10%)			$2,150
		Total Project Cost			**$27,850**

The advantages of the tanks are:

1. Higher storage efficiency due to minimal evaporation (less pumping from wells and sump-well required)
2. Smaller footprint on site
3. Easier to add additional storage
4. Lower risk of contamination of water due to algae or blowing fungi spores
5. Fail safe storage solution: tanks can be used for rainwater or even trucked-in water

The disadvantages of the tanks are as follow:

1. Smaller amount of stored water (than a larger open pond or sump-well expansion)
2. Higher cost per gallon than a 650,000-gallon pond or the expansion of the sump-well hole to store ±125,500 gallons

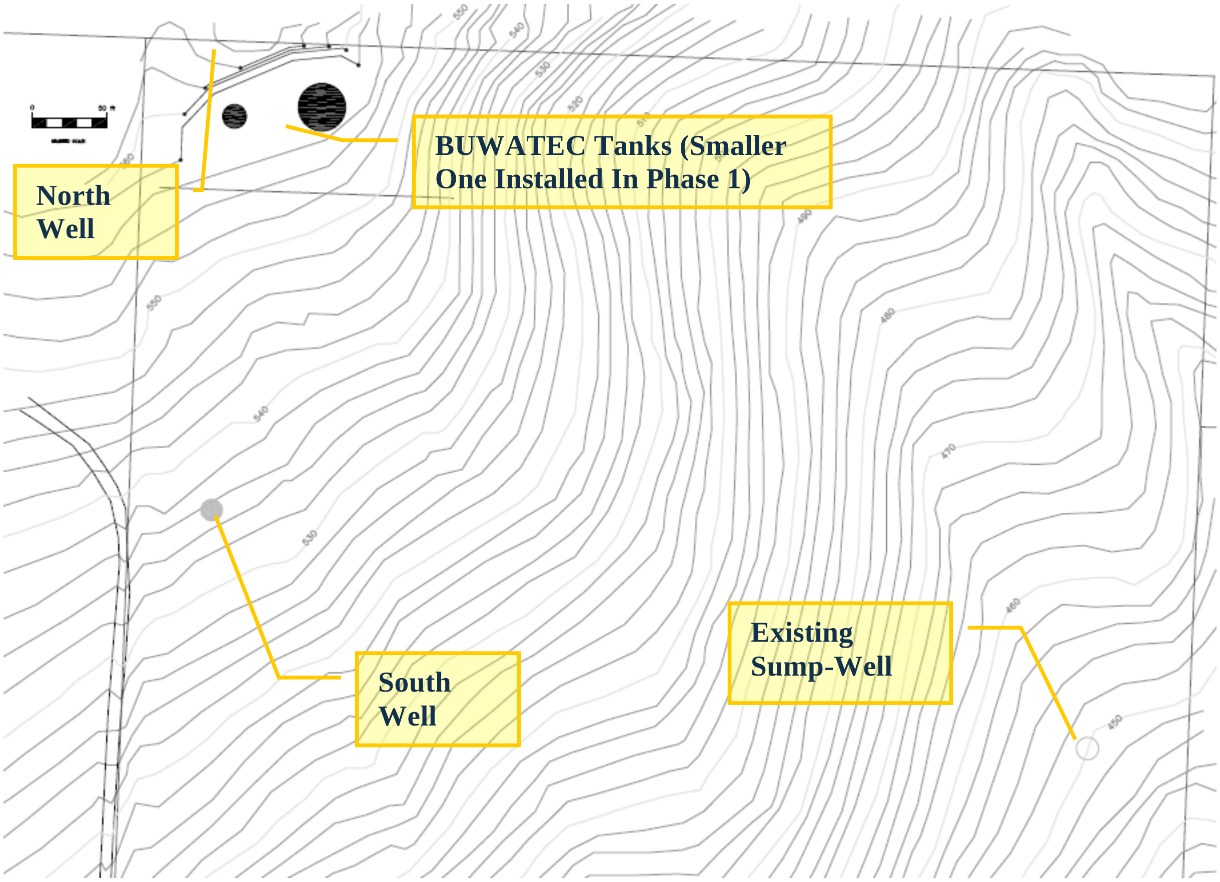


Figure 14 – Two Tanks Shown: One Tank with Capacity of 35,400 Gallons to be Installed in Phase 1. Second Tank with Larger Capacity to be Installed in Phase 2.

