Attachment 2

Tank and Pump Station Evaluations

Prepared for

City of Santa Rosa

June 2018

WEST YOST ASSOCIATES
Consulting Engineers

405-14-16-55

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WEST YOST ASSOCIATES
consulting engineers

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Attachment 2

REPORT | JUNE 2018

Tank and Pump Station Evaluations

Prepared for

City of Santa Rosa

Project No. 405-14-16-55

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City of Santa Rosa

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List of Acronyms and Abbreviations

City	City of Santa Rosa
West Yost	West Yost Associates
UT	Ultrasonic Thickness
ASCE	American Society of Civil Engineers
AWWA	American Water Works Association
IBC	International Building Code
CBC	California Building Code
ACI	American Concrete Institute
NEC	National Electrical Code
CB&I	Chicago Bridge & Iron
DDW	Division of Drinking Water
ATS	Automatic Transfer Switch
MCC	Motor Control Center
PLC	Programmable Logic Controller
SCADA	Supervisory Control and Data Acquisition

CHAPTER 1
Introduction

The City of Santa Rosa (City) has contracted with West Yost Associates (West Yost) to evaluate the condition and make improvement recommendations for several water reservoirs and pump stations located throughout the City.

The following water reservoirs and pump stations were included in this project:

- **Reservoir R-9A**, located at 4800 Annadel Heights Drive.
- **Reservoir R-16 and Pump Station S-17**, located east of Fountaingrove Parkway just south of Hadley Hill Drive.
- **Reservoir R-17**, located behind the City of Santa Rosa Fire Station No. 5 near the corner of Fountaingrove Parkway and Newgate Court.
- **Pump Station S-1**, located on the south side of 280 Fountaingrove Parkway, between Mendocino Avenue and Bicentennial Way.
- **Pump Station S-2**, located on the north side of 1395 Fountaingrove Parkway near Stagecoach Road.
- **Pump Station S-15**, located at 6348 Sonoma Highway.
- **Pump Station S-16**, located off 5401 Montecito Avenue.
- **Pump Station S-18**, located on the north side of Fountaingrove Parkway across the street from Reservoir 17.

Figure 1, located at the end of this Chapter, shows the location of each of the above facilities.

1.1 REPORT FORMAT

This report summarizes the evaluations conducted at the water reservoir and pump station sites and makes recommendations for improvements. Below is an outline of this report.

- Chapter 1: Introduction
- Chapter 2: Reservoir R-9A Evaluations
- Chapter 3: Reservoir R-16 Evaluations
- Chapter 4: Reservoir R-17 Evaluations
- Chapter 5: Pump Stations S-1, S-2, S-15, S-16, S-17 (at R-16 site), and S-18 Electrical Evaluation
- Chapter 6: Implementation

The following is a summary of the evaluations that were conducted for Reservoirs R-9A, R-16, and R-17:

- Safety, Site Security, and Code Evaluation
- Corrosion and Coating Evaluation

- Site Geotechnical Evaluation
- Structural and Seismic Evaluation
- Electrical Evaluation

The following is a summary of the evaluation that was conducted for Pump Stations S-1, S-2, S-15, S-16, S-17 (at Reservoir R-16 site), and S-18:

- Electrical Evaluation

The evaluations were based on field investigation conducted by the evaluation team described below, as-built plans, and other miscellaneous information provided by City staff. Note the shop drawings and the original design calculations were not available for Reservoir R-16; therefore, assumptions were made based on the original construction documents provided for Reservoir R-17 since both Reservoirs R-16 and R-17 tanks were constructed at the same time and by the same tank contractor.

1.2 EVALUATION TEAM

West Yost conducted the safety, security, and code evaluation. This included review of the mechanical and piping systems, safety, general site conditions including drainage and security, and a code review related to AWWA D100, California Title 22, and Cal/OSHA requirements for the reservoirs.

JDH Corrosion Consultants conducted the corrosion and coating evaluation. This assessment included review of existing and potential corrosion and coating issues related to the reservoirs, metal appurtenances, and the associated piping. Field investigation included visual inspection, ultrasonic thickness (UT) survey, site corrosivity evaluation, and cathodic protection system evaluation.

Group Delta Consultants conducted the site geotechnical evaluation. This investigation developed the site-specific recommendations for seismic design parameters with consideration to soil and bedrock conditions at each of the reservoir sites. Recommendations are compliant with the 2012 International Building Code/2013 California Building Code and applicable reference standards including ASCE 7-10 and AWWA D100-11.

Simpson, Gumpertz, & Heger conducted the structural and seismic evaluation. The analysis of each existing water storage reservoir established whether the reservoir meets the current seismic design requirements of the California Building Code and provided rehabilitation recommendations. Applicable codes include: AWWA D100-11, IBC 2012, ASCE 7-10, and the 2013 California Building Code.

ATEEM Electrical conducted the electrical and instrumentation evaluation. The evaluation included review of the generators, grounding, breakers, drivers/starters, and an overall evaluation of the electrical systems.

1.3 APPLICABLE CODES

The following is a list of applicable codes and standards used to conduct the evaluations.

- ASCE 7-10 (American Society of Civil Engineers)
- AWWA D100-11 (American Water Works Association)
- 2015 IBC (International Building Code)
- 2016 CBC (California Building Code)
- ACI 3187-11 (American Concrete Institute)
- California Code of Regulations Title 22 – Chapter 16. California Waterworks Standards, Article 6. Distribution Reservoirs
- California Code of Regulations Title 8 (Cal/OHSA)
- 2017 NEC (National Electrical Code)

1.4 REFERENCE DOCUMENTS

The following is a list of reference documents used to conduct the evaluations. All of the below listed documents are included on a CD attached in Appendix A.

- "City of Santa Rosa Water Master Plan Update," prepared by West Yost Associates on August 2014, 228 pages.
- Original Civil and MEP drawings for tanks R-16 and R-17, and their respective pump houses, created by Carlile / Associates, dated April 1993, 36 sheets.
- Document with filename "Reservoir Misc01.pdf," containing reservoir operational data for tanks R-16 and R-17, source and date unknown.
- Document with filename "Stations Misc01.pdf" containing pumping information for pump stations S-16, S-17, and S-18, source and date unknown.
- Original construction permit submittal calculations and drawings for Tank R-17, prepared by Trusco Tank Inc., dated 1993 to 1995, 181 pages.
- Geotechnical investigation report for Tank R-17, prepared by Kleinfelder, Inc., dated 26 November 1992, 26 pages.
- Original Civil and MEP drawings for Tank R-9A, created by Mitchell & Heryford on November 1976, 8 sheets.
- Report titled "Steel Tank Seismic Summary of Fifteen Steel Tanks," prepared by Harper & Associates Engineering, Inc. on December 1998, 31 pages.
- Report titled "Reservoir Seismic Upgrade and Improvement Program Report: Bennett Valley R9-A Reservoir," prepared by Brelje & Race, November 2003, 12 pages.
- Report titled "Structural Evaluation of Existing Tank at Reservoir R-9A," prepared by Peoples Associates, dated 12 March 2004, 18 pages.

1.5 EVALUATION SUMMARY

A summary of the key information for each reservoir and pump station is provided in Table 1-1 and Table 1-2, respectively.

Table 1-1. Existing Reservoir Summary

Parameter Year Erected	Reservoir R-16 1994	Reservoir R-17 1994	Reservoir R-9A 1977
Design Code	AWWA D100-84	AWWA D100-84	AWWA D100-73
Tank Manufacturer	Trusco Tank Inc.	Trusco Tank Inc.	Chicago Bridge & Iron (CB&I)
Nominal Capacity, gallons	250,000	750,000	2,000,000
Nominal Diameter, feet	36	47	92
Top Capacity Level (TCL), feet	34	57.83	40
Nominal Shell Height, feet	35	59	42
Anchorage	Anchorage with bolts	Anchorage with bolts	Self-anchored
Foundation Type	Concrete Ringwall		
Roof Type	Cone shape steel plate with steel rafters, center support column, & knuckle		

Table 1-2. Existing Pump Station Summary

Parameter	S-1	S-2	S-15	S-16	S-17	S-18
Number of Pumps	4	4	3	2	2	2
HP (each pump)	125	100	(2) 10, (1) 50	75	75	30
Total Capacity, gpm	4,275	3,000	1,842	1,500	1,650	1,600
Firm Capacity, gpm	3,634	2,550	1,454	750	825	800
Standby Power, kW	300	150	135	150	150	100
Standby Power Fuel	Natural Gas/ Propane	Natural Gas/ Propane	Natural Gas/ Propane	Natural Gas/ Propane	Natural Gas/ Propane	Natural Gas/ Propane

gpm = gallons per minute
kW = kilowatt

Below is a summary of the general findings common to all reservoir sites. A detailed description of the recommended improvements can be found in the following chapters.

Safety, site security, and code evaluation recommendations common among the three tank sites include the following:

- Addition of a secondary roof opening.
- Emergency venting in the event the center vent becomes clogged.
- Separate inlet and outlet piping to improve water quality and limit short-circuiting.
- Modify the tank overflow to provide an air gap and remove the direct connection to the storm drain system.
- Modify the tank drain to remove the direct connection to the storm drain system.
- Addition of a ladder-up and Saf-T-Climb extension to improve safety when entering the tank through the roof access hatch.
- Replace the interior ladder.

Corrosion and coating evaluation recommendations common among the three tank sites include the following:

- Plate and seal weld the existing handholes and roof plates to permanently remove the previous cathodic protection system
- Clean the exterior annular ring cavities where lifting has occurred and seal to prevent moisture accumulation and corrosion.
- Inspect the tank every 5-years on a regular maintenance schedule.

The interior and exterior coating for all three reservoirs are in pretty good condition. However, the original dark green exterior color of the Reservoirs R-16 and R-17 tanks have faded creating a chalk like appearance. City staff suggested, and West Yost agrees it would it would improve aesthetics to recoat these tanks in a tan color.

The site geotechnical investigation found that the soils beneath all three tanks are adequate to support the water reservoirs.

The structural and seismic analysis discovered significant errors in the original design calculations for Reservoirs R-16 and R-17, which results in deficiencies in structural performance. These deficiencies include the following:

- Concrete ringwall foundation instability and inadequate reinforcing steel.
- Inadequate embedment of the anchorage.
- Several of the shell courses are inadequate and have excessive stress.
- Insufficient freeboard distance between the maximum operation water level and the roof structure is provided.
- The interior center column that supports the roof does not have enough strength.

Reservoir R-9A has many of the same deficiencies, but the deficiencies are attributed to the 1977 tank construction, which is prior to the significant code changes and design approach.

To bring the reservoirs into structural and seismic code compliance and maintain current storage capacity, the structural and seismic analysis improvements require replacing and/or strengthening the center column and roof in addition to strengthening the shell and anchorage at each reservoir. The operating water levels should be significantly reduced if these deficiencies are not addressed.

The existing electrical and instrumentation systems at the three tanks evaluated for this study are in good condition and no improvements are required at this time.

Replacing the existing generators is recommended at all pump station sties. Emergency backup power at all six pump stations is currently provided by natural gas/propane generators. City staff desires the replacement generators to be diesel powered.

The following chapters and appendices provide a more detailed description of the findings and site-specific recommendations resulting from this evaluation.

The estimated costs for each tank and pump station site are included in Table 6-2. These costs incorporate the feedback received from City staff and include all improvements recommended in this report. The total cost for all tank and pump station sites is $11,093,500.

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Attachment 2

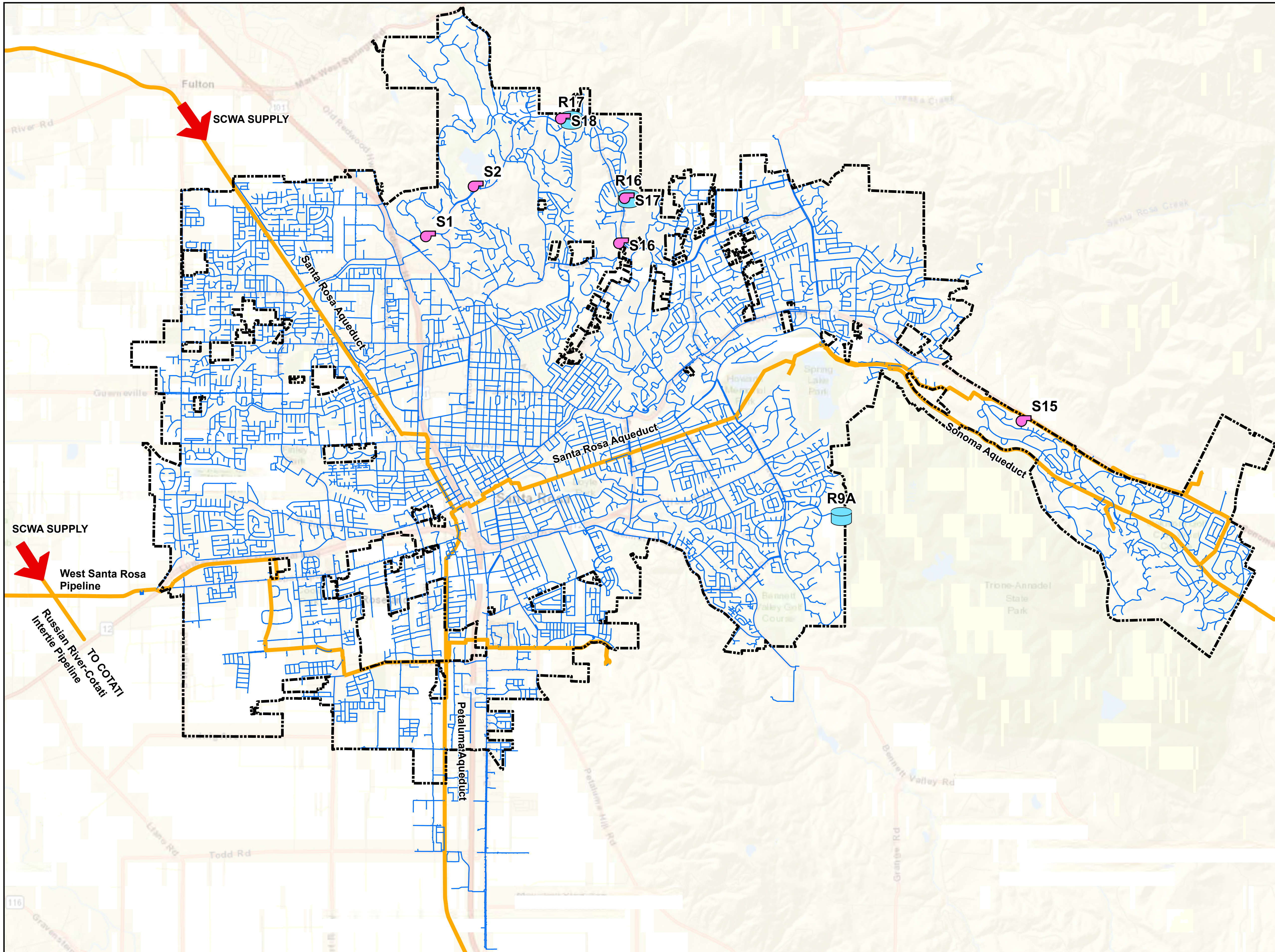


FIGURE 1

City of Santa Rosa

FACILITIES EVALUATED

N

0 2,500 5,000

Scale in Feet

LEGEND

- City Limits
- Reservoir Evaluated
- Pump Station Evaluated
- SCWA Aqueduct
- City Pipeline

City of Santa Rosa

WEST YOST ASSOCIATES

CHAPTER 2
Reservoir R-9A Evaluation

2.1 INTRODUCTION

Reservoir R-9A is a welded steel tank and has a water storage capacity of 2 million gallons. The tank has an inside diameter of 92 feet, with water depth of about 40 feet, and shell height of 42 feet. The tank was constructed in 1977 by CB&I and is located at 4800 Annadel Heights Drive.

The following evaluation of Reservoir R-9A were conducted:

- Safety, Site Security, and Code Evaluation
- Corrosion and Coating Evaluation
- Site Geotechnical Evaluation
- Structural and Seismic Evaluation
- Electrical Evaluation
- Reservoir R-9A Evaluation Recommendations

2.2 SAFETY, SITE SECURITY, AND CODE EVALUATION

The Reservoir R-9A evaluation included the following items:

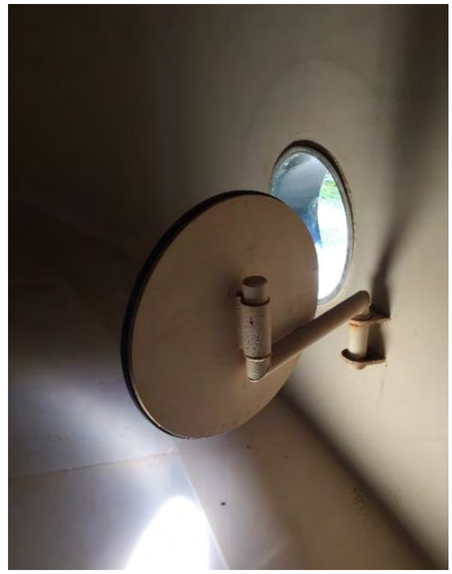
- Code Evaluation
- Safety and Site Security Evaluation
- Safety, Site Security and Code Evaluation Summary

2.2.1 Code Evaluation

Appendix B provides a summary of the code evaluation for Reservoir R-9A including references to the associated codes or standards.

A summary of the items that do not meet current codes or standards includes the following:

- **Secondary roof opening near center of the tank (AWWA D100-11, 7.4.3.2):** Although a removable tank roof vent is an acceptable means of meeting this requirement, at Reservoir R-9A the roof cone of the tank's interior column nearly blocks the entire roof vent opening. The requirement calls for a minimum of a 20-inch opening. See Photo 4-1 for Reservoir R-17, which has the same configuration as Reservoir R-9A.
- **Shell Manways (AWWA D100-11, 7.4.4):** Although the existing shell access manways meet code requirements, City operations staff have requested, and West Yost agrees it would be reasonable, to replace the existing manways with two hanging swing type 30-inch diameter manways similar to the existing manways at Reservoir R-16 and Reservoir R-17 (see Photo 2-1). ReservoirR-9A currently has one 30-inch and one 24-inch swing arm type access manway (see Photo 2-2).

	
Photo 2-1. Reservoir R-16 Existing Access Manway (Hanging Swing Type)	**Photo 2-2. Reservoir R-9A Existing Access Manway (Swing Arm Type)**

- **Additional or emergency vent (AWWA D100-11, 7.5 – Vent):** If the main center vent becomes clogged, an additional or emergency vent is required to prevent a vacuum pressure from forming in the tank. Reservoir R-9A has no means to allow venting if the main center vent screen becomes clogged. The following two options are available to resolve this issue:
  - Install a new vent that includes a mechanism to allow emergency venting should the vent screens become clogged.
  - Install a pressure/vacuum relief valve. This is a separate vent/relief valve and would require cutting a hole tank roof and welding a flanged connection to the tank.
- **Freeboard distance (AWWA D100-11, 13.5.4.4):** The required freeboard distance between the maximum water level and the tank roof structure is not sufficient. This is discussed further in Section 2.5.
- **Pipe connection displacement (AWWA D100-11, 13.6.1):** The piping connections do not have sufficient flexibility to withstand the estimated movement during a seismic event. This is discussed further in Section 2.5.
- **Separate inlet and outlet piping (California Title 22, Chapter 16, Article 6, 64585(b)(4)):** Water flow in and out of the tank is currently provided by a single pipe. Current code requires that the tank include separate inlet and outlet pipes to improve water quality by limiting short-circuiting. The following options are available to resolve this issue:
  - Reroute and modify the existing piping to provide separate inlet and outlet connections configured to prevent short-circuiting.
  - Install a mechanical mixer system inside the tank. DDW has approved a wavier to this requirement if active mixing is provided.

- **Direct connection of drainage facilities to a sanitary sewer or storm drain (California Title 22, Chapter 16, Article 6, 64585(b)(5)):** The tank overflow and drain pipes are directly connected to the storm drain system as shown in Photo 2-3. Current code requires an air gap between the storm drain system and the tank overflow and drain pipe. The following options are available to resolve this issue:
  - The overflow modification could be accomplished by cutting off the overflow pipe above the drain inlet and welding a flange to install an insert screen.
  - The tank drain modification requires rerouting the outlet to above grade, which would require pumping of the last three feet of water in order to drain the tank. A possible alternative that DDW has approved in the past includes installing a blind flange on the end of the drain in the storm drain inlet to prevent cross-connection.

Photo 2-3. Tank Overflow

- **Fall Protection (Cal/OSHA, 1670(a)):** Fall protection is required if personnel are exposed to falling in excess of 7.5 feet. A Saf-T-Climb fall prevention system and ladder cage are provided which meet the code requirements and prevent a fall during ladder climbing. However, when entering the tank through the roof access hatch, a potential fall in excess of 7.5 feet occurs. Therefore, it is recommended to install a ladder-up and Saf-T-Climb extension to improve safety and fall protection.
- **Guardrails (Cal/OSHA, 3209(c)(2)):** Guardrails and posts are required to be constructed of 1.5-inch minimum diameter pipe. Reservoir R-9A as-built drawings indicate the guardrails are 1.25-inch diameter and therefore do not meet the minimum standard.

2.2.2 Safety and Site Security Evaluation

The Reservoir R-9A safety and site security evaluation included the following items:

- Safety Analysis
- Drainage Issues
- City Staff Requested Improvements

2.2.2.1 Safety Analysis

A safety analysis of Reservoir R-9A was performed during site investigations and noted the following safety issues:

- Interior ladder: Although the existing interior ladder meets current standards and does not show signs of corrosion, it is constructed of carbon steel. The City standard for interior ladders is stainless-steel. Generally, installing large stainless-steel components in carbon steel water storage tanks is not recommended because the dissimilar materials may result in increased corrosion. However, AWWA does provide guidance when installing stainless-steel inside a carbon steel tank, which includes installing dielectric insulators and coating all stainless-steel components.
- **Interior ladder Saf-T-Climb:** The existing interior ladder Saf-T-Climb has a large amount of corrosion product on the surface (see Photo 2-4). During field inspection, a small amount of the corrosion material was removed and it appeared the corrosion is on the surface and the material structure is still intact. Therefore, the recommended first step is to remove the surface corrosion and determine the condition of the steel material. Should the material structure be compromised, then the Saf-T-Climb should be replaced.

Photo 2-4. Interior Ladder Saf-T-Climb with Corrosion Product on the Surface

- **Roof ventilation:** Condensation was observed on the interior roof during field inspections. Therefore, additional roof vents are recommended to improve ventilation. Three additional roof vents near the perimeter of the roof should be sufficient.

2.2.2.2 Drainage Issues

No drainage issues were noted during site investigations and maintenance staff indicated that they were not aware of any drainage issues.

2.2.2.3 Site Security Evaluation

No site security issues were noted during site investigations and maintenance staff indicated that they were not aware of any site security issues.

2.2.1 Safety, Site Security, and Code Evaluation Summary

The Reservoir R-9A code recommendations include the following:

- Install a secondary roof opening near the center of the tank.
- Replace the existing shell manways with two hanging swing type 30-inch diameter manways.
- Install additional roof vents for emergency venting.
- Separate inlet and outlet piping to prevent short circuiting. The City currently uses a Tideflex mixing system on other upgraded tanks. Use of this system does not require maintenance or electricity but will require modifications to separate the inlet and outlet piping. The City is satisfied with the Tideflex system and therefore, this system is recommended for Reservoir R-9A.
- Modify the tank overflow to provide an air gap and remove the direct connection to the storm drain system.
- Modify the tank drain to remove the direct connection to the storm drain system.
- Install a ladder-up and Saf-T-Climb extension to improve safety and fall protection when entering the tank from the roof.
- Replace tank guardrails.

The Reservoir R-9A safety and site security recommendations include the following:

- Replace the interior ladder.
- Replace the interior ladder Saf-T-Climb system.
- Install three additional perimeter roof vents to prevent condensation and corrosion. These vents can also be used for emergency venting.

2.3 CORROSION AND COATING EVALUATION

The corrosion and coating evaluation of the reservoir included the following items:

- Visual Inspection
- UT Survey
- Site Corrosivity Evaluation
- Cathodic Protection System Evaluation
- Corrosion and Coating Evaluation Summary

2.3.1 Visual Inspection

Visual inspection noted that Reservoir R-9A appears to be lifting at the annular ring wall. It appears the void was previously filled with some type of caulk. No moss or minor corrosion activity was present at the seam. The exterior coating is in fair condition with no major concern or pitting activity. No exterior corrosion was noted. Exterior coating has several patches from previous repairs likely due to rock damage. The interior tank walls and floor coatings are in good condition with very little corrosion noted. The roof appears to have minor corrosion located at the seams. The interior climbing ladder has large amounts of corrosion present on the surface.

2.3.2 UT Survey

Manual UT wall thickness readings were recorded at sections along the tank. Thickness results can be found in Appendix C.

2.3.3 Site Corrosivity Evaluation

The soil corrosivity evaluation was done at the tank site. Soil resistivity is primarily dependent upon the chemical content and moisture content of the soil mass. The results at Reservoir R-9A ranged from 2,499 to 3,308 ohm-cm, which results in a classification of “moderately corrosive”.

2.3.4 Cathodic Protection System Evaluation

There currently is no cathodic protection system installed at the tank. Upon inspection, the tank previously had an impressed current system installed as evidenced by the remaining anodes inside of the tank.

Cathodic protection systems are generally recommended to increase the life of the interior coating system for water storage tanks. Nevertheless, there are many factors that effective the life of an interior coating system of a water storage tank, including water quality, climate, ventilation, quality of coating application, chlorine concentration, and materials. As a result, many coating systems do well without a cathodic protection system. The interior coating for the R-9A tank appears to be in good condition. Furthermore, City staff has indicated that the City standard is not to include a cathodic protection system; therefore, cathodic protection system are not recommended. City staff has requested that the remaining handholes covers from the previous cathodic protection system be permanently removed.

2.3.5 Corrosion and Coating Evaluation Summary

Overall, Reservoir R-9A was found to be in satisfactory condition. The exterior coating appears to be in fair condition with minor repairs recommended throughout. However, rock damage is present on the exterior of the tank. The annular ring of the tank is elevated off the concrete and the void is sealed. The interior coating is in good condition with minor corrosion present.

The tank corrosion and coating recommendations include:

- Plate and seal weld the existing handholes and roof plates to permanently remove the previous cathodic protection system
- Clean the exterior annular ring cavities where lifting occurred and seal to prevent moisture accumulation and corrosion
- Inspect the tank every 5-years on a regular maintenance schedule

2.4 SITE GEOTECHNICAL EVALUATION

The site geotechnical evaluation of the reservoir included the following items:

- Field Exploration Borings
- Subsurface Conditions
- Bearing Capacities
- Site Geotechnical Evaluation Summary

2.4.1 Field Exploration Borings

The geotechnical evaluation of Reservoir R-9A consisted of a field exploration including three borings to a depth varying from 16.5 to 36.5 feet below existing grade. The test borings were drilled in the pavement area surrounding the tank exterior.

2.4.2 Subsurface Conditions

The subsurface conditions consisted of volcanic bedrock at shallow depths. This bedrock was made up of weak and moderately to intensely weathered rock to the maximum depth explored. Laboratory tests indicated Plasticity Index levels ranging from 25 to 28, which would classify the soil as a Fat Clay and Elastic Silt. Groundwater was not encountered during the field exploration of the tank site.

2.4.3 Bearing Capacities

Based on the information provided, geotechnical bearing capacities were derived which can be found in Appendix D. Soil liquefaction, seismic compaction, and subsidence are not considered to be potential hazards at the tank site but the site may experience severe seismic shaking in the future due to nearby fault ruptures. Seismic design parameters for the site may also be found in Appendix D.

2.4.4 Site Geotechnical Evaluation Summary

In conclusion, Reservoir R-9A appears to be performing adequately under the current gravity loads and there are no apparent signs of tank settlement.

2.5 STRUCTURAL AND SEISMIC EVALUATION

The structural and seismic evaluation of the reservoir included the following items:

- Desktop Design Evaluation
- Tank Operation and Modification Discussion
- Structural and Seismic Evaluation Summary

2.5.1 Desktop Design Evaluation

The structural and seismic evaluation utilized reference information provided by West Yost and the geotechnical analysis. The analysis found that in its current condition the tank does not comply with requirements of AWWA D100-11. The structural and seismic evaluation found the following primary tank deficiencies:

- **Tank Wall Stress:** Shell courses 1, 2, 3, and 4 do not satisfy the minimum thickness requirements for the current operations with a maximum fill height of 40 feet. Shell course thickness is adequate for a maximum fill height of 13 feet.
- **Ringwall Foundation:** The ringwall does not have sufficient steel to resist the twist moment or hoop tension during a seismic event for a fill height of 40 feet or 13 feet.
- **Bearing Pressures:** Soil bearing capacity is inadequate when the tank is operated at the maximum fill height of 40 feet.
- **Freeboard and Sloshing:** Reservoir R-9A has no available freeboard. Minimum freeboard required is 11.1 feet.
- **Attached Piping:** Based on the observation, it is highly unlikely that the attached piping will have adequate flexibility for the required displacement demand.

A complete description of the deficiencies along with structural calculations can be found in Appendix E.

2.5.2 Tank Operation and Modification Discussion

Due to the above-mentioned tank deficiencies, modification of the tank or operations are required in order to be incompliance with AWWA D100-11. The following options are potential mitigation measures:

1. Operate the tank at the existing storage capacity by adding anchorage and strengthening the foundation, shell, and roof of the tank.

2. Strengthen the foundation of the tank only and decrease the maximum fill height to 24 feet. Based on the results of the structural and seismic evaluation, strengthening the foundation alone will require a reduction of the maximum fill height to 24 feet to avoid overstressing the tank shell. This would decrease the capacity from 2 million gallons to approximately 1.2 million gallons. The overflow would also need to be lowered to be in compliance with AWWA D100-11, 13.5.4.4 and 1.2.
3. Redefine the service requirements such that the currently serviced facilities are not dependent on the tank for essential or emergency purposes. This would allow the Importance Factor to be reduced from 1.5 to 1.25, resulting in a decrease of the required loads used in the analysis.
4. Reconfigure piping to provide flexibility and withstand a seismic event. Modifications are required to be in compliance with AWWA D100-11, 13.6.1.

A complete description of the mitigation concepts can be found in Appendix E.

2.5.3 Structural and Seismic Evaluation Summary

Only the potential mitigation measure Option 1 discussed in the above section would bring the reservoir into current structural and seismic code compliance without decreasing the storage capacity. Option 4 is also required in order for the tank to withstand a seismic event. Therefore, Options 1 and 4 are the recommended mitigation measures. Option 4 is not a standalone alternative and should be implemented regardless of the mitigation option selected.

2.6 ELECTRICAL EVALUATION

The electrical evaluation of Reservoir R-17 included the following items:

- Visual Inspection
- Electrical Evaluation Summary

2.6.1 Visual Inspection

A visual inspection of the electrical equipment and instrumentation was performed at the R-9A tank site. A general listing of equipment and field notes are included in Appendix F and include the following topics:

- Electrical Service
- Generator and ATS
- Instrumentation and Controls

2.6.2 Electrical Conclusions

The electrical equipment and controls still have useful life remaining and no improvements are recommended.

2.7 RESERVOIR R-9A EVALUATION RECOMMENDATIONS

The recommended improvements for Reservoir R-9A are summarized below and include the following:

- Safety, Site Security, and Code Recommendations
- Corrosion and Coating Recommendations
- Site Geotechnical Recommendations
- Structural and Seismic Recommendations
- Electrical Recommendations

2.7.1 Safety, Site Security, and Code Recommendations

The Reservoir R-9A code recommendations include the following:

- Install a secondary roof opening near the center of the tank.
- Replace the existing shell manways with two hanging swing type 30-inch diameter manways.
- Install additional roof vents for emergency venting.
- Separate inlet and outlet piping to prevent short circuiting. The City currently uses a Tideflex mixing system on other upgraded tanks. Use of this system does not require maintenance or electricity but will require modifications to separate the inlet and outlet piping. The City is satisfied with the Tideflex system and therefore, this system is recommended for Reservoir R-9A.
- Modify the tank overflow to provide an air gap and remove the direct connection to the storm drain system.
- Modify the tank drain to remove the direct connection to the storm drain system.
- Install a ladder-up and Saf-T-Climb extension to improve safety and fall protection when entering the tank from the roof.
- Replace tank guardrails.

The Reservoir R-9A safety and site security recommendations include the following:

- Replace the interior ladder.
- Replace the interior ladder Saf-T-Climb system.
- Install three additional perimeter roof vents to prevent condensation and corrosion.

2.7.2 Corrosion and Coating Recommendations

Reservoir R-9A corrosion and coating recommendations include:

- Plate and seal weld the existing handholes and roof plates to permanently remove the previous cathodic protection system.

- Clean the exterior annular ring cavities where lifting occurred and seal to prevent moisture accumulation and corrosion.
- Inspect the tank every 5-years on a regular maintenance schedule.

2.7.3 Site Geotechnical Recommendations

Reservoir R-9A has no apparent signs of tank settlement and is performing adequately under the current gravity loads. No improvements are recommended.

2.7.4 Structural and Seismic Recommendations

In order to maintain the existing tank storage capacity and bring the reservoir into current structural and seismic code compliance, Reservoir R-9A structural and seismic recommendations include:

- Strengthen the foundation, shell, and roof.
- Add anchorage.
- Reconfigure piping to provide flexibility to withstand a seismic event.

2.7.5 Electrical Recommendations

The electrical equipment and controls still have useful life remaining and no improvements are recommended.

Chapter 3
Reservoir R-16 Evaluations

3.1 INTRODUCTION

Reservoir R-16 is an anchored welded steel tank and has a water storage capacity of 250,000 gallons. The tank has an inside diameter of 36 feet, with water depth of about 34 feet and shell height of 35 feet. The tank was constructed in 1994 by Trusco Tank Inc., and is located east of Fountaingrove Parkway, just south of Hadley Hill Drive.

The following evaluations of Reservoir R-16 were conducted:

- Safety, Site Security, and Code Evaluation
- Corrosion and Coating Evaluation
- Site Geotechnical Evaluation
- Structural and Seismic Evaluation
- Electrical Evaluation
- Reservoir R-16 Evaluation Recommendations

3.2 SAFETY, SITE SECURITY, AND CODE EVALUATION

The Reservoir R-16 evaluation included the following items:

- Code Evaluation
- Safety and Site Security Evaluation
- Safety, Site Security, and Code Evaluation Summary

3.2.1 Code Evaluation

Appendix B provides a summary of the code evaluation for Reservoir R-16 including references to the associated codes or standards.

A summary of the items that do not meet current codes or standards includes the following:

- **Secondary roof opening near center of the tank (AWWA D100-11, 7.4.3.2):** Although a removable tank roof vent is an acceptable means of meeting this requirement, at Reservoir R-16 the roof cone of the tank's interior column nearly blocks the entire roof vent opening. The requirement calls for a minimum of a 20-inch opening. See Photo 4-1 for Reservoir R-17, which has the same configuration as Reservoir R-16.
- **Additional or emergency venting (AWWA D100-11, 7.5 – Vent):** If the main center vent becomes clogged, an additional or emergency vent is required to prevent a vacuum pressure from forming in the tank. Reservoir R-16 has no means to allow venting if the main center vent screen becomes clogged. The following two options are available to resolve this issue:
  - — Install new vent that includes a mechanism to allow emergency venting should the vent screens become clogged.
  - — Install pressure/vacuum relief valve. This is a separate vent/relief valve and would require cutting a hole tank roof and welding a flanged connection to the tank.

- **Freeboard distance (AWWA D100-11, 13.5.4.4):** The required freeboard distance between the maximum water level and the tank roof structure is not sufficient. This is discussed further in Section 3.5.
- **Sample tap (California Title 22, Chapter 16, Article 6, 64585(a)(3):** Although a sample tap is provided and meets the code requirements, City operations staff have requested, and West Yost agrees it would be reasonable, to extend the sample line further into the tank to get a better representative sample. Currently, the sample tap terminates at the tank shell. See Photo 3-1.

Photo 3-1. Reservoir R-16 Tank Sampling Equipment

Separate inlet and outlet piping (California Title 22, Chapter 16, Article 6, 64585(b)(4)): Water flow in and out of the tank is currently provided by a single pipe. Current code requires that the tank include separate inlet and outlet pipes to improve water quality by limiting short-circuiting. The following options are available to resolve this issue:

— Reroute and modify the existing piping to provide separate inlet and outlet connections configured to prevent short-circuiting.

— Install a mechanical mixer system inside the tank. The Division of Drinking Water (DDW) has approved a wavier to this requirement if active mixing is provided.

- **Direct connection of drainage facilities to a sanitary sewer or storm drain (California Title 22, Chapter 16, Article 6, 64585(b)(5)):** The tank overflow and drain pipes are directly connected to the storm drain system as shown in Photo 3-2. Current code requires an air gap between the storm drain system and the tank overflow and drain pipe. The following options are available to resolve this issue:
  - — The overflow modification could be accomplished by cutting off the overflow pipe above the drain inlet and welding a flange to install an insert screen.
  - — The tank drain modification requires rerouting the outlet to above grade, which would require pumping of the last three feet of water in order to drain the tank. A possible alternative that DDW has approved in the past includes installing a blind flange on the end of the drain in the storm drain inlet to prevent cross-connection.

Photo 3-2. Reservoir R-16 Overflow Direct Connection to the Storm Drain System

- **Fall Protection (Cal/OSHA, 1670(a)):** Fall protection is required if personnel are exposed to falling in excess of 7.5 feet. A Saf-T-Climb fall prevention system and ladder cage are provided which meet the code requirements and prevent a fall during ladder climbing. However, when entering the tank through the roof access hatch, a potential fall in excess of 7.5 feet occurs. Therefore, it is recommended to install a ladder-up and Saf-T-Climb extension to improve safety and fall protection.
- **Toeboards (Cal/OSHA, 3210(a) and 3209(d)):** Toeboards are required on the ladder platform located at the tank roof to prevent objects from falling on employees beyond. Reservoir R-16 does not currently have toeboards.

