CAMP BEN LOMOND AND CAMP SHAWNEE WATER TANK ANALYSIS
Project ID: CEEn_2017CPST_012

by

Genesis Engineering
Seth Richardson
Michael Reynolds
Kyler Ashby
Jeremy Fowler

A Capstone Project Final Report
Submitted to

Roy McDaniel & Steve Terry
The Church of Jesus Christ of Latter Day Saints

Department of Civil and Environmental Engineering
Brigham Young University

04/17/18

Executive Summary

PROJECT TITLE: Church Camp Water Tank Analysis
PROJECT ID: CEEn-2017CPST-012
PROJECT SPONSOR: The Church of Jesus Christ of Latter-Day Saints
TEAM NAME: Genesis Engineering

Two water tanks that supply water to the Ben Lomond and Shawnee Campgrounds near Liberty, UT were inspected in order to determine the best course of action in improving them. After two site inspections, non-destructive materials testing, and consultation of experts, recommendations were decided upon for the improvement of the tanks. The recommended improvements are:

1. Replace the T-switch valve near the raw water tank with two seperate intake lines.
2. Coat the top and inside of each tank with Xypex.
3. Perform further advanced testing within the next 10 years.
    a. Cover-meter test
    b. Resistivity test
    c. Half-cell electrical potential test (optional)
    d. Ultrasonic test (optional)

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Introduction

Two concrete water tanks are currently in use at Ben Lomond and Shawnee Campground, just North of Liberty, Utah. These tanks are owned and operated by The Church of Jesus Christ of Latter-Day Saints. One tank is a raw water tank, where water from two spring sources and one domestic source is stored. The other tank stores the water after treatment to be used throughout the campground. Currently, the raw water tank can only accommodate having one source open at a time to fill the tank. The client desired to be more efficient in usage and to have multiple sources open at a time. Our task was to determine what changes are needed to accommodate these requests.

Also, due to the tanks having been in operation for an extended period, an evaluation of the tanks was performed to determine what needs to be done. Specifically, the evaluation determined whether the tanks need to be replaced, refurbished, or are acceptable for the immediate future. Said evaluation was done to ensure that water needs for the campground are met, while at the same time helping the client avoid any unnecessary expenditures. A cost analysis was generated to help the client determine the best course of action.

Schedule

Important Dates:

9/14/17 - Project Assigned
10/21/17 - Site Visit #1
11/02/17 - Project Proposal Submitted
1/11/18 - Meeting with graduate student advisor
1/11/18 - 2/26/18 - Various coordination meetings
2/26/18 - 50% report submitted
3/10/18 - Site Visit #2
4/10/18 - Presentation to Sponsor
4/12/18 - Presentation at BYU
4/12/18 - Poster Presentation in Clyde Building at BYU
4/17/18 - Final Report Submitted

Assumptions & Limitations

Limitations included inability to access advanced testing equipment. Advanced testing equipment for concrete water tanks is very expensive and requires a qualified professional to operate. For these reasons, testing on the structure of the concrete tanks was limited. Another impactful limitation was that concrete tanks did not have engineering plans that could be found. Not having engineering plans made it difficult to estimate the structural strength of the concrete tanks, as well as the details of their connections.

Design, Analysis & Results

Observations

In October 2017, a preliminary site visit was performed to observe the general condition of the two water tanks. This visit helped to better reveal the scope of the project. From the site visit we could easily see that the tanks were rather old. The top of the south tank exhibited spalling and exposed rebar. There were, additionally, signs of past leakage through cracks on the sides of both tanks. Included below are pictures of the north tank, and south tank respectively.

North Tank - Treated Water

South Tank - Raw Water

The tanks are built partially into a hillside. Signs of past leakage are visible on both tanks. It also appears that the tanks were built at different times, or in different manners. This is evident from small differences in lids, tank tops, color, and general condition. The north tank appears to be newer than the south tank.