Figure 15 – Field-Erected Storage Tanks from Dutch Company BUWATEC

Figure 16 – Installation of BUWATEC Tanks (Panels, Sand-base, Blanket, Liner & Pipe)

<u>Pond Storage Project Considerations</u>
The water balance conducted in Section 4.0 indicates that 550,000 to 650,000 gallons of pond storage would be needed if the orchard were to be expanded from the current, already planted 10 acres to a full 20 acres. The construction of the pond could come in Phase 3, after both above-ground storage tanks have been installed (the first one in 2013, the second one by 2016). The pond could also be an alternative to the larger tank that is planned in Phase 2. The pond would thus move to Phase 2, to work in conjunction with the smaller tank installed in Phase 1.

To maximize the storage volume and minimize the surface area (to minimize evaporation), and to fit the topography of the land, the possibility of a square pond was analyzed. Using 3:1 side slopes and a water depth of 12 feet (total depth of 15 feet), the footprint of this pond would take up a significant amount of space, encroaching over 150 feet into the existing Zone A (see Figure 17). This would require moving hundreds of well-established trees. This is clearly <u>not an option</u>.

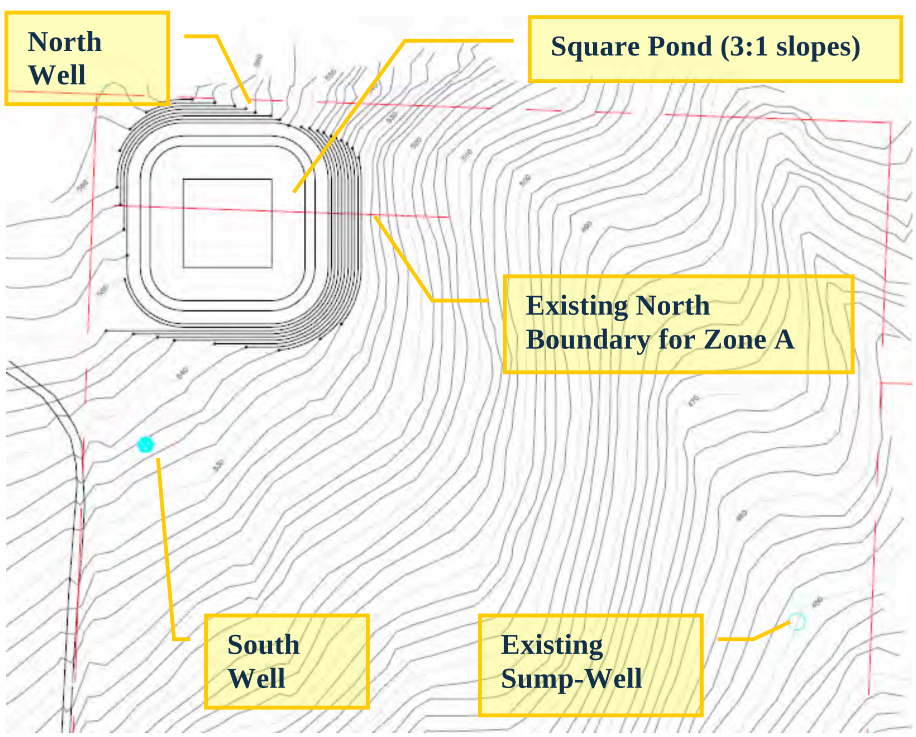


Figure 17 – Storage Pond at Highest Point (NW Corner). Square Pond with 3:1 Slopes Encroaches 150' Into Existing Orchard Zone A.

