CINNAMON CREEK CAMPGROUND POWER SUPPLY FEASIBILITY STUDY

Project ID: CEEn_2016CPST_011

by

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A Capstone project submitted to

Roy McDaniel

The Church of Jesus Christ of Latter Day Saints

Department of Civil and Environmental Engineering

Brigham Young University

April, 2017

PROJECT TITLE: Cinnamon Creek Campground Power Supply Feasibility Study
PROJECT ID: CEEn-2016CPST-011
PROJECT SPONSOR: The Church of Jesus Christ of Latter Day Saints
TEAM NAME: J.A.M. Engineering

EXECUTIVE SUMMARY

The following feasibility study was completed by request of and is presented to Mr. Roy McDaniel. Said study was performed to consider an appropriate method to supply power to the Cinnamon Creek Campground. Cinnamon Creek Campground is owned and operated by the Church of Jesus Christ of Latter-day Saints. It is used primarily as a recreational property in the summer, providing a venue for large group events. During the winter months the campground is unused. Power is used to light bathrooms, light pavilions, run sound systems, and provide for small appliances in the camp kitchens. Currently, campers use their own flashlights, lanterns, and generators to provide for their needs. The objective of this report is to present two possible systems capable of providing sufficient power to Cinnamon Creek Campground and provide cost estimates for the two systems. The greatest source of uncertainty in this study is the lack of historic power usage data. All calculations included herein are based on data provided by the requestor and conservative estimates. All assumptions are clearly listed in this report.

The first proposed system for providing power to Cinnamon Creek Campground integrates both solar and hydroelectric power, whereas the second proposed systems involves solely solar power. Both systems have comparable costs, however, due to the perceived preference of the facilities manager, we recommend that the first proposed system be implemented. We propose that the overflow from the lower spring box collection area be run through a pipe to the standing chlorination building. In the chlorination building we propose that a hydroelectric turbine be installed through which the water may be run before returning to the streambed to flow into the Little Bear River. This turbine would be used to provide power to the lower camp area. Solar panels may be installed on roofs of the facilities in the upper camp areas. A battery system may be used store the excess electricity from both the solar panels and hydroelectric turbines. Therefore, the hydroelectric generator will provide power to the bottom camp facilities, and the solar system will deliver power to the upper camp facilities. A detailed description of our proposed solution, and subsequent cost analysis findings are included in this report for the benefit of Mr. Roy McDaniel in his capacity as engineer for the Church of Jesus Christ of Latter-Day Saints. It is expected that further consultation from licensed engineers will be sought out by the before mentioned parties before either of these systems are executed.

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INTRODUCTION

The Cinnamon Creek Campground is located near Paradise, UT [Figure 4]. The Camp consists of nine separate camp areas spread out over two miles. The camp areas are situated along the base of a canyon with steep walls. Up to 1,100 campers may be attending events at Cinnamon Creek at any given time during the summer. The camp provides amenities such as RV parking, toilets, sinks, hot-showers, amphitheaters, and kitchens to its guests. However, the camp does not have any electricity or sufficient lighting at night for the patrons. The purpose of this project is to perform a feasibility study for installing solar panels and a hydro-electric generator. This electricity would be used to provide lighting throughout the pavilions in the campgrounds.

Due to the weather conditions, a camp site visit was not practical. Never having visited the camp site, we relied heavily on the camp facilities manager Steve for camp details. The camp is used each year from May through September. A power system should be expected to deliver power during the summer months. It should be recognized that J.A.M. Engineering does not employ any Professional Engineers. Any proposed solution for the Cinnamon Creek Campground power delivery systems should be reviewed by Roy McDaniel of the Church of Jesus Christ of Latter-day Saints, who will decide whether or not to implement our recommendations.

A challenge in this report was evaluating appropriate power demand. We conservatively assumed 4 hours of sunlight per day due to the steep canyon walls and limited direct sunlight. In addition, we added a safety factor of 6 kWh for miscellaneous usage to the total kilowatt-hours needed. The assumed life span of the project was 20 years. The 20-year life span cost estimates are broken down into yearly costs, combined with the total life span costs. The Hydroelectric generator specified a maintenance free 6-year lifespan. However, we chose 5 years as the lifespan to take into account the possibility of adverse operating conditions. Also included in this study, by request, is a lighting coverage calculation based off a conservative estimate using a single 8W LED bulb.

The remainder of this feasibility report will provide a full summary of the financial implications of each proposed design solution. The LDS Church may determine their future course of action based on this report in order to make a reliable decision on powering their facilities for campers at their Cinnamon Creek Campground.

SCHEDULE

Task	Timeline
Meetings and coordination	October-April
Collect Data	January - March
Analysis	February - March
Preliminary report	February
Design	March
Final Report	April
Poster and presentation	April

ASSUMPTIONS & LIMITATIONS

- Design life of 20 years
- Power demand of 12.5 KWh per day
- Sunlight of 4 hours per day
- Spring flow of 30 gallons per minute
- Solar panel options (250 W,280 W,320 W,350 W)
- Camp open for 5 months per year
- 800 lumen 8W LED bulbs used for lighting

POWER DEMANDS

The following tables were produced using estimates for lighting and power usage demand.

Table 1 – Lighting and power usage demands

Building	Area to light [ft^2]	Bulbs Needed	Demand [kW]
Upper Pavilion/Kitchen	5850	74	0.592
Upper Pavilion	5950	75	0.6
Upper Bathroom	230	3	0.024
Lower Pavilion/Kitchen	2250	29	0.232
Lower Bathroom 1	230	3	0.024
Lower Bathroom 2	1000	13	0.104
Total	15510	197	1.576

The above table was created under the assumption that 800 lumen bulbs would be used. In this study we assumed that lights would be utilized for about four hours each day. With the exception of external bathroom lights, which we assumed would be lit for nine hours each night.

SOLAR & HYDROELECTRIC POWER SOLUTION

Upper Camp Solar Details

The upper camp area consists of the Upper Pavilion, the Upper Pavilion-Kitchen, and the Upper Bathroom [Figure 5]. Lighting needs to be supplied to all of these facilities along with some additional power to the pavilions and kitchen for the use of sound and cooking equipment. It has been determined that there is sufficient sunlight during the summer to produce the needed power. Solar panels may be affixed to the roof of the Upper Pavilion [Figure 6], the Upper Pavilion-Kitchen [Figure 7], and the Upper Bathroom [Figure 8]. Figure 1 is a general graphical representation of power output vs the number of solar panels needed. As a result, variations may be easily calculated.