Possible Solutions

To address the issue of the deteriorating tanks, several options were explored. The main solutions are tank replacement or tank refurbishment. The majority of work was spent researching the details of either replacing the tanks, or doing some repairs and preventative maintenance. Other potential solutions are also to be mentioned later on.

Option 1 - Tank Replacement

The first option we have for improving the water tank system is to replace the existing tanks with new 25,000 gallon fiberglass tanks (FRP). The main benefits of this approach are that it is the most effective way to increase the longevity and reliability of the water system. The existing concrete tanks appeared to be intact, but the risk of a failure of some kind increases with time.

During our site visit a few months ago, we observed several signs of wear that could result in tank failure at some point. The first thing that we observed was significant spalling on the South tank. The top of the tank had significant amounts of concrete worn off, exposing the aggregate on top (see picture below).

Spalling on top of the South Tank

Another related sign of wear was that of exposed rebar on the South Tank (see picture below).

Exposed Rebar on top of the South Tank

It is unknown if these defects will directly lead to the failure of the tank, but it is cause for concern.

The principal disadvantage to the tank replacement approach is the high costs of replacement compared to refurbishment. The estimated total cost to replace both tanks is shown in the table below. Estimates were made using fiberglass tank prices from supplier websites, and represent only the prices of the tanks.

Table 1: Replacement Cost Estimations

	Above Ground	Below Ground
1 tank	$ 22,196.99	$ 57,999.99
2 tanks	$ 44,393.98	$ 115,999.98

Requesting quotes from local companies will be required to be able to estimate additional shipping and installation costs.

Option 2 - Tank Refurbishment

The second option for the water system improvement plan is to refurbish the existing tanks. This option is appealing because it would involve a much lower initial cost, as opposed to the tank replacement option. The main challenge to this option is determining if the concrete tanks will remain usable for a number of years to come with minimal repairs or maintenance.

The site visit was helpful in determining the general condition of the tanks. After further research though, it has been decided that an additional site visit will be useful in producing a

more accurate determination of the strength and usability of the tanks, especially if access can be obtained to observe the inside of the tank. This is obviously challenging under the current weather conditions, because of several snow storms in the last few weeks. It is hoped that within the next few weeks the weather conditions will permit us to travel to the site and further evaluate the tanks. On our last site visit, we were not able to see the inside of the tanks because the keys to the locks could not be found. We especially feel that seeing the inside of the tanks would help us determine their structural integrity since we do not have structural drawings.

As stated earlier, the refurbishment option will be significantly cheaper than replacing the tanks. It has yet to be determined everything that would need to be done to fully refurbish the tanks, but from initial cost estimates it is obvious that those would cost much less than brand new tanks. This is especially true, because the client has requested that if replacement is the recommended option, that the new tanks be at least the same size as the existing tanks.

Refurbishment of the tanks will likely involve installing a lining on the inside of the tanks to reduce water leakage through cracks. There are several products available that are used to coat the inside of concrete tanks to prevent leaking. From our research, and by comparing different options, Xypex appears to be the most promising. Xypex would be especially effective for several reasons. For one, it is relatively cheap when compared to other products available. It is also simple to apply, and does not require a professional for application. It does, however, require NSF approval because of contact with potable water. Another reason it is an appealing option, is that after application it is considered permanent, and requires no maintenance. Included below are some tables detailing the dimensions of the existing tanks, and the estimated cost to apply Xypex to the inside of both tanks.

Table 2: Xypex Cost Estimations

Approximate Tank Dimensions		
Outer Diameter	19	ft
Inner Diameter	18	ft
Inner Radius	9	ft
Inner Volume	25000	gal
Inner Volume	3342.0	ft^3
Inner height	13.13	ft
Inner Surface Area	1251.6	ft^2
Top Surface Area	283.5	ft^2

Xypex Info	
1.5	lb/yd^2
60	lbs/bucket
169.4	$/bucket

Amount needed	Lbs	Buckets	**Cost**
One Tank	319.8	6	**$1,016.40**
Both Tanks	639.6	11	**$1,863.40**

As can be seen, simply applying a lining would be much cheaper. But making a decision based on cost will not necessarily give the best results. Lining the inside of the tank is completely dependant upon whether or not the tanks are structurally sound. If they are not, then it will be necessary to replace the tanks.