Rather, the pond could be constructed as an excavated hole, as opposed to a pond requiring a dike, with 1:1 side slopes, and 14-foot high fencing all around it to prevent wildlife and humans from entering the pond area (as well as a 3-foot "safety shelf" and ladders at the pond edges, in case humans do enter the pond – see Figures 18a and 18b). Such an option would reduce the footprint of the pond to about 10,200 square feet. This would also significantly reduce evaporation.

The pond would be located between elevations 440 and 430 (minimum level of the pond). This would not make possible any irrigation from the pond via gravity. Therefore, the solar PV-powered pumping system that will have been installed in 2013 near the sump-well (to move water from the sump-well to the storage tank) would be moved, in order to pump water stored in the pond to the 35,400-gallon storage tank (located at the highest elevation at the site), from where it can be released into the micro-irrigation system.[2]

Table 7 – Cost Estimate for 650,000-gallon Pond (1:1 Side Slopes, Fenced)

650,000-gallon Pond Cost Estimate					
Item No.	**Description**	**Units**	**Quantity**	**Unit Cost**	**Total Cost**
1	Excavation, dump truck	CY	3600	$4.50	$16,200
2	HDPE Liner	SF	15,600	$0.40	$6,240
3	Solar Pumping System	LS	1	$5,500	$5,500
4	Fencing, gate	LS	1	$2,400	$2,400
		Construction Total			$30,340
		Contingency (@20%)			$6,068
		Engineering (@20%)			$6,068
		Total Project Cost			**$42,476**

[2] It may be possible to utilize the existing topography with a small dam/dike structure (see Figure 20). Based on the rough aerial photographic topography, it is estimated that to construct a 16,000 SF pond to hold 650,000 gallons, a 220-foot long, 14-foot wide dike would be required. This results in approximately 700 CY of earthwork for the dike, which could be completed in conjunction with some pond excavation. Owner should construct a diversion ditch around the pond to prevent the accumulation of surface runoff (the storage of which would complicate water rights issues). This would, however, result in a much larger footprint, which is subject to additional evaporation and would reduce the number of trees that could be planted.