3.2.2 Safety and Site Security Evaluation

The Reservoir R-16 safety and site security evaluation included the following items:

- Safety Analysis
- Drainage Issues
- Site Security Evaluation

3.2.2.1 Safety Analysis

A safety analysis of Reservoir R-16 was performed during site investigations and noted the following safety issue:

- **Interior ladder:** Although the existing interior ladder meets current standards and does not show signs of corrosion, it is constructed of carbon steel. The City standard for interior ladders is stainless-steel. Generally, installing large stainless-steel components in carbon steel water storage tanks is not recommended because the dissimilar materials may result in increased corrosion. However, AWWA does provide guidance when installing stainless-steel inside a carbon steel tank, which includes installing dielectric insulators and coating all stainless-steel components.

3.2.2.2 Drainage Issues

No drainage issues were noted during site investigations and maintenance staff indicated that they were not aware of any drainage issues.

3.2.2.3 Site Security Evaluation

A site security evaluation of Reservoir R-16 was performed during site investigations and noted the following security issues:

- **Replace security fence:** City staff suggested improving the security of the site by replacing the existing 6-foot high chain link fence with an 8-foot high anti-climb fence. There are many types of anti-climb fencing, which include the following:
  - A 7-foot chain link fence with 3-strand barbed wire (total height of 8-feet with barbed wire)
  - Welded wire fence
  - Mini-mesh chain link fence
  - Ornamental high security "wrought-iron" style fence

The least expensive option is the chain link fence with 3-strand barbed wire which costs about $50 per linear foot, while the most expensive is the ornamental high security fence which costs about $150 per linear foot.

3.2.3 Safety, Site Security, and Code Evaluation Summary

The Reservoir R-16 code recommendations include the following:

- Install a secondary roof opening near the center of the tank.
- Install additional roof vents for emergency venting.
- Extend the existing sample line further into the tank.
- Separate inlet and outlet piping to prevent short circuiting. The City currently uses a Tideflex mixing system on other upgraded tanks. Use of this system does not require maintenance or electricity but will require modifications to separate the inlet and outlet piping. The City is satisfied with the Tideflex system and therefore, this system is recommended for Reservoir R-17.
- Modify the tank overflow to provide an air gap and remove the direct connection to the storm drain system.
- Modify the tank drain to remove the direct connection to the storm drain system.
- Install a ladder-up and Saf-T-Climb extension to improve safety and fall protection when entering the tank from the roof.
- Install exterior toeboard platform.

The Reservoir R-16 safety and site security recommendations include the following:

- Replace the interior ladder.
- Replace the site security fence with a 7-foot chain link fence with 3-strand barbed wire.

3.3 CORROSION AND COATING EVALUATION

The corrosion and coatings evaluation of the reservoir included the following items:

- Visual Inspection
- UT Survey
- Site Corrosivity Evaluation
- Cathodic Protection System Evaluation
- Corrosion and Coating Evaluation Summary

3.3.1 Visual Inspection

Visual inspection noted that Reservoir R-16 appears to be lifting at the annular ring wall which has moss growing with minor corrosion activity present. The annular ring requires cleaning and sealant to prevent future corrosion. The exterior coating is in fair condition with no major concern or pitting activity. No exterior corrosion was noted. The interior tank walls, ladder, and floor coatings are in good condition with very little corrosion noted. The roof appears to have minor corrosion.

3.3.2 UT Survey

Manual UT wall thickness readings were recorded at sections along the tank. Thickness results can be found in Appendix C.

3.3.3 Site Corrosivity Evaluation

A soil corrosivity evaluation was conducted at the tank site. Soil resistivity is primarily dependent upon the chemical content and moisture content of the soil mass. The results at Reservoir R-16 ranged from 10,370 to 15,339 ohm-cm which results in a classification of "mildly corrosive."

3.3.4 Cathodic Protection System Evaluation

There currently is no cathodic protection system installed at the tank. Upon inspection, the tank previously had an impressed current system installed as evidenced by the remaining anodes inside of the tank.

Cathodic protection systems are generally recommended to increase the life of the interior coating system for water storage tanks. Nevertheless, there are many factors that effective the life of an interior coating system of a water storage tank, including water quality, climate, ventilation, quality of coating application, chlorine concentration, and materials. As a result, many coating systems do well without a cathodic protection system. The interior coating for the Reservoir R-16 tank appears to be in good condition. Furthermore, City staff has indicated that the City standard is not to include a cathodic protection system; therefore, cathodic protection system are not recommended. City staff has requested that the remaining handholes covers from the previous cathodic protection system be permanently removed.

3.3.5 Corrosion and Coating Evaluation Summary

Overall, Reservoir R-16 was found to be in satisfactory condition. The exterior coating appears to be in fair condition with minor repairs recommended throughout. However, the original dark green color of the tank has faded creating a chalk like appearance. City staff suggested, and West Yost agrees, it would improve the aesthetics to recoat the exterior of the tank in tan or beige. Additionally, it was also suggested that the exterior cabinets attached to or near the tank should also be coated to match the new tank color. The interior coating is in good condition with minor corrosion present.

The tank corrosion and coating recommendations include:

- Recoat the exterior of the tank and attached exterior cabinets in tan to improve tank aesthetics.
- Plate and seal weld the existing handholes and roof plates to permanently remove the previous cathodic protection system.
- Clean the exterior annular ring cavities where lifting occurred and seal to prevent moisture accumulation and corrosion.
- Inspect the tank every 5 years on a regular maintenance schedule.

3.4 SITE GEOTECHNICAL EVALUATION

The site geotechnical evaluation of the reservoir included the following items:

- Field Exploration Borings
- Subsurface Conditions
- Bearing Capacities
- Site Geotechnical Evaluation Summary

3.4.1 Field Exploration Borings

The geotechnical evaluation at Reservoir R-16 consisted of a field exploration including three borings to a depth varying from 16.5 to 36.5 feet below existing grade. The test borings were drilled in the pavement area surrounding the tank exterior.

3.4.2 Subsurface Conditions

The subsurface conditions encountered at the Reservoir R-16 tank site consisted of volcanically-derived soils. The soils were primarily comprised of Elastic Silt with a Plasticity Index ranging from 26 to 40. The exploration results found the soils in the first 10 feet below existing grade were generally very stiff and relatively weak. However, samples collected below the 10-depth were of a medium stiff consistency. Volcanic bedrock was encountered between 13 and 30 feet below the surface. This varying depth to bedrock indicates a moderately steep bedding, which is consistent with the geologic formations in the region. Groundwater was encountered between 13.5 and 23 feet below the ground surface. It is important to note that groundwater is most likely accumulated on relatively impervious layers as perched water and seepage.

3.4.3 Bearing Capacities

Based on the information provided, geotechnical bearing capacities were derived which can be found in Appendix D. Soil liquefaction, seismic compaction, and subsidence are not considered to be potential hazards at the tank site but the site may experience severe seismic shaking in the future due to nearby fault ruptures. Seismic design parameters for the site may also be found in Appendix D.

3.4.4 Site Geotechnical Evaluation Summary

In conclusion, Reservoir R-16 appears to be performing adequately under the current gravity loads and there are no apparent signs of tank settlement. The foundation for the tank is adequate from a geotechnical standpoint considering current codes.

3.5 STRUCTURAL AND SEISMIC EVALUATION

The structural and seismic evaluation of the reservoir included the following items:

- Desktop Design Evaluation
- Tank Operation and Modification Discussion
- Structural and Seismic Evaluation Summary

It is important to note that detailed data was lacking for Reservoir R-16. Therefore, the analysis used assumptions and information from the Reservoir R-17 design and analysis since these tanks were designed at the same time and constructed by the same tank contractor.

3.5.1 Desktop Design Evaluation

The structural and seismic desktop design evaluation utilized reference information provided from the code evaluation and the site geotechnical evaluation. The structural and seismic analysis found that in its current condition Reservoir R-16 does not comply with requirements of AWWA D100-11. The following primary tank deficiencies were noted:

- **Tank Ringwall Stability:** At the current fill height, the ringwall uplifts due to the overturning moment.
- **Tank Wall Stress:** Shell courses 2 and 3 are exceeded at the current fill height.
- **Freeboard and Sloshing:** The available freeboard of 1 foot is inadequate for sloshing. Minimum freeboard required is 7.6 feet. It is anticipated that the loads on the roof produced by the sloshing wave will overstress the roof framing.
- **Interior Column:** It is probable that the strength of the column supporting the roof of the tank is inadequate. The shop drawings and the original design calculations were not available for T-16; therefore, assumptions were made based on the original construction documents provided for Reservoir R-17 since both Reservoir R-16 and Reservoir R-17 tanks were constructed at the same time and by the same tank contractor.
- **Ringwall Foundation:** It is probable that the ringwall of the tank has inadequate reinforcement to resist twist moments induced by lateral seismic loading. The shop drawings and the original design calculations were not available for T-16; therefore, assumptions were made based on the original construction documents provided for Reservoir R-17 since both Reservoir R-16 and Reservoir R-17 tanks were constructed at the same time and by the same tank contractor.
- **Anchorage:** It is probable that the anchors do not have adequate embedment into the foundation or sufficient supplemental tension reinforcement to resist concrete breakout. The shop drawings and the original design calculations were not available for T-16; therefore, assumptions were made based on the original construction documents provided for Reservoir R-17 since both Reservoir R-16 and Reservoir R-17 tanks were constructed at the same time and by the same tank contractor.

A complete description of the deficiencies along with structural calculations can be found in Appendix E.

3.5.2 Tank Operation and Modification Discussion

Due to the above-mentioned tank deficiencies, modification of the tank or operations are required in order to be incompliance with AWWA D100-11. The following options are potential mitigation measures:

1. Operate the tank at the existing storage capacity by replacing/strengthening the column and roof and strengthening the shell and anchorage.
2. Avoid structural improvements to the tank by decreasing the maximum fill height of the tank. Based on the results of the structural and seismic evaluation, the fill height should be reduced to 27 feet. This would decrease the capacity from 0.25 million gallons to approximately 0.2 million gallons. The overflow would also need to be lowered to be in compliance with AWWA D100-11, 13.5.4.4 and 1.2. See Photo 3-3, which shows the overflow cone near the tank roof.

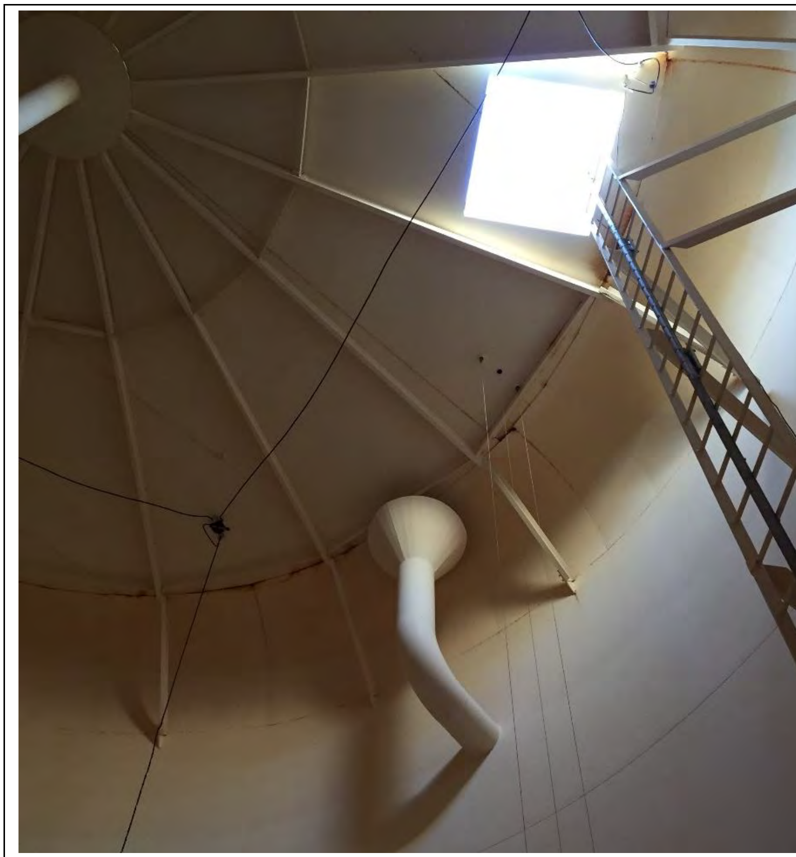


Photo 3-3. Reservoir R-16 Overflow Cone.

3. Redefine the tank service requirements such that the serviced facilities are not dependent on the tank for essential or emergency purposes. This would allow the Importance Factor to be reduced from 1.5 to 1.25, resulting in a decrease of the required loads used during the evaluation.

A complete description of the mitigation concepts can be found in Appendix E.

3.5.3 Structural and Seismic Evaluation Summary

Only the potential mitigation measure Option 1 discussed in the above section would bring the reservoir into structural and seismic code compliance without decreasing the storage capacity; therefore, Option 1 is the recommended mitigation.

It is important to note that detailed data was lacking for Reservoir R-16. Therefore, the analysis used assumptions and information from the Reservoir R-17 design and analysis since these tanks were designed at the same time and constructed by the same tank contractor.

3.6 ELECTRICAL EVALUATION

The electrical evaluation of Reservoir R-16 included the following items:

- Visual Inspection
- Electrical Evaluation Summary

3.6.1 Visual Inspection

A visual inspection of the electrical equipment and instrumentation was performed at the Reservoir R-16 tank site. A general listing of equipment and field notes are included in Appendix F and include the following topics:

- Electrical Service
- Utility Metering
- Generator and ATS
- Instrumentation and Controls

3.6.2 Electrical Evaluation Summary

The electrical equipment and controls still have useful life remaining and no improvements are required at this time.

3.7 RESERVOIR R-16 EVALUATION RECOMMENDATIONS

The recommended improvements for Reservoir R-16 are summarized below and include the following categories:

- Safety, Site Security, and Code Recommendations
- Corrosion and Coating Recommendations
- Site Geotechnical Recommendations
- Structural and Seismic Recommendations
- Electrical Recommendations

3.7.1 Safety, Site Security, and Code Recommendations

The Reservoir R-16 code recommendations include the following:

- Install a secondary roof opening near the center of the tank.
- Install additional roof vents for emergency venting.
- Extend the existing sample line further into the tank.
- Separate inlet and outlet piping to prevent short circuiting. The City currently uses a Tideflex mixing system on other upgraded tanks. Use of this system does not require maintenance or electricity but will require modifications to separate the inlet and outlet piping. The City is satisfied with the Tideflex system and therefore, this system is recommended for Reservoir R-17.
- Modify the tank overflow to provide an air gap and remove the direct connection to the storm drain system.
- Modify the tank drain to remove the direct connection to the storm drain system.
- Install a ladder-up and Saf-T-Climb extension to improve safety and fall protection when entering the tank from the roof.
- Install exterior toeboard platform.

The Reservoir R-16 safety and site security recommendations include the following:

- Replace the interior ladder.
- Replace the site security fence with a 7-foot chain link fence with 3-strand barbed wire.

3.7.2 Corrosion and Coating Recommendations

Reservoir R-16 corrosion and coatings recommendations include:

- Recoat the exterior of the tank and attached exterior cabinets in tan to improve tank aesthetics
- Plate and seal weld the existing handholes and roof plates to permanently remove the previous cathodic protection system
- Clean the exterior annular ring cavities where lifting occurred and seal to prevent moisture accumulation and corrosion
- Inspect the tank every 5-years on a regular maintenance schedule

3.7.3 Site Geotechnical Recommendations

Reservoir R-16 has no apparent signs of tank settlement and the foundation for the tank is adequate from a geotechnical standpoint considering current codes. No improvements are recommended.

3.7.4 Structural and Seismic Recommendations

In order to maintain the existing tank storage capacity and bring the reservoir into current structural and seismic code compliance, Reservoir R-16 structural and seismic recommendations include:

- Strengthen the column and roof
- Strengthen the shell and anchorage

It is important to note that detailed data was lacking for Reservoir R-16. Therefore, the analysis used assumptions and information from the Reservoir R-17 design and analysis since these tanks were designed at the same time and constructed by the same tank contractor.

3.7.5 Electrical Recommendations

The electrical equipment and controls still have useful life remaining and no improvements are required at this time.

CHAPTER 4
Reservoir R-17 Evaluation

4.1 INTRODUCTION

Reservoir R-17 is an anchored welded steel tank and has a water storage capacity of 750,000 gallons. The tank has an inside diameter of 47 feet, with water depth of about 57.8 feet, and shell height of 59 feet. The tank was constructed in 1994 by Trusco Tank Inc., and is located behind the City's Fire Station No. 5 near the corner of Fountaingrove Parkway and Newgate Court.

The following evaluations of Reservoir R-17 were conducted:

- Safety, Site Security, and Code Evaluation
- Corrosion and Coating Evaluation
- Site Geotechnical Evaluation
- Structural and Seismic Evaluation
- Electrical Evaluation
- Reservoir R-17 Evaluation Recommendations

4.2 SAFETY, SITE SECURITY, AND CODE EVALUATION

The Reservoir R-16 evaluation included the following items:

- Code Evaluation
- Safety and Site Security Evaluation
- Safety, Site Security, and Code Evaluation Summary

4.2.1 Code Evaluation

Appendix B provides a summary of the code evaluation for Reservoir R-17 including references to the associated codes or standards. Reservoir R-17 was constructed at the same time as Reservoir R-16; therefore, many of the deficiencies and recommendations are similar to those in Chapter 3.

A summary of the items that do not meet current codes or standards includes the following:

- **Secondary roof opening near center of the tank (AWWA D100-11, 7.4.3.2):** Although a removable tank roof vent is an acceptable means of meeting this requirement, at Reservoir R-17 the roof cone of the tank's interior column nearly blocks the entire roof vent opening. The requirement calls for a minimum of a 20-inch opening. See Photo 4-1.

Photo 4-1. Reservoir R-17 Center Vent (with vent hood removed)

- **Additional or emergency venting (AWWA D100-11, 7.5 – Vent):** If the main center vent becomes clogged, an additional or emergency vent is required to prevent a vacuum pressure from forming in the tank. Reservoir R-17 has no means to allow venting if the main center vent screen becomes clogged. The following two options are available to resolve this issue:
  - — Install new vent that includes a mechanism to allow emergency venting should the vent screens become clogged.
  - — Install pressure/vacuum relief valve. This is a separate vent/relief valve and would require cutting a hole tank roof and welding a flanged connection to the tank.
- **Freeboard distance (AWWA D100-11, 13.5.4.4):** The required freeboard distance between the maximum water level and the tank roof structure is not sufficient. This is discussed further in Section 4.5.
- **Separate inlet and outlet piping (California Title 22, Chapter 16, Article 6, 64585(b)(4)):** Water flow in and out of the tank is currently provided by a single pipe. Current code requires that the tank include separate inlet and outlet pipes to improve water quality by limiting short-circuiting. The following options are available to resolve this issue:
  - — Reroute and modify the existing piping to provide separate inlet and outlet connections configured to prevent short-circuiting.
  - — Install a mechanical mixer system inside the tank. DDW has approved a wavier to this requirement if active mixing is provided.

- **Direct connection of drainage facilities to a sanitary sewer or storm drain (California Title 22, Chapter 16, Article 6, 64585(b)(5)):** The tank overflow and drain pipes are directly connected to the storm drain system as shown in Photo 4-2. Current code requires an air gap between the storm drain system and the tank overflow and drain pipe. The following options are available to resolve:
  - The overflow modification could be accomplished by cutting off the overflow pipe above the drain inlet and welding a flange to install an insert screen.
  - The tank drain modification requires rerouting the outlet to above grade, which would require pumping of the last three feet of water in order to drain the tank. A possible alternative that DDW has approved in the past includes installing a blind flange on the end of the drain in the storm drain inlet to prevent cross-connection.

Photo 4-2. Reservoir R-17 Overflow Direct Connection to the Storm Drain System

- **Fall Protection (Cal/OSHA, 1670(a)):** Fall protection is required if personnel are exposed to falling in excess of 7.5 feet. A Saf-T-Climb fall prevention system and ladder cage are provided which meet the code requirements and prevent a fall during ladder climbing. However, when entering the tank through the roof access hatch, a potential fall in excess of 7.5 feet occurs. Therefore, it is recommended to install a ladder-up and Saf-T-Climb extension to improve safety and fall protection.

- **Toeboards (Cal/OSHA, 3210(a) and 3209(d)):** Toeboards are required on the ladder platform located at the tank roof to prevent objects from falling on employees beyond. Reservoir R-17 does not currently have toeboards.

4.2.2 Safety and Site Security Evaluation

The Reservoir R-17 safety and site security evaluation included the following items:

- Safety Analysis
- Drainage Issues
- Site Security Evaluation

4.2.2.1 Safety Analysis

A safety analysis of Reservoir R-17 was performed during site investigations and noted the following safety issues:

- **Manway access staircase:** The existing manway access staircase used to access the tank interior through one of the shell manways extends into the driveway and is a safety hazard. See Photo 4-3. City staff suggested, and West Yost agrees it would be reasonable to modify or replace the existing staircase so that it does not extend into the driveway.

Photo 4-3. Manway Access Staircase

- **Interior ladder:** Although the existing interior ladder meets current standards and does not show signs of corrosion, it is constructed of carbon steel. The City standard for interior ladders is stainless-steel. Generally, installing large stainless-steel components in carbon steel water storage tanks is not recommended because the dissimilar materials may result in increased corrosion. However, AWWA does provide guidance when installing stainless-steel inside a carbon steel tank, which includes installing dielectric insulators and coating all stainless-steel components.

4.2.2.2 Drainage Issues

No drainage issues were noted during site investigations and maintenance staff indicated that they were not aware of any drainage issues.

4.2.2.3 Site Security Evaluation

A site security evaluation of Reservoir R-17 was performed during site investigations and noted the following security issues:

- **Security fence:** City staff suggested, and West Yost agrees it would be reasonable, to improve the security of the site by replacing the existing 6-foot high chain link fence with an 8-foot high anti-climb fence. There are many types of anti-climb fencing, which include the following:
  - 7-foot chain link fence with 3-strand barbed wire (total height of 8-feet with barbed wire)
  - Welded wire fence
  - Mini-mesh chain link fence
  - Ornamental high security "wrought-iron" style fence

  The least expensive option is chain link fence with 3-strand barbed wire which costs about $50 per linear foot, while the most expensive is the ornamental high security fence which costs about $150 per linear foot.

4.2.3 Safety, Site Security, and Code Evaluation Summary

The Reservoir R-17 code recommendations include the following:

- Install a secondary roof opening near the center of the tank.
- Install additional roof vents for emergency venting.
- Separate inlet and outlet piping to prevent short circuiting. The City currently uses a Tideflex mixing system on other upgraded tanks. Use of this system does not require maintenance or electricity but will require modifications to separate the inlet and outlet piping. The City is satisfied with the Tideflex system and therefore, this system is recommended for Reservoir R-17.
- Modify the tank overflow to provide an air gap and remove the direct connection to the storm drain system.

- Modify the tank drain to remove the direct connection to the storm drain system.
- Install a ladder-up and Saf-T-Climb extension to improve safety and fall protection when entering the tank from the roof.
- Install exterior toeboard platform.

The Reservoir R-17 safety and site security recommendations include the following:

- Modify the manway access staircase.
- Replace the interior ladder.
- Replace the site security fence with a 7-foot chain link fence with 3-strand barbed wire.

4.3 CORROSION AND COATING EVALUATION

The corrosion and coatings evaluation of the reservoir included the following items:

- Visual Inspection
- UT Survey
- Site Corrosivity Evaluation
- Cathodic Protection System Evaluation
- Corrosion and Coating Evaluation Summary

4.3.1 Visual Inspection

Visual inspection noted that Reservoir R-17 appears to be lifting at the annular ring wall which has moss growing with minor corrosion activity present. The annular ring requires cleaning and sealant to prevent future corrosion. The exterior coating is in fair condition with no major concern or pitting activity. No exterior corrosion was noted. The interior tank walls, ladder, and floor coatings are in good condition with very little corrosion noted. The roof appears to have minor corrosion.

4.3.2 UT Survey

Manual UT wall thickness readings were recorded at sections along the tank. Thickness results can be found in Appendix C.

4.3.3 Site Corrosivity Evaluation

A soil corrosivity evaluation was conducted at the tank site. Soil resistivity is primarily dependent upon the chemical content and moisture content of the soil mass. The results at Reservoir R-17 ranged from 10,762 to 13,142 ohm-cm, which results in a classification of "mildly corrosive".

4.3.4 Cathodic Protection System Evaluation

There currently is no cathodic protection system installed at the tank. Upon inspection, the tank previously had an impressed current system installed as evidenced by the remaining anodes inside of the tank.

Cathodic protection systems are generally recommended to increase the life of the interior coating system for water storage tanks. Nevertheless, there are many factors that effective the life of an interior coating system of a water storage tank, including water quality, climate, ventilation, quality of coating application, chlorine concentration, and materials. As a result, many coating systems do well without a cathodic protection system. The interior coating for the R-17 tank appears to be in good condition. Furthermore, City staff has indicated that the City standard is not to include a cathodic protection system; therefore, cathodic protection system are not recommended. City staff have requested that the remaining handholes covers from the previous cathodic protection system be permanently removed.

4.3.5 Corrosion and Coating Evaluation Summary

Overall, Reservoir R-17 was found to be in satisfactory condition. The exterior coating appears to be in fair condition with minor repairs recommended throughout. However, the original dark green color of the tank has faded creating a chalk like appearance. City staff suggested, and West Yost agrees, it would improve the aesthetics to recoat the exterior of the tank in tan or beige. Additionally, it was also suggested that the exterior cabinets attached to or near the tank should also be coated to match the new tank color. The interior coating is in good condition with minor corrosion present.

The tank corrosion and coating recommendations include:

- Recoat the exterior of the tank and attached exterior cabinets in tan to improve tank aesthetics
- Plate and seal weld the existing handholes and roof plates to permanently remove the previous cathodic protection system
- Clean the exterior annular ring cavities where lifting occurred and seal to prevent moisture accumulation and corrosion
- Inspect the tank every five years on a regular maintenance schedule

4.4 SITE GEOTECHNICAL EVALUATION

The site geotechnical evaluation of the reservoir included the following items:

- Field Exploration Borings
- Subsurface Conditions
- Bearing Capacities
- Site Geotechnical Evaluation Summary

4.4.1 Field Exploration Borings

The geotechnical evaluation of Reservoir R-17 consisted of a field exploration including four borings to a depth varying from 2 to 49.5 feet below existing grade. The test borings were drilled in the pavement area surrounding the tank exterior.

4.4.2 Subsurface Conditions

During the subsurface field exploration, fill was encountered approximately 2 to 3 feet thick. The fill consisted of Fat Clay and was well compacted with a very stiff to hard consistency. Volcanic fragments were also observed in the fill, which indicated the material was derived from bedrock cuts at the site. Underneath the fill, the soil is highly variable with rock of the Sonoma Volcanics Formation. Footings are embedded approximately 4 feet deep and likely penetrate the fill and bear on to the Sonoma Volcanics Formation. On the north and east sides of the tank, the underlying soil consisted of very hard to extremely hard and slightly to moderately weathered volcanic rock. On the south and west side of the tank, the soil conditions are primarily comprised of the Sonoma Volcanics which generally consists of stiff to very stiff Lean Clay and Fat Clay. The Plasticity Index values range from 28 to 40. Groundwater was not encountered during the field exploration of the tank site.

4.4.3 Bearing Capacities

Based on the information provided, geotechnical bearing capacities were derived which can be found in Appendix D. Soil liquefaction, seismic compaction, and subsidence are not considered to be potential hazards at the tank site but the site may experience severe seismic shaking in the future due to nearby fault ruptures. Seismic design parameters for the site may also be found in Appendix D.

4.4.4 Site Geotechnical Evaluation Summary

In conclusion, Reservoir R-17 appears to be performing adequately under the current gravity loads and there are no apparent signs of tank settlement. The foundation for the tank is adequate from a geotechnical standpoint considering current codes.

4.5 STRUCTURAL AND SEISMIC EVALUATION

The structural and seismic evaluation of the reservoir included the following items:

- Desktop Design Evaluation
- Tank Operation and Modification Discussion
- Structural and Seismic Evaluation Summary

4.5.1 Desktop Design Evaluation

The structural and seismic evaluation utilized reference information provided by West Yost and the geotechnical analysis. The evaluation found major errors in the original design calculations for Reservoir R-17 which has led to deficiencies. In its current condition, Reservoir R-17 does not comply with requirements of AWWA D100-11. The structural and seismic evaluation found the following primary tank deficiencies:

- **Tank Ringwall Stability:** At the current fill height, the ringwall uplifts due to the overturning moment.
- **Tank Wall Stress:** Shell courses 2, 3, 4, and 5 are exceeded at the current fill height.
- **Freeboard and Sloshing:** The available freeboard of 1.2 feet is inadequate for sloshing. Minimum freeboard required is 8.9 feet. The steel roof plate, the rafter beams, and their bolted connections do not have adequate strength to resist the sloshing loads exerted on the roof.
- **Interior Column:** The column supporting the roof does not have enough strength to resist the lateral force of water during a seismic event.
- **Ringwall Foundation:** The ringwall of the tank has inadequate reinforcement to resist twist moments generated during a seismic event.
- **Anchorage:** The concrete breakout strength of the anchors is exceeded during a design level seismic event.

A complete description of the deficiencies along with structural calculations can be found in Appendix E.

4.5.2 Tank Operation and Modification Discussion

Due to the above-mentioned tank deficiencies, modification of the tank or operations are required in order to be incompliance with AWWA D100-11. The following options are potential mitigation measures:

1. Operate the tank at the existing storage capacity by replacing/strengthening the column and roof and strengthening the shell and anchorage.
2. Avoid structural improvements to the tank by decreasing the maximum fill height of the tank. Based on the results of the structural and seismic evaluation, the fill height should be reduced to 13 feet. This would decrease the capacity from 0.75 million gallons to approximately 0.17 million gallons. The overflow would also need to be lowered to be in compliance with AWWA D100-11, 13.5.4.4 and 1.2.
3. Replace/strengthen the interior tank column only. Based on the results of the structural and seismic evaluation, if the interior column is replaced/strengthened, the maximum fill height of the tank is 34 feet. This would decrease the storage capacity from 0.75 million gallons to 0.45 million gallons. The overflow would also need to be lowered to be in compliance with AWWA D100-11, 13.5.4.4 and 1.2.

4. Replace/strengthen the interior tank column and strengthen shell course 4 only. Based on the results of the structural and seismic evaluation, if these tank modifications are performed, the maximum fill height of the tank is 42 feet. This would decrease the storage capacity from 0.75 million gallons to 0.57 million gallons. The overflow would also need to be lowered to be in compliance with AWWA D100-11, 13.5.4.4 and 1.2.
5. Replace/strengthen the interior tank column and strengthen shell courses 3, 4, and 5 only. Based on the results of the structural and seismic evaluation, if these tank modifications are performed, the maximum fill height of the tank is 45 feet. This would decrease the storage capacity from 0.75 million gallons to 0.58 million gallons. The overflow would also need to be lowered to be in compliance with AWWA D100 11, 13.5.4.4 and 1.2.
6. Redefine the service requirements such that the currently serviced facilities are not dependent on the tank for essential or emergency purposes. This would allow the Importance Factor to be reduced from 1.5 to 1.25, resulting in a decrease of the required loads used in the analysis.

A complete description of the mitigation concepts can be found in Appendix E.

4.5.3 Structural and Seismic Evaluation Summary

Only the potential mitigation measure Option 1 discussed in the above section would bring the reservoir into structural and seismic code compliance without decreasing the storage capacity; therefore, Option 1 is the recommended mitigation.

4.6 ELECTRICAL EVALUATION

The electrical evaluation of Reservoir R-17 included the following items:

- Visual Inspection
- Electrical Evaluation Summary

4.6.1 Visual Inspection

A visual inspection of the electrical equipment and instrumentation was performed at the Reservoir R-17 tank site. A general listing of equipment and field notes are included in Appendix F and include the following topics:

- Electrical Service
- Utility Metering
- Generator and ATS
- Instrumentation and Controls

4.6.2 Electrical Evaluation Summary

The electrical equipment and controls still have useful life remaining and no improvements are recommended.

4.7 RESERVOIR R-17 EVALUATION RECOMMENDATIONS

The recommended improvements for Reservoir R-17 are summarized below and include the following:

- Safety, Site Security, and Code Recommendations
- Corrosion and Coating Recommendations
- Site Geotechnical Recommendations
- Structural and Seismic Recommendations
- Electrical Recommendations

4.7.1 Safety, Site Security, and Code Recommendations

The Reservoir R-17 code recommendations include the following:

- Install a secondary roof opening near the center of the tank.
- Install additional roof vents for emergency venting.
- Separate inlet and outlet piping to prevent short circuiting. The City currently uses a Tideflex mixing system on other upgraded tanks. Use of this system does not require maintenance or electricity but will require modifications to separate the inlet and outlet piping. The City is satisfied with the Tideflex system and therefore, this system is recommended for Reservoir R-17.
- Modify the tank overflow to provide an air gap and remove the direct connection to the storm drain system.
- Modify the tank drain to remove the direct connection to the storm drain system.
- Install a ladder-up and Saf-T-Climb extension to improve safety and fall protection when entering the tank from the roof.
- Install exterior toeboard platform.

The Reservoir R-17 safety and site security recommendations include the following:

- Modify the manway access staircase.
- Replace the interior ladder.
- Replace the site security fence with a 7-foot chain link fence with 3-strand barbed wire.

4.7.2 Corrosion and Coating Recommendations

Reservoir R-17 corrosion and coatings recommendations include:

- Recoat the exterior of the tank and attached exterior cabinets in tan to improve tank aesthetics
- Plate and seal weld the existing handholes and roof plates to permanently remove the previous cathodic protection system
- Clean the exterior annular ring cavities where lifting occurred and seal to prevent moisture accumulation and corrosion
- Inspect the tank every 5-years on a regular maintenance schedule

4.7.3 Site Geotechnical Recommendations

Reservoir R-17 has no apparent signs of tank settlement and the foundation for the tank is adequate from a geotechnical standpoint considering current codes. No improvements are recommended.

4.7.4 Structural and Seismic Recommendations

In order to maintain the existing tank storage capacity and bring the reservoir into current structural and seismic code compliance, Reservoir R-17 structural and seismic recommendations include:

- Strengthen the column and roof
- Strengthen the shell and anchorage

4.7.5 Electrical Recommendations

The electrical equipment and controls still have useful life remaining and no improvements are recommended.

CHAPTER 5
Pump Station Evaluations

5.1 INTRODUCTION

The following pump stations were included in this project:

- **Pump Station S-1:** located on the south side of 280 Fountaingrove Parkway, between Mendocino Avenue and Bicentennial Way.
- **Pump Station S-2:** located on the north side of 1395 Fountaingrove Parkway near Stagecoach Road.
- **Pump Station S-15:** located at 6348 Sonoma Highway.
- **Pump Station S-16:** located off 5401 Montecito Avenue.
- **Pump Station S-17:** located east of Fountaingrove Parkway just south of Hadley Hill Drive.
- **Pump Station S-18:** located on the north side of Fountaingrove Parkway across the street from Reservoir 17.

The analysis of all pump stations consisted of an electrical evaluation only. The electrical evaluation included the following items:

- Visual Inspection
- Electrical Evaluation Summary

5.2 VISUAL INSPECTION

A visual inspection of the electrical equipment and instrumentation was performed at each pump station site. A general listing of equipment and field notes are included in Appendix G and includes the following topics:

- Electrical Service
- Utility Metering
- Pump Control and Building
- Generator and ATS
- Instrumentation and Controls
- Site

5.3 ELECTRICAL EVALUATION SUMMARY

The recommendations made for each evaluated pump station site are summarized below.

5.3.1 Pump Station S-1

The exiting generator at Pump Station S-1 sustained some damage during the recent 2017 fires and needs to be replaced. The City would like to replace the natural gas/propane powered generator with a diesel-powered generator. Therefore, is it recommended that the existing generator be replaced with a diesel operated generator rated to about 300 KW. The new generator will replace the existing generator and be installed in the generator room of the pump station building.

Revision of arc flash labeling is recommended for all electrical panels in order to comply with current NEC code.

The remaining electrical equipment and controls still have useful life remaining and no improvements are required at this time.

5.3.2 Pump Station S-2

The exiting generator at Pump Station S-2 failed in February 2017 and needs to be replaced. The City would like to replace the natural gas/propane powered generator with a diesel-powered generator. Therefore, is it recommended that the existing generator be replaced with a diesel operated generator rated to about 250 KW, with an external fuel tank to be located where the existing propane fuel tank is located. The new generator will replace the existing generator and be installed in the generator room of the pump station building.

It is recommended that the air inlet to the generator room be modified to allow proper air flow during generator operation.

Revision of arc flash labeling is recommended for all electrical panels in order to comply with current NEC code.

The remaining electrical equipment and controls still have useful life remaining and no improvements are required at this time.

5.3.3 Pump Station S-15

During load bank testing the exiting generator exhaust became “extremely hot” and the testing was halted. The City would like to replace the natural gas/propane powered generator with a diesel-powered generator. Therefore, is it recommended that the existing generator be replaced with a diesel operated generator rated to about 135 KW.

The City has expressed a wish to install an active harmonic filter at this station to address any harmonic issues, similar to the harmonic filter pilot project installed at Pump Station S-3. Should the pilot project at Pump Station S-3 be successful, West Yost agrees it would be reasonable to install a harmonic filter at Pump Station S-15. Therefore, a harmonic filter is recommended.

City staff have expressed concerns about the circuit breaker type ATS currently installed at the pump station. To alleviate concerns, a new modernized ATS is recommended.

Revision of arc flash labeling is recommended for all electrical panels in order to comply with current NEC code.

The remaining electrical equipment and controls still have useful life remaining and no improvements are required at this time.

5.3.4 Pump Station S-16

Emergency backup power at Pump Station S-16 is currently provided by a natural gas/propane fueled generator that is only able to provide sufficient power to operate one pump. City staff desires, and West Yost agrees it would be reasonable, to operate two pumps under emergency power. Furthermore, the City would like to replace the natural gas/propane powered generator with a diesel-powered generator. Therefore, is it recommended that the generator be replaced with a diesel operated generator capable of powering two 75-hp pumps.

The remaining electrical equipment and controls still have useful life remaining and no improvements are required at this time.