Hydraulic Analysis

Regarding the issue of the competing spring flows, a hydraulic modeling program was used to model a possible solution. As it stands, a T-check valve wherein both spring flows move through to enter the raw water tank is in use. However, due to the higher pressure of one of the spring sources, it causes the T-check valve to remain closed the majority of the time on the other spring flow. Therefore instead of having both flows being utilized to fill the raw water tank only one spring is contributing. In order to have both flows enter simultaneously into the tank it's proposed that the two water lines be separated and fed directly into the raw water tank. This situation was modeled using EPANet. The results below are the results given from the program after entering in the appropriate parameters. The results generated insinuate that running two seperate lines into the tank is a viable option.

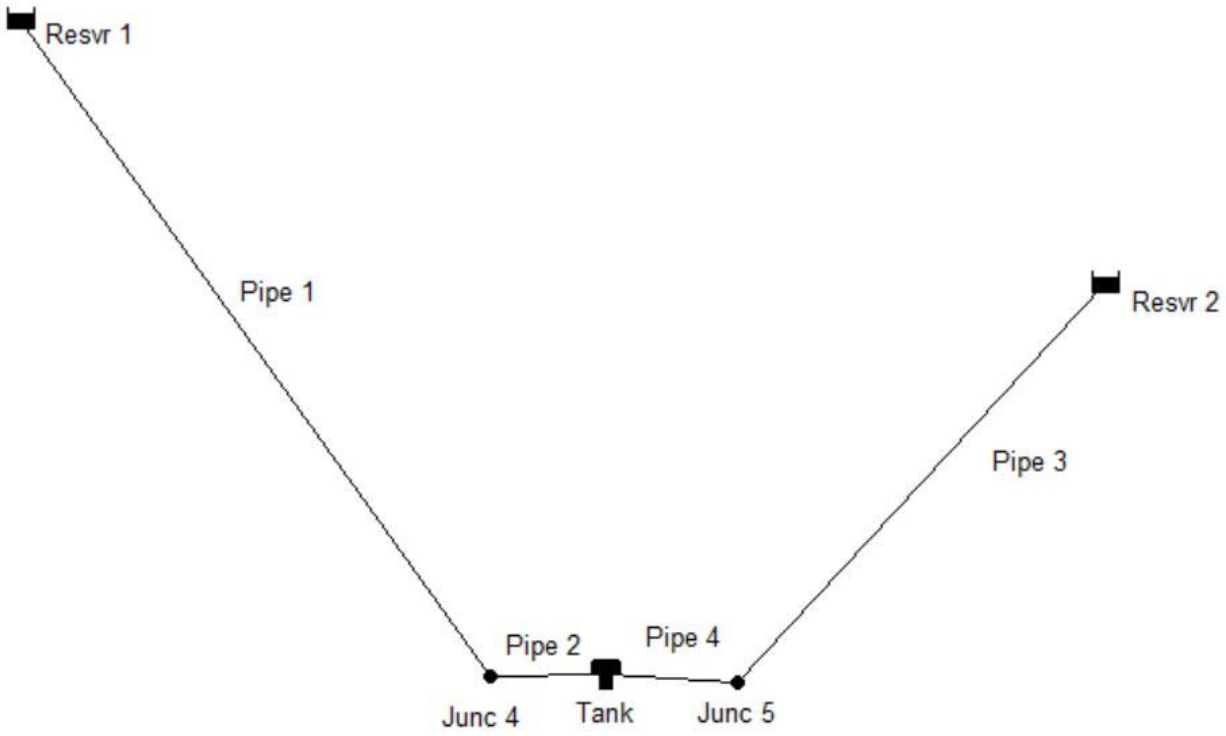

Figure 1: Representation of possible flow solution

Table 3: Node IDs and corresponding results for hydraulic analysis

Node ID	Demand GPM	Head (ft)	Pressure (psi)
Junc 4	0.00	5580.27	4.45
Junc 5	0.00	5580.20	4.42
Resvr 1	-109.56	5610.00	0.00
Resvr 2	-92.17	5600.00	0.00
Tank	201.73	5580.00	4.72