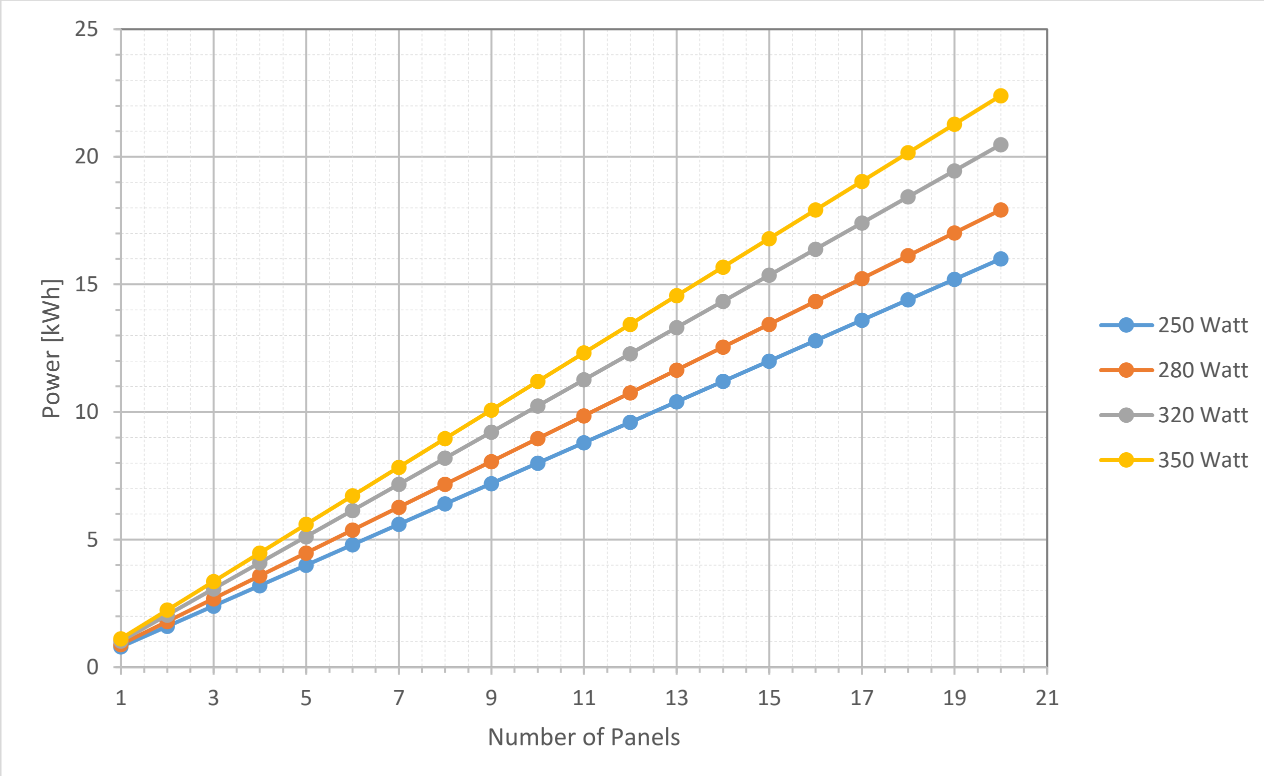

Figure 1 - Number and Type of Panels with Corresponding Power Output

Lower Camp Hydroelectric Details

One of the focuses of this study was to harnessing the hydraulic energy of the water from the existing spring. Currently, the spring collection box flows into a tank nearby until the tank is full. Once the tank has reached its storage capacity the spring box overflows into a creek bed. Said creek bed flows down into the canyon and eventually into the East Fork Little Bear River. A pipe may be fixed to the overflow outlet from the spring collection box. The pipe would run any overflow down the side of the canyon and through a turbine to produce power. The pipe would preserve the water's head as it flows. After passing the overflow through the turbine the pipe would then return it to the creek bed as shown in Figure 9.

This feasibility study was carried out with the assumption that the spring produced a flow of at least 30 gallons per minute. Figure 2 illustrates the potential power produced given the springs flowrate, the pipe size, and material used. Figure 2 was produced assuming that a turbine of 60% efficiency would be used. We assumed that during the day there would be enough water usage from the camp facilities to prevent any flow though the turbine. If the spring does produce a minimum of 30 gallons per minute, then the turbine should be capable of producing the needed power through the night after the tank has filled to capacity and begins to overflow. The provided drawings of the Cinnamon Creek campsite layout show the location of these facilities [Appendix D]. The calculations of the potential energy were done using equation 1 [below]. At the lower spring, there is 160 feet of elevation head. Head loss is dependent on the size of the water line installed to carry the overflow to the turbine. However, if the line is greater than 2 inches in diameter the losses should be negligible [Figure 2].

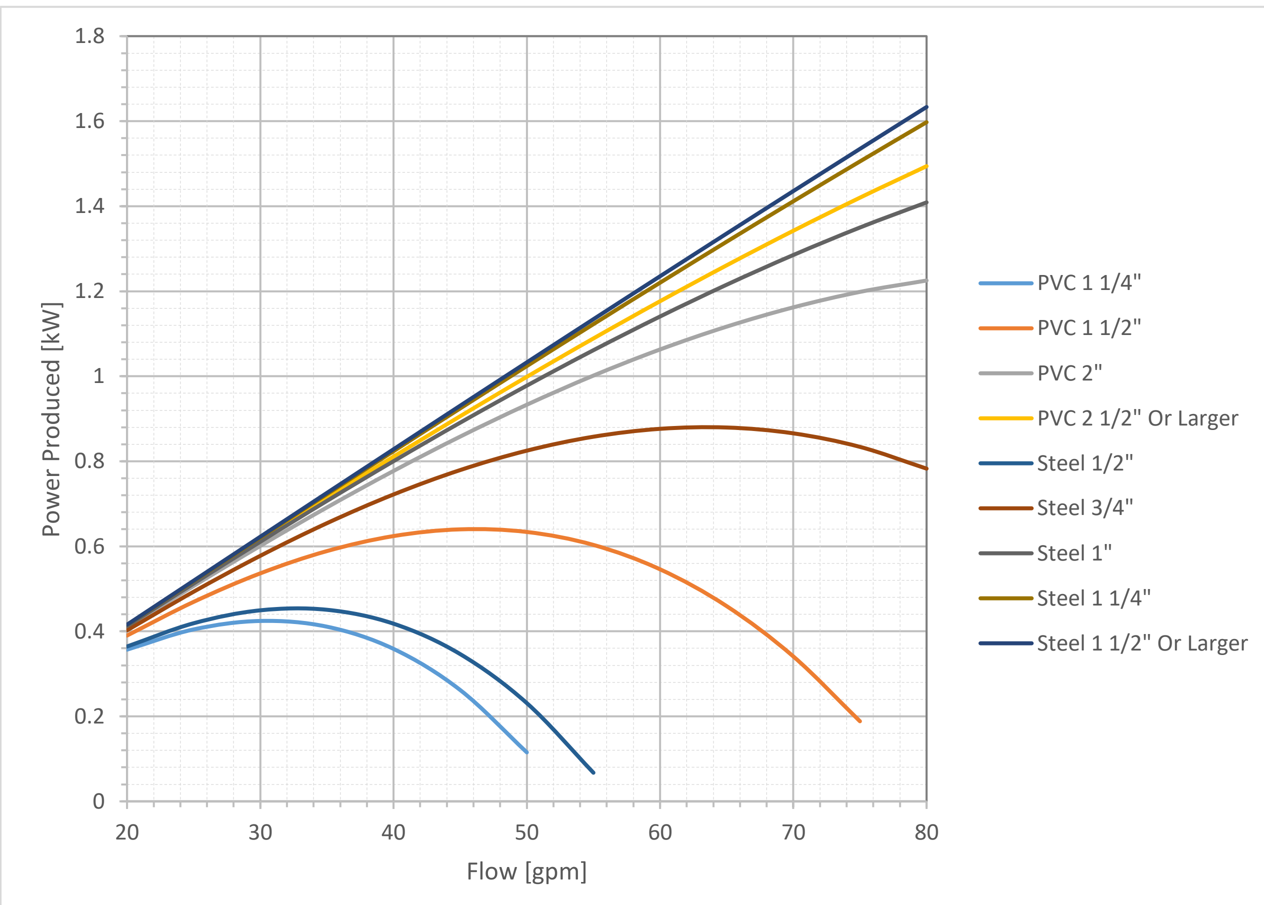

Figure 2 - Power Production by Line Size and Material

The power from elevation head of water was calculated as follows:

Equation 1:

$P = \rho\ q\ g\ h\ n$

P = power available (Watts)
ρ = density (kg/m3) (~ 1000 kg/m3 for water) q = water flow (m3/s)
g = acceleration of gravity(9.81m/s2)
h = elevation head (m)
n= efficiency of turbine (assume 60%, 0.6)

We calculated power based on a flow of 30 gallons per minute even though the maximum flow from the spring in the summer will likely be greater. The amount of power resulting from the given head and flow will power the necessary facilities in the lower camp area.