5.3.5 Pump Station S-17

Emergency backup power at Pump Station S-17 is currently provided by a natural gas/propane fueled generator that is only able to provide sufficient power to operate one pump. City staff desires, and West Yost agrees it would be reasonable, to operate two pumps under emergency power. Furthermore, the City would like to replace the natural gas/propane powered generator with a diesel-powered generator. Therefore, is it recommended that the generator be replaced with a diesel operated generator capable of powering two 75-hp pumps.

Addition of arc flash labeling is recommended for all electrical panels in order to comply with current NEC code.

The remaining electrical equipment and controls still have useful life remaining and no improvements are required at this time.

5.3.6 Pump Station S-18

Emergency backup power at Pump Station S-18 is currently provided by a natural gas/propane fueled generator that is only able to provide sufficient power to operate one pump. City staff desires, and West Yost agrees it would be reasonable, to operate two pumps under emergency power. Furthermore, the City would like to replace the natural gas/propane powered generator with a diesel-powered generator. Therefore, is it recommended that the generator be replaced with a diesel operated generator capable of powering two 30-hp pumps.

Addition of arc flash labeling is recommended for all electrical panels in order to comply with current NEC code.

The remaining electrical equipment and controls still have useful life remaining and no improvements are required at this time.

CHAPTER 6
Implementation

This chapter summarizes the recommended improvements for each water reservoir and pump station site and includes the following:

- Recommended Improvements
- Estimated Costs

6.1 RECOMMENDED IMPROVEMENTS

The recommended improvements from the evaluations outlined in Chapters 2 through 5 are summarized in Table 6-1 below.

Table 6-1. Recommended Improvement Summary

Recommended Improvement	Facility Site								
	R-9A	R-16	R-17	S-1	S-2	S-15	S-16	S-17	S-18
Safety, Security, and Code Evaluation									
1 Install Secondary Roof Opening	x	x	x						
2 Shell Manway Replacement	x								
3 Install Emergency Venting	x	x	x						
4 Extend Sample Tap		x							
5 Separate Inlet/Outlet Piping	x	x	x						
6 Overflow Air Gap	x	x	x						
7 Tank Drain Modification	x	x	x						
8 Install Saf-T-Climb Extension	x	x	x						
9 Replace Guardrails	x								
10 Install Toeboards		x	x						
11 Modify Exterior Access Staircase			x						
12 Replace Interior Ladder	x	x	x						
13 Replace Interior Ladder Saf-T-Climb	x								
14 Install Additional Roof Ventilation	x								
15 Replace Security Fence		x	x						
Corrosion and Coating Evaluation									
16 Recoat Tank Exterior		x	x						
17 Plate and Seal Weld Existing Handholes	x	x	x						
18 Clean and Seal Exterior Annular Ring	x	x	x						
19 Inspect Tank Every 5 Years	x	x	x						
Structural and Seismic Evaluation									
20 Strengthen Column and Roof	x	x	x						
21 Strengthen Shell and Anchorage		x	x						
22 Strengthen Foundation	x								
23 Add Anchorage	x								
24 Replace Pipe Connections	x								
Electrical Evaluation									
25 Replace Generator				x	x	x	x	x	x
26 Modify Generator Room Air Inlet					x				
27 Install Harmonic Filter						x			
28 Replace ATS						x			
29 Add Arc Flash Labeling				x	x	x		x	x

Each of the recommended improvements in Table 6-1 are described below.

1. Install Secondary Roof Opening: Install a minimum of a 20-inch diameter opening on the roof of the tank.
2. Replace Shell Manways: Replace the two existing swing arm type shell access manways with two 30-inch diameter hanging swing type access manways.
3. Install Emergency Venting: Replace existing center vent to standardize with other upgraded City tanks. Since the proposed standardized center vent is screened and could become clogged, a perimeter vent is recommended at each tank. The perimeter vent could also meet the secondary roof opening requirement.
4. Extend Sample Tap: Extend the sample line further into the tank.
5. Separate Inlet/Outlet Piping: Separate inlet and outlet piping to prevent short circuiting. The City currently uses a Tideflex mixing system on other upgraded tanks. Use of this system does not require maintenance or electricity but will require modifications to separate the inlet and outlet piping. The City is satisfied with the Tideflex system.
6. Overflow Air Gap: Modify the tank overflow to provide an air gap and remove the direct connection to the storm drain system.
7. Tank Drain Modification: Modify the tank drain to remove the direct connection to the storm drain system. The City provided a detail of a valve vault installed at other tanks that allows the City to pump the tank drain line back into the distribution system. The concern with the detail provided is that although a check valve is specified, there is still a direct connection to the storm drain system. It is not clear whether or not DDW would approve such a design or if they have done so in the past. The costs for this item were increased to allow for the valve vault installation should the design be approved by DDW.
8. Install Saf-T-Climb Extension: Install a ladder-up and Saf-T-Climb extension to improve safety and fall protection when entering the tank from the roof.
9. Replace Guardrails: Replace tank guardrails to improve safety.
10. Install Toeboard: Install exterior toeboard platform.
11. Modify Exterior Access Staircase: Modify the manway access staircase so that it doesn’t protrude into the tank driveway.
12. Replace Interior Ladder: Replace existing interior ladder with coated stainless-steel ladder and dielectric insulators.
13. Replace Interior Ladder Saf-T-Climb: Replace interior ladder Saf-T-Climb to improve safety.
14. Install Additional Roof Ventilation: Install three perimeter roof vents to prevent interior rood condensation.
15. Replace Security Fence: Replace the site security fence with a 7-foot chain link fence with 3-strand barbed wire.

16. Recoat Tank Exterior: Recoat the exterior of the tank and attached exterior cabinets in tan to improve tank aesthetics.
17. Plate and Seal Weld Existing Handholes: Plate and seal weld the existing handholes and roof plates to permanently remove the previous cathodic protection system.
18. Clean and Seal Exterior Annular Ring: Clean the exterior annular ring cavities where lifting occurred and seal to prevent moisture accumulation and corrosion
19. Inspect Tank Every 5 Years: Inspect the tank every 5 years on a regular maintenance schedule
20. Strengthen Column and Roof: Strengthen existing interior column and roof.
21. Strengthen Shell and Anchorage: Strengthen existing shell courses and anchorage.
22. Strengthen Foundation: Strengthen existing tank foundation ringwall.
23. Add Anchorage: Install anchors on existing tank.
24. Replace Pipe Connections: Reconfigure piping to provide flexibility to withstand a seismic event.
25. Replace Generator: Replace existing natural gas/propane generator with diesel powered generator.
26. Modify Generator Room Air Inlet: Modify the air inlet to the generator room to allow proper air flow during generator operations.
27. Install Harmonic Filter: Install harmonic filter to address any harmonic issues.
28. Replace ATS: Replace existing circuit breaker type ATS with a new modernized ATS.
29. Add Arc Flash Labeling: Perform an arc flash study and add arc flash labeling to electrical panels.

6.2 ESTIMATED COSTS

The estimated costs for each tank and pump station site are included in Table 6-2. These costs incorporate the feedback received from City staff and include all improvements recommended in this report. The total cost for all tank and pump station sites is $11,093,500.

Attachment 2

Table 6-2. Summary of Recommended Improvements and Estimated Costs

	Improvement		Reservoir/Pump Station Site								
			R-9A Total	R-16 Total	R-17 Total	S-1 Total	S-2 Total	S-15 Total	S-16 Total	S-17 Total	S-18 Total
1	General Conditions & Mob./Demob.		117,700	48,900	69,300	19,300	17,500	19,500	16,000	16,500	10,000
2	Partial Demo of (E) Ringwall		48,000	42,000	69,000	0	0	0	0	0	0
3	Build New Ringwall & Replace / Install Anchors		283,000	86,000	134,000	0	0	0	0	0	0
4	Strengthen Tank Roof		229,000	70,000	79,000	0	0	0	0	0	0
5	Strengthen (E) Column		33,000	8,600	9,000	0	0	0	0	0	0
6	Strengthen (E) Shell Courses		350,000	159,000	237,000	0	0	0	0	0	0
7	Interior Recoating		565,000	145,000	268,000	0	0	0	0	0	0
8	Install New Center Vent (Standardized)		11,800	11,800	11,800	0	0	0	0	0	0
9	Add Additional Roof Vents		18,000	6,000	6,000	0	0	0	0	0	0
10	Replace Pipe Connections		14,000	0	0	0	0	0	0	0	0
11	In/Outlet Modifications with Check Valve		45,000	45,000	45,000	0	0	0	0	0	0
12	Overflow Airgap Modification		14,000	14,000	18,000	0	0	0	0	0	0
13	Tank Drain Modification		10,000	10,000	10,000	0	0	0	0	0	0
14	Replace Safety Climb System and Guardrails		14,000	0	0	0	0	0	0	0	0
15	Add Exterior Toeboard Platform		0	2,000	2,000	0	0	0	0	0	0
16	Replace Interior Ladder and Safety Climb		19,000	18,000	28,000	0	0	0	0	0	0
17	Extend Sample Tap		0	5,000	0	0	0	0	0	0	0
18	Recoat Exterior of Tank		409,000	108,000	224,000	0	0	0	0	0	0
19	Recoat Cabinets		0	2,000	2,000	0	0	0	0	0	0
20	Replace Security Fence		0	25,000	20,000	0	0	0	0	0	0
21	Replace Shell Access Manway (30-inch)		8,500	0	0	0	0	0	0	0	0
22	Replace Shell Access Manway (24-inch)		17,000	0	0	0	0	0	0	0	0
23	Modify / Replace Manway Access Staircase		0	0	2,500	0	0	0	0	0	0
24	Remove Cathodic Protection System Handholes and Repair		10,000	7,000	7,000	0	0	0	0	0	0
25	Clean and Seal Annular Ring Wall at Concrete Pad		2,500	2,500	2,500	0	0	0	0	0	0
26	Replace Generator		0	0	0	375,000	340,000	275,000	320,000	320,000	190,000
27	Perform Arc Flash Studies		0	0	0	10,000	10,000	10,000	0	10,000	10,000
28	Install Harmonic Filter		0	0	0	0	0	80,000	0	0	0
29	Install Automatic Transfer Switch		0	0	0	0	0	25,000	0	0	0
30	Modify Generator Room Air Inlet		0	0	0	0	2,000	0	0	0	0
31	Miscellaneous Site Work		66,000	26,000	38,000	39,000	35,000	39,000	32,000	33,000	20,000
	Subtotal Construction Cost:		$2,284,500	$841,800	$1,282,100	$443,300	$404,500	$448,500	$368,000	$379,500	$230,000
	Estimating Contingency (rounded):	30%	685,400	252,600	384,700	133,000	121,400	134,600	110,400	113,900	69,000
	Construction Contingency (rounded):	10%	228,500	84,200	128,300	44,400	40,500	44,900	36,800	38,000	23,000
	Total Construction Cost:		$3,198,400	$1,178,600	$1,795,100	$620,700	$566,400	$628,000	$515,200	$531,400	$322,000
	Design & CM[(a)] (rounded):	20%	594,000	218,900	333,400	115,300	105,200	116,700	95,700	98,700	59,800
	Total Cost:		$3,792,400	$1,397,500	$2,128,500	$736,000	$671,600	$744,700	$610,900	$630,100	$381,800

(a) Does not include City Admin time

APPENDIX A

Reference Documents

APPENDIX B

Code Evaluation Tables

Table B-1. R-9A Tank Code Evaluation

Code Section	Requirement	Comments	Code Compliance
AWWA D100-11 – Welded Carbon Steel Tanks for Water Storage			
7.3 – Overflow	Overflow capacity shall be at least equal to inlet flow rate.	The overflow and associated storm drain system have a minimum conveyance capacity of about 1,230 gpm, while the required overflow rate is about 1,000 gpm.	Yes
7.3 – Overflow	Overflow outlet shall be covered with coarse, corrosion resistant screen, or flap valve.	As-built drawings indicate that screens are provided on the overflow outlet; however, this was not confirmed during field investigations since the outlet is below grade.	Yes
7.4.3.1	Provide roof opening near exterior tank with lockable hinged cover and minimum opening of 24 inches.	A 30-inch square roof opening near the tank shell is provided.	Yes
7.4.3.2	Provide additional opening near or at the center of the tank. Opening shall have removable cover with minimum opening of 20 inches. The tank vent is acceptable means of meeting this requirement, provided the vent is removeable.	Although the center vent is removable the center column roof support prevents access to the interior of the tank. Therefore, the intent of this regulation is not met.	No
7.4.4	Two shell manways are required within the first shell ring. One opening shell be 30 inches in diameter, while the other may be 24 inches minimum.	One 30-inch and one 24-inch diameter manways are provided and located within the first shell ring. However, operation staff has requested two hanging swing type 30-inch diameter manways similar to the existing manways at Tank R-16 and Tank R-17.	Yes
7.5 - Vent	Vent shall be provided and located near or at the center of the tank.	A roof vent is provided and located near the center of the tank.	Yes
7.5 - Vent	Vent shall be designed to prevent entrance of birds or animals. If a screen is used, a mechanism shall be provided to allow venting if screen becomes clogged with insects.	Vents include screens; however, no means is provided to allow venting if the screen becomes clogged. There are two options: install new vent mechanism to allow continued venting if the screens become plugged, or install pressure/vacuum relief valve on tank roof.	No
13.5.4.4	Freeboard shall be the distance between the Maximum operating level and lowest level of roof framing, and shall be at least the calculated sloshing wave.	The freeboard requirement is not met, see Structural and Seismic Evaluation for further discussion.	No
13.6.1	Piping connections to the tank shall provide for minimum design displacements as defined by this standard.	Piping connections do not have sufficient flexibility for the estimated movement during a seismic event, see Structural and Seismic Evaluation.	No

Table B-1. R-9A Tank Code Evaluation			
Code Section	Requirement	Comments	Code Compliance
California Code of Regulations Title 22 – Chapter 16. California Waterworks Standards, Article 6. Distribution Reservoirs			
§64585(a)(2)	Vents and other openings shall prevent entry of rainwater, birds, insects, rodents, of other animals.	This requirement is met.	Yes
§64585(a)(3)	Provide at least one sample tap.	Sample taps are provided.	Yes
§64585(b)(4)	Provide one separate inlet and outlet, and configure to minimize short-circuiting.	The inlet and outlet are not separate. Two potential options include separating the inlet and outlet with additional piping and valving, or installing a mechanical mixer.	No
§64585(b)(5)	Drainage facilities and overflow device shall not be directly connected to a sanitary sewer or storm drain.	Both the overflow and tank drain are connected directly to the storm drain system. An air gap is required between the storm drain system and the overflow and tank drain.	No
§64585(b)(6)	Equipped with controls to maintain and monitor water levels.	Tank water levels are monitored and controlled.	Yes
§64585(b)(7)	Equipped to prevent access by unauthorized persons.	Locked ladder door prevents access to the tank roof. The roof access is also locked.	Yes
§64585(b)(8)	Designed to allow authorized access and lighting for inspection, cleaning, or repair.	Adequate access and lighting were observed during field investigations.	Yes
§64585(b)(9)	Equipped with isolation valves located within 100 feet of tank.	Isolation valves are located within 10 feet of the tank; therefore, this requirement is met.	Yes
§64585(b)(10)	Constructed to prevent entry of surface runoff, subsurface flow, or drainage into tank.	This requirement is met. The tank bottom is set above surrounding finish grades, and the existing ground surface slopes away from the tank.	Yes

Table B-1. R-9A Tank Code Evaluation			
Code Section	Requirement	Comments	Code Compliance
California Code of Regulations Title 8 (Cal/OHSA)			
§1670(a)	Fall arrest or fall protection shall be provided if personnel are exposed to falling in excess of 7.5 feet.	The ladder includes a Saf-T-Climb fall prevention system and ladder cage, and the tank roof includes fall prevention cables.	Yes
§3277(d)(2)	Fixed Ladder: Distance between ladder rungs shall be 12 inches.	As-built drawings and field observations confirm requirement is met.	Yes
§3277(d)(3)	Fixed Ladder: Distance between ladder rails shall be 16 inches.	As-built drawings and field observations confirm requirement is met.	Yes
§3277 – Fig. 1	7 inches minimum clearance shall be provided between ladder rungs and tank shell.	As-built drawings and field observations confirm requirement is met.	Yes
§3277(e)(3)	Cages shall extend minimum 42 inches above landing platform.	As-built drawings and field observations confirm requirement is met.	Yes
§3277(e)(4)	Cages shall extend down the ladder not less than 7 feet nor more than 8 feet above the base of the ladder.	As-built drawings and field observations confirm requirement is met.	Yes
§3210(a) & (11)	Guardrails are required if work area is more than 30 inches above the ground level, unless workers are protected by a fall restraint/fall arrest system.	Guardrails are provided at the roof to transition from the exterior ladder to the tank roof, fall prevention cables are provided in areas not protected by guardrails. Therefore, this requirement is met.	Yes
§3209(a)	Guardrails shall consist of top rail and mid-rail, and shall have a vertical height of between 42 and 45 inches above surface.	As-built drawings and field observations confirm requirement is met.	Yes
§3209(c)(2)	Rails and post shall be 1.5-inch minimum diameter pipe, post spacing shall not exceed 8 feet.	As-built drawings indicate the guardrails are 1.25-inch diameter and therefore do not meet the minimum standard.	No
§3210(a)	Toeboards are required if platform is 6 feet or greater above normal work area.	As-built drawings and field observations confirm requirement is met.	Yes
§3209(d)	The top of toeboards shall not be less than 3.5 inches above platform.	As-built drawings and field observations confirm requirement is met. Toeboards provided are 4 inches high.	Yes

Table B-2. R-16 Tank Code Evaluation			
Code Section	Requirement	Comments	Code Compliance
AWWA D100-11 – Welded Carbon Steel Tanks for Water Storage			
7.3 – Overflow	Overflow capacity shall be at least equal to inlet flow rate.	The overflow and associated storm drain system have a minimum conveyance capacity of about 2,000 gpm, while the required overflow rate is 1,120 gpm (estimated inflow rate).	Yes
7.3 – Overflow	Overflow outlet shall be covered with coarse, corrosion resistant screen, or flap valve.	As-built drawings indicate that screens are provided on the overflow outlet; however, this was not confirmed during field investigations since the outlet is below grade.	Yes
7.4.3.1	Provide roof opening near exterior tank with lockable hinged cover and minimum opening of 24 inches.	A 30-inch square roof opening near the tank shell is provided.	Yes
7.4.3.2	Provide additional opening near or at the center of the tank. Opening shall have removable cover with minimum opening of 20 inches. The tank vent is acceptable means of meeting this requirement, provided the vent is removeable.	Although the center vent is removable, the center column roof support prevents access to the interior of the tank. Therefore, the intent of this requirement is not met.	No
7.4.4	Two shell manways are required within the first shell ring. One opening shell be 30 inches in diameter, while the other may be 24 inches minimum.	Two 36-inch diameter manways are provided and located within the first shell ring.	Yes
7.5 - Vent	Vent shall be provided and located near or at the center of the tank.	A roof vent is provided and located near the center of the tank.	Yes
7.5 - Vent	Vent shall be designed to prevent entrance of birds or animals. If a screen is used, a mechanism shall be provided to allow venting if the screen becomes clogged with insects.	Vents include screens; however, no means is provided to allow venting if the screen becomes clogged. There are two options: install new vent mechanism to allow continued venting if the screens become plugged, or install pressure/vacuum relief valve on tank roof.	No
13.5.4.4	Freeboard shall be the distance between the maximum operating level and lowest level of roof framing, and shall be at least the calculated sloshing wave.	The provided freeboard is 1 foot, while the minimum code required freeboard is 7.6 feet. The freeboard requirement is not met, see Structural and Seismic Evaluation for further discussion.	No
13.6.1	Piping connections to the tank shall provide for minimum design displacements as defined by this standard.	As-built drawings indicate that EBAA Iron Flex-tends joints are provided for all pipe connections to the tank.	Yes

Table B-2. R-16 Tank Code Evaluation

Code Section	Requirement	Comments	Code Compliance
California Code of Regulations Title 22 – Chapter 16. California Waterworks Standards, Article 6. Distribution Reservoirs			
§64585(a)(2)	Vents and other openings shall prevent entry of rainwater, birds, insects, rodents, of other animals.	This requirement is met.	Yes
§64585(a)(3)	Provide at least one sample tap.	Sample taps are provided. However, operations staff has requested that the sample lines extend into the tank.	Yes
§64585(b)(4)	Provide one separate inlet and outlet, and configure to minimize short-circuiting.	The inlet and outlet are not separate. Two potential options include separating the inlet and outlet with additional piping and valving, or installing a mechanical mixer.	No
§64585(b)(5)	Drainage facilities and overflow device shall not be directly connected to a sanitary sewer or storm drain.	Both the overflow and tank drain are connected directly to the storm drain system. An air gap between the storm drain system and the overflow and tank drain are required.	No
§64585(b)(6)	Equipped with controls to maintain and monitor water levels.	Tank water levels are monitored and controlled.	Yes
§64585(b)(7)	Equipped to prevent access by unauthorized persons.	Locked ladder door prevents access to the tank roof. The roof access is also locked.	Yes
§64585(b)(8)	Designed to allow authorized access and lighting for inspection, cleaning, or repair.	Adequate access and lighting were observed during field investigations.	Yes
§64585(b)(9)	Equipped with isolation valves located within 100 feet of tank.	Isolation valves are located within 10 feet of the tank; therefore, this requirement is met.	Yes
§64585(b)(10)	Constructed to prevent entry of surface runoff, subsurface flow, or drainage into tank.	This requirement is met. The tank bottom is set above surrounding finished grades, and the existing ground surface slopes away from the tank.	Yes

Table B-2. R-16 Tank Code Evaluation

Code Section	Requirement	Comments	Code Compliance
California Code of Regulations Title 8 (Cal/OHSA)			
§1670(a)	Fall arrest or fall protection shall be provided if personnel are exposed to falling in excess of 7.5 feet.	The ladder includes a Saf-T-Climb fall prevention system and ladder cage, and the tank roof includes fall prevention cables.	Yes
§3277(d)(2)	Fixed Ladder: Distance between ladder rungs shall be 12 inches.	As-built drawings and field observations confirm requirement is met.	Yes
§3277(d)(3)	Fixed Ladder: Distance between ladder rails shall be 16 inches.	As-built drawings and field observations confirm requirement is met.	Yes
§3277 – Fig. 1	7 inches minimum clearance shall be provided between ladder rungs and tank shell.	As-built drawings and field observations confirm requirement is met.	Yes
§3277(e)(3)	Cages shall extend minimum 42 inches above landing platform.	As-built drawings and field observations confirm requirement is met.	Yes
§3277(e)(4)	Cages shall extend down the ladder not less than 7 feet nor more than 8 feet above the base of the ladder.	As-built drawings and field observations confirm requirement is met.	Yes
§3210(a) & (11)	Guardrails are required if work area is more than 30 inches above the ground level, unless workers are protected by a fall restraint/fall arrest system.	Guardrails are provided at the roof to transition from the exterior ladder to the tank roof, fall prevention cables are provided in areas not protected by guardrails. Therefore, this requirement is met.	Yes
§3209(a)	Guardrails shall consist of top rail and mid-rail, and shall have a vertical height of between 42 and 45 inches above surface.	As-built drawings and field observations confirm requirement is met.	Yes
§3209(c)(2)	Rails and posts shall be 1.5-inch minimum diameter pipe, post spacing shall not exceed 8 feet.	As-built drawings and field observations confirm requirement is met.	Yes
§3210(a)	Toeboards are required if platform is 6 feet or greater above normal work area.	Toeboards are required for the ladder platform, but are not included.	No
§3209(d)	The top of toeboards shall not be less than 3.5 inches above platform.	Toeboards are not included, see above comment.	No

Table B-3. R-17 Tank Code Evaluation

Code Section	Requirement	Comments	Code Compliance
AWWA D100-11 – Welded Carbon Steel Tanks for Water Storage			
7.3 – Overflow	Overflow capacity shall be at least equal to inlet flow rate.	The overflow and associated storm drain system have a minimum conveyance capacity of about 2,055 gpm, while the required overflow rate is 1,505 gpm (estimated inflow rate, assumes R-17 does not fill from both S-17 & S-18 at the same time).	Yes
7.3 – Overflow	Overflow outlet shall be covered with coarse, corrosion resistant screen, or flap valve.	As-built drawings indicate that screens are provided on the overflow outlet; however, this was not confirmed during field investigations since the outlet is below grade.	Yes
7.4.3.1	Provide roof opening near exterior tank with lockable hinged cover and minimum opening of 24 inches.	A 30-inch square roof opening near the tank shell is provided.	Yes
7.4.3.2	Provide additional opening near or at the center of the tank. Opening shall have removable cover with minimum opening of 20 inches. The tank vent is acceptable means of meeting this requirement, provided the vent is removeable.	Although the center vent is removable, the center column roof support prevents access to the interior of the tank. Therefore, the intent of this requirement is not met.	No
7.4.4	Two shell manways are required within the first shell ring. One opening shell be 30 inches in diameter, while the other may be 24 inches minimum.	Two 36-inch diameter manways are provided and located within the first shell ring.	Yes
7.5 - Vent	Vent shall be provided and located near or at the center of the tank.	A roof vent is provided and located near the center of the tank.	Yes
7.5 - Vent	Vent shall be designed to prevent entrance of birds or animals. If a screen is used, a mechanism shall be provided to allow venting if screen becomes clogged with insects.	Vents include screens; however, no means is provided to allow venting if the screen becomes clogged. There are two options: install new vent mechanism to allow continued venting if the screens become plugged, or install pressure/vacuum relief valve on tank roof.	No
13.5.4.4	Freeboard shall be the distance between the maximum operating level and lowest level of roof framing, and shall be at least the calculated sloshing wave.	The provided freeboard is 1.2 feet, while the minimum code required freeboard is 8.9 feet. The freeboard requirement is not met, see Structural and Seismic Evaluation for further discussion.	No
13.6.1	Piping connections to the tank shall provide for minimum design displacements as defined by this standard.	As-built drawings indicate that EBAA Iron Flex-tends joints are provided for all pipe connections to the tank.	Yes

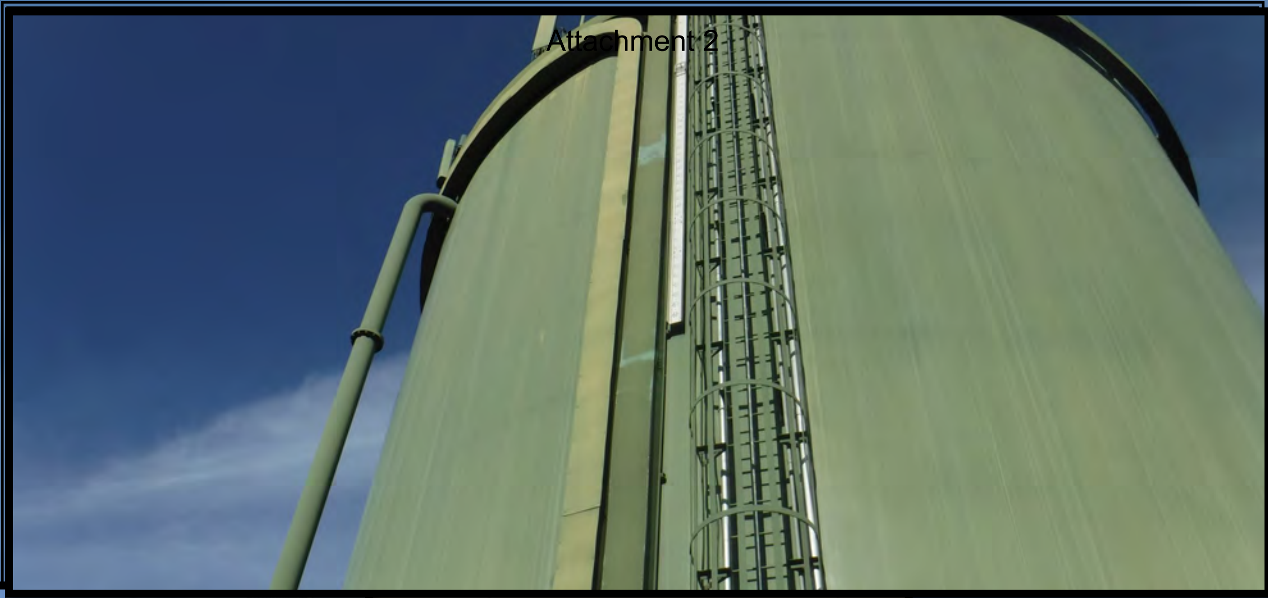
Table B-3. R-17 Tank Code Evaluation			
Code Section	Requirement	Comments	Code Compliance
California Code of Regulations Title 22 – Chapter 16. California Waterworks Standards, Article 6. Distribution Reservoirs			
§64585(a)(2)	Vents and other openings shall prevent entry of rainwater, birds, insects, rodents, of other animals.	This requirement is met.	Yes
§64585(a)(3)	Provide at least one sample tap.	Sample taps are provided.	Yes
§64585(b)(4)	Provide one separate inlet and outlet, and configure to minimize short-circuiting.	The inlet and outlet are not separate. Two potential options include separating the inlet and outlet with additional piping and valving, or installing a mechanical mixer.	No
§64585(b)(5)	Drainage facilities and overflow device shall not be directly connected to a sanitary sewer or storm drain.	Both the overflow and tank drain are connected directly to the storm drain system. An air gap between the storm drain system and the overflow and tank drain are required.	No
§64585(b)(6)	Equipped with controls to maintain and monitor water levels.	Tank water levels are monitored and controlled.	Yes
§64585(b)(7)	Equipped to prevent access by unauthorized persons.	Locked ladder door prevents access to the tank roof. The roof access is also locked.	Yes
§64585(b)(8)	Designed to allow authorized access and lighting for inspection, cleaning, or repair.	Adequate access and lighting were observed during field investigations.	Yes
§64585(b)(9)	Equipped with isolation valves located within 100 feet of tank.	Isolation valves are located within 10 feet of the tank; therefore, this requirement is met.	Yes
§64585(b)(10)	Constructed to prevent entry of surface runoff, subsurface flow, or drainage into tank.	This requirement is met. The tank bottom is set above surrounding finished grades, and the existing ground surface slopes away from the tank.	Yes

Table B-3. R-17 Tank Code Evaluation			
Code Section	Requirement	Comments	Code Compliance
California Code of Regulations Title 8 (Cal/OHSA)			
§1670(a)	Fall arrest or fall protection shall be provided if personnel are exposed to falling in excess of 7.5 feet.	The ladder includes a Saf-T-Climb fall prevention system and ladder cage, and the tank roof include fall prevention cables.	Yes
§3277(d)(2)	Fixed Ladder: Distance between ladder rungs shall be 12 inches.	As-built drawings and field observations confirm requirement is met.	Yes
§3277(d)(3)	Fixed Ladder: Distance between ladder rails shall be 16 inches.	As-built drawings and field observations confirm requirement is met.	Yes
§3277 – Fig. 1	7 inches minimum clearance shall be provided between ladder rungs and tank shell.	As-built drawings and field observations confirm requirement is met.	Yes
§3277(e)(3)	Cages shall extend minimum 42 inches above landing platform.	As-built drawings and field observations confirm requirement is met.	Yes
§3277(e)(4)	Cages shall extend down the ladder not less than 7 feet nor more than 8 feet above the base of the ladder.	As-built drawings and field observations confirm requirement is met.	Yes
§3210(a) & (11)	Guardrails are required if work area is more than 30 inches above the ground level, unless workers are protected by a fall restraint/fall arrest system.	Guardrails are provided at the roof to transition from the exterior ladder to the tank roof, fall prevention cables are provided in areas not protected by guardrails. Therefore, this requirement is met.	Yes
§3209(a)	Guardrails shall consist of top rail and mid-rail, and shall have a vertical height of between 42 and 45 inches above surface.	As-built drawings and field observations confirm requirement is met.	Yes
§3209(c)(2)	Rails and post shall be 1.5-inch minimum diameter pipe, post spacing shall not exceed 8 feet.	As-built drawings and field observations confirm requirement is met.	Yes
§3210(a)	Toeboards are required if platform is 6 feet or greater above normal work area.	Toeboards are required for the ladder platform, but are not included.	No
§3209(d)	The top of toeboards shall not be less than 3.5 inches above platform.	Toeboard are not included, see above comment.	No

APPENDIX C

JDH Corrosion

Attachment 2



Corrosion Evaluation Report

Water Storage Tanks R-16, R-17, & R-9A
Santa Rosa, CA

West Yost Associates , Davie, CA

April 17, 2017

jdh corrosion consultants, inc.

1100 Willow Pass Court, Concord, CA 94520 Tel. No. 925.927.6630 Fax No. 925.927.6634 jdh corrosion consultants, inc.

Protecting the infrastructure through innovative Corrosion Engineering Solutions

April 18, 2017

West Yost Associates
2020 Research Park Drive, Suite 100
Davis, CA 95618

Attention: Jeffery Wanlass

Subject: Corrosion Evaluation Report
Tanks R-16, R-17, & R-9A
Santa Rosa, CA

Dear Jeffery,

Pursuant to your request, *JDH Corrosion Consultants, Inc.*, has conducted a condition assessment of the above referenced structures and we have provided herein our findings and recommendations.

PROJECT BACKGROUND

Three water storage tanks (R-9A, R-16, & R-17) owned and operated by the City of Santa Rosa require a condition assessment of their cathodic protection systems.

PURPOSE

This condition assessment is being conducted for the City of Santa Rosa to evaluate the cathodic protection system on three of their above ground water storage tanks.

TEST METHODS

Our evaluation consisted of the following:

1. Visual Inspection
2. Ultrasonic Thickness Survey
3. Photographic Documentation
4. Site Corrosivity Evaluation
5. Cathodic Protection System Evaluation

VISUAL INSPECTION

Fountain Grove R-16
R-16 was fabricated and erected by Trusco Tank Inc. out of San Luis Obispo, CA in 1994. The contract number was 238. Nominal capacity is .25 MG. Design liquid level is 34 feet. Nominal diameter is 36 feet. Shell height is 35 feet. The exterior of the tank appears to be lifting at the annular ring wall which as moss growing along with corrosion activity present. This should be cleaned and sealed. The exterior coating is in fair condition with chalking. No major concern or pitting activity.

Water is present on the exterior walls. Exterior ladder is in good condition and is coated with the same coating as the exterior of the tank. No exterior corrosion was noted.

The interior of the tank walls, ladder and floors coating is in good condition with very little corrosion noted. There is minor corrosion on the roof.

Horton Tank R-9A
R-9A was fabricated and erected by Chicago Bridge & Iron Company out of Oak Brook, Illinois in 1977. The contract number was 71538. Nominal capacity is 2 MG. Nominal height is 42 feet. Nominal diameter is 92 feet.

The exterior of the tank appears to be lifting at the annular ring wall which has been filled with some sort of caulking. There appears to be no moss or corrosion present along this seam. The exterior coating is in fair condition with chalking. No major concern or pitting activity. Exterior ladder is in good condition and is coated with the same coating as the exterior of the tank. No exterior corrosion was noted. Coating has many patches from previous repairs in the coating, likely due to rock damage from rock rocks being thrown against tank by local youth from outside the fence line.

The interior of the tank walls and floors coating is in good condition with very little corrosion noted, mainly at seams. There is minor corrosion on the roof, again along the seams. Ladder climbing safety system has large amount of corrosion product present on surface.

Fountain Grove R-17
R-17 was fabricated and erected by Trusco Tank Inc. out of San Luis Obispo, CA in 1994. The contract number was 238. Nominal capacity is .75 MG. Design liquid level is 57-10 feet. Nominal diameter is 47 feet. Shell height is 59 feet.

The exterior of the tank appears to be lifting at the annular ring wall which as moss growing along with minor corrosion activity present. This should be cleaned and sealed. The exterior coating is in fair condition with caulking. No major concern or pitting activity. Water is present on the exterior walls. Exterior ladder is in good condition and is coated with the same coating as the exterior of the tank. No exterior corrosion was noted.

The interior of the tank was only accessible from the top hatch as the tank was still in service and contained water. However, from what we could see the walls, ladder and floors coating is in good condition with very little corrosion noted. There is minor corrosion on the roof along seams.

ULTRASONIC THICKNESS SURVEY

Manual UT wall thickness readings were recorded at selected locations along the tanks in order to confirm the thickness of the tank sections.

The UT meter used for all metallic structures is a Model 4+ Plus combination digital/A-scan meter manufactured by Cygnus, Inc. This Meter uses a dual-element transducer to measure the steel thickness. A short duration electrical pulse, which converts the electrical energy into mechanical vibrations or sound waves, excites a piezoelectric transducer. These sound waves pass through the medium and test material and are reflected back from the opposite surface. The receiver section of the transducer receives the reflected sound waves and converts them to electrical pulses. The elapsed time (t) is equal to the total time between the transmitted pulse and the received echo minus the transducer delay time. This relates the thickness (x) and velocity (V) at which sound waves travel through the material by the relationship, $x = Vt / 2$, where;

x	=	thickness of material
V	=	velocity of ultrasonic sound in the material, and
t	=	total measured time.

The tanks are made of steel and as such, the "echo-to-echo" mode of operation was utilized. Each time the echo is reflected back down through the metal, a small portion of the energy comes up through the coating, striking the probe, which now acts as a receiver. The delay between echoes at the probe face is exactly equal to the time taken to pass through the metal twice; therefore, coatings such as paint are ignored, and the meter displays only the metal thickness. This technique works well as long as the subject coating system is well adhered to the steel substrate, without any air gaps or delamination, as was the case for all tested locations.

The "echo-to-echo" mode also automatically compensates for the coating thickness and any couplant thickness simultaneously. Soundsafe ultrasonic couplant was used as the couplant for this survey and was manually applied to the tanks.

Ultrasonic thickness measurements using a digital meter in the fashion described herein will provide valuable data with regard to overall and localized wall thinning. This type of survey technique cannot be used to detect pitting corrosion or other types of corrosion that manifest in relatively small select areas. As a result, some pitting may be excluded from the data set.