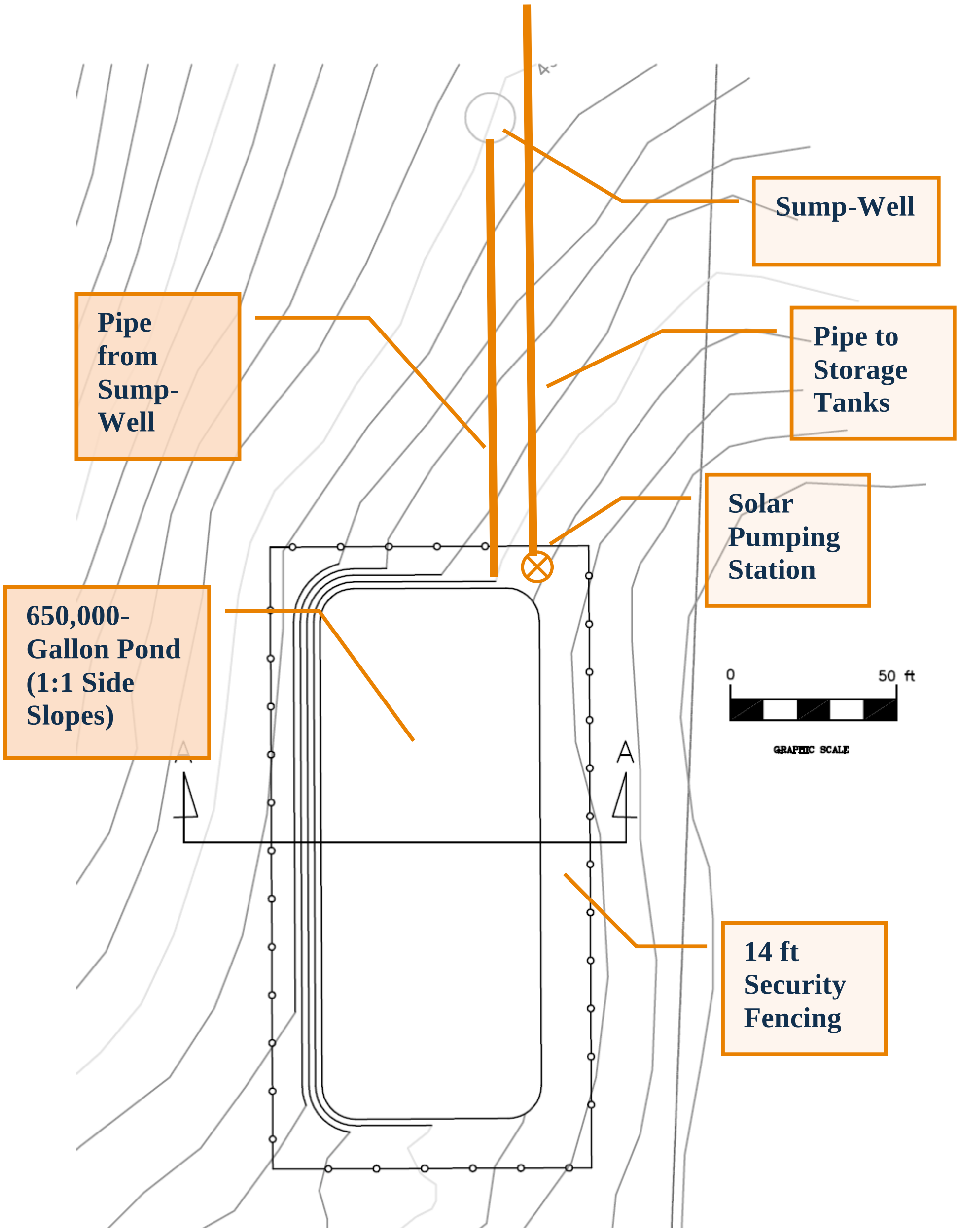


Figure 18a - 650,000-gallon Irrigation Storage Pond near Sump-Well (1:1 Max Side Slope, Fenced for Security)

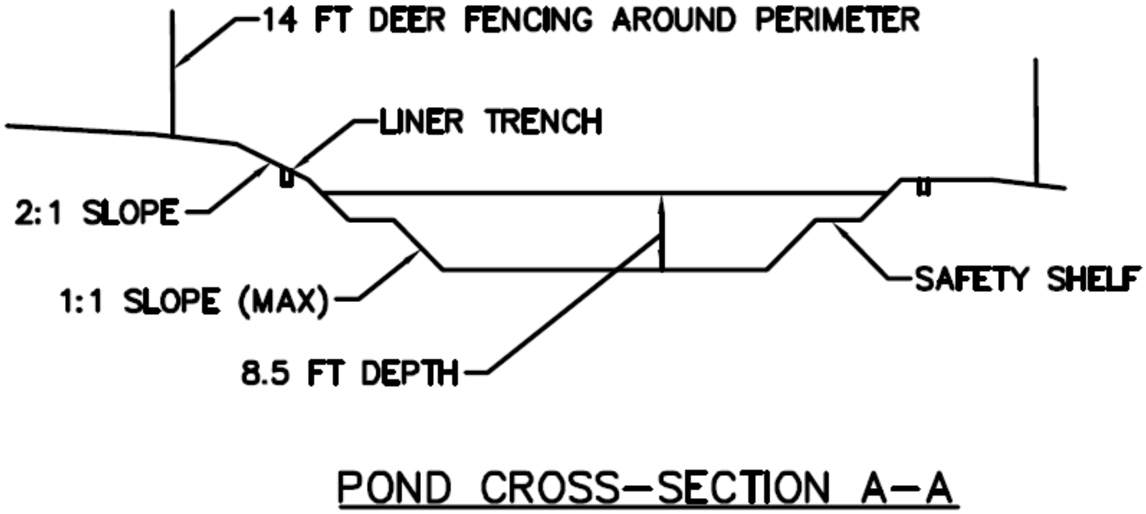


Figure 18b - 650,000-gallon Irrigation Storage Pond near Sump-Well (1:1 Max Side Slope, Fenced for Security) - Cross-Section

The advantages of the 650,000-gallon storage pond are:

1. Lower per-gallon-stored cost
2. The certainty of a large volume of water stored ahead of the irrigation season

The disadvantages of the pond are as follow:

1. Significant evaporation loss of water
2. Large footprint
3. Open ponds are subject to algae growth (an issue for micro-irrigation systems)
4. Open ponds are potential safety issues, attracting wildlife and humans - this would require the additional cost of a 14-foot fence
5. The proposed pond configuration would require pumping of stored water from the pond to the storage tank located at the highest elevation at the site. This might require the additional cost of an upgraded solar-powered pump.