Table 4: Link IDs and corresponding results for hydraulic analysis

Link ID	Flow (GPM)	Velocity (fps)	Unit Headloss (ft/Kft)	Friction Factor
Pipe 1	109.56	4.97	27.03	0.018
Pipe 2	109.56	4.97	27.05	0.018
Pipe 3	92.17	4.18	19.80	0.018
Pipe 4	92.17	4.18	19.82	0.018

Concrete Testing

During one of the site visits the team was able to perform a concrete sounding test on both tanks. The concrete sounding test involved the use of hammers that were lightly tapped across the entire outer surface of the tanks. This test was done to determine if any delamination was present within the tanks, which would be indicated by a hollow sound when tapped with the hammers. Delamination is when cracks form underneath the surface of the concrete, and are often not visible from the outside. When these cracks intersect the reinforcing steel within the concrete, the structural integrity of the concrete can be severely decreased.

Through the testing of both tanks, no signs of delamination could be found, leading to the conclusion that the tanks are likely sound. It is also recommended that further testing be performed to better solidify that conclusion. Further testing, including types of tests, will be discussed in another section.

Final Recommendations

Our final recommendation is to refurbish the tanks. There is a lack of evidence that would justify spending the time, money, and labor to completely replace the tanks. There is no evidence

of significant leaking, the tanks appear to be structurally sound, and are still performing their designed purpose with no issues. Since the integrity of the tanks is not called into question there is little reason to consider replacement of the tanks.

Also, as previously pointed out, the cost of Xypex when compared to the cost of replacement is small (See Figure 1 Below). Xypex has the possibility of extending the lifetime of the tanks for several more years, perhaps even beyond that. According to the Xypex website, if installed properly it is considered permanent and requires no maintenance. With that in mind it would appear the best course of action.