After further research into small hydroelectric turbines, it was found that a Pelton-type turbine [Figure 10] would best fit the site needs. The Pelton turbine passes water through nozzles; the water jet turns blades mounted on a wheel. The water then spins the wheel which powers an electric generator. We found the “PowerSpout” Pelton turbine to be of necessary quality. A picture of a “PowerSpout” turbine is shown in [Figure 10]. During peak hours the power will be used from battery storage. During low use, water will flow through the overflow and charge the batteries. The turbine will generate high amounts of energy during the night, then the storage will be used the following day. A qualified electrical professional should be contracted to connect the correct inverters to switch on and off during peak hours, along with running needed wires to each facility [Figure 11,Figure 12,Figure 13].

Solar & Hydroelectric Power Cost Estimate

For the purposes of this project, detailed lists of cost estimates were based off best gathered information. The following tables identify the estimated costs of the system [Table 2, Table 3]. All the materials and equipment used for this estimate are listed in Appendix B.

Table 2 – Cost estimates for solar/hydro solution

Solar				
	250 Watt	280 Watt	320 Watt	350 Watt
Number of Panels	10	9	8	8
Average Cost to Install [Price/Watt]	$4.43	$4.43	$4.43	$4.43
Cost to Install	$11,075.00	$11,163.60	$11,340.80	$12,404.00
Total Cost Over Life	$18,075.00	$17,763.60	$17,540.80	$18,604.00
Hydro				
Turbine	PowerSpout Hydro Turbine PLT			
Total Cost of Turbines	$7,600.00			
Total Cost of Pipe Installation	$6,660.00			
Total Cost Over Life	$14,260.00			
Storage				
Bank	Goal Zero Yeti			
Price	$1,599.99			
Total Price of Group of Banks	$17,599.89			
Total Cost of Banks Over Life	$126,399.21			
Wiring				
Total Material Cost	$8,360.00			
Installation cost	$7,620.00			
Total Cost	$15,980.00			

Table 3 – Total cost estimates for solar/hydro solution

	250 Watt	280 Watt	320 Watt	350 Watt
Total Cost	$174,714.21	$174,402.81	$174,180.01	$175,243.21
Cost/yr	$8,735.71	$8,720.14	$8,709.00	$8,762.16

SOLAR POWER SOLUTION

Upper Camp Solar Power Details

The recommendation of solar power supply to the upper camp area is no different for this solution option as it was for the previous. The upper camp area consists of the Upper Pavilion, the Upper Pavilion-Kitchen, and the Upper Bathroom. Lighting needs to be supplied to all of these facilities along with some additional power to the pavilions and kitchen for the use of sound and cooking equipment. It has been determined that there is sufficient sunlight during the summer to produce the needed power. Solar panels may be affixed to the roof of the Upper Pavilion, the Upper Pavilion-Kitchen, and the Upper Bathroom. The details of the placement of solar panels may be found in Appendix D.

Lower Camp Solar Power Details

In a similar fashion, solar panels may be affixed to the roofs of the lower campground facilities to provide power. The lower camp area consists of the Lower Bathroom 1, the Lower Pavilion-Kitchen, and the Lower Bathroom 2 [Figure 15]. Lighting needs to be supplied to all of these facilities along with some additional power to the pavilions and kitchen for the use of sound and cooking equipment. It has been determined that there is sufficient sunlight during the summer to produce the needed power. Solar panels may be affixed to the roof of the Lower Bathroom 2 [Figure 16]. Wires can be run from Lower Bathroom 2 to Lower Pavilion-Kitchen and to Lower Bathroom 1.

Solar Power Cost Estimate

For the purposes of this project, detailed lists of cost estimates were based off best gathered information. The following tables identify the estimated costs of the system [Table 4,Table 5] Specific detailed specs were not found, so cost was best estimated.

Table 4 – Cost Estimates for Solar Solution

Solar				
	250 Watt	280 Watt	320 Watt	350 Watt
Number of Panels	16	14	13	12
Average Cost to Install [Price/Watt]	$4.43	$4.43	$4.43	$4.43
Cost to Install	$17,720.00	$17,365.60	$18,428.80	$18,606.00
Total Cost Over Life	$27,120.00	$25,965.60	$26,628.80	$26,406.00
Hydro				
Turbine	PowerSpout Hydro Turbine PLT			
Total Cost of Turbines	$7,600.00			
Total Cost of Pipe Installation	$6,660.00			
Total Cost Over Life	$14,260.00			
Storage				
Bank	Goal Zero Yeti			
Price	$1,599.99			
Total Price of Group of Banks	$17,599.89			
Total Cost of Banks Over Life	$126,399.21			
Wiring				
Total Material Cost	$6,800.00			
Installation cost	$7,620.00			
Total Cost	$14,420.00			

Table 5 – Total Cost Estimates for Solar Solution

	250 Watt	280 Watt	320 Watt	350 Watt
Total Cost	$167,939.21	$166,784.81	$167,448.01	$167,225.21
Cost/yr	$8,396.96	$8,339.24	$8,372.40	$8,361.26

CONCLUSION

In summary, the first power supply system that we considered integrates hydraulic and solar sources, whereas the second proposed system involves solely solar power. Both systems may be installed at comparable cost. Nevertheless, we came to the conclusion that the first system should be installed. due to the perceived preference of the facilities manager, we recommend that the first proposed system be implemented. This system will provide for the power needs of the entire Cinnamon Creek Campground. Acknowledgement should be given to Dr. Borup of BYU, Dr. Lee of BYU, and Mr. Roy McDaniel of LDS AEC.

RECOMMENDATIONS

Both solutions provide the necessary power at similar costs. Incorporating the hydroelectric generator for the lower facilities allows greater use of the spring resource provided. For this reason, we propose the use of a system in which solar and hydroelectric power sources are integrated to meet demands. The particular setup that should be used is eight 320 Watt panels with the PowerSpout Hydro Turbine. With the proposed installation of the solar and hydroelectric power system, the electricity could be sufficient to power the entire camp facility needs. Table 6 compares the final costs between each system solution.

Table 6 - Cost comparison between solutions over 20 year lifespan (proposed solution bolded)

Solar/Hydro				
	250 Watt	280 Watt	**320 Watt**	350 Watt
Total Cost/yr/Watt	$0.00201	$0.00199	**$0.00197**	$0.00187
Total Cost	$174,714.21	$174,402.81	**$174,180.01**	$175,243.21
Cost/yr	$8,735.71	$8,720.14	**$8,709.00**	$8,762.16
Solar				
	250 Watt	280 Watt	320 Watt	350 Watt
Total Cost/yr/Watt	$0.00180	$0.00182	$0.00172	$0.00170
Total Cost	$167,939.21	$166,784.81	$167,448.01	$167,225.21
Cost/yr	$8,396.96	$8,339.24	$8,372.40	$8,361.26

APPENDIX

A - Resumes

Matthew Heninger
1874 S. 424 E.
Orem, UT 84058
(801) 420-5640
maheninger@gmail.com

Structural Engineering is fascinating and my skills and education have prepared me to be able to perform with precision and efficiency in this field. My work within sports teams and communication classes have made me a better team player and communicator. I would be a great fit on your team.