8.0 Environmental Considerations

A critical element for consideration as part of this evaluation is the impact of this agricultural development on the environment. In respect to the options considered in this document, the following advantages/disadvantages of each of the options considered are as follow:

Storm Water Capture:

Advantages:

1. Reduces the use of groundwater for irrigation
2. Prevents surface water discharge through both treatment and beneficial reuse

Disadvantages:

1. Risk of contamination of truffle crop (judged to be fatal flaw for this option).

Open Pond Storage:

Advantages:

1. The certainty of a large volume of water stored ahead of the irrigation season
2. Could reduce the pumping of groundwater during the irrigation season

Disadvantages:

1. Significant water loss to evaporation
2. Large footprint and major site disturbance during construction
3. Need to pump water from pond up to the tank to achieve adequate irrigation pressures
4. Open ponds can become source for mosquito breeding, algae growth, etc. (though aeration can be provided by a solar-powered air diffusion system to limit this impact)
5. Risk for wildlife and humans

Closed Tank Storage:

Advantages:

1. Higher storage efficiency due to minimal evaporation (less pumping from wells and sump-well required)
2. Smaller footprint and little disturbance of site during tank installation
3. Easier to add additional storage
4. Lower risk of contamination of water due to algae or blowing fungi spores

Disadvantages:

1. Smaller volume of water stored ahead of the irrigation season
2. Shorter life span than earthen reservoirs, requiring eventual reconstruction of tanks (manufacturer's warranty extends to 7 years on panels and liner)

From a strictly environmental perspective, the reclamation of storm water is the most attractive option; however, the risk of contamination to the truffle orchard is determined to be unacceptable. Therefore, the most attractive remaining option from an environmental impact perspective is the construction of closed storage tanks for the storage of groundwater from the deep wells and the sump-well. By covering the tank(s) the owner will significantly reduce evaporation. The solar-powered, slowly pumping wells and sump-well, coupled with storage and highly efficient micro-irrigation designed to minimize water loss, all make for a very low impact farm. Pumping/collecting groundwater in the wet season and slow pumping in general puts significantly lower pressure on the aquifer than a full-quantity irrigation system. The total estimated impact of the farm on the ground water resource is less than 2 gpm at the maximum rate.

9.0 Project Recommendations

Phase 1 Improvements

Based on the analysis included in this report, we strongly advise La Creole Orchards to pursue the following improvements (see Phase 1 Improvements on Figure 19 in blue):

1. Secure water rights for use of groundwater from the sump-well;
2. Secure water rights to appropriate for storage up to 3 acre feet of groundwater (2 acre feet to be appropriated during the November 1 to June 30 period, and 1 acre foot to be added as "pond maintenance" year-around, including from July 1 to October 31);
3. Install a covered tank with a capacity of 35,400 gallons at highest elevation at the site, as an immediate stop-gap measure for 2013 and possibly until 2016;
4. Install a solar-powered pumping station (up to 9.6 gpm with 1,000 watts of solar PV panels) and 2" pipeline to deliver water from the sump-well to the covered tank;
5. Install a solar-powered air diffuser to maintain algae-free water in the sump-well;
6. Possibly spot seal and/or slightly expand the sump-well.