R-16

Structure	Thickness (mils)
Roof	180
Knuckle	230
Shell Ring 4	240
Shell Ring 3	245
Shell Ring 2	250
Shell Ring 1	505
Annular Ring	240
Floor	235

R-17

Structure	Thickness (mils)
Roof	175
Knuckle	235
Shell Ring 6	295
Shell Ring 5	250
Shell Ring 4	255
Shell Ring 3	375
Shell Ring 2	500
Shell Ring 1	765

R-9A

Structure	Thickness (mils)
Roof	195
Knuckle	260
Shell Ring 5	250
Shell Ring 4	265
Shell Ring 3	330
Shell Ring 2	440
Shell Ring 1	525
Annular Ring	375
Floor	225

PHOTOGRAPHIC DOCUMENTATION

Photographs are provided below to document the as-found condition of the water storage tanks.

Photo No. 1 – Fountain Grove R-16 Identification plate.

Photo No. 2 – Exterior view of R-16.

Photo No. 3 – Remains of abandoned cathodic protection system on R-16.

Photo No. 4 – Interior view of R-16 with anodes still suspended from ceiling.

Photo No. 5 – Annular ring wall with moss growing under tank.

Photo No. 6 – Fountain Grove R-17 identification plate.

Photo No. 7 – R-17 interior view with debris on bottom.

Photo No. 8 – Interior roof view of R-17 with minor corrosion on roof seams.

Photo No. 9 – Annular ring of R-17 with corrosion product on ring.

Photo No. 10 – Exterior view of R-17.

Photo No. 11 – Horton Tank R-9A identification plate.

Photo No. 12 – Exterior view of R-9A.

Photo No. 13 – Interior of R-9A with anodes still suspended from roof.

Photo No. 14 – Interior of R-9A with minor corrosion at seams.

Photo No. 15 – R-9A with corrosion product on ladder climbing safety system.

Photo No. 16 – Exterior of R-9A with chalking present on exterior coating.

Photo No. 17 – R-9A annular ring with sealant between annular space and concrete pad.

Photo No. 18 – Exterior coating repair of R-9A likely from rock damage.

SITE CORROSIVITY EVALUATION

Corrosion of a metal is an electro-chemical process and is accompanied by the flow of electric current. Resistivity is a measure of the ability of a soil to conduct an electric current and is, therefore, an important parameter in consideration of corrosion data. Soil resistivity is primarily dependent upon the chemical content and moisture content of the soil mass.

The greater the amount of chemical constituents present in the soil, the lower the resistivity will be. As moisture content increases, resistivity decreases until maximum solubility of dissolved chemicals is attained. Beyond this point, an increase in moisture content results in dilution of the chemical concentration and resistivity increases. The corrosion rate of steel in soil normally increases as resistivity decreases. Therefore, in any particular group of soils, maximum corrosion will generally occur in the lowest resistivity areas. The following classification of soil corrosivity, developed by William J. Ellis[1], is used for the analysis of the soil data for the project site.

Resistivity (Ohm-cm)	Corrosivity Classification
0 – 500	Severely Corrosive
501 – 2,000	Corrosive
2,001 – 8,000	Moderately Corrosive
8,001 – 32,000	Mildly Corrosive
> 32,000	Progressively Less Corrosive

TABLE 1: Resistivity Analysis (In-Situ)

Site	Range of Results	Corrosion Classification
R-16	10,370 – 15,339 ohms-cm	Mildly Corrosive
R-17	10,762 – 13,142 ohm-cm	Mildly Corrosive
R-9A	2,499 – 3,308 ohm-cm	Moderately Corrosive

CATHODIC PROTECTION SYSTEM EVALUATION

There currently are no cathodic protection systems installed on any of the tanks. However, upon inspection, all tanks previously had an impressed current system installed as evidenced by the remaining anodes inside of the tank. The rectifiers that were once installed and in operation have since been removed by water district staff.

DISCUSSION AND ANALYSIS

Overall the tanks were found to be in satisfactory condition. No significant sagging or shifting of the structures has occurred.

The exterior coatings on all tanks appear to be in fair condition with chalking and minor repairs throughout. R-9A has more repairs to its exterior coating from rock damage. The annular ring of each tank is elevated off the concrete pad and at R-16 and R-17 are not sealed and have corrosion present on the ring.

The interior coatings are in good condition overall with minor corrosion present at the seams along the roof on all tanks.

Each tank had an impressed current cathodic protection system installed at some point, as evidenced by the anodes still suspended on all tanks, which has been removed for unknown reasons.

RECOMMENDATIONS

1. JDH recommends that the previously removed rectifiers be reinstalled and cathodic protection systems re-energized to extend the life of the coatings.

2. The exterior annular ring cavities beneath the tanks where lifting should be cleaned and sealed to prevent moisture from accumulating, allowing corrosion to occur.

3. The tanks should be inspected on a 5-year maintenance schedule, except as warranted following future inspections.

LIMITATIONS

The conclusions and recommendations contained in this report are based on the information and assumptions referenced herein. All services provided herein were performed by persons who are experienced and skilled in providing these types of services and in accordance with the standards of workmanship in this profession. No other warrantees expressed or implied are provided.

We appreciate the opportunity to be of service to West Yost, on this project and trust that you find the analysis and conclusions contained herein satisfactory.

If you have any questions concerning the findings from this evaluation or the contents of this report or if we can be of any additional assistance, please do not hesitate to contact us at (925) 927-6630.

Respectfully submitted,

REGISTERED PROFESSIONAL ENGINEER
J. DARBY HOWARD, JR.
No. CR 1055
Exp. June 30, 2019
CORROSION
STATE OF CALIFORNIA

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JD Howard
JDH Corrosion Consultants, Inc.
Corrosion Control

APPENDIX D

Code Group Delta Geotechnical Evaluation

GROUP DELTA

GEOTECHNICAL INVESTIGATION
SEISMIC EVALUATION OF R-9A, R-16, AND R-17 WATER STORAGE TANKS
SANTA ROSA, CALIFORNIA

Prepared for:

WEST YOST ASSOCIATES, INC
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Prepared by:

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Tel: (510) 671-0010

Group Delta Project No. BA024
May 12, 2017

May 12, 2017

West Yost Associates, Inc
2020 Research Park Drive, Suite 100
Davis, CA 95618

Attention: Jeffrey Wanlass, PE

Subject: Geotechnical Investigation
Seismic Evaluation of R-9A, R-16, and R-17 Water Storage Tanks
Santa Rosa, California
Group Delta Project No. BA024

Dear Mr. Wanlass:

Group Delta is pleased to submit the enclosed geotechnical report in support of the seismic evaluation of the existing R-9A, R-16, and R-17 water storage tanks in Santa Rosa, California. Our services were performed in general accordance with our agreement dated March 15, 2016. The results of our exploration, analyses, and conclusions are presented in the enclosed report.

If you have any questions regarding this report, please feel free to call at (510) 671-0010.

Sincerely,

Group Delta Consultants, Inc.

Ali Salehian, PhD, PE
Project Engineer

Benjamin Serna, PE, GE
Associate Engineer

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GROUP DELTA

1.0 INTRODUCTION

The City of Santa Rosa (City) has retained West Yost Associates, Inc., to perform a seismic evaluation of the existing steel water storage tanks R-9A, R-16, and R-17 in Santa Rosa, California, relative to current applicable design codes. The tanks are located at the locations shown on the Vicinity Maps included as Figures 1A, 1B, and 1C. This report presents the results of our geotechnical evaluation of the three tanks. The evaluation includes a geotechnical assessment of existing foundation support and seismic design parameters with consideration to site-specific geotechnical data collected by Group Delta. Group Delta's geotechnical input will be provided to the design team including the structural engineer, Simpson Gumpertz & Heger (SGH) in support of their structural evaluation of the tanks. A summary of information provided by the City and description of each tank site, along with the project objective and scope of services, are summarized below.

1.1 Information Provided by the City

As part of our investigation, we reviewed existing geotechnical reports, plans, design calculations, structural analysis reports, and other documents provided by the City. The information reviewed as part of our investigation is summarized below.

- Improvement Plans, Bennet Valley 2.0 MG Steel Reservoir, Mitchell & Heryford, 1976.
- Geotechnical Report, Alternative R-9B Water Reservoir, Kleinfelder, 2000.
- Geotechnical Report, Fountaingrove Parkway Extension, Kleinfelder, 1992.
- Improvement Plans, Fountaingrove Parkway Extension, Carlile Associates, 1993.
- Seismic Hazard Analysis Report, Fountaingrove Parkway Extension, Kleinfelder, October 1994.
- Safe Bearing Capacities at Tanks R-16 and R-17, Kleinfelder, May 1995.
- Safe Bearing Capacities at Tanks R-16 and R-17, Kleinfelder, July 1995.
- Review Comments on Design Calculations (dated 8/1/95), Tank R-17, Kleinfelder, August 1995.
- Review Comments on Sliding Calculations (dated 8/25/95), Tank R-17, Kleinfelder, August 1995.
- Response to Friction Factor Comment, Tank R-17, Kleinfelder, October 1995.
- Calculation Package, Fountaingrove Parkway Extension, R-17 Standpipe, Trusco Tank, Inc. October 1995, Rev. November 1995.

1.2 Project Description

1.2.1 Tank R-9A

We understand Tank R-9A is a 2 million-gallon (MG) steel water storage tank constructed in the late 1970s. A geotechnical report for Tank R-9A was not provided, but a geotechnical report prepared by others for Tank R-9B located northwest of Tank R-9A was made available for review. An evaluation of Tank R-9B is not in the scope of this project. Although we have some geotechnical data in the site vicinity, we are not aware of the geotechnical design criteria used for Tank R-9A. The tank is an unanchored welded steel tank with a shell about 92 feet in diameter and 40 feet tall.

Based on the improvement plans by Mitchell & Heryford (1976), the tank is supported on a reinforced concrete ringwall footing about 1 ½ feet deep and 1 foot wide. We understand the City does not have as-built records or tank shop drawings. A structural evaluation of the tank has been performed by Peoples Associates Structural Engineers (PASE) as summarized in a report dated March 12, 2004. The PASE report indicates the maximum permissible water height for the tank is 13 feet without exceeding a Demand/Capacity ration of 1.0. The foundation details shown on the improvement plans appear consistent with observed conditions in the field and are assumed to represent as-built conditions.

1.2.2 Tanks R-16 and R-17

We understand Tanks R-16 and R-17 are anchored welded steel tanks constructed in the early 1990s as part of the Fountaingrove Parkway extension project. A geotechnical report for Tanks R-16 and R-17 was prepared by Kleinfelder (1992) and includes the same foundation design criteria for both tanks. The 0.25 MG Tank R-16 has a shell about 36 feet in diameter and 36 feet tall. The 0.75 MG Tank R-17 has a shell about 47 feet in diameter and 60 feet tall.

Improvement plans prepared by Carlile Associates (1993), which include information for Tanks R-16 and R-17, indicate both tanks are supported on a concrete ringwall footing about 3 feet deep and 2 feet wide. Based on our observations of the ringwall footings visible from the exterior of the tanks, the actual footing dimensions are larger than indicated on the improvement plans. The Tank Design Submittal prepared by the tank contractor for Tank R-17 (Trusco Tank, Inc.) with a revision dated of November 21, 1995, includes foundation details that indicate the tank is supported on a ringwall foundation system with an embedment of about 4 feet deep and 12 feet wide. A Tank Design Submittal for Tank R-16 was not provided. Understanding the two tanks had the same geotechnical engineer, designer, and contractor, Trusco Tank, Inc., we have assumed footing dimensions of 3 feet deep and 8 feet wide for Tank R-16 based on footing dimensions for Tank R-17 scaled down with consideration to the relative overall dimensions between the two tanks.

1.3 Scope of Services

Our scope of services consisted of performing a geotechnical investigation to serve as the basis for the development of foundation design capacities in support of a seismic evaluation of the existing tanks. The scope of our services performed as part of our evaluation is summarized below.

- Site reconnaissance to observe the conditions of the tank exterior and site.
- Review of information provided by the City.
- Review of geologic maps and existing geotechnical data.
- Drilling, logging, and sampling of test borings at each site.
- Performance of laboratory tests to determine index, strength, and corrosion properties of the soil and bedrock materials.
- Development of seismic design parameters in accordance with the 2015 International Building Code/2016 California Building Code and applicable reference standards including ASCE 7-10 and AWWA D100-11.
- Performance of an evaluation of geologic and seismic hazards.
- Develop geotechnical recommendations for the existing tanks foundations for use in the structural evaluation to be performed by SGH as part of the overall seismic evaluation of the existing tanks.
- Preparation of this report.

2.0 GEOTECHNICAL INVESTIGATION

2.1 Field Exploration Program

Site-specific geotechnical data was collected at each tank site. Test borings were performed using a truck-mounted solid fight auger drill rig. During drilling, samples were collected using Modified California and Standard Penetration Test (SPT) samplers. The samplers were driven into the soil 18 inches or to refusal (50 blows per inches) with an automatic 140-pound safety hammer falling 30 inches. All samples were taken to the laboratory for further visual examination and laboratory testing. A hammer efficiency of 81.5 percent was reported by the driller, Clear Heart Drilling; this value was used to correct the blow counts. Raw (N) and corrected blow counts (N_{60}) are shown on the boring logs presented in Appendix A. A summary of the geotechnical exploration performed at each tank site is summarized in more detail below.

2.1.1 Tank R-9A

At the Tank R-9A site, the field exploration consisted of a geotechnical reconnaissance of the site and drilling of 3 test borings to depths of about 11 ½ feet below existing grade at each site. The test borings were drilled in the pavement area surrounding the tank exterior at the approximate locations shown on Figure 2A. Logs of the borings are presented in Appendix A.

2.1.2 Tank R-16

At the Tank R-16 site, the field exploration consisted of a geotechnical reconnaissance of the site and drilling of 3 test borings to depths of about 16 ½ to 36 ½ feet below existing grade at each site. The test borings were drilled in the pavement area surrounding the tank exterior at the approximate locations shown on Figure 2B. Logs of the borings are presented in Appendix A.

2.1.3 Tank R-17

At the Tank R-17 site, the field exploration consisted of a geotechnical reconnaissance of the site and drilling of 4 test borings to depths of about 2 to 49 ½ feet below existing grade at each site. The test borings were drilled in the pavement area surrounding the tank exterior at the approximate locations shown on Figure 2C. Logs of the borings are presented in Appendix A.

2.2 Laboratory Testing Program

Laboratory tests were performed on select samples in support of the development of characterization of the subsurface materials encountered during our exploration. The tests performed included the following.

- Moisture and density
- Gradation
- Atterberg limits
- Undrained shear strength
- pH, Redox, sulfates, chlorides, and electrical resistivity

The results of the laboratory tests are provided in Appendix B and include an evaluation of the corrosion potential and potential impacts on site improvements.

2.3 Existing Geotechnical Data

As part of this investigation, we reviewed the existing geotechnical data for the sites provided by the City. A geotechnical report for Tank R-9A was not provided, but a geotechnical report for Tank R-9B located northwest of Tank R-9A prepared by Kleinfelder (2000) includes logs of 2 borings and 5 test pits performed at grades that existed prior to cuts were made for Tank R-9B pad preparation. An evaluation of Tank R-9B is not in the scope of our investigation. The borings were advanced using rotary coring methods and extend to about elevation 531 to 533 feet (about 2 to 4 feet below the existing Tank R-9A pad elevation). Core recovery and Rock Quality Designation (RQD) was recorded for the rock cores. The logs indicate that slightly to intensely weathered volcanic rock with various amounts of clay was encountered at the about the pad elevation of Tank R-9A (about elevation 535 feet). These conditions appear consistent with the Sonoma Volcanics formation encountered during our exploration at Tank R-9A.

A geotechnical report for Tanks R-16 and R-17 prepared by Kleinfelder (1992) includes logs for one boring drilled at each of tank site. Solid flight auger drilling methods were used to collect drive samples in the borings. Both borings encountered intensely weathered volcanic rock at the pad elevation of the tanks to the bottom of the borings. These conditions appear consistent with the Sonoma Volcanics formation encountered during our exploration at Tank R-9A.

3.0 SITE AND SUBSURFACE CONDITIONS

3.1 Site Conditions

Tank R-9A site is located on the southeast edge of Santa Rosa, south of Spring Lake Park, and near the west boundary of Annadel State Park. The site is accessed by a gated asphalt concrete road extending about 1,000 feet east from Annadel Heights Drive. Topographically, the site is located on a ridgeline with gentle north to northwest trending slopes of 5 to 1 (horizontal to vertical) to 10 to 1. Based on the improvement plans (Mitchell & Heryford, 1976), the pad elevation is approximately 535 feet (NGVD29). The area northeast of the tank includes moderate to steep slopes extending below the tank pad over 200 feet in elevation to Spring Creek. The cut slopes to the east and south of the tank extend up to 30 feet high above the tank pad at inclinations of about 1 to 1. Tank R-9B is located about 10 feet northwest of tank R-9A. The tank is surrounded by an asphalt concrete maintenance driveway about 12 feet wide.

Tank R-16 is located on the north side of Santa Rosa, off Fountaingrove Parkway, on a relatively wide ridgeline generally sloping towards the south. The site is accessed by a gated asphalt concrete road extending north from Newgate Court. Topographically, the general vicinity of Tank R-16 is sloping moderately south to southeast. Based on improvement plans for the tank (Carlile Associates, 1993), the pad elevation for Tank R-16 is approximately 726 feet (NGVD29). The site is in a cut condition with a slope extending above the north side of tank pad and a natural slope extending south below the tank pad. The tank is surrounded by an asphalt concrete maintenance driveway about 15 feet wide. A pump station is located west of the tank.

Tank R-17 is located in the north side of Santa Rosa, off Fountaingrove Parkway, on a relatively wide ridgeline generally sloping towards the south. The site is accessed by a gated asphalt concrete road extending east from Fountaingrove Parkway. Topographically, the general vicinity of Tank R-16 is sloping moderately west to southwest. Based on the improvement plans (Carlile Associates, 1993), the pad elevation for Tank R-17 is approximately 894 feet (NGVD29). The site is in a cut condition with a cut slope inclined at about 2 to 1 extending above the tank pad on the north and west sides of the tank. The tank is surrounded by an asphalt concrete maintenance driveway about 15 feet wide that sits near the top of a retaining wall separating the tank pad and a fire station parking lot to the south below. A private residence is located east of the tank.

3.2 Regional Geology and Seismicity

The project sites are located in the Coast Range Geomorphic Province of California. Much of the Coast Range Province is composed of marine sedimentary deposits and volcanic rocks that form northwest trending mountain ridges and valleys running subparallel to the San Andreas Fault Zone.

All three tank sites are mapped in an area of Volcanic rocks (Tpmv), Pliocene and early Miocene, of the Sonoma Volcanics formation as show on Figure 3. This formation is highly variable and complex generally consisting of lava flows, tuff, and andesitic to basaltic lava flows. The formation also include soil-like components due to weathering and depositional processes. A large portion of the surrounding areas is generally mapped as Alluvium of Holocene age (Qha) as shown on Figure 3.

According to the USGS, major seismic sources within 10 miles of the sites include the Hayward-Rogers Creek fault with a Moment Magnitude (M_w) of 7.3 at a closest distance of about 1 ½ to 2 miles from the tanks and the Maacama-Garberville fault with a M_w = 7.4 that is about 6 to 10 miles from the sites. Both faults are capable of producing large earthquakes and strong ground motions at the site. A list of the closest major active faults is included in Section 4 of this report and Figure 4 shows the site location relative to these faults.

3.3 Geologic Units and Subsurface Conditions

3.3.1 Tank R-9A

At the Tank R-9A site, the subsurface conditions consisted of volcanic bedrock at shallow depth. The bedrock consisted of weak and moderately to intensely weathered rock to the maximum depth explored. Laboratory testing on the bedrock samples indicates Plasticity Index values ranging from 25 to 28, which classifies the soil derived from these materials as Fat Clay (CH) and Elastic Silt (MH).

3.3.2 Tank R-16

Volcanically-derived soils were encountered at the Tank R-16 site. The soils primarily consisted of Elastic Silt (MH) with Plasticity Index values ranging from 26 to 40. The soils encountered in the upper 10 feet were generally very stiff and relatively weak with medium stiff consistencies below this depth. Volcanic bedrock was encountered at about 13 feet to 30 feet of depth below the ground surface. The varying depth to bedrock indicates a moderately steep bedding, which appears to be consistent with the regional geology.

3.3.3 Tank R-17

At Tank R-17 site, fill was encountered blanketing the site. The fill encountered was about 2 to 3 feet thick and was likely placed during tank pad construction. The fill primarily consisted of Fat Clay (CH) and appeared to be well compacted with very stiff to hard consistency. Volcanic rock fragments were observed in the fill, which indicates the material was derived from bedrock cuts at the site.

The fill was underlain by highly variable soil and rock of the Sonoma Volcanics formation. Given that the footings are embedded about 4 feet deep, they likely penetrate the fill and bear on the underlying Sonoma Volcanics formation. On the north and east sides of the tank, we encountered very hard to extremely hard and slightly to moderately weathered volcanic rock directly beneath the fill layer. On the south and west sides of the tank, we encountered soils of the Sonoma Volcanics formation generally consisting of stiff to very stiff Lean Clay (CL) and Fat Clay (CH). Laboratory testing on select native soils indicate Plasticity Index values range from 28 to 40.

3.4 Groundwater

Groundwater was not encountered during our exploration at Tank R-9A and Tank R-17 sites. At Tank R-16 site, groundwater was encountered between 13 ½ feet to 23 feet below the ground surface. However, groundwater is most likely accumulated on relatively impervious layers as perched water and seepage.

4.0 EVALUATION OF EXISTING FOUNDATIONS

In support of the structural evaluation of the existing tanks with consideration to current seismic design requirements, we developed the following geotechnical bearing capacities for the tank ringwall footings based on the foundation dimensions summarized in Table 1 below considering the site-specific geotechnical data collected as part of our investigation. This summary also includes the preliminary bearing demands provided by SGH for comparison to the estimated bearing capacities. As shown below, the capacities exceed demands for the gravity only and gravity plus seismic loading conditions.

Table 1. Foundation Bearing Capacities and Demands

Bearing Capacities and Demands (psf)	**Tank R-9A** D = 92 ft. / H = 40 ft. (b = 1 ft. / d = 1.5 ft.)	**Tank R-16** D = 36 ft. / H = 36 ft. (b = 8 ft. / d = 4 ft.)	**Tank R-17** D = 47 ft. / H = 60 ft. (b = 12 ft. / d = 4 ft.)
Ultimate Net Bearing Capacity	16,500	12,500	16,000
Allowable Bearing Capacity (Gravity Only)	5,500	4,100	5,300
Bearing Demand (Gravity Only)	*1,900*	*2,070*	*2,900*
Allowable Bearing Capacity (Gravity + Seismic)	7,300	5,500	7,100
Bearing Demand (Gravity + Seismic)	*4,550*	*3,900*	*6,590*

Notes: Gravity Only Factor of Safety = 3.0. Gravity + Seismic Factor of Safety = 2.25.
D = Tank Diameter. H = Tank Height. b = Footing Width. d = Footing Embedment Depth.

Settlement under seismic demands is expected to be less than ½ inch. The footing depths summarized above are depths of the footing below the lowest adjacent grade (pavement exterior to the tanks). An ultimate coefficient of friction of 0.40, which represents the value between the footings and earth, can be used to compute the tank's sliding resistance. Since the footings may have been constructed by forming and placing backfill adjacent to the footings, we provide passive resistance of 400 psf, which includes a factor of safety of 1.5. The embedded portions of the footings confined by pavement, indicated as footing depth above, can be used to estimate passive resistance.

To evaluate lateral loads transferred to the ringwall from the surcharge loading (water), an at-rest lateral earth pressure coefficient (K_o) of 0.5 can be used to estimate the lateral load transferred. Although the portion of lateral pressure imparted on the ringwall by the soil will be relatively minor, a unit weight of 125 pounds per cubic foot (and $K_o = 0.5$) can be used to estimate this pressure.

5.0 EVALUATION OF GEOLOGIC AND SEISMIC HAZARDS

We have evaluated the potential geotechnical and geologic hazards as part of an overall geologic and seismic hazard assessment of Tanks R-9A, R-16, and R-17. Our conclusions regarding potential geologic and seismic hazards including landslides, surface fault rupture, other deformation mechanisms, and earthquake ground motions are summarized below.

5.1 Potential Seismic Hazards

Potential geologic and seismic hazards include surface fault rupture, ridgetop spreading, subsidence, liquefaction, seismic compaction and settlement, tsunamis/flooding, and seismic shaking. Considering the subsurface materials encountered at the sites, soil liquefaction, seismic compaction, and subsidence are not considered to be potential hazards at the tank sites.

In addition, all three sites are high in elevation and far enough from the coast to preclude the hazards of a tsunami. Considering we did not observe any indication of ridgetop spreading during our exploration, in our opinion, the risk of ridge-top spreading at the three tank sites is low. We provide a summary of our conclusions regarding surface fault rupture and seismic shaking below.

5.1.1 Surface Fault Rupture

None of the sites are located within an Alquist-Priolo Earthquake Fault Zone (CDMG, 1983). The nearest active fault to the three sites is the Hayward-Rogers Creek fault located about 1 ½ to 2 miles to the west. A Regional Fault Map is shown on Figure 4. The risk of ground surface rupture at the sites is low.

5.1.2 Seismicity

As is the case with most of Northern California, the site is located within an active seismic area. The coordinates of the site locations for Tanks R-9A, R-16, and R-17 are provided in Table 2 below. The sites may experience severe seismic shaking in the future due to nearby fault rupture. A summary of faults considered capable of producing significant shaking at the site, as published in the 2008 United States National Seismic Hazard Maps developed by the United States Geological Survey (USGS), is provided in the table below. Figure 4 shows the site location relative to the closest faults considered by the USGS in development of the 2008 US National Seismic Hazard Maps.

Table 2. Summary of Faults

	Tank R-9A (38.435468°, -122.648841°)		Tank R-16 (38.48090°, -122.68842°)		Tank R-17 (38.49213°, -122.69899°)	
Abbreviated Fault Name	Max. Magnitude (Mw)*	Closest Distance (Miles)	Max. Magnitude (Mw)*	Closest Distance (Miles)	Max. Magnitude (Mw)*	Closest Distance (Miles)
Hayward-Rogers creek	7.3	1.9	7.3	1.6	7.3	1.5
Maacama-Garberville	7.4	9.96	7.4	6.5	7.4	5.8
West Napa	6.7	15.3	6.7	18	6.7	18.7
San Andreas	8.1	21.9	8.1	21.8	8.1	21.8

*Based on Ellsworth and Hanks relation (USGS 2008).

5.1.3 Seismic Design Parameters

The seismic design parameters were developed in accordance with the 2016 California Building Code (CBC) and ASCE 7-10. All three sites can generally be classified as a Site Class C based on the data collected at the site. We recommend the following seismic design parameters for the sites, which were calculated using the USGS Seismic Design Maps Tool. These parameters can be used for evaluation of seismic design in accordance with AWWA D100-05 (referenced by ASCE 7-10).

Table 3. ASCE 7-10 Seismic Design Parameters

Tank Site	R-9A[1]	R-16[2]	R-17[3]
Parameter	Value	Value	Value
Site Class	C	C	C
Mapped MCE Spectral Response Acceleration at Short Period (S_S)	2.081g	2.170g	2.202g
Mapped MCE Spectral Response Acceleration at Period of 1 Second (S_1)	0.853g	0.895g	0.911g
Site Coefficient, F_a	1.0	1.0	1.0
Site Coefficient, F_v	1.3	1.3	1.3
Adjusted MCE Spectral Response Acceleration at Short Period (S_{MS})	2.081g	2.170g	2.202g
Adjusted MCE Spectral Response Acceleration at Period of 1 Second (S_{M1})	1.109g	1.164g	1.184g
Design Earthquake Spectral Response Acceleration at Short Period (S_{DS})	1.387g	1.446g	1.468g
Design Earthquake Spectral Response Acceleration at Period of 1 Second (S_{D1})	0.739g	0.776g	0.789g
MCE Geometric Mean Peak Ground Acceleration Adjusted for Site Class (PGA_M)	0.800g	0.833g	0.846g
Long-Period Transition Period (T_L)	8 sec	8 sec	8 sec

1: Latitude: 38.435468°, Longitude: -122.648841°
2: Latitude: 38. 480900°, Longitude: -122. 688420°
3: Latitude: 38.492130°, Longitude: -122. 698990°

6.0 CONCLUSIONS

Based on our observations of the existing tanks in the field, there are no apparent signs of tank settlement and the tanks appear to be performing adequately under current gravity loads. These gravity loads will increase due to seismically-induced impulsive and convective loads. We have discussed the results of our evaluation of bearing capacities for the existing tanks with SGH considering the preliminary estimates of bearing demands (gravity only and gravity plus seismic) provided for each tank. We understand SGH's preliminary conclusion is that the foundation for Tank R-9A is inconsistent with a 40-foot tank height and water levels need to be limited to maintain safety factors. The foundations for Tanks R-16 and R-17 are more likely adequate from a geotechnical standpoint considering current codes.

7.0 LIMITATIONS

The report, exploration logs, and other materials resulting from Group Delta's efforts were prepared exclusively for use by West Yost Associates, Inc., and their consultants in support of the project. The report is not intended to be suitable for reuse on extensions or modifications of the project or for use on any project other than the current scope of work. This report may not contain sufficient or appropriate information for such uses. If this report or portions of this report are provided to contractors or included in specifications, it should be understood that they are provided for information only.

This report presents conclusions pertaining to the subject sites based on the assumptions that the subsurface conditions do not deviate appreciably from those disclosed by Group Delta's subsurface exploration. In view of the general geology of the area, the possibility of different conditions cannot be discounted. It is the responsibility of the owner to bring any deviations or unexpected conditions observed during construction to the attention of the Geotechnical Engineer. This will allow for any required supplemental recommendations to be made with minimum delays.

This investigation was performed in accordance with generally accepted geotechnical engineering principles and practice. The professional engineering work and judgments presented in this report meet the standard of care of our profession at this time. No other warranty, expressed or implied, is made.

8.0 REFERENCES

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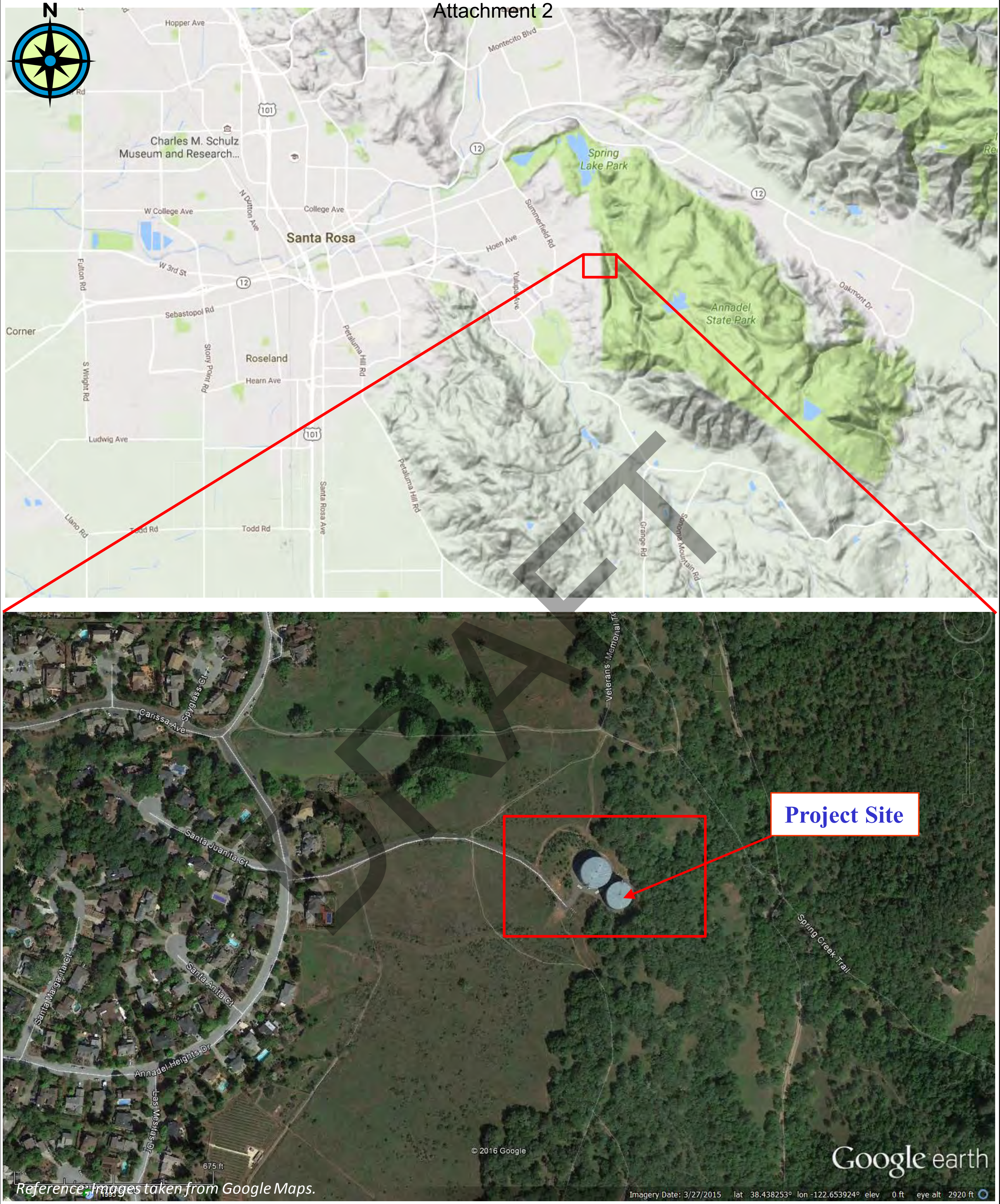
Safe Bearing Capacities at Tanks R-16 and R-17 along Fountaingrove Parkway Extension, Santa Rosa, California, Kleinfelder, July 7, 1995

Seismic Hazard Analysis Report for the Proposed Water Tanks along Fountaingrove Parkway Extension, Santa Rosa, California, Kleinfelder, October 3, 1994

Figures

Attachment 2

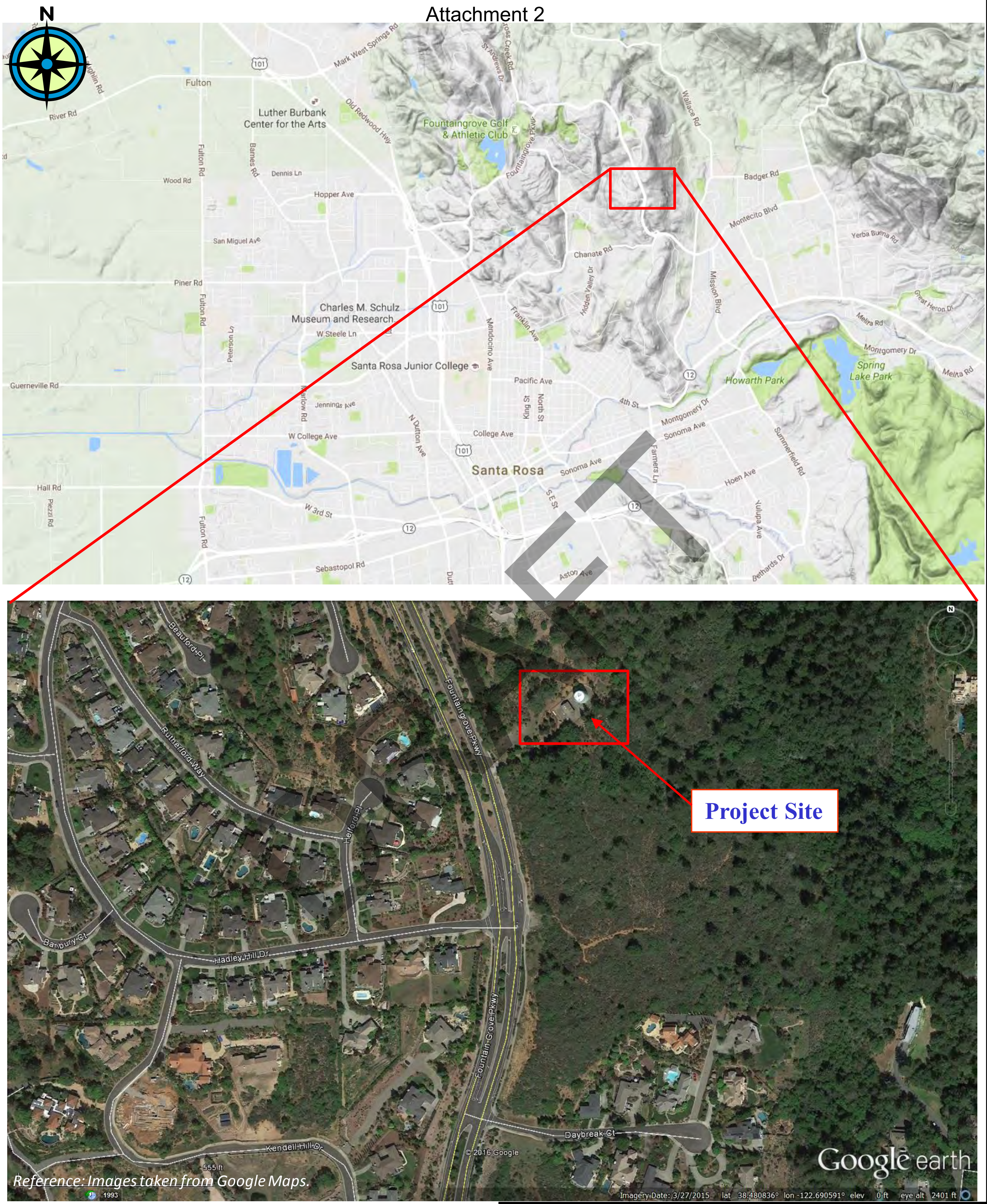


Reference: Images taken from Google Maps.

Project Location

GROUP DELTA	Project No. BA024
	City of Santa Rosa Water Tank Evaluation Tank R-9A
	Vicinity Map
	Figure 1A

Attachment 2



Reference: Images taken from Google Maps.