Skills

- Basic use of AutoCAD
- Basic knowledge in Revit
- Excellent in facilitating discussion

Education

Expected Dec. 2017

Bachelors of Science – Civil Engineering
Brigham Young University
- Learned many design software classes, such as AutoCAD and Revit
- Excelled in structural classes
- ASCE member

Sept. 2012-May 2014

Associates of Science with Integrated Studies
LDS Business College
- Acquired Certificate in Professional Sales
- Worked with many groups and teams and developed teamwork skills
- Took persuasive communications classes to improve communication with others

Work Experience

Aug. 2016 - Present

Project Manager
Vector Structural Engineers
Here I learned to work with other engineers and how engineers handle problems. I learned the basics of analyzing roof trusses and rafters.
- Learned how to distribute loads over a system.
- Began to learn basic software like Risa 3D
- Improved speed of computer skills.

Summer 2015

Site Development Crew Member
Brigham Young University Grounds
It is one thing to plan a construction job, but another to understand how it is carried out. Now I can plan my work so that it can be carried out by a crew easily.
- Functioned well within large crew
- Firsthand experience on how construction jobs are carried out

Alexander Barrow

abarrow91@gmail.com | (281) 912-4032 | www.linkedin.com/in/alexanderbarrow

EXPERIENCE

Workflow Automation Intern | Trailhead Engineering | Salt Lake City, Utah May 2016 - Present

- Offer of full time employment extended
- Maintain equipment datasheets as well as calculation tools and design software
- Write Visual Basic scripts that drive design software (backend and frontend). Focus on manipulating HYSYS

Cost Estimation Specialist | Trailhead Engineering | Salt Lake City, Utah September 2015 – May 2016

- Created and managed a procurement database, used primarily for cost estimation and capital planning
- Coordinated technical communications between engineering disciplines
- 90% accuracy of predicting certain equipment costs, accelerating bidding process greatly
- Drafted proposals and bids for prospective work

Project Engineer Intern | Trailhead Engineering | Salt Lake City, Utah May 2015 – September 2015

- Invited to continue working at the end of the internship
- On design team for a 40 MMSCFD LPG Plant, oversaw all pump and line sizing
- Saw plant through to commissioning, assisting in as-build design drafting and equipment logistics

Intellectual Property Intern | Novatek, a Schlumberger company | Provo, Utah April 2014 – April 2015

- Successfully won 3 patents
- Drafted patents related to cutting edge drilling technologies and coal extraction equipment
- Provided intellectual property asset value analysis to board members

Environmental Compliance Specialist | BYU Risk Management | Provo, Utah February 2014 – April 2014

- Worked to analyze air emissions laws and operating permits to ensure compliance to regulations

Roustabout | First American Oil Company LLC | Jim Hogg County, Texas March 2013 – August 2013

- Operated a producing asset, 110% production increase in 5 months
- Conveyed direction from engineers to contractors on a regular basis while assisting to oversee maintenance, construction, drilling and completion work done by contractors
- Interpreted drilling engineer's direction to Spanish speaking workers

Asset Recovery Worker | BTU Solutions | Kemah, Texas December 2010 – February 2011

- Assisted in the demolition and dismantling of a 2300MW power generating station with the objective of recovering valuable assets for resale

EDUCATION

BS Civil Engineering, Brigham Young University, December 2017

- Serves as Vice President of the Society of Petroleum Engineers Student Chapter at BYU
- Member of the SPE executive council for four years (two years as vice president)
- Member of ASCE

MISCELLANEOUS

- Extremely proficient with VBA, experience with C+
- Spanish fluency
- Experience with CAD systems such as, but not limited to NX8, CATIA, AutoCAD, HYSYS, ProE, Solid Works, Revitt, & SketchUp.
- Eagle Scout, BSA
- Served as a full time volunteer missionary in Tuxtla Gutierrez, Mexico from February 2011 until March 2013

JENCE KOFOED

801-960-7595
jencekofoed@gmail.com
Spanish Fork, UT

PROFESSIONAL PROFILE

- Entry-level engineer eager to find a challenging and rewarding engineering position with an ambitious company that offers opportunities for career development
- Comprehensive understanding of basic civil engineering principles
- Possess fundamental knowledge of reinforced concrete and steel design
- Proficient with CATIA/CAD, GIS, EXCEL, and MICROSOFT WORD

EDUCATION

BRIGHAM YOUNG UNIVERSITY
B.S. IN CIVIL ENGINEERING Major
GPA 3.58
Concentration on Structures
Provo, UT
April 2017

UTAH VALLEY UNIVERSITY
ASSOCIATES DEGREE Orem, UT
2012-2014

SKILLS

Optimistic
Innovative
Disciplined
Reliable
Effective problem solver
Fluent in Russian
Manual labor
Heavy equipment Operation
Team leadership
Adept to process information
Proficient communicator

EMPLOYMENT & WORK EXPERIENCE

Maintenance Manager
Affiliated First Title | Orem, UT | JANUARY 2013 – Present

- Manage the cleaning and building maintenance for a 6-office complex
- Budget for all supplies and cut previous costs by over 30 % in the first 3-6 months

Intern
Willowstick Technologies | Sandy, UT | JUNE 2015 – AUG 2015

- Conducted geophysical groundwater investigations, measured and recorded data
- Assisted with research and development in seismic electric techniques

Sales Representative
Berett Pest Control | Houston, TX | MAY 2013 – AUG 2013

- Attained top salesman out of a branch of 17 salesmen while working 70+ hours per week
- Generated over $60k in company revenue in 3 months

Project Manager
All-American Vinyl | Provo, UT | MARCH 2012 – AUG 2012

- Managed the precision, materials shop and oversaw warehouse labor and logistics
- Completed 50+ projects on time and within budget
- Increased shop efficiency and improved labor crew organization

VOLUNTEER EXPERIENCE

Full- time Missionary
The Church of Jesus Christ of Latter-day Saints | Donetsk, Ukraine|
FEBRUARY 2010 - MARCH 2012

- Appointed to the highest leadership position available to missionaries for 4 months
- Taught, trained and supervised 60+ full-time missionaries

Sarva T. Pulla

431 E 1600 S, Orem, Utah 84058
801-906-3191 sarvateja@gmail.com

Education

Brigham Young University — Expected Graduation April 2017
Master of Science: Civil Engineering — *Provo, Utah*
- Cumulative GPA: 3.71

Brigham Young University — December 2015
Bachelor of Science: Civil Engineering — *Provo, Utah*
- President BYU ASCE, *Fall 2015*
- Second Vice-President BYU ASCE, *Fall 2011 and Winter 2015*
- Teaching Assistant for Engineering Applications of GIS, *Fall 2015 and Fall 2016*
- Teaching Assistant for GIS Programming, *Winter 2016*
- Netherlands Water Resources Study Abroad Program, *Spring 2016*
- Chine Mega-Structures and Mega-Cities Study Abroad Program, *Spring 2015*

Work Experience

Brigham Young University — January 2016 – Present
Graduate Research Assistant — *Provo, Utah*
- Develop web applications for SERVIR Global hub
- Maintain worldwater.byu.edu (A Data Portal for Hydrologic Information)
- Integrate National Water Model into Tethys Framework (A Django based web-framework for developing web-applications)

Brigham Young University — August 2015 – Present
Teaching Assistant — *Provo, Utah*
- Helped with ongoing development and design of curriculum for CE 414 and CE 514
- Provided effective and timely feedback on lab assignments
- Taught a weekly lab section for CE 414

Brigham Young University — October 2014 – December 2015
Undergraduate Research Assistant — *Provo, Utah*
- Maintained and developed HydroServer Lite (A web application for managing, storing and retrieving hydrological information)
- Developed a web application for calculating ecosystems services for NRPA (National Recreation and Parks Association)

Volunteer Experience

The Church of Jesus Christ of Latter-day Saints
Missionary — January 2012 – January 2014
Queens, New York
- Taught others about the LDS Church
- Trained other missionaries in teaching and communication skills
- Coordinated religious and service activities with local leaders