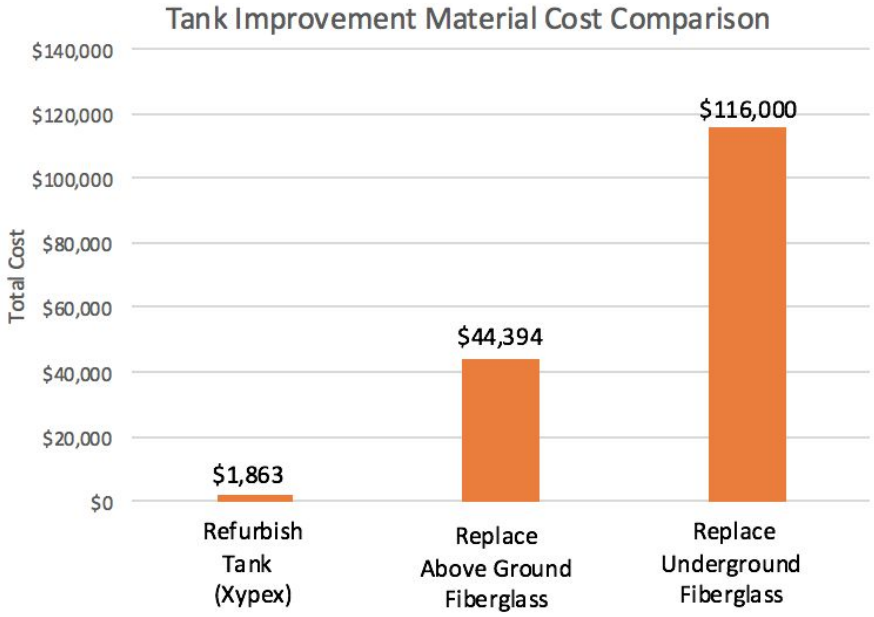

Figure 2: Price Comparison of Replacement Options

To further specify the recommended course of action, Xypex concentrate should be used to coat the insides of both tanks, and the outer tops of both tanks, to prevent further wear from precipitation. In areas where cracks larger that 0.4 mm are found, the cracks will have to be chipped out to a depth of 1.5 inches and width of 1 inch, then cleaned and wetted, to apply a brush coat of Xypex concentrate. After drying the rest of the crack must be filled with Dry Pac, which is another product sold by the same company. After all the Xypex has been applied, it must be allowed to cure for 3 days, and set for 12 days before filling again with water. More detailed instructions on the use of Xypex can be found on the product data sheets available on their website. It is estimated that 11 of the 60 lb buckets of Xypex Concentrate will be needed to complete the task.

In addition to coating the tanks with Xypex, it is recommend to replace the T-check valve (that connects the two springs to the raw water tank) be replaced with two independant inlet pipes. This will eliminate the problem of one valve being forced closed by the spring with greater flow.

Further Testing

As previously mentioned, it is recommended that further testing be performed on the tanks. While some testing was performed, it was limited in its scope and precision. More advanced testing materials could better help to determine the structural integrity of the tanks, and could potentially indicate the need for replacement. Specifically, 2 tests are suggested, with another 2 tests also given mention.

The most highly recommended test for these tanks is a Cover-Meter test. This test is used to determine the location of reinforcing steel within concrete, and depending on the equipment, can also determine the size of the reinforcement. This test would be especially helpful with these tanks, because no structural drawings or plans are currently available for them. Knowing the size and location of reinforcing steel would significantly improve any estimate of how strong the tanks actually are.

Another highly recommended test is a Resistivity test. This test uses electrical currents to determine if the reinforcing steel in the concrete is corroding. If it is that would be alarming, and indicate that the steel may not be providing the strength it was intended to.

Another similar test is the Half-Cell Electrical Potential test. This test is similar to the Resistivity test, as it measures the risk of corrosion in the reinforcing steel. This would be another helpful test to determine the structural integrity of the tanks.

Lastly, an ultrasonic test would also be useful with these tanks. An ultrasonic test uses acoustic waves to measure the elastic properties of the concrete, and detect any anomalies within the concrete, such as voids, sub-surface cracks, delamination, etc.

Many of these tests are available at BYU, but require specific training, and accompaniment of Faculty. With greater notice, another Capstone Project could be performed, where these tests could be used with advanced notice.

Conclusion

Many things were learned through the accomplishment of this capstone project. It was learned that weather can be an obstacle. Difficulties were experienced on the second site visit because of persistent winter weather. Timing is critical in accomplishing a project on time.

Diverse teams can be a help or a hindrance. Each member of the team brought different ideas, methods, and experience to our project. Initially the team member differences initially caused the decision process to slow down. Once a plan was decided on, however, it was a smooth process to carry it out. A team with very similar opinions might not have been able to see or work through several nuances and flaws in our initial plan.

Appendix

Timothy Seth Richardson

2108 N 120 W APT 289 Provo, UT 801-719-9727 t.seth.richardson@gmail.com

Objective

Seeking an internship or entry level employment with the church

Experience

Construction Management Intern

Staker-Parson May 2016–Aug 2016

- Assisted project managers in interpreting and processing engineering plans in order to make bids
- Wrote and distributed detailed notes of coordination meetings to help managers remember main points of the meeting and know what assigned tasks they should perform by the next meeting
- Programmed custom Excel spreadsheets for Operations Manager to make his work more efficient
- Helped Grading Systems Engineer in obtaining measurements and setting up equipment on job sites
- Learned to use Business Center and Plan Swift software

Computer Lab Attendant

Brigham Young University Jan 2015-Present

- Proctored 3-5 language oral interviews a week for students seeking to obtain language certification
- Maintained lab audio and visual equipment for student and employee use
- Managed 2-4 digitization projects for department faculty each week
- Trained new employees in work policies and procedures
- Helped resolve student and employee questions and concerns.