Project Location

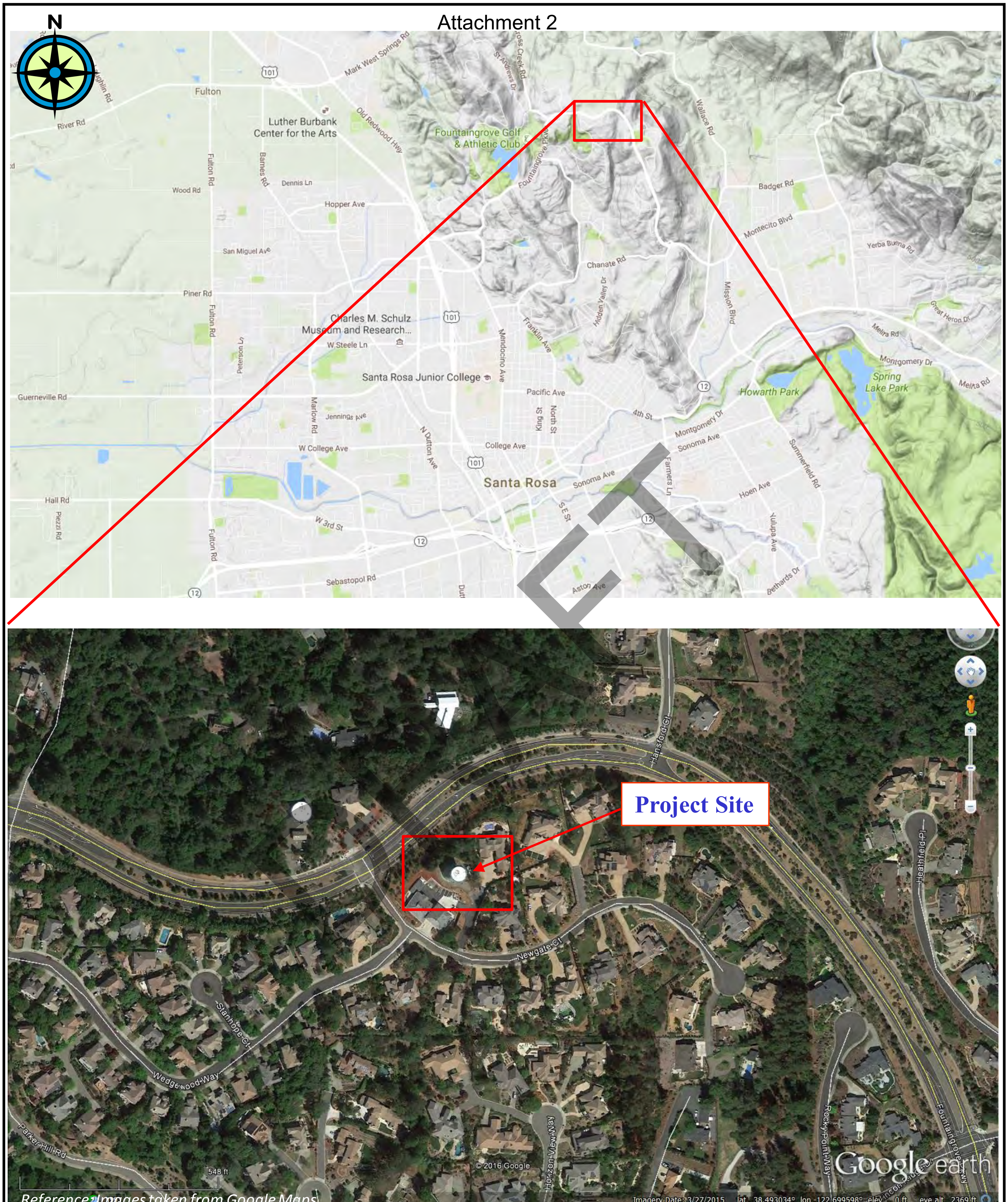
Project No. BA024

City of Santa Rosa Water Tank Evaluation
Tank R-16

Vicinity Map

Figure 1B

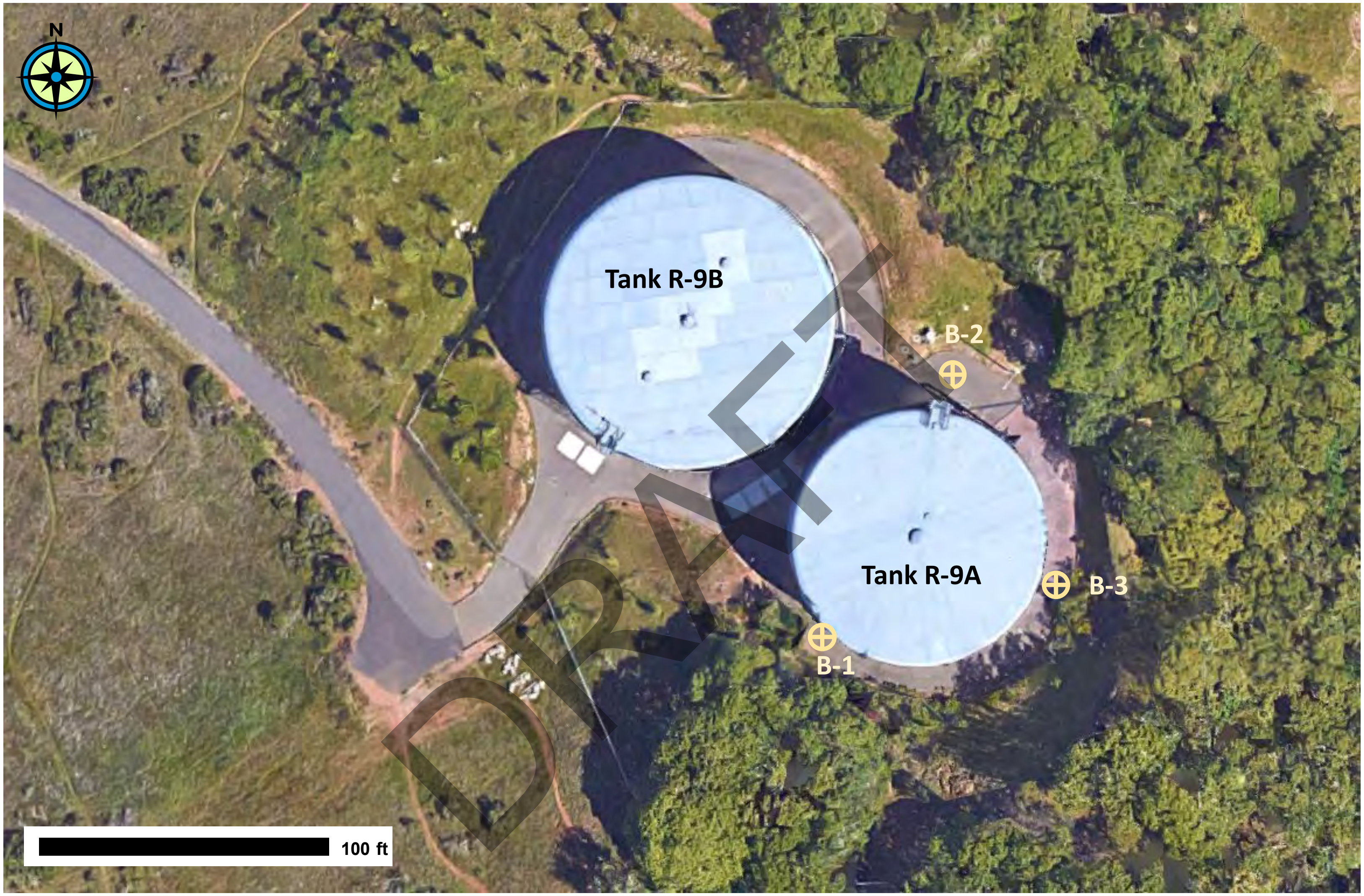
Attachment 2



Project Location

GROUP DELTA	Project No. BA024
	City of Santa Rosa Water Tank Evaluation Tank R-17
	Vicinity Map
	Figure 1C

Attachment 2



Reference Map: Google Earth

B-3 ⊕ APPROXIMATE LOCATION OF BORINGS

GROUP DELTA	Project No. BA024
	City of Santa Rosa Water Tank Evaluation Tank R-9A **Exploration Plan** Figure 2A

Attachment 2

Reference Map: Google Earth

B-4 ⊕ APPROXIMATE LOCATION OF BORINGS

GROUP DELTA

Project No. BA024

City of Santa Rosa Water Tank Evaluation Tank R-16

Exploration Plan

Figure 2B

Attachment 2

Reference Map: Google Earth

B-4 ⊕ APPROXIMATE LOCATION OF BORINGS

GROUP DELTA

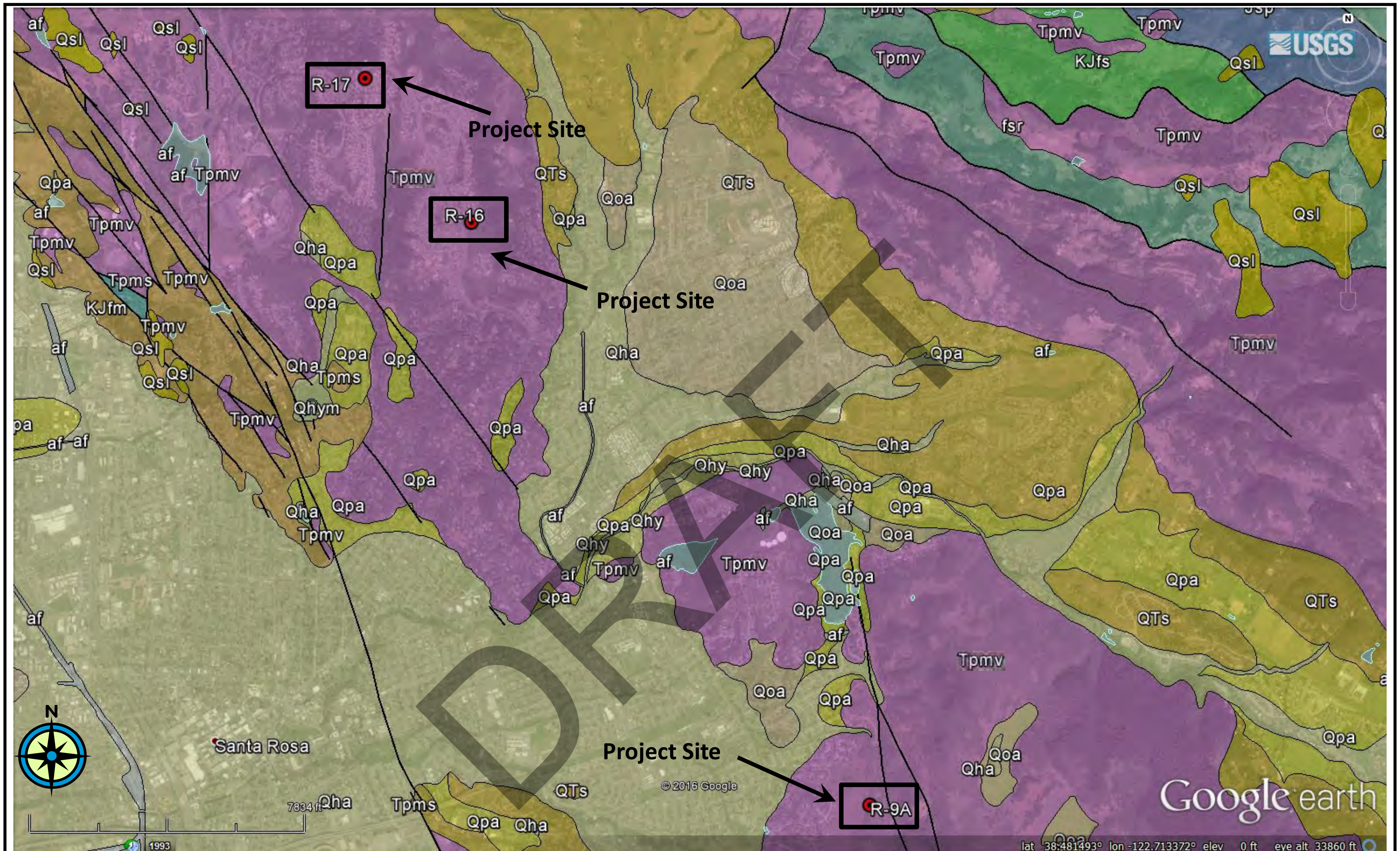
Project No. BA024

City of Santa Rosa Water Tank Evaluation
Tank R-17

Exploration Plan

Figure 2C

Attachment 2



List of Map Units:

Symbol	Description
Tpmv	Volcanic rocks (Pliocene and early Miocene)
Qha	Alluvium (Holocene)
QTs	Sediments (early Pleistocene and (or) Pliocene)
Qoa	Alluvium (early Pleistocene)
Qsl	Hillslope deposits (Quaternary)
fsr	Franciscan Complex mélange (Eocene, Paleocene, and (or) Late Cretaceous)
KJfs	Franciscan Complex sedimentary rocks (Early Cretaceous and (or) Late Jurassic)
Tpms	Sedimentary rocks (Pliocene and early Miocene)
af	Artificial fill

GROUP DELTA

Project No. BA024

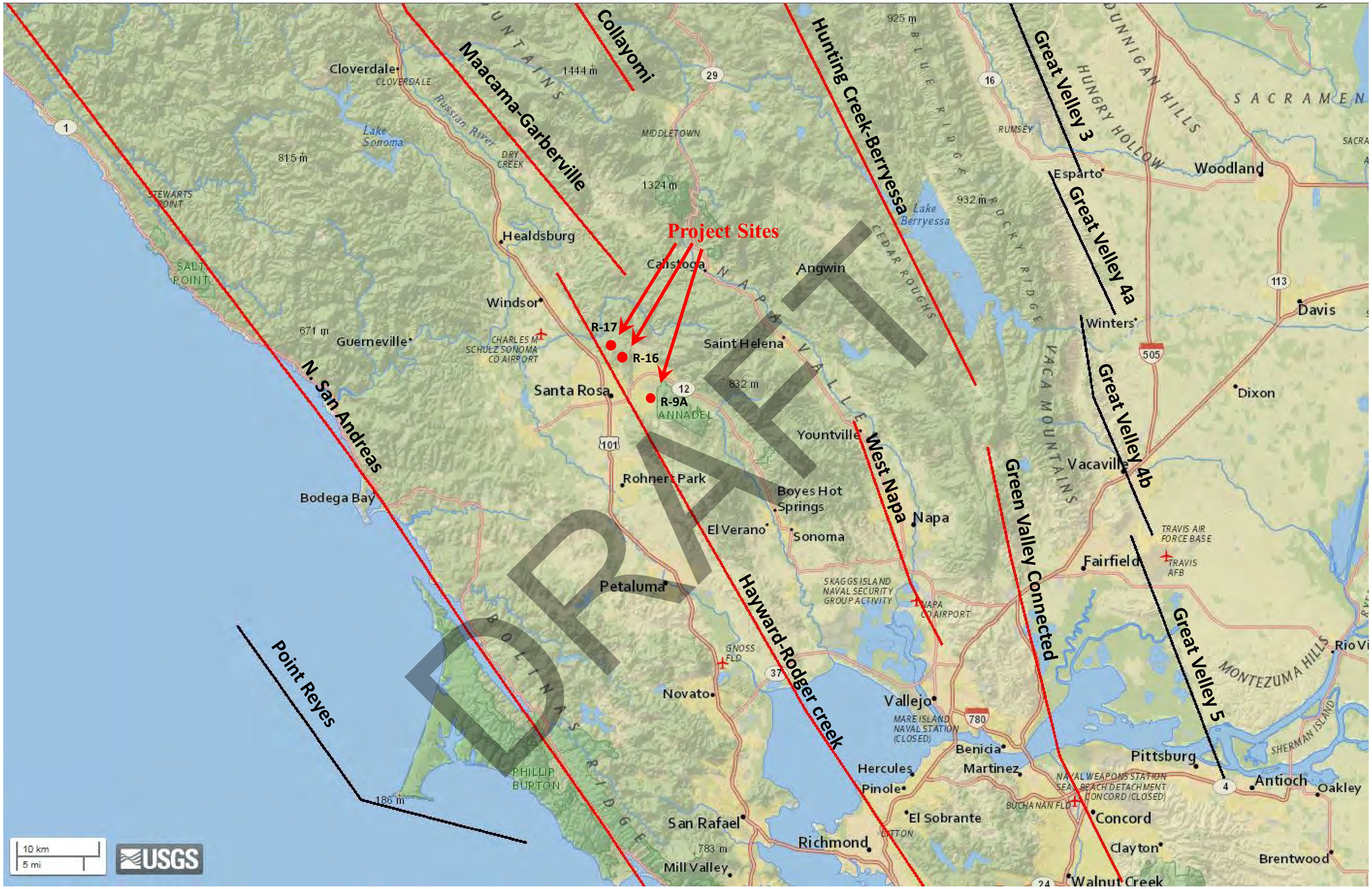
City of Santa Rosa Water Tank Evaluation
Tanks R-9A, R-16, R-17

Geologic Map

Figure 3

USGS. Map of the San Francisco Bay Region. Scientific Investigations Map 2918. Graymer. R. W., et al. (2006).

Attachment 2



	Project No. BA024
GROUP DELTA	**City of Santa Rosa Water Tank Evaluation R-9A, R-16, and R-17**
	Regional Fault Map
	Figure 4

REFERENCE: USGS 2008 UNITED STATES NATIONAL SEISMIC HAZARD MAPS

Appendix A – Field Exploration

APPENDIX A
FIELD EXPLORATION

A.1 Introduction

The subsurface conditions at the City of Santa Rosa R-9A, R-16, and R-17 water tank evaluation project sites were investigated by performing a total of 10 solid flight auger borings on June 16 and 17, 2016. The locations of the explorations are presented on Figure 2A to 2C of the main report. A summary of field explorations is presented in Table A-1.

Prior to beginning the exploration program, access permission and drilling permits were obtained as necessary from Sonoma County and City of Santa Rosa. Subsurface utility maps were reviewed prior to selecting locations for subsurface investigations. Underground Service Alert (USA) was notified and each exploration location was cleared for underground utilities. The exploration methods are described in the following sections.

A.2 Soil Drilling and Sampling

Drilling, Logging, and Soil / Rock Classification

Borings were performed by Clear Heart Drilling under the continuous technical supervision of a Group Delta Consultant (GDC) field geologist, who visually inspected the soil samples, measured groundwater levels, maintained detailed records of the borings, and visually / manually classified the soils in accordance with the ASTM D 2488 and the Unified Soil Classification System (USCS). Logging and classification was performed in general accordance with Caltrans "Soil and Rock Logging, Classification, and Presentation Manual (2010 Edition)". A Boring Record Legend and Key for Soil Classification are presented in Figures A-1A through A-1F. The boring records are presented in Figures A-2 through Figure A-11.

Sampling

Bulk samples of soil cuttings were collected at selected depths and drive samples were collected at a typical interval of 5 feet from the borings. The sampling was performed using Standard Penetration Test (SPT) samplers in accordance with ASTM D 1586 and Ring-Lined "California" Split Barrel samplers in accordance with ASTM D 3550. Bulk samples were collected from auger cuttings and placed in plastic bags.

SPT drive samples were obtained using a 2-inch outside diameter and 1.375-inch inside diameter split-spoon sampler without lining. The soil recovered from the SPT sampling was sealed in plastic bags to preserve the natural moisture content.

California drive samples were collected with a 3-inch outside diameter 2.5-inch inside diameter split barrel sampler with a 2.42-inch inside diameter cutting shoe. The sampler barrel is lined with 18-inches of metal rings for sample collection and has an additional length of waste barrel. Stainless steel or brass liner rings for sample collection are 1-inch high, 2.42-

inch inside diameter, and 2.5-inch outside diameter. California samples were removed from the sampler, retained in the metal rings and placed in sealed plastic canisters to prevent loss of moisture.

At each sampling interval, the drive samplers were fitted onto sampling rod, lowered to the bottom of the boring, and driven 18 inches or to refusal (50 blows per 6 inches) with a 140-lb hammer free-falling a height of 30-inches using an automatic, downhole, Kelly Bar, or other hammer. Compared to the SPT, the California sampler provides less disturbed samples. The number of hammer blows required to penetrate the samplers each 6-inch increment is presented on the boring records.

<u>Borehole Abandonment</u>

The borings were abandoned by backfilling the holes with neat cement grout. The paved surfaces were patched with cold mix asphalt concrete to match the existing condition. The site was restored to its original condition at the completion of our field work.

A.3 List of Attached Tables and Figures

The following tables and figures are attached and complete this appendix:

List of Figures

Figure A-1A through A-1D	Boring Record Legend
Figure A-1E and A-1F	Key for Soil Classification
Figures A-2 through A-11	Boring Records

Attachment 2

SOIL IDENTIFICATION AND DESCRIPTION SEQUENCE

Sequence		Refer to Section: Field	Refer to Section: Lab	Required	Optional
1	Group Name	2.5.2	3.2.2	●	
2	Group Symbol	2.5.2	3.2.2	●	
	Description Components				
3	Consistency of Cohesive Soil	2.5.3	3.2.3	●	
4	Apparent Density of Cohesionless Soil	2.5.4		●	
5	Color	2.5.5		●	
6	Moisture	2.5.6		●	
7	Percent or Proportion of Soil	2.5.7	3.2.4	●	◍
	Particle Size	2.5.8	2.5.8	●	◍
	Particle Angularity	2.5.9			○
	Particle Shape	2.5.10			○
8	Plasticity (for fine-grained soil)	2.5.11	3.2.5		○
9	Dry Strength (for fine-grained soil)	2.5.12			○
10	Dilatency (for fine-grained soil)	2.5.13			○
11	Toughness (for fine-grained soil)	2.5.14			○
12	Structure	2.5.15			○
13	Cementation	2.5.16		●	
14	Percent of Cobbles and Boulders	2.5.17		●	
	Description of Cobbles and Boulders	2.5.18		●	
15	Consistency Field Test Result	2.5.3		●	
16	Additional Comments	2.5.19			○

Describe the soil using descriptive terms in the order shown

Minimum Required Sequence:

USCS Group Name (Group Symbol); Consistency or Density; Color; Moisture; Percent or Proportion of Soil; Particle Size; Plasticity (optional).

◍ = optional for non-Caltrans projects

Where applicable:

Cementation; % cobbles & boulders;
Description of cobbles & boulders;
Consistency field test result

Ref.: Caltrans Soil and Rock Logging Classification, and Presentation Manual (2010)

HOLE IDENTIFICATION

Holes are identified using the following convention:

H-YY-NNN

Where:
H: Hole Type Code
YY: 2-digit year
NNN: 3-digit number (001-999)

Hole Type Code	Description
A	Auger boring (hollow or solid stem, bucket)
R	Rotary drilled boring (conventional)
RC	Rotary core (self-cased wire-line, continuously-sampled)
RW	Rotary core (self-cased wire-line, not continuously sampled)
P	Rotary percussion boring (Air)
HD	Hand driven (1-inch soil tube)
HA	Hand auger
D	Driven (dynamic cone penetrometer)
CPT	Cone Penetration Test
O	Other (note on LOTB)

Description Sequence Examples:

SANDY lean CLAY (CL); very stiff; yellowish brown; moist; mostly fines; some SAND, from fine to medium; few gravels; medium plasticity; PP=2.75.

Well-graded SAND with SILT and GRAVEL and COBBLES (SW-SM); dense; brown; moist; mostly SAND, from fine to coarse; some fine GRAVEL; few fines; weak cementation; 10% GRANITE COBBLES; 3 to 6 inches; hard; subrounded.

Clayey SAND (SC); medium dense, light brown; wet; mostly fine sand,; little fines; low plasticity.

GROUP DELTA CONSULTANTS, INC. GEOTECHNICAL ENGINEERS AND GEOLOGISTS	FIGURE NUMBER A-1A
PROJECT NAME City of Santa Rosa Water Tank Evaluation	PROJECT NUMBER BA 024
BORING RECORD LEGEND #1	

Attachment 2

GROUP SYMBOLS AND NAMES

Graphic / Symbol	Group Names
GW	Well-graded GRAVEL Well-graded GRAVEL with SAND
GP	Poorly graded GRAVEL Poorly graded GRAVEL with SAND
GW-GM	Well-graded GRAVEL with SILT Well-graded GRAVEL with SILT and SAND
GW-GC	Well-graded GRAVEL with CLAY (or SILTY CLAY) Well-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
GP-GM	Poorly graded GRAVEL with SILT Poorly graded GRAVEL with SILT and SAND
GP-GC	Poorly graded GRAVEL with CLAY (or SILTY CLAY) Poorly graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
GM	SILTY GRAVEL SILTY GRAVEL with SAND
GC	CLAYEY GRAVEL CLAYEY GRAVEL with SAND
GC-GM	SILTY, CLAYEY GRAVEL SILTY, CLAYEY GRAVEL with SAND
SW	Well-graded SAND Well-graded SAND with GRAVEL
SP	Poorly graded SAND Poorly graded SAND with GRAVEL
SW-SM	Well-graded SAND with SILT Well-graded SAND with SILT and GRAVEL
SW-SC	Well-graded SAND with CLAY (or SILTY CLAY) Well-graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)
SP-SM	Poorly graded SAND with SILT Poorly graded SAND with SILT and GRAVEL
SP-SC	Poorly graded SAND with CLAY (or SILTY CLAY) Poorly graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)
SM	SILTY SAND SILTY SAND with GRAVEL
SC	CLAYEY SAND CLAYEY SAND with GRAVEL
SC-SM	SILTY, CLAYEY SAND SILTY, CLAYEY SAND with GRAVEL
PT	PEAT
	COBBLES COBBLES and BOULDERS BOULDERS

Graphic / Symbol	Group Names
CL	Lean CLAY Lean CLAY with SAND Lean CLAY with GRAVEL SANDY lean CLAY SANDY lean CLAY with GRAVEL GRAVELLY lean CLAY GRAVELLY lean CLAY with SAND
CL-ML	SILTY CLAY SILTY CLAY with SAND SILTY CLAY with GRAVEL SANDY SILTY CLAY SANDY SILTY CLAY with GRAVEL GRAVELLY SILTY CLAY GRAVELLY SILTY CLAY with SAND
ML	SILT SILT with SAND SILT with GRAVEL SANDY SILT SANDY SILT with GRAVEL GRAVELLY SILT GRAVELLY SILT with SAND
OL	ORGANIC lean CLAY ORGANIC lean CLAY with SAND ORGANIC lean CLAY with GRAVEL SANDY ORGANIC lean CLAY SANDY ORGANIC lean CLAY with GRAVEL GRAVELLY ORGANIC lean CLAY GRAVELLY ORGANIC lean CLAY with SAND
OL	ORGANIC SILT ORGANIC SILT with SAND ORGANIC SILT with GRAVEL SANDY ORGANIC SILT SANDY ORGANIC SILT with GRAVEL GRAVELLY ORGANIC SILT GRAVELLY ORGANIC SILT with SAND
CH	Fat CLAY Fat CLAY with SAND Fat CLAY with GRAVEL SANDY fat CLAY SANDY fat CLAY with GRAVEL GRAVELLY fat CLAY GRAVELLY fat CLAY with SAND
MH	Elastic SILT Elastic SILT with SAND Elastic SILT with GRAVEL SANDY elastic SILT SANDY elastic SILT with GRAVEL GRAVELLY elastic SILT GRAVELLY elastic SILT with SAND
OH	ORGANIC fat CLAY ORGANIC fat CLAY with SAND ORGANIC fat CLAY with GRAVEL SANDY ORGANIC fat CLAY SANDY ORGANIC fat CLAY with GRAVEL GRAVELLY ORGANIC fat CLAY GRAVELLY ORGANIC fat CLAY with SAND
OH	ORGANIC elastic SILT ORGANIC elastic SILT with SAND ORGANIC elastic SILT with GRAVEL SANDY elastic ELASTIC SILT SANDY ORGANIC elastic SILT with GRAVEL GRAVELLY ORGANIC elastic SILT GRAVELLY ORGANIC elastic SILT with SAND
OL/OH	ORGANIC SOIL ORGANIC SOIL with SAND ORGANIC SOIL with GRAVEL SANDY ORGANIC SOIL SANDY ORGANIC SOIL with GRAVEL GRAVELLY ORGANIC SOIL GRAVELLY ORGANIC SOIL with SAND

FIELD AND LABORATORY TESTS

C	Consolidation (ASTM D 2435-04)
CL	Collapse Potential (ASTM D 5333-03)
CP	Compaction Curve (CTM 216 - 06)
CR	Corrosion, Sulfates, Chlorides (CTM 643 - 99; CTM 417 - 06; CTM 422 - 06)
CU	Consolidated Undrained Triaxial (ASTM D 4767-02)
DS	Direct Shear (ASTM D 3080-04)
EI	Expansion Index (ASTM D 4829-03)
M	Moisture Content (ASTM D 2216-05)
OC	Organic Content (ASTM D 2974-07)
P	Permeability (CTM 220 - 05)
PA	Particle Size Analysis (ASTM D 422-63 [2002])
PI	Liquid Limit, Plastic Limit, Plasticity Index (AASHTO T 89-02, AASHTO T 90-00)
PL	Point Load Index (ASTM D 5731-05)
PM	Pressure Meter
PP	Pocket Penetrometer
R	R-Value (CTM 301 - 00)
SE	Sand Equivalent (CTM 217 - 99)
SG	Specific Gravity (AASHTO T 100-06)
SL	Shrinkage Limit (ASTM D 427-04)
SW	Swell Potential (ASTM D 4546-03)
TV	Pocket Torvane
UC	Unconfined Compression - Soil (ASTM D 2166-06) Unconfined Compression - Rock (ASTM D 2938-95)
UU	Unconsolidated Undrained Triaxial (ASTM D 2850-03)
UW	Unit Weight (ASTM D 4767-04)
VS	Vane Shear (AASHTO T 223-96 [2004])

SAMPLER GRAPHIC SYMBOLS

- Standard Penetration Test (SPT)
- Standard California Sampler
- Modified California Sampler
- Shelby Tube
- Piston Sampler
- NX Rock Core
- HQ Rock Core
- Bulk Sample
- Other (see remarks)

DRILLING METHOD SYMBOLS

- Auger Drilling
- Rotary Drilling
- Dynamic Cone or Hand Driven
- Diamond Core

WATER LEVEL SYMBOLS

- First Water Level Reading (during drilling)
- Static Water Level Reading (after drilling, date)

Ref.: Caltrans Soil and Rock Logging Classification, and Presentation Manual (2010)

DEFINITIONS FOR CHANGE IN MATERIAL

Term	Definition	Symbol
Material Change	Change in material is observed in the sample or core, and the location of change can be accurately measured.	———
Estimated Material Change	Change in material cannot be accurately located because either the change is gradational or because of limitations in the drilling/sampling methods used.	- - - - - - - - -
Soil/Rock Boundary	Material changes from soil characteristics to rock characteristics.	∼∼∼

DRAFT

GROUP DELTA CONSULTANTS	GROUP DELTA CONSULTANTS, INC. GEOTECHNICAL ENGINEERS AND GEOLOGISTS	FIGURE NUMBER A-1B
	PROJECT NAME City of Santa Rosa Water Tank Evaluation	PROJECT NUMBER BA 024
	BORING RECORD LEGEND #2	

Attachment 2

CONSISTENCY OF COHESIVE SOILS

Descriptor	Shear Strength (tsf)	Pocket Penetrometer, PP Measurement (tsf)	Torvane, TV. Measurement (tsf)	Vane Shear, VS. Measurement (tsf)
Very Soft	< 0.12	< 0.25	< 0.12	< 0.12
Soft	0.12 - 0.25	0.25 - 0.50	0.12 - 0.25	0.12 - 0.25
Medium Stiff	0.25 - 0.50	0.50 - 1.0	0.25 - 0.50	0.25 - 0.50
Stiff	0.50 - 1.0	1.0 - 2.0	0.50 - 1.0	0.50 - 1.0
Very Stiff	1.0 - 2.0	2.0 - 4.0	1.0 - 2.0	1.0 - 2.0
Hard	> 2.0	> 4.0	> 2.0	> 2.0

APPARENT DENSITY OF COHESIONLESS SOILS

Descriptor	SPT N_{60} - Value (blows / foot)
Very Loose	0 - 5
Loose	5 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	> 50

MOISTURE

Descriptor	Criteria
Dry	No discernable moisture
Moist	Moisture present, but no free water
Wet	Visible free water

PERCENT OR PROPORTION OF SOILS

Descriptor	Criteria
Trace	Particles are present but estimated to be less than 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

PARTICLE SIZE

Descriptor		Size (in)
Boulder		> 12
Cobble		3 - 12
Gravel	Coarse	3/4 - 3
	Fine	1/5 - 3/4
Sand	Coarse	1/16 - 1/5
	Medium	1/64 - 1/16
	Fine	1/300 - 1/64
Silt and Clay		< 1/300

PLASTICITY OF FINE-GRAINED SOILS

Descriptor	Criteria
Nonplastic	A 1/8-inch thread cannot be rolled at any water content.
Low	The thread can barely be rolled, and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll, and not much time is required to reach the plastic limit; it cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

CONSISTENCY OF COHESIVE SOILS VS. N_{60}

Description	SPT N_{60} (blows / foot)
Very Soft	0 - 2
Soft	2 - 4
Medium Stiff	4 - 8
Stiff	8 - 15
Very Stiff	15 - 30
Hard	> 30

Ref: Peck, Hansen, and Thornburn, 1974, “Foundation Engineering”, Second Edition

Note: Only to be used (with caution) when pocket penetrometer or other data on undrained shear strength are unavailable. Not allowed by Caltrans Soil and Rock Logging and Classificaton Manual, 2010

CEMENTATION

Descriptor	Criteria
Weak	Crumbles or breaks with handling or little finger pressure.
Moderate	Crumbles or breaks with considerable finger pressure.
Strong	Will not crumble or break with finger pressure.

Ref.: Caltrans Soil and Rock Logging Classification, and Presentation Manual (2010), with the exception of consistency of cohesive soils vs. N_{60}.

DRAFT

GROUP DELTA CONSULTANTS

GROUP DELTA CONSULTANTS, INC. GEOTECHNICAL ENGINEERS AND GEOLOGISTS	FIGURE NUMBER A-1C
PROJECT NAME City of Santa Rosa Water Tank Evaluation	PROJECT NUMBER BA 024

BORING RECORD LEGEND #3

Attachment 2

ROCK GRAPHIC SYMBOLS
IGNEOUS ROCK
SEDIMENTARY ROCK
METAMORPHIC ROCK

BEDDING SPACING

Descriptor	Thickness or Spacing
Massive	> 10 ft
Very thickly bedded	3 to 10 ft
Thickly bedded	1 to 3 ft
Moderately bedded	3-5/8 inches to 1 ft
Thinly bedded	1-1/4 to 3-5/8 inches
Very thinly bedded	3/8 inch to 1-1/4 inches
Laminated	< 3/8 inch

WEATHERING DESCRIPTORS FOR INTACT ROCK

	Diagnostic Features					
	Chemical Weathering-Discoloration-Oxidation		Mechanical Weathering and Grain Boundary Conditions	Texture and Solutioning		
Descriptor	Body of Rock	Fracture Surfaces		Texture	Solutioning	General Characteristics
Fresh	No discoloration, not oxidized	No discoloration or oxidation	No separation, intact (tight)	No change	No solutioning	Hammer rings when crystalline rocks are struck.
Slightly Weathered	Discoloration or oxidation is limited to surface of, or short distance from, fractures; some feldspar crystals are dull	Minor to complete discoloration or oxidation of most surfaces	No visible separation, intact (tight)	Preserved	Minor leaching of some soluble minerals may be noted	Hammer rings when crystalline rocks are struck. Body of rock not weakened.
Moderately Weathered	Discoloration or oxidation extends from fractures usually throughout; Fe-Mg minerals are "rusty"; feldspar crystals are "cloudy"	All fracture surfaces are discolored or oxidized	Partial separation of boundaries visible	Generally preserved	Soluble minerals may be mostly leached	Hammer does not ring when rock is struck. Body of rock is slightly weakened.
Intensely Weathered	Discoloration or oxidation throughout; all feldspars and Fe-Mg minerals are altered to clay to some extent; or chemical alteration produces in situ disaggregation (refer to grain boundary conditions)	All fracture surfaces are discolored or oxidized; surfaces are friable	Partial separation, rock is friable; in semi-arid conditions, granitics are disaggregated	Altered by chemical disintegration such as via hydration or argillation	Leaching of soluble minerals may be complete	Dull sound when struck with hammer; usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures or veinlets. Rock is significantly weakened.
Decomposed	Discolored of oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspars and Fe-Mg minerals are completely altered to clay		Complete separation of grain boundaries (disaggregated)	Resembles a soil; partial or complete remnant rock structure may be preserved; leaching of soluble minerals usually complete		Can be granulated by hand. Resistant minerals such as quartz may be present as "stringers" or "dikes".

Note: Combination descriptors (such as "slightly weathered to fresh") are used where equal distribution of both weathering characteristics is present over significant intervals or where characteristics present are "in between" the diagnostic feature. However, combination descriptors should not be used where significant identifiable zones can be delineated. Only two adjacent descriptors shall be combined. "Very intensely weathered" is the combination descriptor for "decomposed to intensely weathered".