B - Calculations

Table 7 - Watt usage of LED bulbs vs incandescent bulbs

Light Output	LED	ILB
Lumens	Watts	Watts
450	5	40
800	8	60
1100	13	75

Table 8 - Lighting specs, allowable number of panels, and bulb comparison

Lighting Specs			
Building		Area to Cover [ft^2]	# of Fitting Panels to Pass Code
Upper Pavilion/Kitchen		5850	13
Upper Pavilion		5950	48
Upper Bathroom		230	3
Lower Pavilion/Kitchen		2250	19
Lower Bathroom 1		230	5
Lower Bathroom 2		1000	0
Total		15510	
Lumens/ft^2		Lumens Needed [L]	
10		155100	
Incandescent Bulb Equivalent	# Bulbs Needed	LED Usage [kW]	ILB Usage [kW]
40 W Bulb	344.6666667	1.723333333	13.78666667
60 W Bulb	193.875	1.551	11.6325
75 W Bulb	141	1.833	10.575

Table 9 - Number of each bulb needed

Building	Area to Cover [ft^2]	450 Lumen Bulbs Needed	Usage [kW]	800 Lumen Bulbs Needed	Usage [kW]	1100 Lumen Bulbs Needed	Usage [kW]
Upper Pavilion/Kitchen	5850	130	0.65	74	0.592	54	0.702
Upper Pavilion	5950	133	0.67	75	0.6	55	0.715
Upper Bathroom	230	6	0.03	3	0.024	3	0.039
Lower Pavilion/Kitchen	2250	50	0.25	29	0.232	21	0.273
Lower Bathroom 1	230	6	0.03	3	0.024	3	0.039
Lower Bathroom 2	1000	23	0.12	13	0.104	10	0.13
Totals	15510	348	1.74	197	1.576	146	1.898

Table 10 - Total kWh usage of camp per day for 800 lumen bulb

Watts Needed for Camp Using 800 Lumen Bulbs		
Building	Run Time [hrs]	Total Usage [kWh]
Upper Pavilion/Kitchen	4	2.368
Upper Pavilion	4	2.4
Upper Inside Bathroom	2	0.048
Upper Outside Bathroom	9	0.144
Lower Pavilion/Kitchen	4	0.928
Lower Inside Bathroom 1	2	0.048
Lower Outside Bathroom 1	9	0.144
Lower Inside Bathroom 2	2	0.208
Lower Outside Bathroom 2	9	0.144
	Total	6.432

Table 11 - Hydro/solar system usage breakdown

Watts Needed for Camp Using 800 Lumen Bulbs		
Building	Hydro Usage [kWh]	Solar Usage [kWh]
Upper Pavilion/Kitchen	0	2.368
Upper Pavilion	0	2.4
Upper Inside Bathroom	0	0.048
Upper Outside Bathroom	0	0.144
Lower Pavilion/Kitchen	0.928	0
Lower Inside Bathroom 1	0.048	0
Lower Outside Bathroom 1	0.144	0
Lower Inside Bathroom 2	0.208	0
Lower Outside Bathroom 2	0.144	0
Totals	1.472	4.96

Table 12 - Solar only usage breakdown

Watts Needed for Camp Using 800 Lumen Bulbs		
Building	Run Time [hrs]	Total Usage [kWh]
Upper Pavilion/Kitchen	4	2.368
Upper Pavilion	4	2.4
Upper Outside Bathroom	9	0.048
Upper Inside Bathroom	2	0.144
Lower Pavilion	4	0.928
Lower Inside Bathroom 1	2	0.048
Lower Outside Bathroom 1	9	0.144
Lower Inside Bathroom 2	2	0.208
Lower Outside Bathroom 2	9	0.144
	Totals	6.432

Table 13 - Solar information for 250 Watt panel system of solar/hydro system

SOLAR (250 Watt Panel System)					
Panel Information					
Panel Rating [W]	Life Span [yrs]	Average Cost to Install [Price/Watt]	Inspection Cost/yr	Cleaning Cost/Panel/yr	Area of Panel [ft^2]
250	20	$ 4.43	$ 150.00	$ 20.00	17.60
Solar Demands					
Need/Day with Safety [kWh]	Sunlight/Day [hrs]	AC Power Needed [kW]	DC Power Needed [kW]	Number of Panels	
7.96	4	1.99	2.4875	10.0	
Costs					
	Cost to Install	Install Cost/yr	Maintenance Cost/yr	Total Cost Over Life	
	$11,075.00	$553.75	$350.00	$18,075.00	
Cost Comparison					
		Total Area Needed [ft^2]	Cost/yr		
		176.0417	$903.75		

Table 14 - Solar information for 280 Watt panel system of solar/hydro system

SOLAR (280 Watt Panel System)					
Panel Information					
Panel Rating [W]	Life Span [yrs]	Average Cost to Install [Price/Watt]	Inspection Cost/yr	Cleaning Cost/Panel/yr	Area of Panel [ft^2]
280	20	$ 4.43	$ 150.00	$ 20.00	17.60
Solar Demands					
Need/Day with Safety [kWh]	Sunlight/Day [hrs]	AC Power Needed [kW]	DC Power Needed [kW]	Number of Panels	
7.96	4	1.99	2.4875	9.0	
Costs					
	Cost to Install	Install Cost/yr	Maintenance Cost/yr	Total Cost Over Life	
	$11,163.60	$558.18	$330.00	$17,763.60	
Cost Comparison					
		Total Area Needed [ft^2]	Cost/yr		
		158.4375	$888.18		

Table 15 - Solar information for 320 Watt panel system of solar/hydro system

SOLAR (320 Watt Panel System)					
Panel Information					
Panel Rating [W]	Life Span [yrs]	Average Cost to Install [Price/Watt]	Inspection Cost/yr	Cleaning Cost/Panel/yr	Area of Panel [ft^2]
320	20	$ 4.43	$ 150.00	$ 20.00	17.60
Solar Demands					
Need/Day with Safety [kWh]	Sunlight/Day [hrs]	AC Power Needed [kW]	DC Power Needed [kW]	Number of Panels	
7.96	4	1.99	2.4875	8.0	
Costs					
	Cost to Install	Install Cost/yr	Maintenance Cost/yr	Total Cost Over Life	
	$11,340.80	$567.04	$310.00	$17,540.80	
Cost Comparison					
		Total Area Needed [ft^2]	Cost/yr		
		140.833333	$877.04		

Table 16 - Solar information for 350 Watt panel system of solar/hydro system

SOLAR (350 Watt Panel System)					
Panel Information					
Panel Rating [W]	Life Span [yrs]	Average Cost to Install [Price/Watt]	Inspection Cost/yr	Cleaning Cost/Panel/yr	Area of Panel [ft^2]
350	20	$ 4.43	$ 150.00	$ 20.00	17.60
Solar Demands					
Need/Day with Safety [kWh]	Sunlight/Day [hrs]	AC Power Needed [kW]	DC Power Needed [kW]	Number of Panels	
7.96	4	1.99	2.4875	8.0	
Costs					
	Cost to Install	Install Cost/yr	Maintenance Cost/yr	Total Cost Over Life	
	$12,404.00	$620.20	$310.00	$18,604.00	
Cost Comparison					
		Total Area Needed [ft^2]	Cost/yr		
		140.8333333	$930.20		