Full-time Volunteer Representative

The Church of Jesus Christ of Latter-day Saints Oct 2012-Nov 2014

- Increased self-discipline through 10-14 hours of daily service and personal study
- Taught English as a Second Language (ESL) classes for up to 12 students
- Led a group of 20-30 volunteers, conducted weekly training meetings, and submitted weekly progress reports

Food Service Worker

Polynesian Cultural Center Jun 2008-Oct 2012

- Fulfilled various assignments based on customer need
- Earned employee of the month 3 times for excellent customer service

Education

BS in Civil Engineering

Brigham Young University—Provo, UT Jan 2015–Present

- Member of Tau Beta Pi, Phi Kappa Phi, and Phi Eta Sigma Honor Societies
- BYU Full Academic Scholarship
- GPA 3.92/4.0

Mathematics

Brigham Young University—Laie, HI Jun 2011–Aug 2012

- Obtained recognition on the college dean's list.
- GPA 4.0/4.0

Kyler Ashby

kr4shby4@gmail.com
567 N. University Ave, Provo, UT 84601
(480) 662-7007

Education

Brigham Young University

December 2018 (anticipated graduation) **BS Civil Engineering**

- **Gained invaluable organizational skills**
- **Learned how to work as a member of team**
- **Obtained time management skills through long term projects and various other assignments**

Experience

Brigham Young University | 155 E 1230 N, Provo, UT 84602

Custodian ***August 2015 – April 2017***

Jobs hours were from 5am to 8am. Performed various jobs involving general cleaning and upkeep of the facilities in the Clyde Engineering building.

Helped fill in for other students when they were unable to complete their assigned duties.

Skills

- **Great attention to detail**
- **Well-versed in Microsoft programs (Word, Excel, Powerpoint, etc.)**
- **Knowledgeable of VBA functions in Excel**
- **Average 88 WPM typing speed**
- **Fluent in Spanish**

Other Notes

- **Eagle Scout**
- **LDS Missionary**
- **Served as Financial Secretary for the Veracruz-Mexico mission**

MICHAEL REYNOLDS

2112 N 40 W #347 michael.reynolds457@gmail.com
Provo UT, 84604 801-427-3223

EDUCATION

Brigham Young University – Bachelors in Civil and Environmental Engineering

- Expected Graduation: April 2018
- Current GPA: 3.34
- Passed FE Exam: November 2017

INVOLVEMENT

- President of BYU Earthquake Engineering Research Institute (EERI) Club.
- Both a Local and National Member of ASCE. Weekly attendance at Local Meetings.

EXPERIENCE

Research Assistant - BYU Civil Engineering Dept. 09/2017 - Present
- Research studying the characteristics of Self-Consolidating Grout (SCG)

Technical Support Intern – Aquaveo LLC: 02/2017 - 09/2017
- Engineering Internship troubleshooting software bugs and licensing issues

Rental Assistant – BYU Vehicle Rentals: 05/2016 – 02/2017
- Performed routine cleaning of vehicles, and assisted customers

Receiver – BYU Catering: 09/2014 – 05/2016
- Led other receivers through high pressure work of receiving and delivering supplies

Shipping Clerk – Blue Bell Creameries: 05/2011 – 08/2014
- Quickly unloaded Semi-trailers and loaded shipping trucks daily

TECHNICAL SKILLS

Experience with Microsoft Excel, Word, and PowerPoint, AutoCAD, Revit, and ArcGIS.

VOLUNTEER EXPERIENCE

Missionary for The Church of Jesus Christ of Latter-Day Saints
- Trained and taught new missionaries, and performed 6-10 hour of community service weekly

Habitat for Humanity
- Building homes for families in need, and volunteering at Donation Center
- Volunteering at local ReStore