RELATIVE STRENGTH OF INTACT ROCK

Descriptor	Uniaxial Compressive Strength (psi)
Extremely	> 30,000
Very Strong Strong	14,500 - 30,000
Strong	7,000 - 14,500
Medium Strong	3,500 - 7,000
Weak	700 - 3,500
Very Weak	150 - 700
Extremely Weak	< 150

ROCK HARDNESS

Descriptor	Criteria
Extremely Hard	Specimen cannot be scratched with pocket knife or sharp pick; can only be chipped with repeated heavy hammer blows
Very hard	Specimen cannot be scratched with pocket knife or sharp pick; breaks with repeated heavy hammer blows
Hard	Specimen can be scratched with pocket knife or sharp pick with heavy pressure; heavy hammer blows required to break specimen
Moderately Hard	Specimen can be scratched with pocket knife or sharp pick with light or moderate pressure; breaks with moderate hammer blows
Moderately Soft	Specimen can be grooved 1/6 in. with pocket knife or sharp pick with moderate or heavy pressure; breaks with light hammer blow or heavy hand pressure
Soft	Specimen can be grooved or gouged with pocket knife or sharp pick with light pressure, breaks with light to moderate hand pressure
Very Soft	Specimen can be readily indented, grooved, or gouged with fingernail, or carved with pocket knife; breaks with light hand pressure

CORE RECOVERY CALCULATION (%)

$$\frac{\Sigma \text{ Length of the recovered core pieces (in.)}}{\text{Total length of core run (in.)}} \times 100$$

RQD CALCULATION (%)

$$\frac{\Sigma \text{ Length of intact core pieces > 4 in.}}{\text{Total length of core run (in.)}} \times 100$$

FRACTURE DENSITY

Descriptor	Criteria
Unfractured	No fractures
Very Slightly Fractured	Lengths greater 3 ft
Slightly Fractured	Lengths from 1 to 3 ft, few lengths outside that range
Moderately Fractured	Lengths mostly in range of 4 in. to 1 ft, with most lengths about 8 in.
Intensely Fractured	Lengths average from 1 in. to 4 in. with scattered fragmented intervals with lengths less than 4 in.
Very Intensely Fractured	Mostly chips and fragments with few scattered short core lengths

Ref.: Caltrans Soil and Rock Logging Classification, and Presentation Manual (2010)

GROUP DELTA CONSULTANTS	GROUP DELTA CONSULTANTS, INC. GEOTECHNICAL ENGINEERS AND GEOLOGISTS	FIGURE NUMBER A-1D
	PROJECT NAME City of Santa Rosa Water Tank Evaluation	PROJECT NUMBER BA 024
	BORING RECORD LEGEND #4	

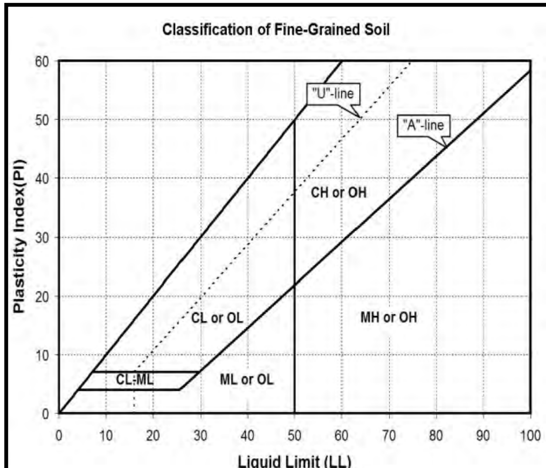
CLASSIFICATION OF INORGANIC FINE GRAINED SOILS (Soils with >50% finer than No. 200 Sieve)

GROUP SYMBOL				GROUP NAME
CL	<30% plus No. 200	<15% plus No. 200		Lean clay
		15-25% plus No. 200	%sand ≥ %gravel	Lean clay with sand
			%sand < %gravel	Lean clay with gravel
	≥30% plus No. 200	% sand ≥ % gravel	<15% gravel	Sandy lean clay
			≥15% gravel	Sandy lean clay with gravel
		% sand < % gravel	<15% sand	Gravelly lean clay
			≥15% sand	Gravelly lean clay with sand
ML	<30% plus No. 200	<15% plus No. 200		Silt
		15-25% plus No. 200	%sand ≥ %gravel	Silt with sand
			%sand < %gravel	Silt with gravel
	≥30% plus No. 200	% sand ≥ % gravel	<15% gravel	Sandy silt
			≥15% gravel	Sandy silt with gravel
		% sand < % gravel	<15% sand	Gravelly silt
			≥15% sand	Gravelly silt with sand
CH	<30% plus No. 200	<15% plus No. 200		Fat clay
		15-25% plus No. 200	%sand ≥ %gravel	Fat clay with sand
			%sand < %gravel	Fat clay with gravel
	≥30% plus No. 200	% sand ≥ % gravel	<15% gravel	Sandy fat clay
			≥15% gravel	Sandy fat clay with gravel
		% sand < % gravel	<15% sand	Gravelly fat clay
			≥15% sand	Gravelly fat clay with sand
MH	<30% plus No. 200	<15% plus No. 200		Elastic silt
		15-25% plus No. 200	%sand ≥ %gravel	Elastic silt with sand
			%sand < %gravel	Elastic silt with gravel
	≥30% plus No. 200	% sand ≥ % gravel	<15% gravel	Sandy elastic silt
			≥15% gravel	Sandy elastic silt with gravel
		% sand < % gravel	<15% sand	Gravelly elastic silt
			≥15% sand	Gravelly elastic silt with sand

Reference:
ASTM D 2487 and 2488

Laboratory Classification of Clay and Silt

REFERENCE: Caltrans Soil and Rock Logging, Classification, and Presentation Manual (2010).



CL: LL<50; above A-Line.

CH: LL≥50; above A-Line.

ML: LL<50; below A-Line, or PI<4, or Non-Plastic

MH: LL≥50; below A-Line.

CL-ML: above A-Line and PI=4 to 7

CL/CH, ML/MH: at or near LL=50

ML/CL, MH/CH: at or near the A-Line

Field Identification of Clays and Silts

Group Symbol	Dry Strength	Dilatancy	Toughness	Plasticity
ML	None to low	Slow to rapid	Low or thread cannot be formed	Low to nonplastic
CL	Medium to high	None to slow	Medium	Medium
MH	Low to medium	None to slow	Low to medium	Low to medium
CH	High to very high	None	High	High

GROUP DELTA

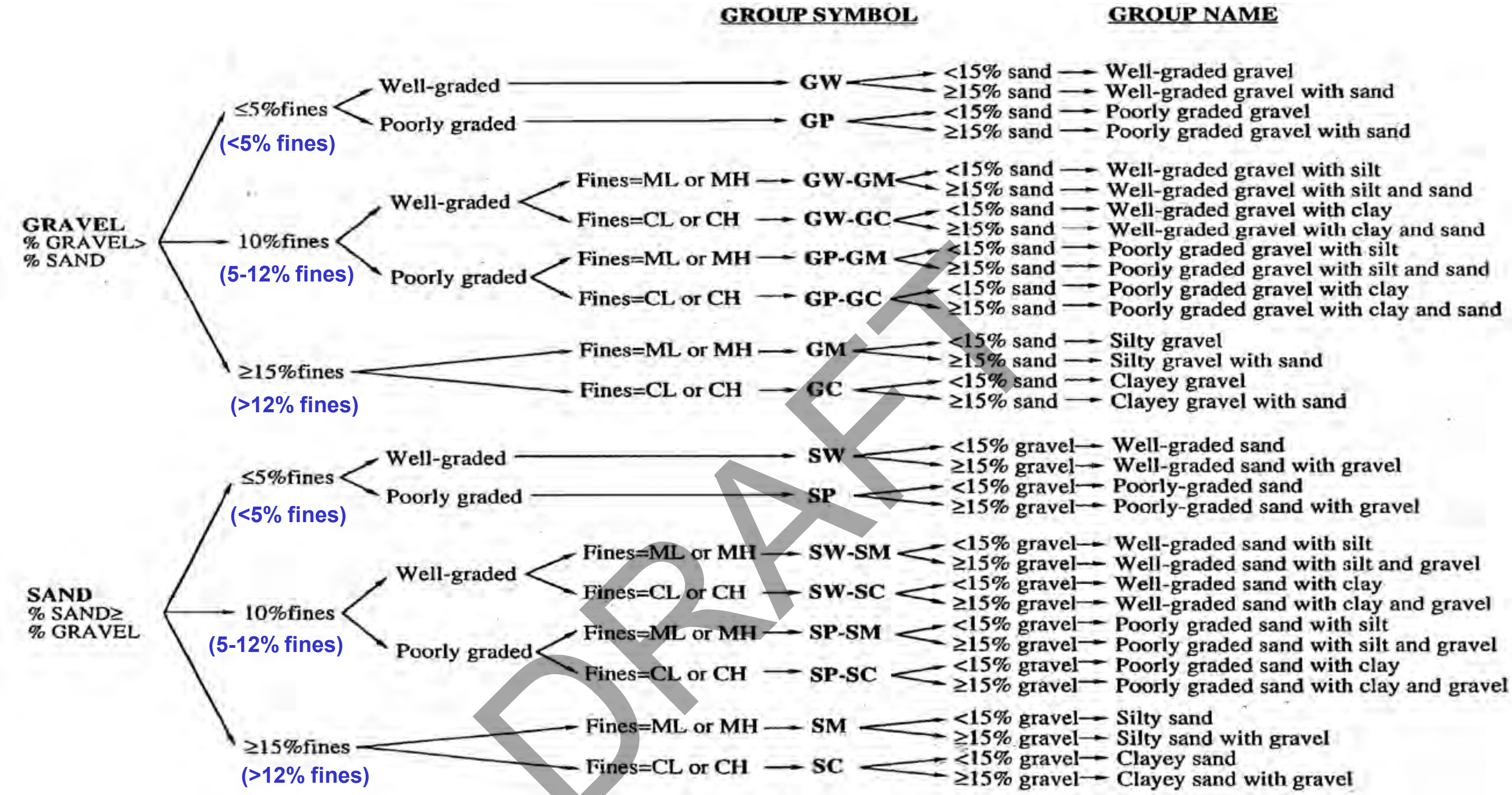
GDC Project No. IR-450

City of Santa Rosa Water Tank Evaluation
Santa Rosa, CA

KEY FOR SOIL CLASSIFICATION #1

Figure A-1E

CLASSIFICATION OF COARSE-GRAINED SOILS (Soils with <50% “fines” passing No. 200 Sieve)



Reference:

ASTM D 2487 and 2488

Note: Values estimated to nearest 5% to be used for visual identification, values in parentheses to be used for classification when based on laboratory grain size data.

Granular Soil Gradation Parameters

Coefficient of Uniformity: $C_u = D_{60}/D_{10}$

Coefficient of Curvature: $Cc = D_{30}^2 / (D_{60} \times D_{10})$

D_{10} = 10% of soil is finer than this diameter

D_{30} = 30% of soil is finer than this diameter

D_{60} = 60% of soil is finer than this diameter

Group Symbol	Gradation or Plasticity Requirement
SW	$C_u > 6$ and $1 \le C_c \le 3$
GW	$C_u > 4$ and $1 \le C_c \le 3$
GP or SP	Clean gravel or sand not meeting requirement for SW or GW
SM or GM	Non-plastic fines or below A-Line or PI<4
SC or GC	Plastic fines or above A-Line and PI>7

GROUP DELTA

GDC Project No. IR-450

City of Santa Rosa Water Tank Evaluation
Santa Rosa, CA

KEY FOR SOIL CLASSIFICATION #2

Figure A-1F

Attachment 2

BORING RECORD

PROJECT NAME	PROJECT NUMBER	HOLE ID
Seismic Evaluation of Tanks - Santa Rosa	BA024	R9A-B-1

SITE LOCATION	START	FINISH	SHEET NO.
Santa Rosa, California	6/17/2016	6/17/2016	1 of 1

DRILLING COMPANY	DRILL RIG	DRILLING METHOD	LOGGED BY	CHECKED BY
Clear Heart Drilling	DR8K Rubber Track	Solid Flight Auger	B. Mallchok	A. Salehian

HAMMER TYPE (WEIGHT/DROP)	HAMMER EFFICIENCY (ERi)	BORING DIA. (in)	TOTAL DEPTH (ft)	GROUND ELEV (ft)	DEPTH/*ELEV.* GW (ft)
Hammer: 140 lbs., Drop: 30 in.	81.5%	4	11.5	535	∇ NE / *NE* DURING DRILLING

DRIVE SAMPLER TYPE(S) & SIZE (ID)	NOTES	AFTER DRILLING
SPT (1.4")	Backfilled with grout, AC Patch	▼ NE / *NE*

DEPTH (feet)	ELEVATION (feet)	SAMPLE TYPE	SAMPLE NO.	PENETRATION RESISTANCE (BLOWS / 6 IN)	BLOW/FT "N"	SPT N^*_{60}	RECOVERY (%)	RQD (%)	MOISTURE (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS (LL:PI)	OTHER TESTS	DRILLING METHOD	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION
															ASPHALT CONCRETE (2")
															AGGREGATE BASE (10")
			S-1	13 15 16	31	42					74:25				Volcanic bedrock; very soft to soft; olive brown to yellowish brown with some orangeish brown staining on fracture surfaces; moderately to intensely weathered; very intensely fractured; some small green olivine phenocrysts; well cemented in zones
			S-2	34 30 45	75	102									
5	530														
10	525														
			S-3	11 16 30	46	63									
															Bottom of borehole at 11' 6" Groundwater was not encountered in the borehole
15	520														
20	515														

GDC_LOG_BORING_2016 BA024_SANTAROSATANKS.GPJ GDC2013.GDT 8/9/16

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THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF THE ACTUAL CONDITIONS ENCOUNTERED.

FIGURE A-2

BORING RECORD

PROJECT NAME	PROJECT NUMBER	HOLE ID
Seismic Evaluation of Tanks - Santa Rosa	BA024	**R9A-B-2**

SITE LOCATION	START	FINISH	SHEET NO.
Santa Rosa, California	6/17/2016	6/17/2016	1 of 1

DRILLING COMPANY	DRILL RIG	DRILLING METHOD	LOGGED BY	CHECKED BY
Clear Heart Drilling	DR8K Rubber Track	Solid Flight Auger	B. Mallchok	A. Salehian

HAMMER TYPE (WEIGHT/DROP)	HAMMER EFFICIENCY (ERi)	BORING DIA. (in)	TOTAL DEPTH (ft)	GROUND ELEV (ft)	DEPTH/*ELEV.* GW (ft)
Hammer: 140 lbs., Drop: 30 in.	81.5%	4	11.5	535	♈ NE / *NE* DURING DRILLING

DRIVE SAMPLER TYPE(S) & SIZE (ID)	NOTES	AFTER DRILLING
SPT (1.4")	Backfilled with grout, AC Patch	NE / *NE*

DEPTH (feet)	ELEVATION (feet)	SAMPLE TYPE	SAMPLE NO.	PENETRATION RESISTANCE (BLOWS / 6 IN)	BLOW/FT "N"	SPT N^*_{60}	RECOVERY (%)	RQD (%)	MOISTURE (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS (LL:PI)	OTHER TESTS	DRILLING METHOD	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION
0	535														ASPHALT CONCRETE (3")
															AGGREGATE BASE (9")
1															Volcanic bedrock; very soft to soft; yellowish brown mottled with reddish-brown; moderately to intensely weathered; intensely fractured; well cemented in zones
3		SPT	S-1	11 12 13	25	34						CR			
5	530	SPT	S-2	12 18 20	38	52									
6		SPT	S-3	29 50/5.5"	50/5.5"	68/5.5"									
10	525														
11		SPT	S-4	43 34 38	72	98									
11.5															Bottom of borehole at 11' 6" Groundwater was not encountered in the borehole
15	520														
20	515														

GDC_LOG_BORING_2016 BA024_SANTAROSATANKS.GPJ GDC2013.GDT 8/9/16

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FIGURE A-3

Attachment 2

BORING RECORD

PROJECT NAME	PROJECT NUMBER	HOLE ID
Seismic Evaluation of Tanks - Santa Rosa	BA024	**R9A-B-3**

SITE LOCATION	START	FINISH	SHEET NO.
Santa Rosa, California	6/17/2016	6/17/2016	1 of 1

DRILLING COMPANY	DRILL RIG	DRILLING METHOD	LOGGED BY	CHECKED BY
Clear Heart Drilling	DR8K Rubber Track	Solid Flight Auger	B. Mallchok	A. Salehian

HAMMER TYPE (WEIGHT/DROP)	HAMMER EFFICIENCY (ERi)	BORING DIA. (in)	TOTAL DEPTH (ft)	GROUND ELEV (ft)	DEPTH/*ELEV.* GW (ft)
Hammer: 140 lbs., Drop: 30 in.	81.5%	4	11.5	535	⊻ NE / *NE* DURING DRILLING

DRIVE SAMPLER TYPE(S) & SIZE (ID)	NOTES	AFTER DRILLING
SPT (1.4")	Backfilled with grout, AC Patch	▼ NE / *NE*

DEPTH (feet)	ELEVATION (feet)	SAMPLE TYPE	SAMPLE NO.	PENETRATION RESISTANCE (BLOWS / 6 IN)	BLOW/FT "N"	SPT N^*_{60}	RECOVERY (%)	RQD (%)	MOISTURE (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS (LL:PI)	OTHER TESTS	DRILLING METHOD	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION
															ASPHALT CONCRETE (2")
															AGGREGATE BASE (14")
															Volcanic bedrock; very soft to soft; olive brown with some orangeish brown staining on fracture surfaces; moderately to intensely weathered; intensely fractured; well cemented in zones; MnOx staining/inclusions
			S-1	19 12 12	24	33					56:28				
			S-2	27 25 12	37	50									
5	530		S-3	11 12 13	25	34									
10	525		S-4	18 13 13	26	35									
															Bottom of borehole at 11' 6" Groundwater was not encountered in the borehole
15	520														
20	515														

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FIGURE
A-4

Attachment 2

BORING RECORD	PROJECT NAME: Seismic Evaluation of Tanks - Santa Rosa		PROJECT NUMBER: BA024	HOLE ID: **R16-B-2**
SITE LOCATION: Santa Rosa, California	START: 6/17/2016	FINISH: 6/17/2016		SHEET NO.: 1 of 1
DRILLING COMPANY: Clear Heart Drilling	DRILL RIG: DR8K Rubber Track	DRILLING METHOD: Solid Flight Auger	LOGGED BY: B. Mallchok	CHECKED BY: A. Salehian
HAMMER TYPE (WEIGHT/DROP): Hammer: 140 lbs., Drop: 30 in.	HAMMER EFFICIENCY (ERi): 81.5%	BORING DIA. (in): 4	TOTAL DEPTH (ft): 16.46	GROUND ELEV (ft): 726
DEPTH/*ELEV.* GW (ft): ⊻ 13.5 / *712.5* DURING DRILLING				
DRIVE SAMPLER TYPE(S) & SIZE (ID): SPT (1.4"), MC (2.4")	NOTES: Backfilled with grout, AC Patch		AFTER DRILLING: NM / *NE*	

DEPTH (feet)	ELEVATION (feet)	SAMPLE TYPE	SAMPLE NO.	PENETRATION RESISTANCE (BLOWS / 6 IN)	BLOW/FT "N"	SPT N^*_{60}	RECOVERY (%)	RQD (%)	MOISTURE (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS (LL:PI)	OTHER TESTS	DRILLING METHOD	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION
0	725														ASPHALT CONCRETE (2.5") AGGREGATE BASE (12")
			S-1	2 1 3	4	5					64:26				Elastic SILT (MH); medium stiff; reddish gray, mottled; moist; high plasticity; some white percipitation; black laminations/inclusions; few SAND; (NATIVE) 6% SAND; 94% fines PP=1.75 tsf
5			R-2	3 4 9	13	12			61.6	62					Stiff UC: Su=0.3 tsf; PP=3.25 tsf
	720														
10	715		S-3	8 4 8	12	16									Very stiff
															⊻
15	710		R-4	13 27 50/5.5'	77/11.5'	70/11.5'									Volcanic bedrock; very soft to soft; olive brown mottled with black and red; intensely weathered to decomposed; very intensely fractured.
															Bottom of borehole at 16' 5 1/2". Groudwater was encountered in the borehole after drilling at 13' 6".
20	705														

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FIGURE A-5

BORING RECORD

PROJECT NAME Seismic Evaluation of Tanks - Santa Rosa	**PROJECT NUMBER** BA024	**HOLE ID** R16-B-3	
SITE LOCATION Santa Rosa, California	**START** 6/17/2016	**FINISH** 6/17/2016	**SHEET NO.** 1 of 1
DRILLING COMPANY Clear Heart Drilling	**DRILL RIG** DR8K Rubber Track	**DRILLING METHOD** Solid Flight Auger	**LOGGED BY** B. Mallchok / **CHECKED BY** A. Salehian
HAMMER TYPE (WEIGHT/DROP) Hammer: 140 lbs., Drop: 30 in.	**HAMMER EFFICIENCY (ERi)** 81.5%	**BORING DIA. (in)** 4 / **TOTAL DEPTH (ft)** 16.5 / **GROUND ELEV (ft)** 726	**DEPTH/*ELEV.* GW (ft)** ∇ 13.5 / *712.5* DURING DRILLING
DRIVE SAMPLER TYPE(S) & SIZE (ID) SPT (1.4"), MC (2.4")	**NOTES** Backfilled with grout, AC Patch		AFTER DRILLING ▼ NM / *NE*

DEPTH (feet)	ELEVATION (feet)	SAMPLE TYPE	SAMPLE NO.	PENETRATION RESISTANCE (BLOWS / 6 IN)	BLOW/FT "N"	SPT N^*_{60}	RECOVERY (%)	RQD (%)	MOISTURE (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS (LL:PI)	OTHER TESTS	DRILLING METHOD	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION
0															ASPHALT CONCRETE (2.5")
	725														AGGREGATE BASE (12")
			S-1	5 6 7	13	18					65:30				Elastic SILT (MH); very stiff; reddish brown motted with gray; moist; trace SAND; small rock fragments; white percipitation/laminations (NATIVE). 5% SAND; 95% fines PP> 4.5 tsf
			R-2-2 R-2-1	8 11 11	22	20			46.9	71		CR			Stiff UC: Su=0.6 tsf; PP = 3.5 tsf
5															
	720														
10															Medium stiff
	715		S-3	1 2 3	5	7									
															∇ Volcanic bedrock, very soft to soft, intensely weathered to decmposed; very intensely fractured; black MnOx, laminations, red mottling, small white phenocrysts.
15															
	710		R-4	10 14 20	34	31									
															Bottom of borehole at 16' 6" Groudwater was encountered in the borehole after drilling at 13' 5".
20															
	705														

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THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF THE ACTUAL CONDITIONS ENCOUNTERED.

FIGURE A-6

BORING RECORD

PROJECT NAME	Seismic Evaluation of Tanks - Santa Rosa	PROJECT NUMBER	BA024
HOLE ID	R16-B-4	SHEET NO.	1 of 2
SITE LOCATION	Santa Rosa, California	START / FINISH	6/16/2016 / 6/17/2016
DRILLING COMPANY	Clear Heart Drilling	DRILL RIG	DR8K Rubber Track
DRILLING METHOD	Solid Flight Auger	LOGGED BY / CHECKED BY	B. Mallchok / A. Salehian
HAMMER TYPE (WEIGHT/DROP)	Hammer: 140 lbs., Drop: 30 in.	HAMMER EFFICIENCY (ERi)	81.5%
BORING DIA. (in)	4	TOTAL DEPTH (ft)	36.5
GROUND ELEV (ft)	726	DEPTH/*ELEV.* GW (ft)	∇ 15.0 / *711.0* DURING DRILLING; ▼ 22.8 / *703.2* 6/17/2016 AFTER DRILLING
DRIVE SAMPLER TYPE(S) & SIZE (ID)	SPT (1.4"), MC (2.4")	NOTES	Backfilled with grout, AC Patch

DEPTH (feet)	ELEVATION (feet)	SAMPLE TYPE	SAMPLE NO.	PENETRATION RESISTANCE (BLOWS / 6 IN)	BLOW/FT "N"	SPT N^*_{60}	RECOVERY (%)	RQD (%)	MOISTURE (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS (LL:PI)	OTHER TESTS	DRILLING METHOD	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION
															ASPHALT CONCRETE (3")
	725														AGGREGATE BASE (15")
		SPT	S-1	5 7 7	14	19									Elastic SILT with SAND (MH); very stiff; reddish brown; moist; trace GRAVEL; trace SAND; (NATIVE). 5% GRAVEL; 24% SAND; 71% fines
		MC	R-2	13 14 13	27	25					76:40				Reddish brown mottled with gray PP = 4.25 tsf PP = 4.5 tsf
5		SPT	S-3	5 4 4	8	11									PP = 3.00 tsf; Stiff PP = 3.25 tsf
	720	MC	R-4	9 10 12	22	20			43.6	78					Very stiff PP = 1.75 tsf UC: Su=1.1 tsf
		SPT	S-5	4 4 4	8	11									Stiff PP = 4.5 tsf
10		MC	R-6	6 6 6	12	11									PP = 1.5 tsf
	715	SPT	S-7	2 2 3	5	7									Medium stiff PP = 1.0 tsf
		SPT	S-8	2 3 3	6	8									PP = 1.00 tsf
15		SPT	S-9	1 3 4	7	10			56.6		64:28				Stiff PP = 1.25 tsf (∇ groundwater during drilling)
	710	SPT	S-10	4 4 6	10	14									With some black laminations PP = 1.25 tsf
		SPT	S-11	5 6 6	12	16									Very stiff
		SPT	S-12	9 13 17	30	41									Hard; olive brown mottled with red and brown; moist; trace SAND, rock fragments
20		SPT	S-13	2 5 4	9	12									Stiff
	705														(▼ groundwater after drilling)

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FIGURE A-7 a

BORING RECORD

PROJECT NAME	PROJECT NUMBER	HOLE ID
Seismic Evaluation of Tanks - Santa Rosa	BA024	**R16-B-4**

SITE LOCATION	START	FINISH	SHEET NO.
Santa Rosa, California	6/16/2016	6/17/2016	2 of 2

DRILLING COMPANY	DRILL RIG	DRILLING METHOD	LOGGED BY	CHECKED BY
Clear Heart Drilling	DR8K Rubber Track	Solid Flight Auger	B. Mallchok	A. Salehian

HAMMER TYPE (WEIGHT/DROP)	HAMMER EFFICIENCY (ERi)	BORING DIA. (in)	TOTAL DEPTH (ft)	GROUND ELEV (ft)	DEPTH/*ELEV.* GW (ft)
Hammer: 140 lbs., Drop: 30 in.	81.5%	4	36.5	726	⊻ 15.0 / *711.0* DURING DRILLING

DRIVE SAMPLER TYPE(S) & SIZE (ID)	NOTES	AFTER DRILLING
SPT (1.4"), MC (2.4")	Backfilled with grout, AC Patch	▼ 22.8 / *703.2* 6/17/2016

DEPTH (feet)	ELEVATION (feet)	SAMPLE TYPE	SAMPLE NO.	PENETRATION RESISTANCE (BLOWS / 6 IN)	BLOW/FT "N"	SPT N^*_{60}	RECOVERY (%)	RQD (%)	MOISTURE (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS (LL:PI)	OTHER TESTS	DRILLING METHOD	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION
	700	SPT	S-14	11 15 17	32	44			50.5		61:23				*(Elastic SILT (MH); hard; black MnOx inclusions; grades orange brown to olive gray)* PP = 3.5 tsf
30	695	SPT	S-15	9 17 34	51	69									Volcanic bedrock; soft; intensely weathered to decomposed; olive gray to olive brown; intensely fractured
35	690	SPT	S-16	5 3 8	11	15									
															Bottom of borehole at 36' 6" Groudwater was encountered in the borehole at 15' and 22' 10", after drilling and after 12 hours, respectively.
40	685														
45	680														

DRAFT

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FIGURE

A-7 b

BORING RECORD

PROJECT NAME	Seismic Evaluation of Tanks - Santa Rosa
PROJECT NUMBER	BA024
HOLE ID	R17-B-1
SITE LOCATION	Santa Rosa, California
START	6/16/2016
FINISH	6/16/2016
SHEET NO.	1 of 2
DRILLING COMPANY	Clear Heart Drilling
DRILL RIG	DR8K Rubber Track
DRILLING METHOD	Solid Flight Auger
LOGGED BY	B. Mallchok
CHECKED BY	A. Salehian
HAMMER TYPE (WEIGHT/DROP)	Hammer: 140 lbs., Drop: 30 in.
HAMMER EFFICIENCY (ERi)	81.5%
BORING DIA. (in)	4
TOTAL DEPTH (ft)	49.3
GROUND ELEV (ft)	894
DEPTH/*ELEV.* GW (ft)	▽ NE / *NE* DURING DRILLING; ▼ NE / *NE* AFTER DRILLING
DRIVE SAMPLER TYPE(S) & SIZE (ID)	SPT (1.4"), MC (2.4")
NOTES	Backfilled with grout, AC Patch

DEPTH (feet)	ELEVATION (feet)	SAMPLE TYPE	SAMPLE NO.	PENETRATION RESISTANCE (BLOWS / 6 IN)	BLOW/FT "N"	SPT N^*_{60}	RECOVERY (%)	RQD (%)	MOISTURE (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS (LL:PI)	OTHER TESTS	DRILLING METHOD	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION
															ASPHALT CONCRETE (2")
															AGGREGATE BASE (6")
			S-1	4 5 6	11	15					60:29				fat CLAY (CH); very stiff; reddish-brown to dark brown mottled with white; moist; little SAND, trace small rock fragments; (FILL) 15% SAND; 85% fines
	890		R-1-2 R-1-1	6 8 10	18	16			53.1	70					fat CLAY (CH); very stiff; reddish-brown to dark brown mottled with white; moist; little SAND, trace small rock fragments; (NATIVE) PP = 4.0 tsf
5															Grades finer; higher plasticity UC: Su=1.1 tsf; PP = 2.5 tsf
			S-3	3 3 4	7	10					70:36				Stiff PP = 2.5 tsf
			R-4-2 R-4-1	5 6 10	16	15									Very Stiff PP = 3.5 tsf
	885														
10			S-5	2 3 3	6	8									Stiff PP = 2.0 tsf
	880														
15			R-6-2 R-6-1	5 5 6	11	10			55.0	68.8					UC: Su=0.3 tsf; PP = 3.0 tsf
															CLAY with SILT (CL/CH); stiff; dark brown mottled with orangeish-brown; moist; some SAND; trace small rock fragments; some white mottling/ native laminations (tuff?)
	875														
20			S-7	2 3 4	7	10									PP = 1.0 tsf
	870		R-8-2	5	9	8									

DRAFT

GDC_LOG_BORING_2016 BA024_SANTAROSATANKS.GPJ GDC2013.GDT 8/9/16

GROUP DELTA CONSULTANTS
1970 Boadway, Suite 1100
Oakland, CA 94612

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF THE ACTUAL CONDITIONS ENCOUNTERED.

FIGURE A-8 a

Attachment 2

BORING RECORD

PROJECT NAME	Seismic Evaluation of Tanks - Santa Rosa
PROJECT NUMBER	BA024
HOLE ID	**R17-B-1**
SITE LOCATION	Santa Rosa, California
START	6/16/2016
FINISH	6/16/2016
SHEET NO.	2 of 2
DRILLING COMPANY	Clear Heart Drilling
DRILL RIG	DR8K Rubber Track
DRILLING METHOD	Solid Flight Auger
LOGGED BY	B. Mallchok
CHECKED BY	A. Salehian
HAMMER TYPE (WEIGHT/DROP)	Hammer: 140 lbs., Drop: 30 in.
HAMMER EFFICIENCY (ERi)	81.5%
BORING DIA. (in)	4
TOTAL DEPTH (ft)	49.3
GROUND ELEV (ft)	894
DEPTH/*ELEV.* GW (ft)	⊻ NE / *NE* DURING DRILLING; ▼ NE / *NE* AFTER DRILLING
DRIVE SAMPLER TYPE(S) & SIZE (ID)	SPT (1.4"), MC (2.4")
NOTES	Backfilled with grout, AC Patch

DEPTH (feet)	ELEVATION (feet)	SAMPLE NO.	PENETRATION RESISTANCE (BLOWS / 6 IN)	BLOW/FT "N"	SPT N^*_{60}	RECOVERY (%)	RQD (%)	MOISTURE (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS (LL:PI)	OTHER TESTS	DESCRIPTION AND CLASSIFICATION
		R-8-1	4, 5									*(CLAY with SILT (CL/CH), continued)* PP = 3.0 tsf
	865											
30		S-9	3, 3, 5	8	11							
												Increase in white mottling
	860											
35		R-10-2, R-10-1	5, 14, 13	27	25							Very stiff PP = 4.5 tsf
	855											
40		S-11	2, 3, 4	7	10							Stiff PP = 2.5 tsf
												CLAY with SAND and SILT (CL); medium stiff; reddish-brown; moist to wet
	850											
45		S-12	7, 50/5"	50/5"	68/5"							CLAY with SILT (CL); gray; very stiff; moist (weathered bedrock) PP = 1.0 tsf
												Volcanic bedrock; extremely hard; olive gray; slightly weathered
	845	S-13	50/4.5"									
												Bottom of borehole: 49' 4-1/2"

Attachment 2

BORING RECORD

PROJECT NAME Seismic Evaluation of Tanks - Santa Rosa		**PROJECT NUMBER** BA024		**HOLE ID** R17-B-2	
SITE LOCATION Santa Rosa, California		**START** 6/16/2016	**FINISH** 6/16/2016	**SHEET NO.** 1 of 1	
DRILLING COMPANY Clear Heart Drilling	**DRILL RIG** DR8K Rubber Track	**DRILLING METHOD** Solid Flight Auger		**LOGGED BY** B. Mallchok	**CHECKED BY** A. Salehian
HAMMER TYPE (WEIGHT/DROP) Hammer: 140 lbs., Drop: 30 in.	**HAMMER EFFICIENCY (ERi)** 81.5%	**BORING DIA. (in)** 4	**TOTAL DEPTH (ft)** 5	**GROUND ELEV (ft)** 894	**DEPTH/*ELEV.* GW (ft)** ▽ NE / *NE* DURING DRILLING; ▼ NE / *NE* AFTER DRILLING
DRIVE SAMPLER TYPE(S) & SIZE (ID) BULK(4")		**NOTES** Backfilled with grout, AC Patch			

DEPTH (feet)	ELEVATION (feet)	SAMPLE TYPE	SAMPLE NO.	PENETRATION RESISTANCE (BLOWS / 6 IN)	BLOW/FT "N"	SPT N^*_{60}	RECOVERY (%)	RQD (%)	MOISTURE (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS (LL:PI)	OTHER TESTS	DRILLING METHOD	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION
															ASPHALT CONCRETE (2")
															AGGREGATE BASE (8")
		B	B-1						58.7	59	54:29	CR			sandy fat CLAY (CH); reddish-brown to dark brown mottled with white; moist; few GRAVEL; some SAND; (FILL) 11% GRAVEL; 33% SAND; 56% fines
	890	B	B-2						31.1	88	71:40				fat CLAY (CH); reddish-brown to dark brown mottled with white; moist; (NATIVE)
5															Bottom of borehole at 5' Groundwater was not encountered in the borehole
	885														
10															
	880														
15															
	875														
20															
	870														

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GDC_LOG_BORING_2016 BA024_SANTAROSATANKS.GPJ GDC2013.GDT 8/9/16

GROUP DELTA

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FIGURE A-9

Attachment 2

BORING RECORD

Field	Value
PROJECT NAME	Seismic Evaluation of Tanks - Santa Rosa
PROJECT NUMBER	BA024
HOLE ID	R17-B-3
SITE LOCATION	Santa Rosa, California
START	6/16/2016
FINISH	6/16/2016
SHEET NO.	1 of 1
DRILLING COMPANY	Clear Heart Drilling
DRILL RIG	DR8K Rubber Track
DRILLING METHOD	Solid Flight Auger
LOGGED BY	B. Mallchok
CHECKED BY	A. Salehian
HAMMER TYPE (WEIGHT/DROP)	Hammer: 140 lbs., Drop: 30 in.
HAMMER EFFICIENCY (ERi)	81.5%
BORING DIA. (in)	4
TOTAL DEPTH (ft)	5.54
GROUND ELEV (ft)	894
DEPTH/*ELEV.* GW (ft)	▽ NE / *NE* DURING DRILLING; ▼ NE / *NE* AFTER DRILLING
DRIVE SAMPLER TYPE(S) & SIZE (ID)	SPT (1.4")
NOTES	Backfilled with grout, AC Patch

DEPTH (feet)	ELEVATION (feet)	SAMPLE TYPE	SAMPLE NO.	PENETRATION RESISTANCE (BLOWS / 6 IN)	BLOW/FT "N"	SPT N^*_{60}	RECOVERY (%)	RQD (%)	MOISTURE (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS (LL:PI)	OTHER TESTS	DRILLING METHOD	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION
															ASPHALT CONCRETE (2")
															AGGREGATE BASE (8")
			S-1	5 3 5	8	11					57:30				fat CLAY with SAND (CH); medium stiff to stiff; orangeish-brown with some small rock fragments; moist; trace SAND; no weathing rinds; (FILL) 3% GRAVEL; 24% SAND; 73% fines PP = 4.5 tsf
			S-2	50/6"	50/6"	68/6"									Volcanic bedrock; very hard; gray; slightly to moderately weathered
	890														
5			S-3	25/0.5"	25/0.5"	34/0.5"									bottom of borehole: 5' 6" Groundwater was not encountered in the borehole
10	885														
15	880														
20	875														
	870														

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FIGURE A-10

BORING RECORD

Field	Value
PROJECT NAME	Seismic Evaluation of Tanks - Santa Rosa
PROJECT NUMBER	BA024
HOLE ID	R17-B-4
SITE LOCATION	Santa Rosa, California
START	6/16/2016
FINISH	6/16/2016
SHEET NO.	1 of 1
DRILLING COMPANY	Clear Heart Drilling
DRILL RIG	DR8K Rubber Track
DRILLING METHOD	Solid Flight Auger
LOGGED BY	B. Mallchok
CHECKED BY	A. Salehian
HAMMER TYPE (WEIGHT/DROP)	Hammer: 140 lbs., Drop: 30 in.
HAMMER EFFICIENCY (ERi)	81.5%
BORING DIA. (in)	4
TOTAL DEPTH (ft)	2.16
GROUND ELEV (ft)	894
DEPTH/*ELEV.* GW (ft)	⊻ NE / *NE* DURING DRILLING; ▼ NE / *NE* AFTER DRILLING
DRIVE SAMPLER TYPE(S) & SIZE (ID)	SPT (1.4")
NOTES	Backfilled with grout, AC Patch

DEPTH (feet)	ELEVATION (feet)	SAMPLE TYPE	SAMPLE NO.	PENETRATION RESISTANCE (BLOWS / 6 IN)	BLOW/FT "N"	SPT N^*_{60}	RECOVERY (%)	RQD (%)	MOISTURE (%)	DRY DENSITY (pcf)	ATTERBERG LIMITS (LL:PI)	OTHER TESTS	DRILLING METHOD	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION
0	894														ASPHALT CONCRETE (2")
															AGGREGATE BASE (6")
1		⊠	S-1	7 50/3"	50/3"	68/3"					59:28				Elastic Silt (MH); stiff; orangeish-brown with some small rock fragments; moist; trace SAND; no weathering rinds (FILL) 3% GRAVEL; 25% SAND; 72% fines PP = 4.5 tsf
															Volcanic bedrock, extremely hard, gray (only two small fragments recovered)
															Bottom of borehole at 2' 2" Groundwater was not encountered in the borehole
	890														
5															
	885														
10															
	880														
15															
	875														
20															
	870														