Table 17 - Hydroelectric turbine system for all solar panel combinations

HYDRO (All Solar System Combinations)					
Hydro Demands and Parameters					
Need/Day with Safety [kWh]	Flow [gpm]	Head [ft]	Density of Water [kg/m^3]	Gravity [m/s^2]	Flow Time/Day [hrs]
4.472	30	160	1000	9.81	9
Turbine Information					
Lifespan [yrs]	Number of Generators over Project	Turbine	Efficiency	Length of Pipe [ft]	Price of Material [Pipe/ft]
5	4	PowerSpout Hydro Turbine PLT	60.00%	750	$ 0.88
Hydro Power					
Flow [m^3/s]	Head [m]	Power Produced [kW]	Energy Produced/hr [kWh]	Energy Produced/Day [kWh]	Usable Power/Day [kWh]
0.001892706	48.768	0.543298	0.54329832	4.88968488	3.9117479
Costs					
Cost of Turbine	Total Cost of Turbines	Cost of Pipe Installation/ft	Total Cost of Pipe Installation	Total Cost	Cost/yr
$ 1,900.00	$ 7,600.00	$ 8.00	$ 6,660.00	$ 14,260.00	$ 713.00

Table 18 - Wiring for all solar/hydro systems

Wiring				
Material Cost [Price/ft]	Total Length [ft]	Total Material Cost	Installation Cost	Cost/yr
$ 8.00	1045	$ 8,360.00	$ 7,620.00	$ 799.00

Table 19 - Solar information for 250 Watt panel system of solar system

SOLAR (250 Watt Panel System)					
Panel Information					
Panel Rating [W]	Life Span [yrs]	Average Cost to Install [Price/Watt]	Inspection Cost/yr	Cleaning Cost/Panel/yr	Area of Panel [ft^2]
250	20	$ 4.43	$ 150.00	$ 20.00	17.60
Solar Demands					
Need/Day with Safety [kWh]	Sunlight/Day [hrs]	AC Power Needed [kW]	DC Power Needed [kW]	Number of Panels	
12.432	4	3.108	3.885	16.0	
Costs					
	Cost to Install	Install Cost/yr	Maintenance Cost/yr	Total Cost Over Life	
	$17,720.00	$886.00	$470.00	$27,120.00	
Cost Comparison					
		Total Area Needed [ft^2]	Cost/yr		
		281.666667	$1,356.00		

Table 20 - Solar information for 280 Watt panel system of solar system

SOLAR (280 Watt Panel System)					
Panel Information					
Panel Rating [W]	Life Span [yrs]	Average Cost to Install [Price/Watt]	Inspection Cost/yr	Cleaning Cost/Panel/yr	Area of Panel [ft^2]
280	20	$ 4.43	$ 150.00	$ 20.00	17.60
Solar Demands					
Need/Day with Safety [kWh]	Sunlight/Day [hrs]	AC Power Needed [kW]	DC Power Needed [kW]	Number of Panels	
12.432	4	3.108	3.885	14.0	
Costs					
	Cost to Install	Install Cost/yr	Maintenance Cost/yr	Total Cost Over Life	
	$17,365.60	$868.28	$430.00	$25,965.60	
Cost Comparison					
		Total Area Needed [ft^2]	Cost/yr		
		246.4583333	$1,298.28		

Table 21 - Solar information for 320 Watt panel system of solar system

SOLAR (320 Watt Panel System)					
Panel Information					
Panel Rating [W]	Life Span [yrs]	Average Cost to Install [Price/Watt]	Inspection Cost/yr	Cleaning Cost/Panel/yr	Area of Panel [ft^2]
320	20	$ 4.43	$ 150.00	$ 20.00	17.60
Solar Demands					
Need/Day with Safety [kWh]	Sunlight/Day [hrs]	AC Power Needed [kW]	DC Power Needed [kW]	Number of Panels	
12.432	4	3.108	3.885	13.0	
Costs					
	Cost to Install	Install Cost/yr	Maintenance Cost/yr	Total Cost Over Life	
	$18,428.80	$921.44	$410.00	$26,628.80	
Cost Comparison					
		Total Area Needed [ft^2]	Cost/yr		
		228.8541667	$1,331.44		

Table 22 - - Solar information for 350 Watt panel system of solar system

SOLAR (350 Watt Panel System)					
Panel Information					
Panel Rating [W]	Life Span [yrs]	Average Cost to Install [Price/Watt]	Inspection Cost/yr	Cleaning Cost/Panel/yr	Area of Panel [ft^2]
350	20	$ 4.43	$ 150.00	$ 20.00	17.60
Solar Demands					
Need/Day with Safety [kWh]	Sunlight/Day [hrs]	AC Power Needed [kW]	DC Power Needed [kW]	Number of Panels	
12.432	4	3.108	3.885	12.0	
Costs					
	Cost to Install	Install Cost/yr	Maintenance Cost/yr	Total Cost Over Life	
	$18,606.00	$930.30	$390.00	$26,406.00	
Cost Comparison					
		Total Area Needed [ft^2]	Cost/yr		
		211.25	$1,320.30		

Table 23 - Wiring for all solar only systems

Wiring				
Material Cost [Price/ft]	Total Length [ft]	Total Material Cost	Installation cost	Cost/yr
$ 8.00	850	$ 6,800.00	$ 7,620.00	$ 721.00

Table 24 - System storage for all systems

STORAGE				
Bank Information				
Bank	Lifespan [cycles]	Price	Capacity [kWh]	
Goal Zero Yeti	500	$ 1,599.99	1.2	
Demands				
Cycles/day	Usage Days/yr	Number of Banks Needed For Solar	Number of Banks Needed For Hydro	Total Number of Banks
1	153	7	4	11
Capacities				
	Lifespan [yrs]	Number of Banks Over System Life	Total Capacity of Group [kW]	
	3.267	79	13.2	
Costs				
	Total Price of Group of Banks	Total Cost of Banks Over System Life	Cost/yr	
	$ 17,599.89	$ 126,399.21	$ 6,319.96	

C - Equipment Details

- Hydro Turbine – PowerSpout Hydro Turbine ME
- Pipe of preference
- Solar Panels – 250, 280, 320, 350 watt panels
- Outdoor electrical wiring
- (Goal zero YETI) Battery Bank