Phase 2 Improvements

The following improvements could be undertaken in Phase 2 (see Phase 2 Improvements on Figure 19 in yellow), no later than 2016:

1. Install a second covered tank with a capacity of up to 125,500 gallons near the first tank (the two tanks would be connected);
2. Possibly construct a spring-box of a seepage-type design to capture the maximum amount of groundwater from the sump-well;
3. Possibly construct an open pond near the sump-well (at an elevation a few feet lower than the minimum level of the sump-well hole), to store up to 650,000 gallons. The solar-powered pumping station installed in Phase 1 at the sump-well would be moved to the pond, and a larger solar-powered air diffuser would be installed in the pond.

Phase 3 Improvements

In Phase 3, the open pond might be undertaken, if it was not already constructed in Phase 2.

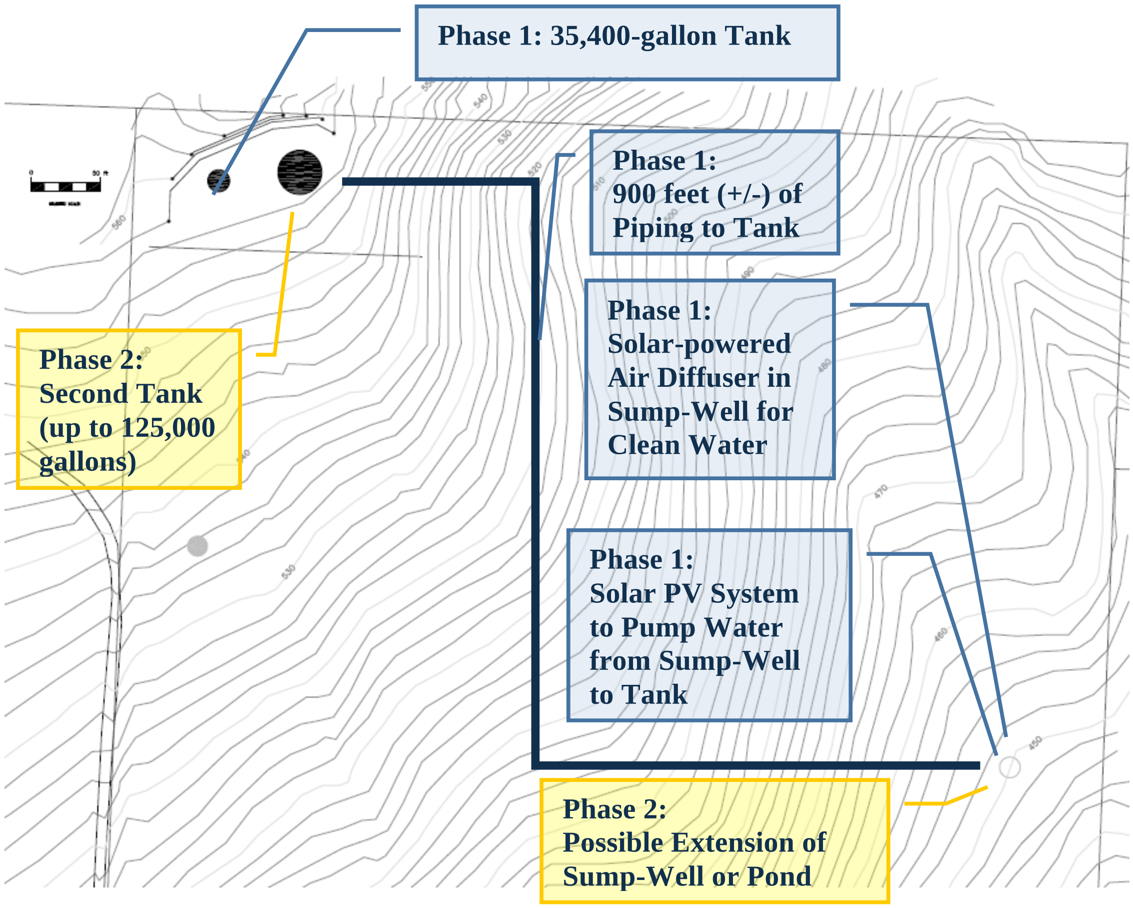


Figure 19 – Recommended Water Storage/Use Improvement Projects for La Creole Orchards (Phases 1 & 2)