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FIGURE A-11

Appendix B – Laboratory Testing

B. HILLEBRANDT SOILS TESTING, INC.

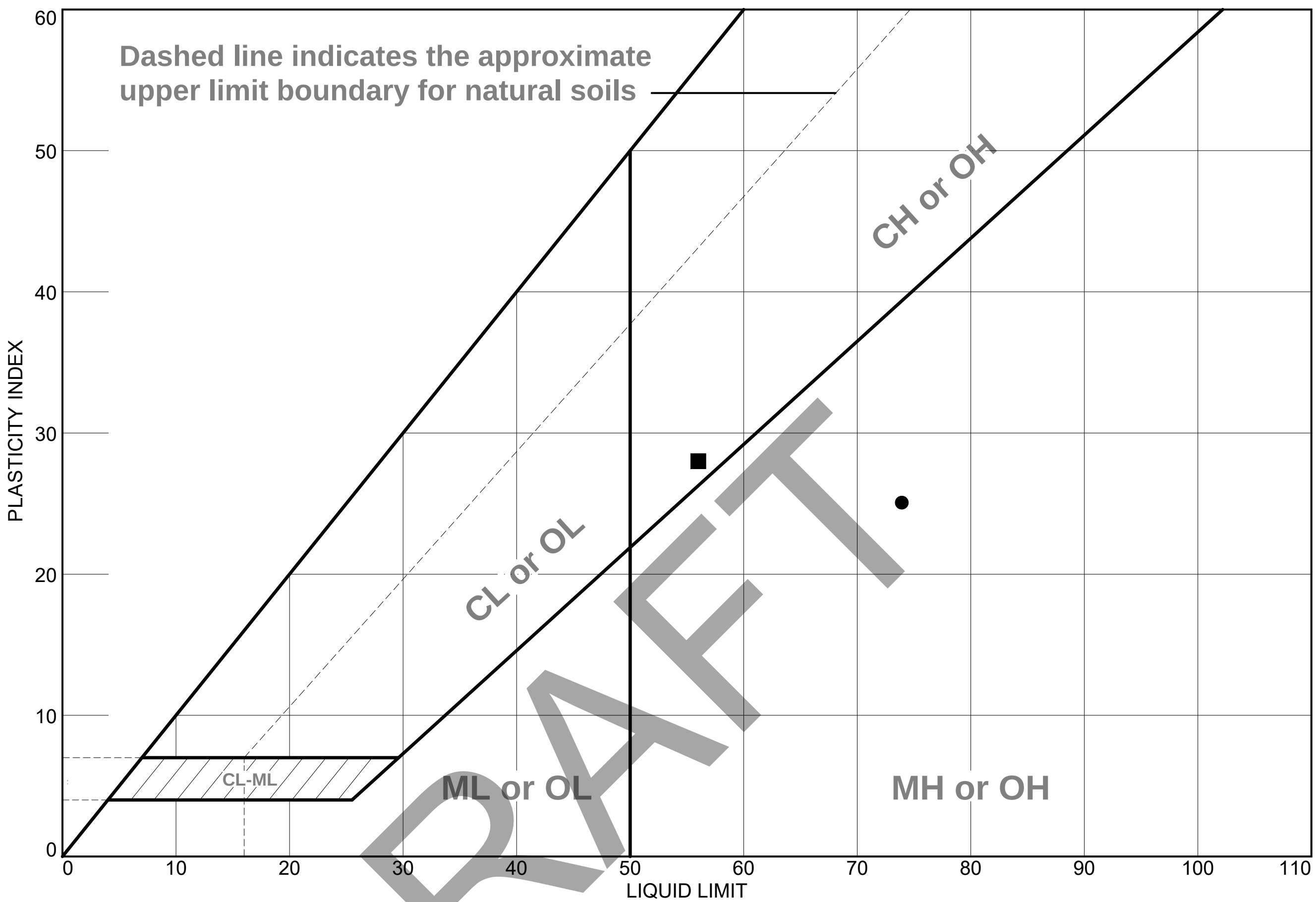
29 Sugarloaf Terrace, Alamo, CA 94507 - Tel: (510) 409-2916 - Fax: (925) 891-9267 - Email: soiltesting@aol.com

LAB RESULTS SUMMARY FORM

Project Number: BA024 **Project Name:** City of Santa Rosa - R-9 Water Tank
Requested By: BS **Request Date:** 6/22/16 **Throw Samples Out On:**

					Atterberg			-200			Compaction				
Boring #	Sample Depth (feet)	Dry Density (pcf)	Moisture Content (%)	Unconfined Compressive (ksf)	Liquid Limit	Plastic Limit	Plasicity Index	Passing #4 Sieve (%)	Passing #40 sieve (%)	Passing #200 sieve (%)	Maximum Dry Density (pcf)	Optimum Moisture (%)	Pocket Penetrometer (tsf)	Torvane (tsf)	Remarks
B-1	1.0 - 2.5				74	49	25								
B-3	1.0 - 2.5				56	28	28								

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Yellowish brown and olive sandy SILT	74	49	25			
■	Brown sandy CLAY with gravel	56	28	28			

Project No. BA-024 **Client:** Group Delta

Project: City of Santa Rosa - R-9A Water Tank Evaluation

● **Source of Sample:** B-1 **Depth:** 1.0 - 2.5' **Sample Number:** S-1

■ **Source of Sample:** B-3 **Depth:** 1.5 - 3.0' **Sample Number:** S-1

Remarks:

B. HILLEBRANDT SOILS TESTING, INC.
+1 510-409-2816
SoilTesting@aol.com

Figure

Tested By: BH

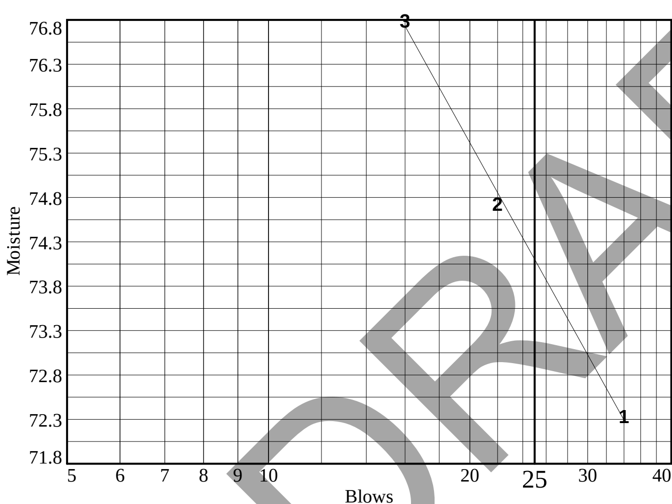
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-9A Water Tank Evaluation
Project Number: BA-024
Location: B-1
Depth: 1.0 - 2.5' **Sample Number:** S-1
Material Description: Yellowish brown and olive sandy SILT
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	24.72	29.31	25.38			
Dry+Tare	19.07	21.59	19.19			
Tare	11.26	11.26	11.13			
# Blows	34	22	16			
Moisture	72.3	74.7	76.8			



Liquid Limit= 74
Plastic Limit= 49
Plasticity Index= 25

Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	18.72	17.42		
Dry+Tare	16.17	15.46		
Tare	11.21	11.33		
Moisture	51.4	47.5		

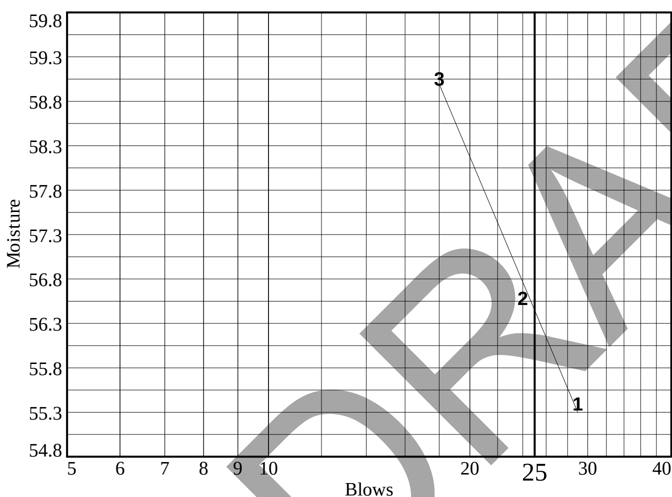
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-9A Water Tank Evaluation
Project Number: BA-024
Location: B-3
Depth: 1.5 - 3.0' **Sample Number:** S-1
Material Description: Brown sandy CLAY with gravel
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	26.84	27.11	25.66			
Dry+Tare	21.3	21.40	20.25			
Tare	11.30	11.31	11.09			
# Blows	29	24	18			
Moisture	55.4	56.6	59.1			



Liquid Limit= 56
Plastic Limit= 28
Plasticity Index= 28

Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	17.55	18.01		
Dry+Tare	16.16	16.55		
Tare	11.32	11.32		
Moisture	28.7	27.9		

B. Hillebrandt Soils Testing, Inc.

Attachment 2

B. HILLEBRANDT SOILS TESTING, INC.

29 Sugarloaf Terrace, Alamo, CA 94507 - Tel: (510) 409-2916 - Fax: (925) 891-9267 - Email: soiltesting@aol.com

LAB RESULTS SUMMARY FORM

Project Number: BA024 **Project Name:** City of Santa Rosa - R-16 Water Tank
Requested By: BS **Request Date:** 6/22/16 **Throw Samples Out On:**

					Atterberg			-200			Compaction				
Boring #	Sample Depth (feet)	Dry Density (pcf)	Moisture Content (%)	UC Shear Strength (psf)	Liquid Limit	Plastic Limit	Plasicity Index	Passing #4 Sieve (%)	Passing #40 sieve (%)	Passing #200 sieve (%)	Maximum Dry Density (pcf)	Optimum Moisture (%)	Pocket Penetrometer (tsf)	Torvane (tsf)	Remarks
B-2	1.0 - 2.5				64	38	26	100	97	94					
B-2	4.5 - 5.0	62	61.6	537											
B-3	1.5 - 3.0				65	35	30	100	98	95					
B-3	4.5 - 5.0	71	46.9	1126											
B-4	4.0 - 4.5				76	36	40	95	80	71					
B-4	7.0 - 7.5	78	43.6	2258											
B-4	13.5 - 15.0		56.6		64	36	28								
B-4	25.0 - 26.5		50.5		61	38	23								

Attachment 2

B. HILLEBRANDT SOILS TESTING, INC.

29 Sugarloaf Terrace, Alamo, CA 94507 - Tel: (510) 409-2916 - Fax: (925) 891-9267 - Email: soiltesting@aol.com

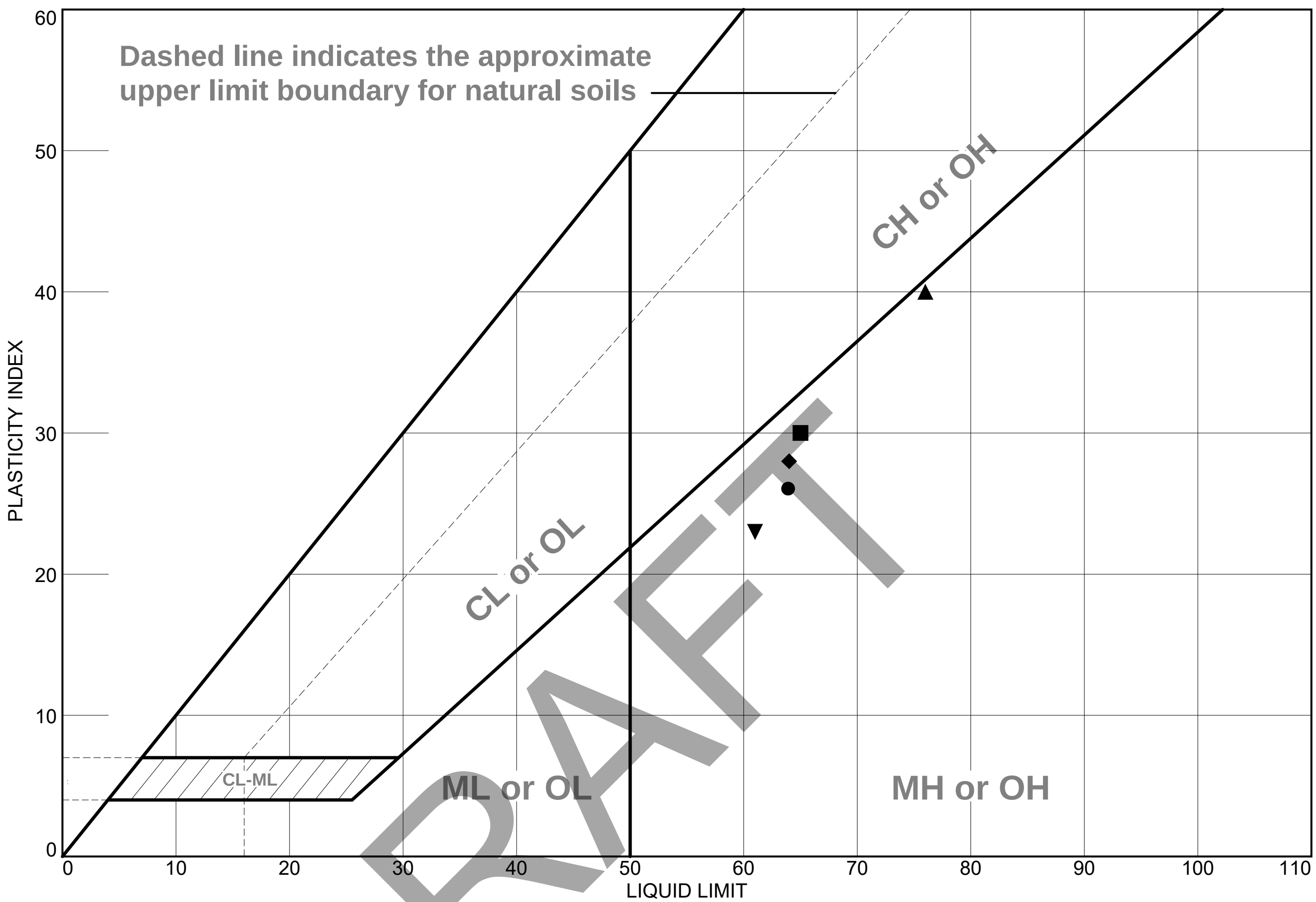
MOISTURE CONTENT WORKSHEET

Job #: BA024
Job Name: City of Santa Rosa - R-16 Water Tank
Date: 6/22/16
Tested by: B. Hillebrandt

Additional Tests:									
Boring #:	B-4	B-4							
Depth:	13.5 - 15.0	25.0 - 26.5							
Sample Description:	Dark reddish brown elastic SILT with sand	Dark brown elastic SILT with sand							
Can #:	367	361							
Wet Sample + can	244.5	285.2							
Dry Sample + can	168.4	201.0							
Weight can	33.9	34.2							
Weight water	76.1	84.2							
Weight Dry Sample	134.5	166.8							
WATER CONTENT (%)	**56.6%**	**50.5%**							

Attachment 2

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Reddish brown elastic SILT	64	38	26	97.2	94.0	MH
■	Dark reddish brown elastic SILT	65	35	30	98.0	95.3	MH
▲	Dark reddish brown elastic SILT with sand	76	36	40	79.9	70.9	MH
◆	Dark reddish brown elastic SILT with sand	64	36	28			
▼	Dark brown elastic SILT with sand	61	38	23			

Project No. BA024 **Client:** Group Delta

Project: City of Santa Rosa - R-16 Watrer Tank Evaluation

●**Source of Sample:** B-2 **Depth:** 1.5 - 3.0' **Sample Number:** S-1
■**Source of Sample:** B-3 **Depth:** 1.5 - 3.0' **Sample Number:** S-1
▲**Source of Sample:** B-4 **Depth:** 4.0 - 4.5' **Sample Number:** R-2
◆**Source of Sample:** B-4 **Depth:** 13.5 -15.0' **Sample Number:** S-9
▼**Source of Sample:** B-4 **Depth:** 25.0 - 26.5' **Sample Number:** S-14

Remarks:

B. HILLEBRANDT SOILS TESTING, INC.
+1 510-409-2816
SoilTesting@aol.com

Figure

Tested By: BH

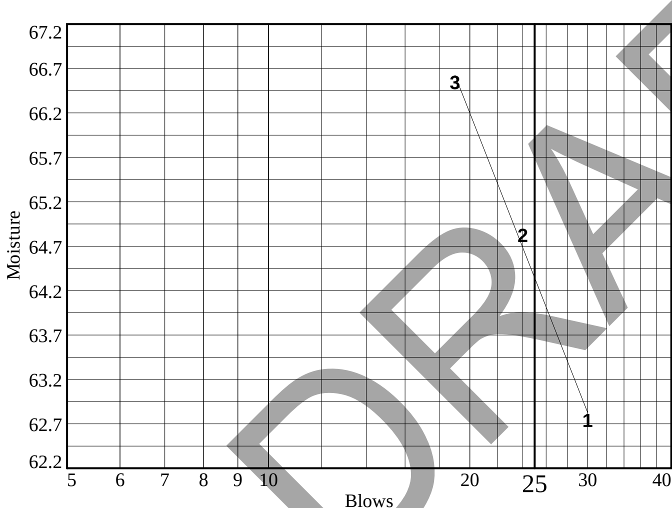
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-16 Watrer Tank Evaluation
Project Number: BA024
Location: B-2
Depth: 1.5 - 3.0' **Sample Number:** S-1
Material Description: Reddish brown elastic SILT
%<#40: 97.2 **%<#200:** 94.0 **USCS:** MH **AASHTO:** A-7-5(32)
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	26.83	27.14	26.02			
Dry+Tare	20.85	20.91	20.15			
Tare	11.32	11.30	11.33			
# Blows	30	24	19			
Moisture	62.7	64.8	66.6			



Liquid Limit= 64
Plastic Limit= 38
Plasticity Index= 26

Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	17.53	17.25		
Dry+Tare	15.79	15.61		
Tare	11.22	11.30		
Moisture	38.1	38.1		

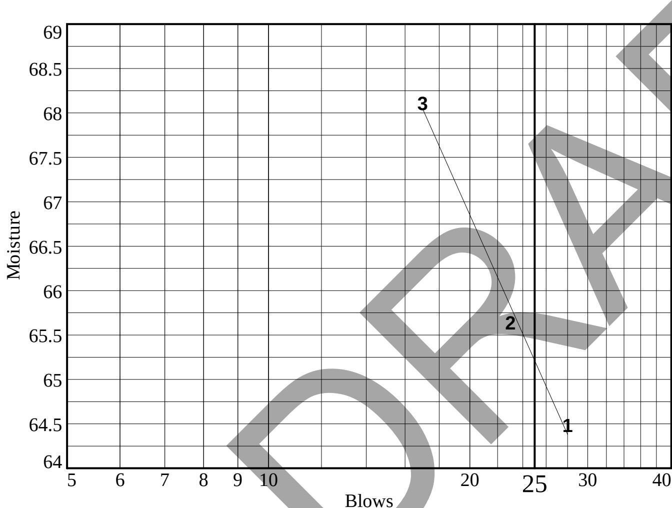
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-16 Watrer Tank Evaluation
Project Number: BA024
Location: B-3
Depth: 1.5 - 3.0' **Sample Number:** S-1
Material Description: Dark reddish brown elastic SILT
%<#40: 98.0 **%<#200:** 95.3 **USCS:** MH **AASHTO:** A-7-5(36)
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	26.89	28.02	24.07			
Dry+Tare	20.77	21.37	18.9			
Tare	11.28	11.24	11.31			
# Blows	28	23	17			
Moisture	64.5	65.6	68.1			



Liquid Limit= 65
Plastic Limit= 35
Plasticity Index= 30

Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	17.84	17.49		
Dry+Tare	16.14	15.88		
Tare	11.36	11.24		
Moisture	35.6	34.7		

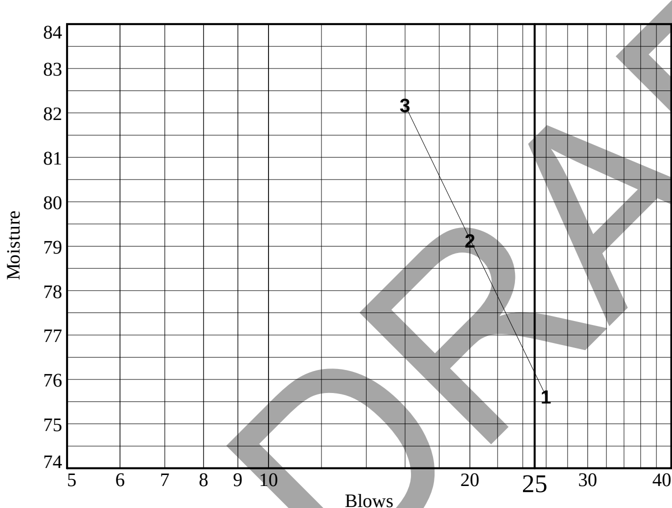
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-16 Watrer Tank Evaluation
Project Number: BA024
Location: B-4
Depth: 4.0 - 4.5' **Sample Number:** R-2
Material Description: Dark reddish brown elastic SILT with sand
%<#40: 79.9 **%<#200:** 70.9 **USCS:** MH **AASHTO:** A-7-5(30)
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	26.66	27.03	26.98			
Dry+Tare	20.05	20.05	19.92			
Tare	11.31	11.23	11.33			
# Blows	26	20	16			
Moisture	75.6	79.1	82.2			



Liquid Limit= 76
Plastic Limit= 36
Plasticity Index= 40

Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	17.75	17.20		
Dry+Tare	16.06	15.6		
Tare	11.36	11.27		
Moisture	36.0	37.0		

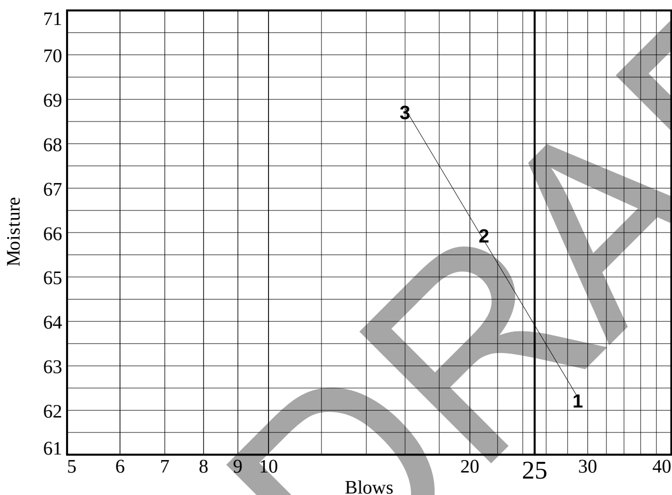
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-16 Watrer Tank Evaluation
Project Number: BA024
Location: B-4
Depth: 13.5 -15.0' **Sample Number:** S-9
Material Description: Dark reddish brown elastic SILT with sand
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	27.81	28.20	27.02			
Dry+Tare	21.5	21.48	20.56			
Tare	11.36	11.29	11.16			
# Blows	29	21	16			
Moisture	62.2	65.9	68.7			



Liquid Limit= 64
Plastic Limit= 36
Plasticity Index= 28
Natural Moisture= 56.6
Liquidity Index= 0.7

Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	17.48	17.83		
Dry+Tare	15.78	16.03		
Tare	11.04	11.07		
Moisture	35.9	36.3		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
244.5	168.4	33.9	56.6

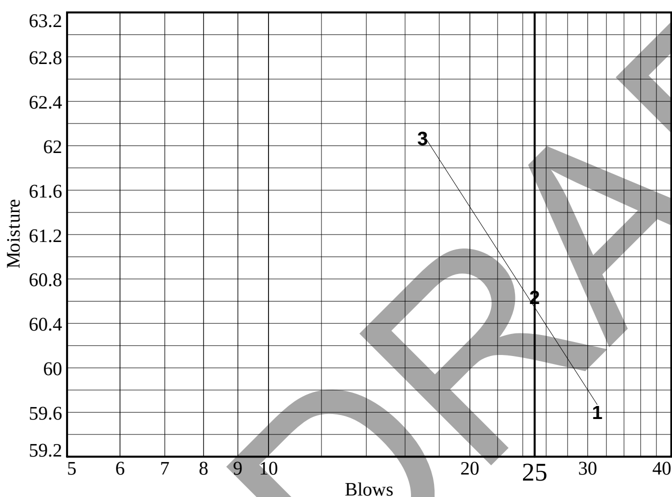
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-16 Watrer Tank Evaluation
Project Number: BA024
Location: B-4
Depth: 25.0 - 26.5' **Sample Number:** S-14
Material Description: Dark brown elastic SILT with sand
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	24.86	25.22	23.75			
Dry+Tare	19.71	19.92	19.02			
Tare	11.07	11.18	11.40			
# Blows	31	25	17			
Moisture	59.6	60.6	62.1			



Liquid Limit= 61
Plastic Limit= 38
Plasticity Index= 23
Natural Moisture= 50.5
Liquidity Index= 0.5

Plastic Limit Data

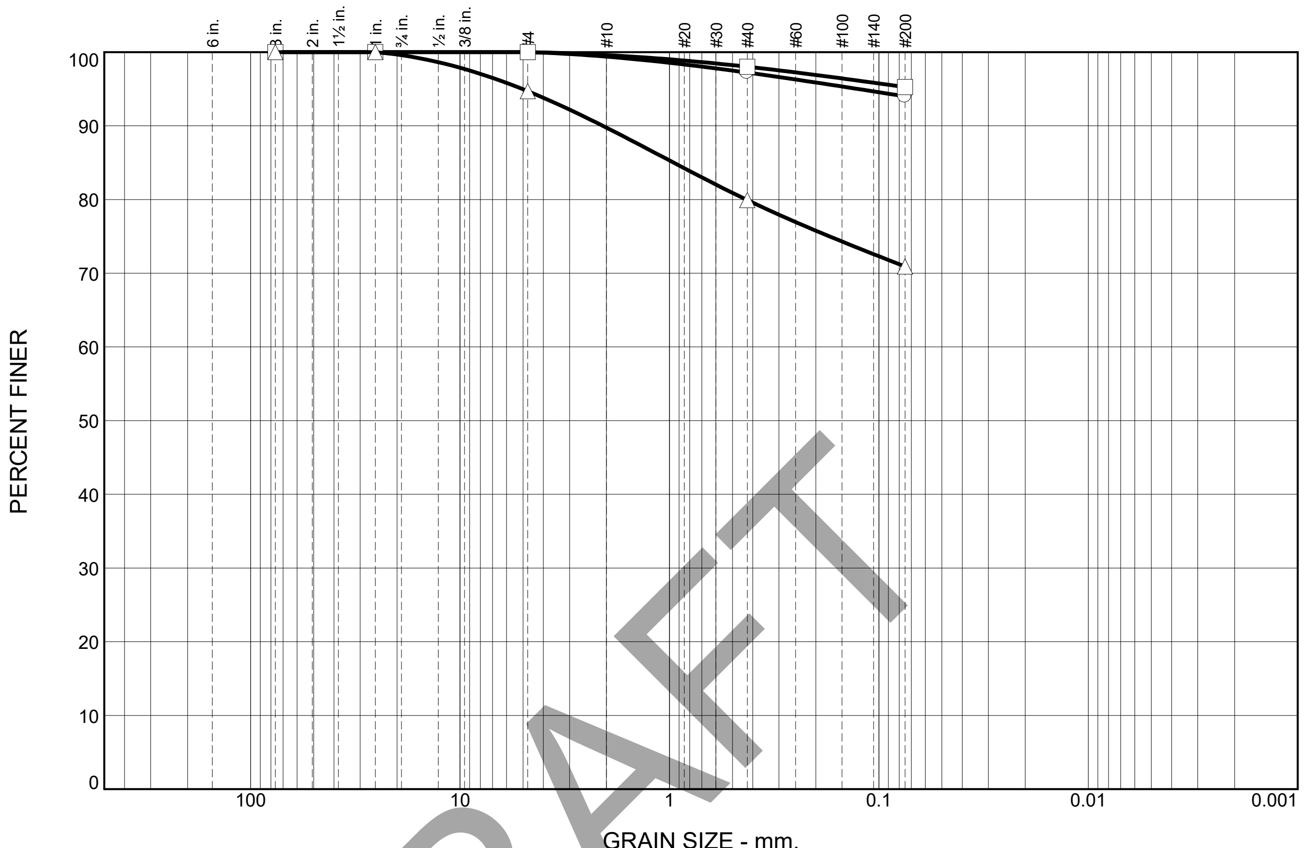
Run No.	1	2	3	4
Wet+Tare	17.52	17.11		
Dry+Tare	15.78	15.51		
Tare	11.31	11.29		
Moisture	38.9	37.9		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
285.2	201.0	34.2	50.5

Attachment 2

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

MATERIAL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	Material Description	USCS
○	B-2	S-1	1.5 - 3.0'	Reddish brown elastic SILT	MH
□	B-3	S-1	1.5 - 3.0'	Dark reddish brown elastic SILT	MH
△	B-4	R-2	4.0 - 4.5'	Dark reddish brown elastic SILT with sand	MH

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Client: Group Delta
Project: City of Santa Rosa - R-16 Watrer Tank Evaluation
Project No.: BA024 **Figure**

Tested By: BH

GRAIN SIZE DISTRIBUTION TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-16 Watrer Tank Evaluation
Project Number: BA024
Location: B-2
Depth: 1.5 - 3.0' **Sample Number:** S-1
Material Description: Reddish brown elastic SILT
USCS: MH
Tested by: BH

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
139.80	37.80	3"	0.00	0.00	100.0
		1"	0.00	0.00	100.0
		#4	0.00	0.00	100.0
		#40	2.83	0.00	97.2
		#200	3.29	0.00	94.0

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	0.0	0.0	0.6	2.2	3.2	6.0			94.0

D_{5}	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
											0.1258

Fineness Modulus
0.12

GRAIN SIZE DISTRIBUTION TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-16 Watrer Tank Evaluation
Project Number: BA024
Location: B-3
Depth: 1.5 - 3.0' **Sample Number:** S-1
Material Description: Dark reddish brown elastic SILT
USCS: MH
Tested by: BH

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
161.50	37.80	3"	0.00	0.00	100.0
		1"	0.00	0.00	100.0
		#4	0.00	0.00	100.0
		#40	2.45	0.00	98.0
		#200	3.41	0.00	95.3

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	0.0	0.0	0.4	1.6	2.7	4.7			95.3

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Fineness Modulus
0.09

GRAIN SIZE DISTRIBUTION TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-16 Watrer Tank Evaluation
Project Number: BA024
Location: B-4
Depth: 4.0 - 4.5' **Sample Number:** R-2
Material Description: Dark reddish brown elastic SILT with sand
USCS: MH
Tested by: BH

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
249.60	38.70	3"	0.00	0.00	100.0
		1"	0.00	0.00	100.0
		#4	11.17	0.00	94.7
		#40	31.16	0.00	79.9
		#200	19.02	0.00	70.9

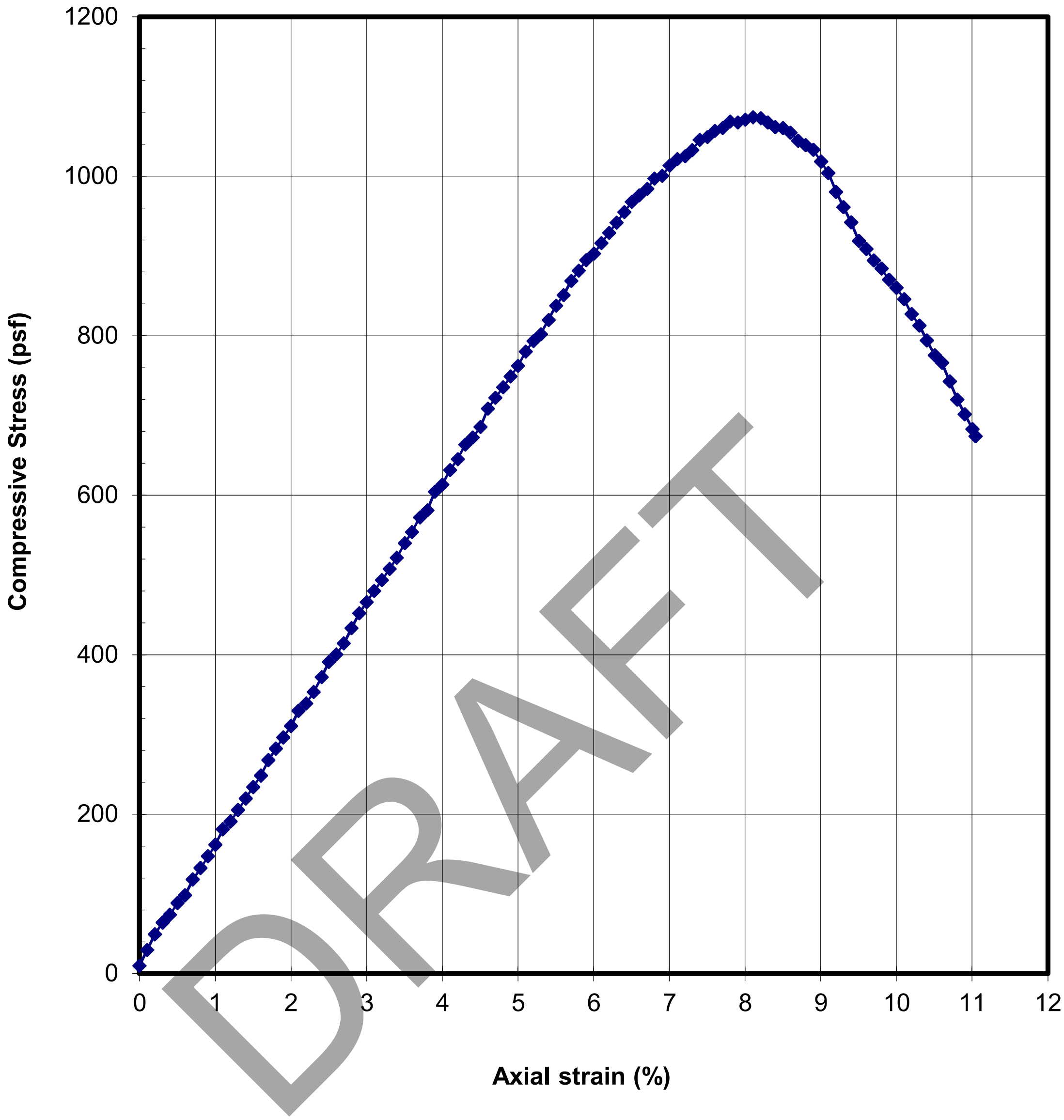
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.4	4.9	5.3	4.9	9.9	9.0	23.8			70.9

D_{5}	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
								0.4301	0.9542	2.0813	5.0410