D - Contacts

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E - Drawings

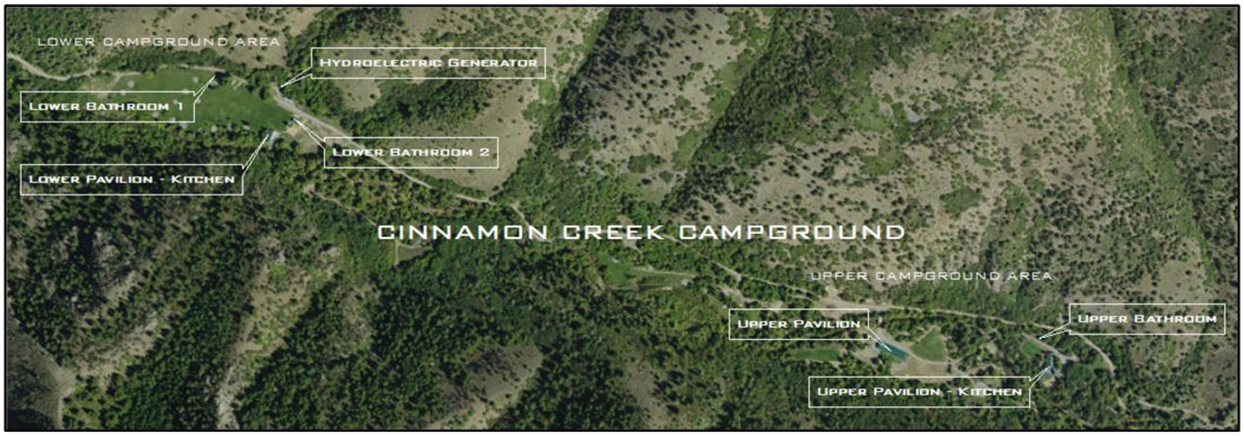

Figure 3 – Cinnamon creek campground

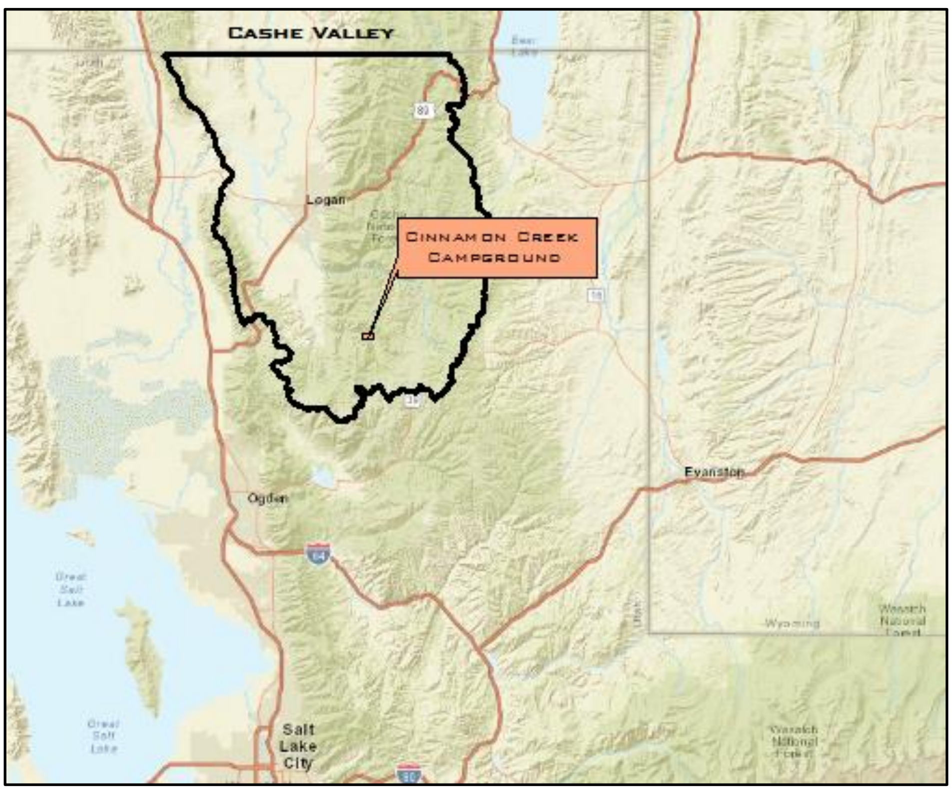

Figure 4 – Cinnamon creek campground location

Figure 5 – Upper campground solar layout

Figure 6 – Upper Pavilion

Figure 7 – Upper Pavilion-Kitchen

Figure 8 – Upper Bathroom

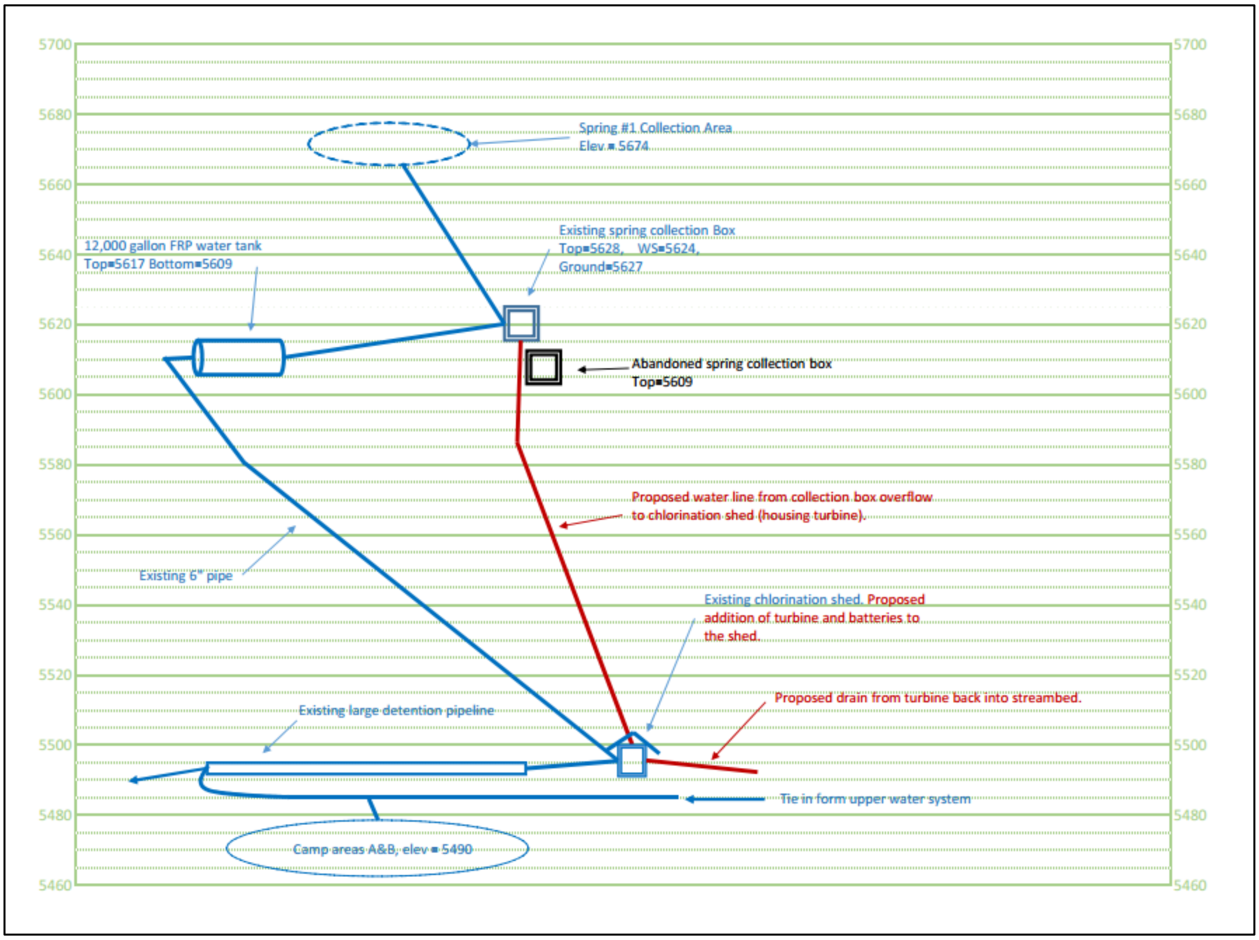

Figure 9 – Hydraulic grade line

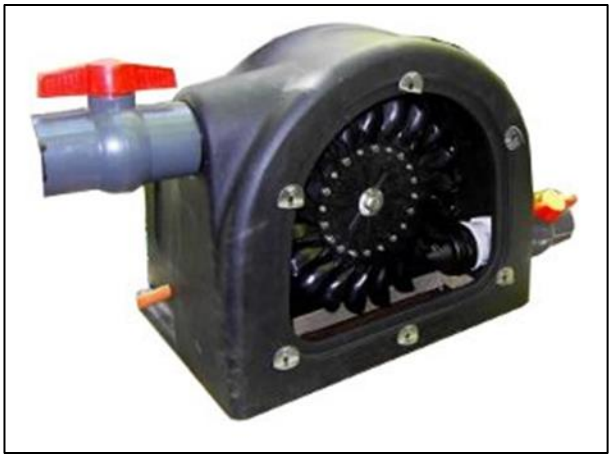

Figure 10 – Hydroelectric Generator

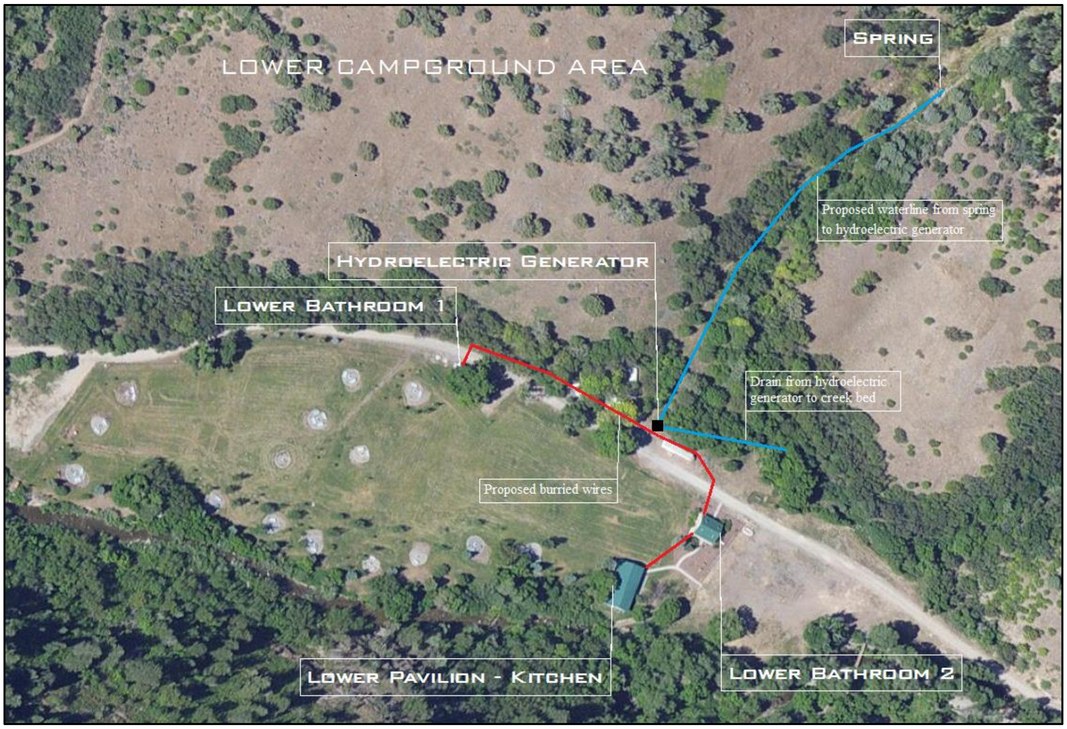

Figure 11 – Lower campground hydroelectric power layout

Figure 12 – Lower Bathroom 2 and pavilion-kitchen hydroelectric power layout

Figure 13 – Lower Bathroom 1 hydroelectric power layout

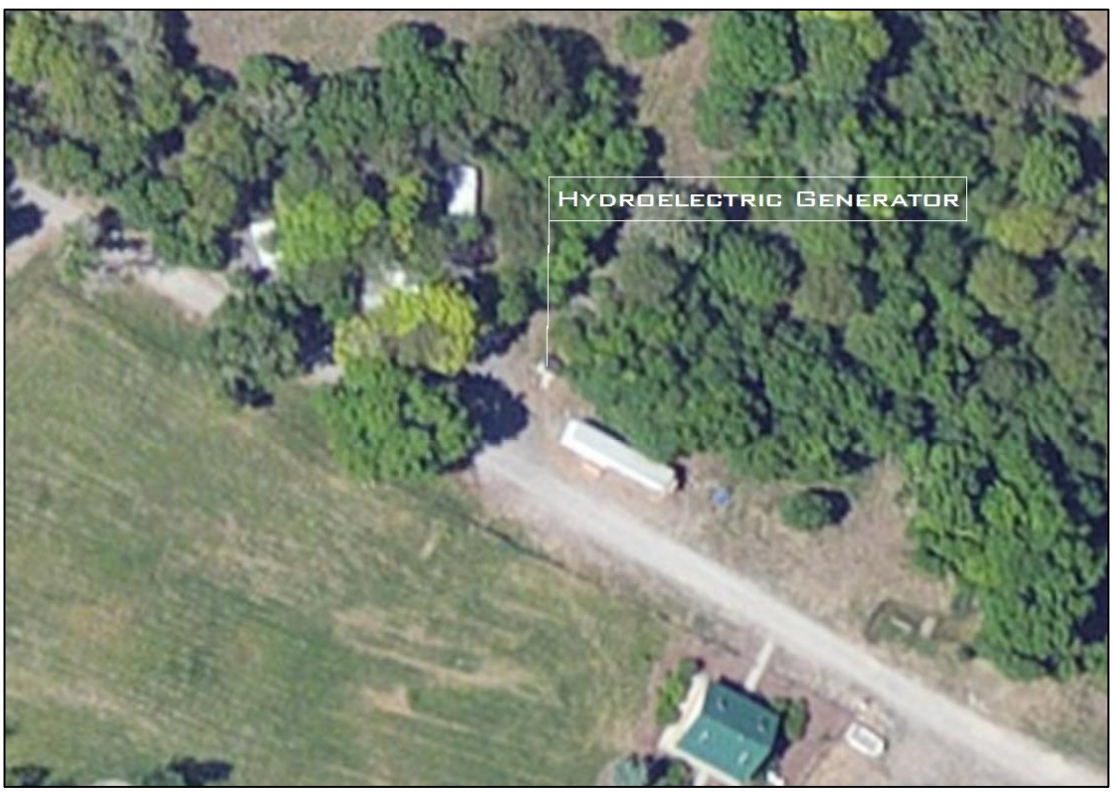

Figure 14 – Hydroelectric generator

Figure 15 – Lower campground solar power layout

Figure 16 – Lower Bathroom 2

Figure 17 - Lower Campground Area

Figure 18 - Lower Campground Area with Spring

F - Sources

SOLAR
www.solarreviews.com
-Installation costs

http://reneweconomy.com.au/hidden-cost-of-rooftop-solar-who-should-pay-for-maintenance-99200/
-Solar maintenance

www.understandsolar.com/calculating-kilowatt-hours-solar-panels-produce/
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-Sunlight hours per day in area

https://cleantechnica.com/2015/10/19/how-long-will-solar-panels-last/
-Lifespan of panels

HYDRO
www.energy.gov/energysaver/planning-microhydropower-system
-Simple Energy formula