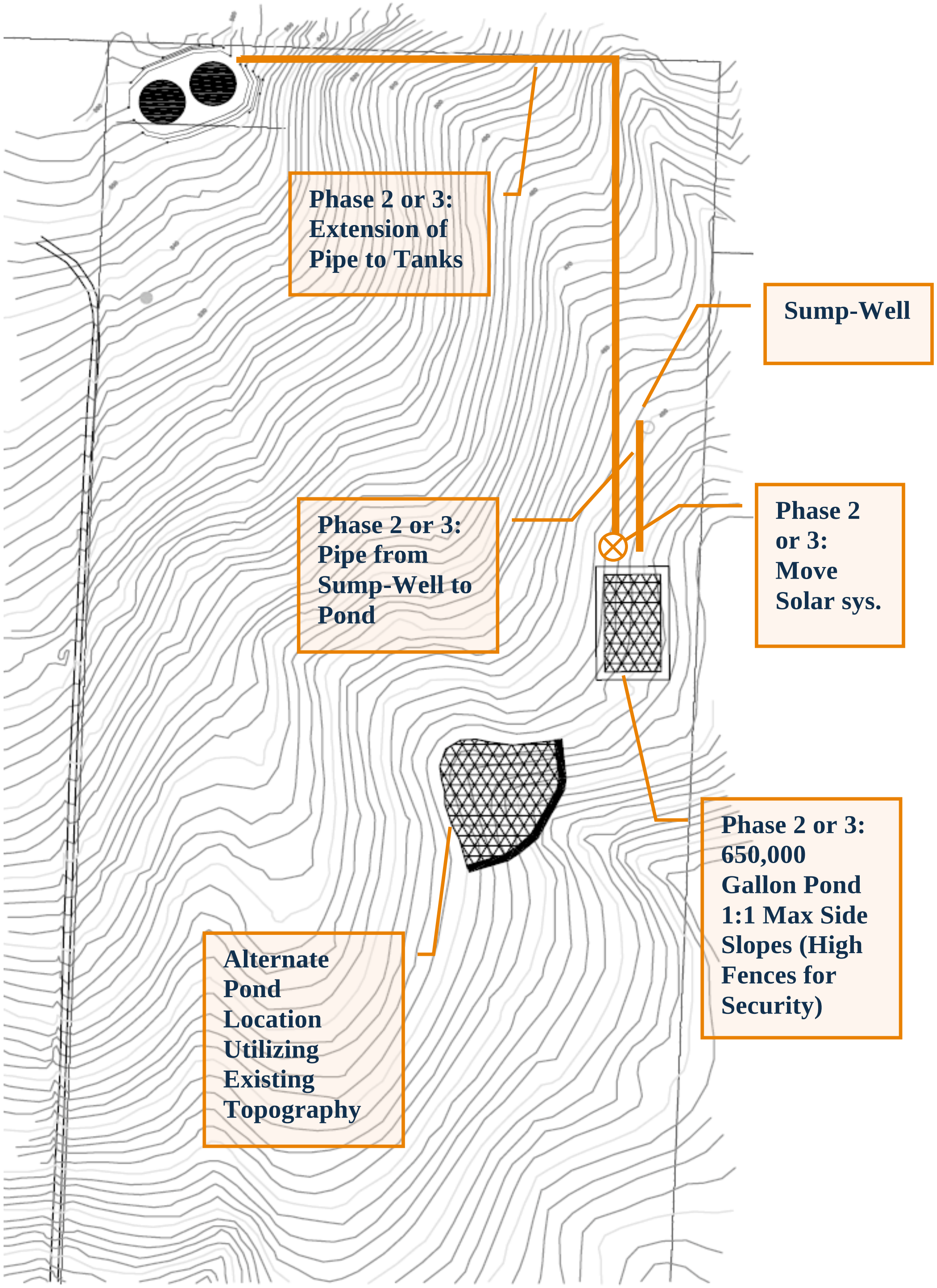


Figure 20 - Recommended Pond Development Project for La Creole Orchards (Phase 2 or 3)