http://www.engineeringtoolbox.com/hydropower-d_1359.html
-Detailed Energy formula

http://www.engineeringtoolbox.com/water-density-specific-weight-d_595.html
-Density of water in slugs

Sprinkler Supply Company (Logan)
-Cost of 2" pvc pipe

www.aurorapower.net/products/categoryid/4/list/1/level/a/productid/325.aspx
-Turbine

STORAGE
http://www.goalzero.com/p/140/goal-zero-yeti-1250-solar-generator
-Goal Zero Yeti

LIGHT
www.designrecycleinc.com/led%20comp%20chart.html
-Lighting chart

www.maximlighting.com/how-much-light
-Lumens needed

WIRING

https://www.fixr.com/costs/electrical-wiring

-Price per foot

https://www.homewyse.com/services/cost_to_install_electrical_wiring.html

-Installation costs

www.homeadvisor.com/cost/electrical/

-Installation costs

G – LESSONS LEARNED

Challenges:

- Researching and finalizing demand data
- Could not complete a site visit
- Intervals with little communication with project manager and sponsor
- Establishing a clear presentation for data

Lessons:

- Early and consistent team efforts made researching the data less demanding.
- Many hands make light work.
- Understanding what red tape was necessary and what was not saved us a lot of time.
- Communicating in a professional and effective manner helped give direction and focus.
- Adapting to changes helps mold a professional report.
- Checking work again and again sands a report into a smooth flowing report.
- Sometimes, you have to make assumptions and run with it.
- Utilize resources, such as calling companies and talking with professors.