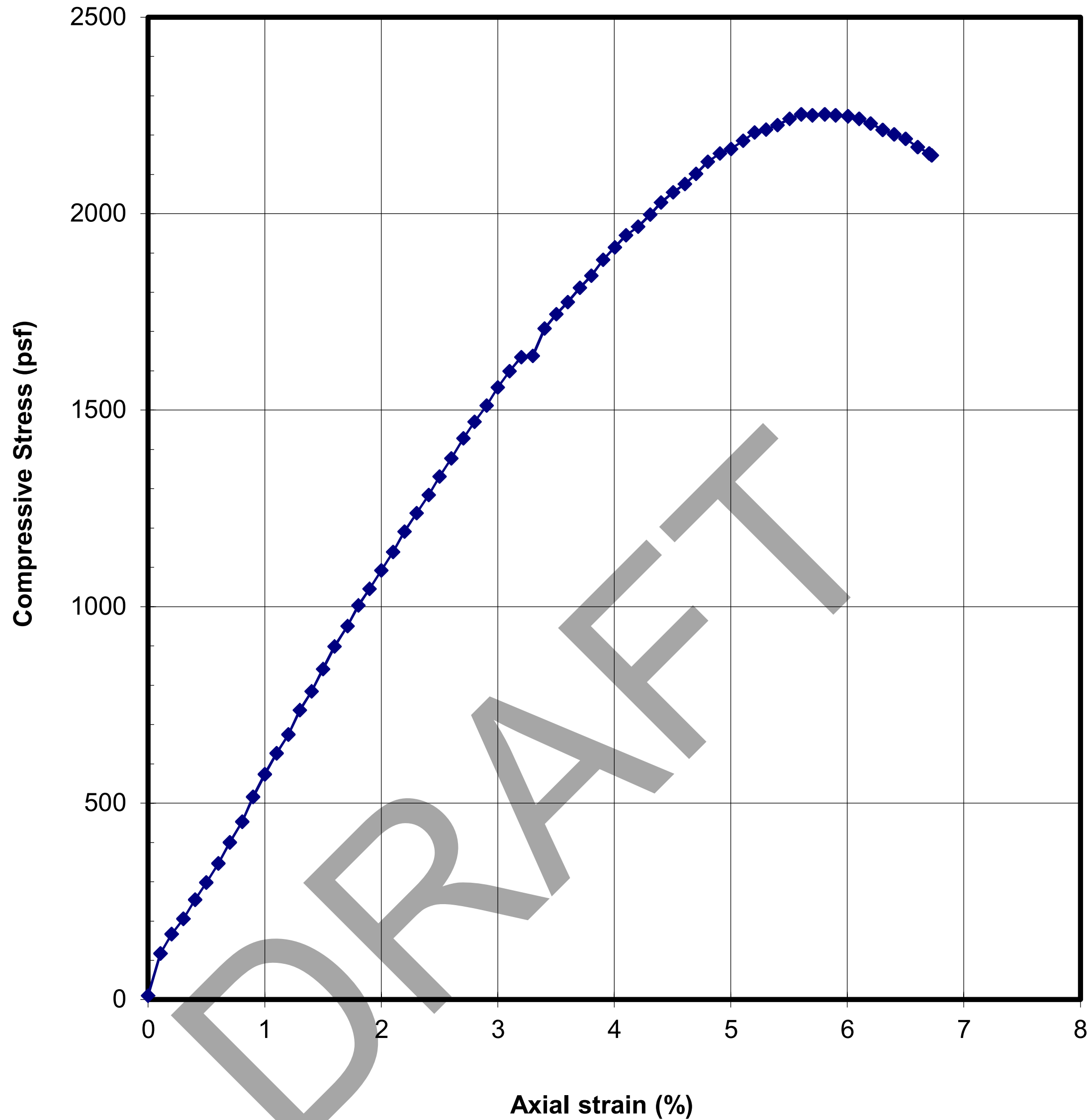
Fineness Modulus
0.97

Attachment 2



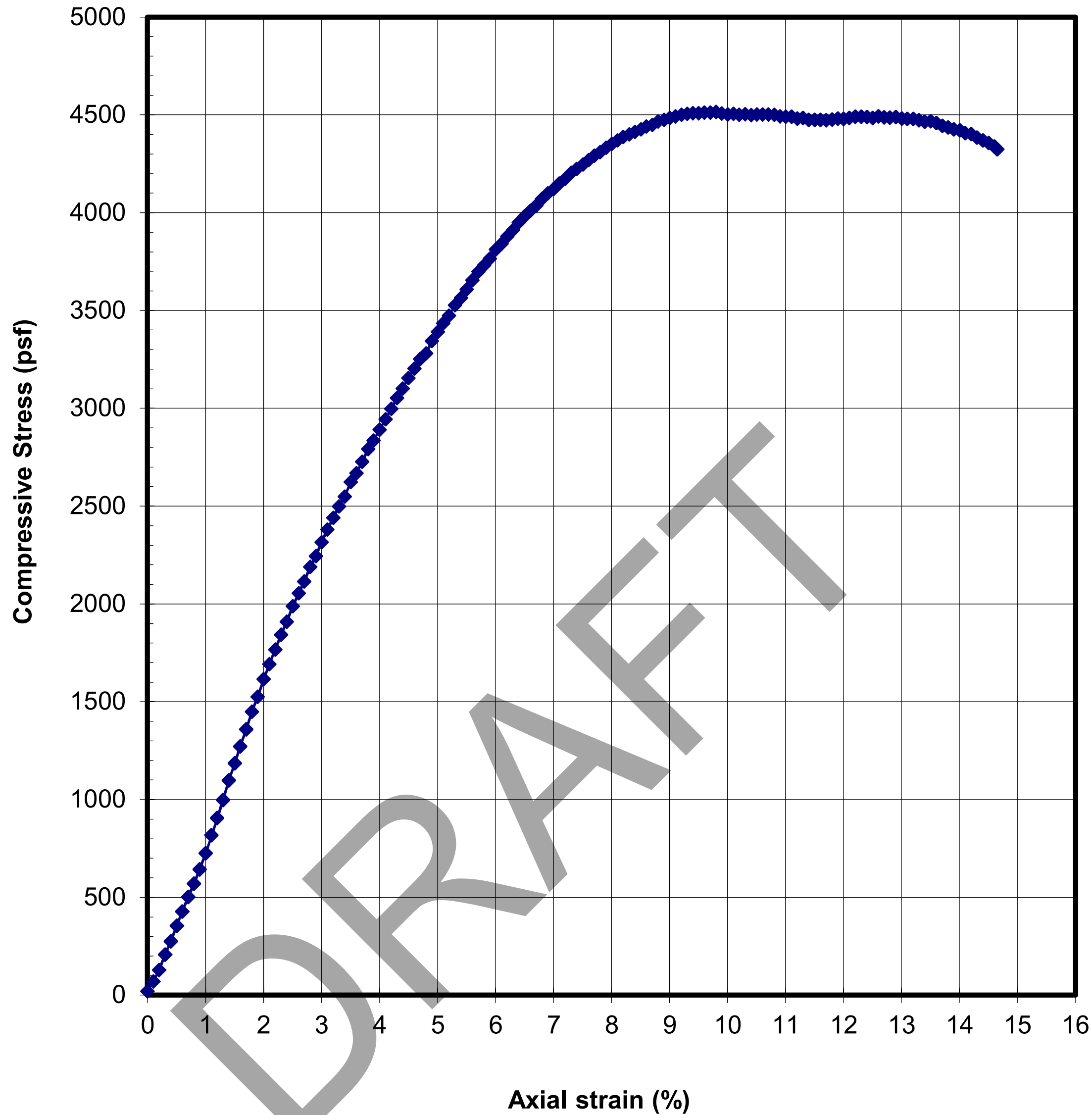
Sampler Type: Mod Cal		Shear Strength:	537 psf
Diameter (in): 2.39	Height (in): 5.75	Strain at Failure:	8.1%
Moisture Content:	62 %	Confining Pressure:	n/a
Dry Density:	62 pcf	Strain Rate:	1%/min
Source:	B-2 at 5.0 feet		
Description:	Dark reddish brown elastic SILT		

CITY OF SANTA ROSA **R-16 WATER TANK EVALUATION**	**UNCONFINED COMPRESSION TEST**		
B. HILLEBRANDT SOILS TESTING, INC	Date: 07/06/16	Project No. BA024	Figure



Sampler Type: Mod Cal			Shear Strength:	1126 psf
Diameter (in): 2.40	Height (in): 5		Strain at Failure:	5.8%
Moisture Content:	47	%	Confining Pressure:	n/a
Dry Density:	71	pcf	Strain Rate:	1%/min
Source: B-3 at 5.0 feet				
Description: Dark reddish brown elastic SILT with sand				

CITY OF SANTA ROSA **R-16 WATER TANK EVALUATION**	**UNCONFINED COMPRESSION TEST**		
B. HILLEBRANDT SOILS TESTING, INC	Date: 07/06/16	Project No. BA024	Figure



Sampler Type: Mod Cal		Shear Strength:	2258 psf
Diameter (in): 2.40	Height (in): 5.85	Strain at Failure:	9.8%
Moisture Content:	44 %	Confining Pressure:	n/a
Dry Density:	78 pcf	Strain Rate:	1%/min
Source: B-4 at 7.5 feet			
Description: Reddish gray elastic SILT with sand			

CITY OF SANTA ROSA **R-16 WATER TANK EVALUATION**	**UNCONFINED COMPRESSION TEST**		
B. HILLEBRANDT SOILS TESTING, INC	Date: 07/06/16	Project No. BA024	Figure

Attachment 2

B. HILLEBRANDT SOILS TESTING, INC.

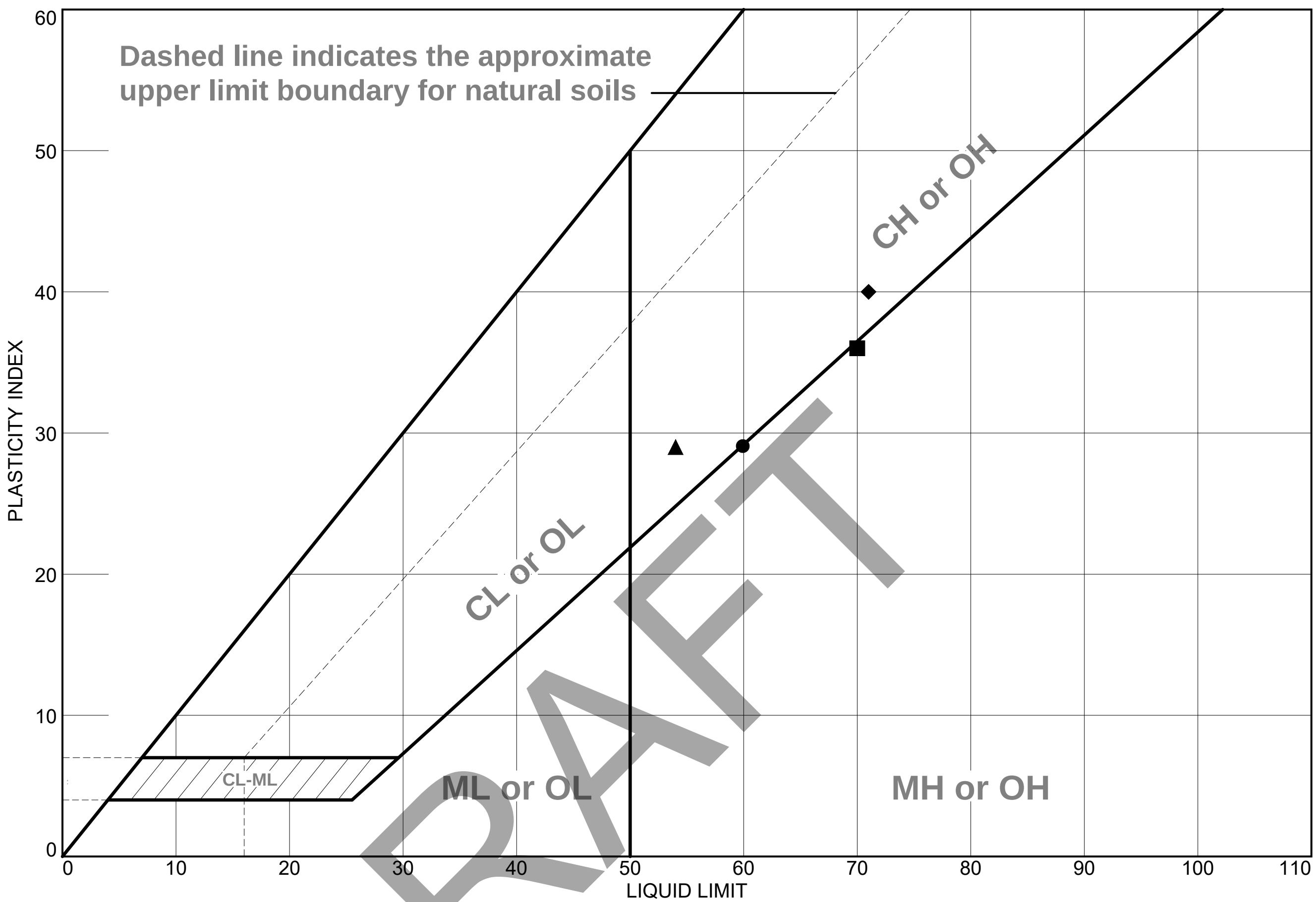
29 Sugarloaf Terrace, Alamo, CA 94507 - Tel: (510) 409-2916 - Fax: (925) 891-9267 - Email: soiltesting@aol.com

LAB RESULTS SUMMARY FORM

Project Number: BA024 **Project Name:** City of Santa Rosa - R-17 Water Tank
Requested By: BS **Request Date:** 6/22/16 **Throw Samples Out On:**

					Atterberg			-200			Compaction				
Boring #	Sample Depth (feet)	Dry Density (pcf)	Moisture Content (%)	Unconfined Compressive (ksf)	Liquid Limit	Plastic Limit	Plasicity Index	Passing #4 Sieve (%)	Passing #40 sieve (%)	Passing #200 sieve (%)	Maximum Dry Density (pcf)	Optimum Moisture (%)	Pocket Penetrometer (tsf)	Torvane (tsf)	Remarks
B-1	1.0 - 2.5				60	31	29	100	93	85					
B-1	4.0 - 4.5	70	53.1	2199											
B-1	5.0 - 6.5				70	34	36								
B-1	15.0 - 15.5	68.8	55.0	570											
B-1	25.0 - 25.5														
B-1	35.0 - 35.5														
B-2	1.0 - 2.5	59	58.7		54	25	29	89	70	56					
B-2	2.5 - 5.0	88	31.1		71	31	40								
B-3	1.0 - 2.5				57	27	30	97	82	73					
B-4	1.0 -1.75				59	31	28	97	84	72					

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Reddish brown fat CLAY	60	31	29	92.7	85.0	CH
■	Dark reddish brown fat CLAY	70	34	36			
▲	Dark reddish brown sandy fat CLAY	54	25	29	70.0	59.5	CH
◆	Dark reddish brown fat CLAY	71	31	40			

Project No. BA024 **Client:** Group Delta

Project: City of Santa Rosa - R-17 Water Tank Evaluation

●**Source of Sample:** B-1 **Depth:** 1.0 - 2.5' **Sample Number:** S-1
■**Source of Sample:** B-1 **Depth:** 5.0 - 6.5' **Sample Number:** S-3
▲**Source of Sample:** B-2 **Depth:** 1.0 - 2.5' **Sample Number:** B-1
◆**Source of Sample:** B-2 **Depth:** 2.5 - 5.0' **Sample Number:** B-2

Remarks:

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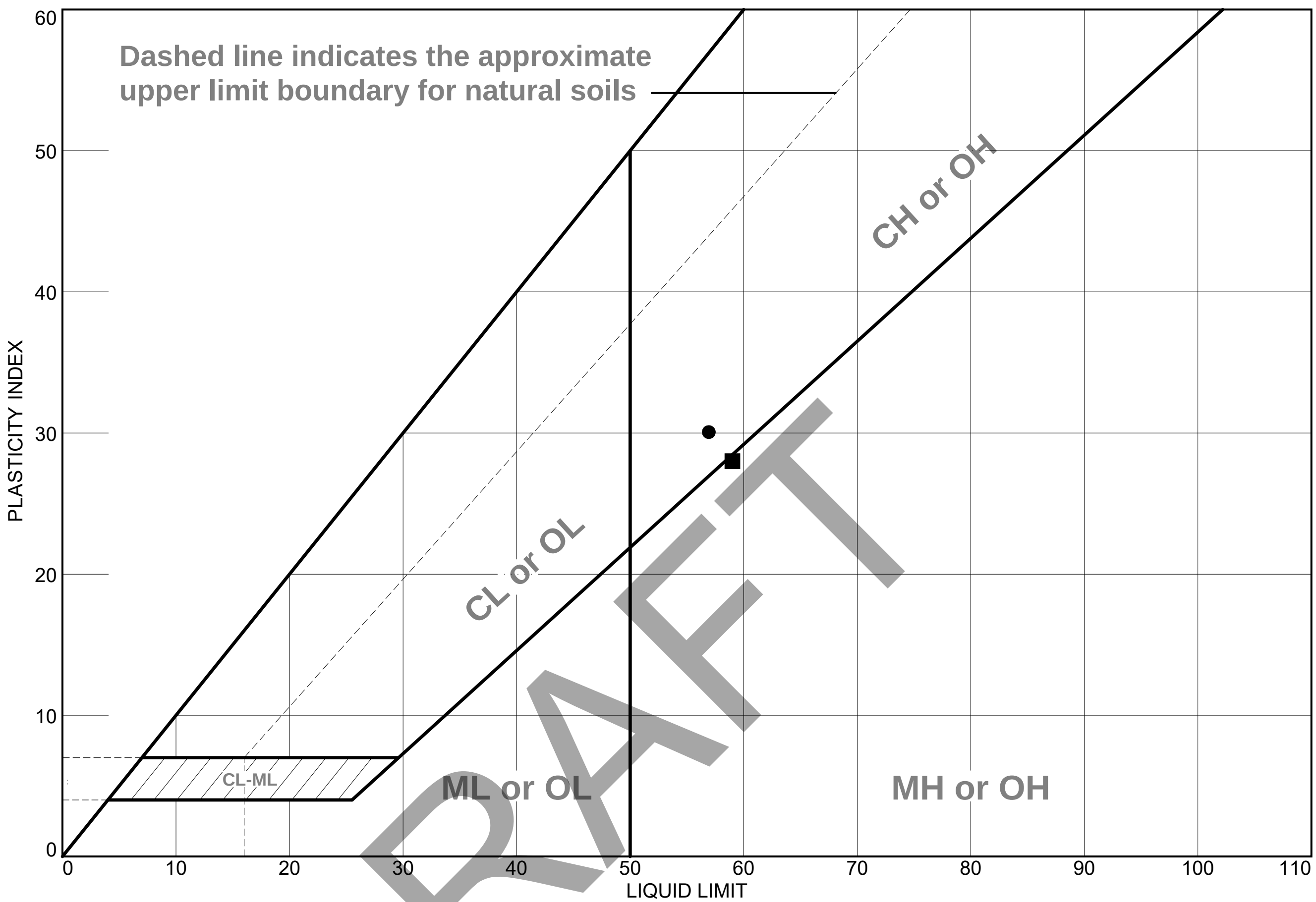
Figure

Tested By: BH

Attachment 2

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Yellowish red fat CLAY with sand	57	27	30	81.6	73.3	CH
■	Yellowish red fat CLAY with some sand	59	31	28	83.5	72.4	CH

Project No. BA024 **Client:** Group Delta

Project: City of Santa Rosa - R-17 Water Tank Evaluation

●**Source of Sample:** B-3 **Depth:** 1.0 - 2.5' **Sample Number:** S-1
■**Source of Sample:** B-4 **Depth:** 1.0 - 1.75' **Sample Number:** S-1

Remarks:

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Figure

Tested By: BH

Attachment 2

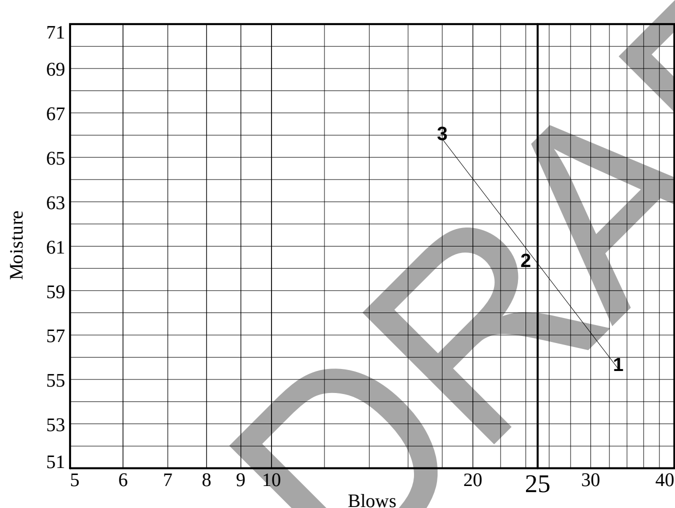
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-17 Water Tank Evaluation
Project Number: BA024
Location: B-1
Depth: 1.0 - 2.5' **Sample Number:** S-1
Material Description: Reddish brown fat CLAY
%<#40: 92.7 **%<#200:** 85.0 **USCS:** CH **AASHTO:** A-7-5(28)
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	26.82	27.57	24.93			
Dry+Tare	21.27	21.41	19.45			
Tare	11.31	11.21	11.16			
# Blows	33	24	18			
Moisture	55.7	60.4	66.1			



Liquid Limit= 60
Plastic Limit= 31
Plasticity Index= 29

Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	17.64	16.99		
Dry+Tare	16.12	15.58		
Tare	11.29	11.06		
Moisture	31.5	31.2		

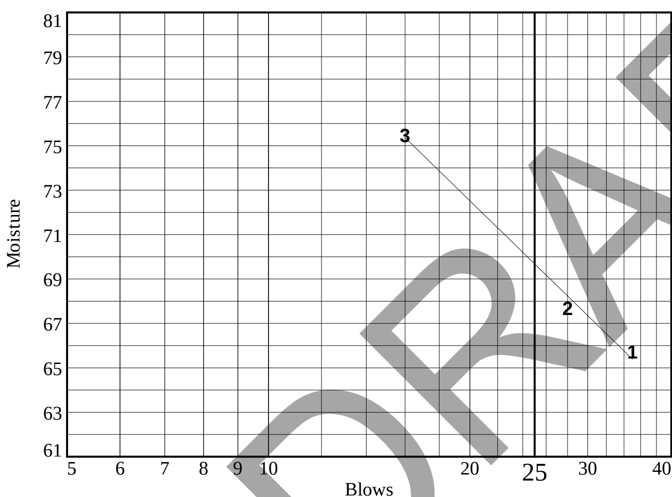
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-17 Water Tank Evaluation
Project Number: BA024
Location: B-1
Depth: 5.0 - 6.5' **Sample Number:** S-3
Material Description: Dark reddish brown fat CLAY
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	26.29	28.27	26.79			
Dry+Tare	20.30	21.41	20.13			
Tare	11.19	11.28	11.31			
# Blows	35	28	16			
Moisture	65.8	67.7	75.5			



Liquid Limit= 70
Plastic Limit= 34
Plasticity Index= 36

Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	17.66	17.89		
Dry+Tare	16.05	16.22		
Tare	11.25	11.29		
Moisture	33.5	33.9		

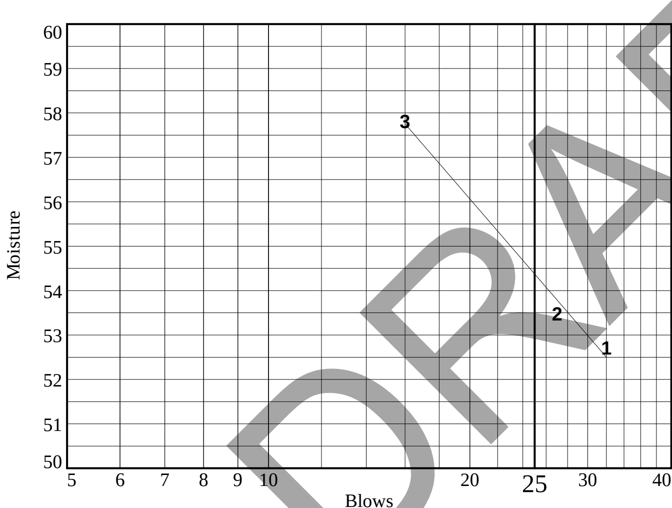
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-17 Water Tank Evaluation
Project Number: BA024
Location: B-2
Depth: 1.0 - 2.5' **Sample Number:** B-1
Material Description: Dark reddish brown sandy fat CLAY
%<#40: 70.0 **%<#200:** 59.5 **USCS:** CH **AASHTO:** A-7-6(15)
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	23.77	27.12	30.02			
Dry+Tare	19.42	21.60	23.15			
Tare	11.17	11.28	11.27			
# Blows	32	27	16			
Moisture	52.7	53.5	57.8			



Liquid Limit= 54
Plastic Limit= 25
Plasticity Index= 29

Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	17.36	17.65		
Dry+Tare	16.10	16.33		
Tare	11.18	11.12		
Moisture	25.6	25.3		

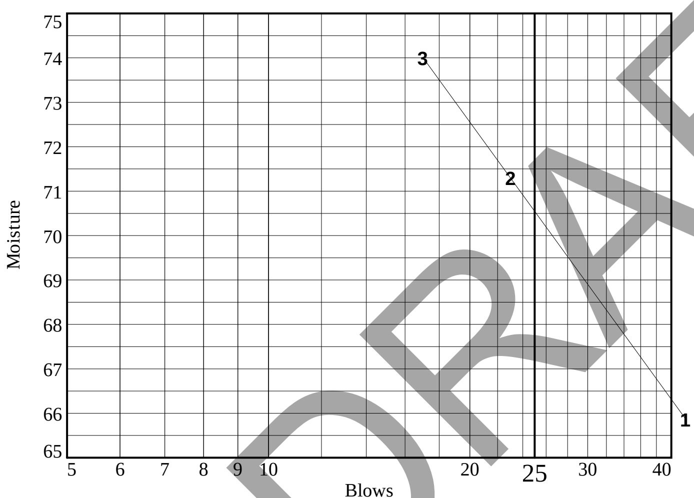
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-17 Water Tank Evaluation
Project Number: BA024
Location: B-2
Depth: 2.5 - 5.0'   **Sample Number:** B-2
Material Description: Dark reddish brown fat CLAY
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	28.46	27.78	25.73			
Dry+Tare	21.57	20.92	19.58			
Tare	11.11	11.30	11.27			
# Blows	42	23	17			
Moisture	65.9	71.3	74.0			



Liquid Limit= 71
Plastic Limit= 31
Plasticity Index= 40

Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	17.05	17.25		
Dry+Tare	15.68	15.85		
Tare	11.21	11.27		
Moisture	30.6	30.6		

Attachment 2

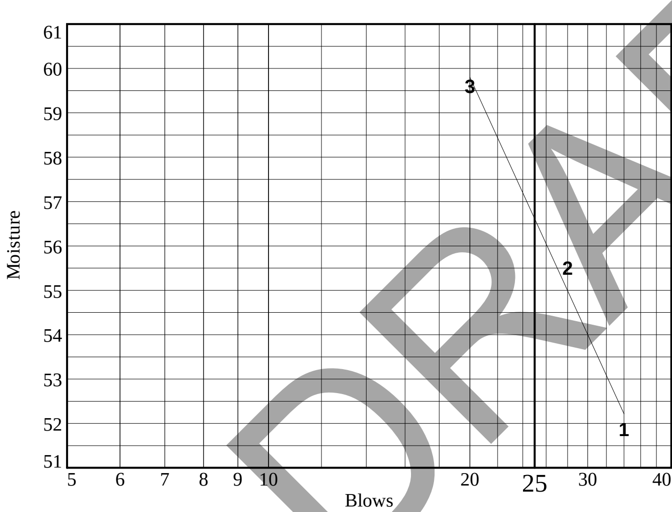
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-17 Water Tank Evaluation
Project Number: BA024
Location: B-3
Depth: 1.0 - 2.5' **Sample Number:** S-1
Material Description: Yellowish red fat CLAY with sand
%<#40: 81.6 **%<#200:** 73.3 **USCS:** CH **AASHTO:** A-7-6(22)
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	27.85	26.49	25.87			
Dry+Tare	22.20	21.06	20.38			
Tare	11.31	11.28	11.17			
# Blows	34	28	20			
Moisture	51.9	55.5	59.6			



Liquid Limit= 57
Plastic Limit= 27
Plasticity Index= 30

Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	17.37	17.00		
Dry+Tare	16.05	15.74		
Tare	11.26	11.09		
Moisture	27.6	27.1		

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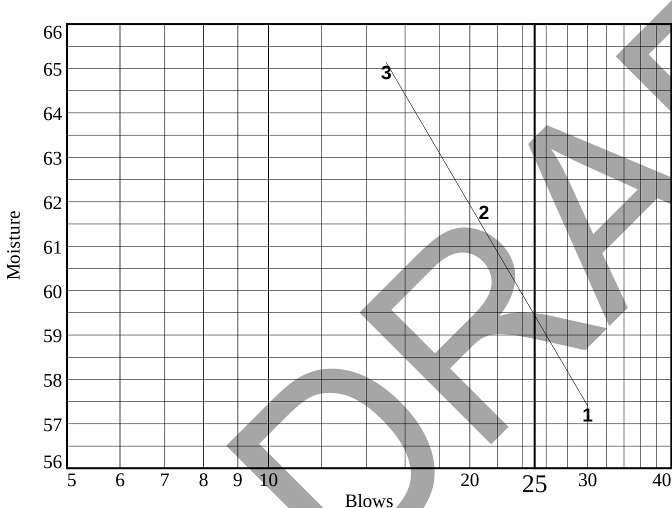
LIQUID AND PLASTIC LIMIT TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-17 Water Tank Evaluation
Project Number: BA024
Location: B-4
Depth: 1.0 - 1.75' **Sample Number:** S-1
Material Description: Yellowish red fat CLAY with some sand
%<#40: 83.5 **%<#200:** 72.4 **USCS:** CH **AASHTO:** A-7-5(21)
Tested by: BH

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	27.35	26.48	25.55			
Dry+Tare	21.52	20.71	19.94			
Tare	11.33	11.37	11.30			
# Blows	30	21	15			
Moisture	57.2	61.8	64.9			

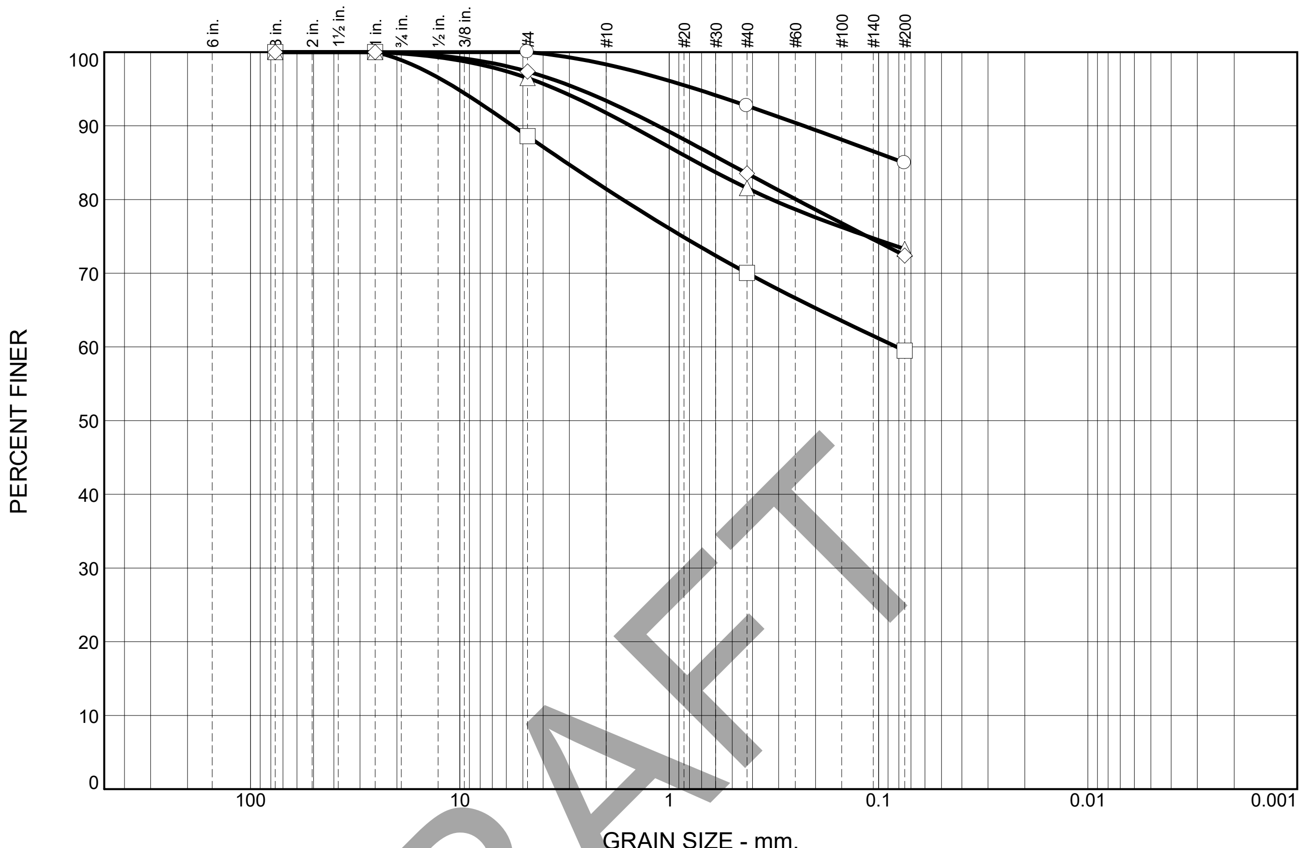


Liquid Limit= 59
Plastic Limit= 31
Plasticity Index= 28

Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	17.27	17.85		
Dry+Tare	15.86	16.29		
Tare	11.27	11.31		
Moisture	30.7	31.3		

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

MATERIAL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	Material Description	USCS
○	B-1	S-1	1.0 - 2.5'	Reddish brown fat CLAY	CH
□	B-2	B-1	1.0 - 2.5'	Dark reddish brown sandy fat CLAY	CH
△	B-3	S-1	1.0 - 2.5'	Yellowish red fat CLAY with sand	CH
◇	B-4	S-1	1.0 - 1.75'	Yellowish red fat CLAY with some sand	CH

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Client: Group Delta
Project: City of Santa Rosa - R-17 Water Tank Evaluation

Project No.: BA024 **Figure**

Tested By: BH

GRAIN SIZE DISTRIBUTION TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-17 Water Tank Evaluation
Project Number: BA024
Location: B-1
Depth: 1.0 - 2.5' **Sample Number:** S-1
Material Description: Reddish brown fat CLAY
USCS: CH
Tested by: BH

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
173.90	33.80	3"	0.00	0.00	100.0
		1"	0.00	0.00	100.0
		#4	0.00	0.00	100.0
		#40	10.21	0.00	92.7
		#200	10.85	0.00	85.0

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	0.0	0.0	1.7	5.6	7.7	15.0			85.0

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
									0.0755	0.2277	0.7439

Fineness Modulus
0.31

GRAIN SIZE DISTRIBUTION TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-17 Water Tank Evaluation
Project Number: BA024
Location: B-2
Depth: 1.0 - 2.5' **Sample Number:** B-1
Material Description: Dark reddish brown sandy fat CLAY
USCS: CH
Tested by: BH

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
254.80	37.60	3"	0.00	0.00	100.0
		1"	0.00	0.00	100.0
		#4	24.75	0.00	88.6
		#40	40.32	0.00	70.0
		#200	22.92	0.00	59.5

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	1.1	10.3	11.4	7.2	11.4	10.5	29.1			59.5

D_{5}	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
							0.0819	1.6688	3.0980	5.5871	10.2460

Fineness Modulus
1.54

GRAIN SIZE DISTRIBUTION TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-17 Water Tank Evaluation
Project Number: BA024
Location: B-3
Depth: 1.0 - 2.5'
Sample Number: S-1
Material Description: Yellowish red fat CLAY with sand
USCS: CH
Tested by: BH

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
191.10	38.00	3"	0.00	0.00	100.0
		1"	0.00	0.00	100.0
		#4	5.37	0.00	96.5
		#40	22.87	0.00	81.6
		#200	12.65	0.00	73.3

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.2	3.3	3.5	4.7	10.2	8.3	23.2			73.3

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
								0.3229	0.7309	1.5286	3.4788

Fineness Modulus
0.84

GRAIN SIZE DISTRIBUTION TEST DATA

7/8/2016

Client: Group Delta
Project: City of Santa Rosa - R-17 Water Tank Evaluation
Project Number: BA024
Location: B-4
Depth: 1.0 - 1.75' **Sample Number:** S-1
Material Description: Yellowish red fat CLAY with some sand
USCS: CH
Tested by: BH

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
189.50	38.50	3"	0.00	0.00	100.0
		1"	0.00	0.00	100.0
		#4	3.97	0.00	97.4
		#40	20.88	0.00	83.5
		#200	16.82	0.00	72.4

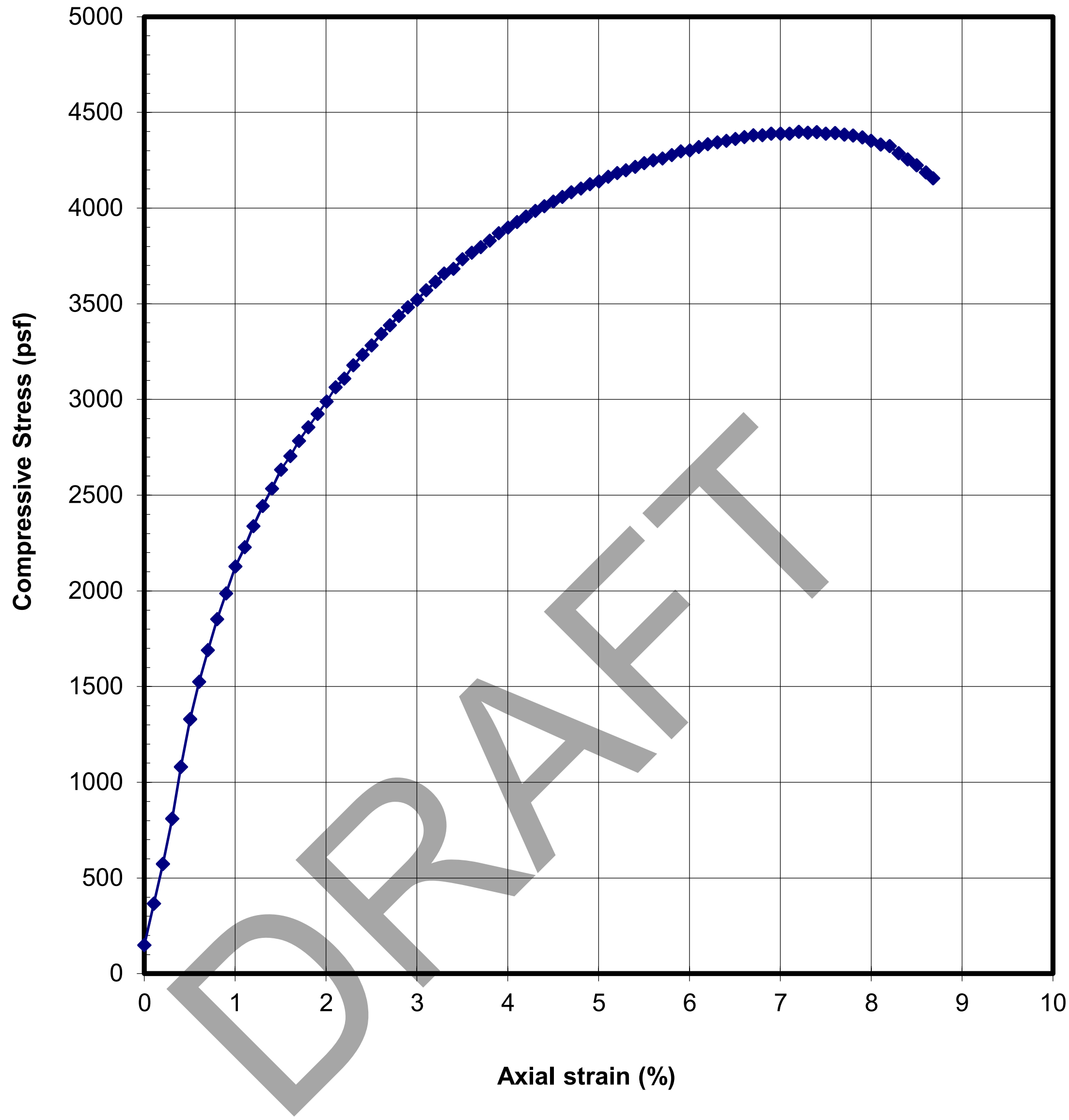
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.1	2.5	2.6	4.0	9.9	11.1	25.0			72.4

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
								0.2474	0.5288	1.1313	2.7126

Fineness Modulus
0.75

Attachment 2



Sampler Type: Mod Cal		Shear Strength:	2199 psf
Diameter (in): 2.39	Height (in): 5.8	Strain at Failure:	7.4%
Moisture Content: 53 %		Confining Pressure:	n/a
Dry Density: 70 pcf		Strain Rate:	1%/min
Source: B-1 at 4.5 feet			
Description: Dark reddish brown elastic SILT			

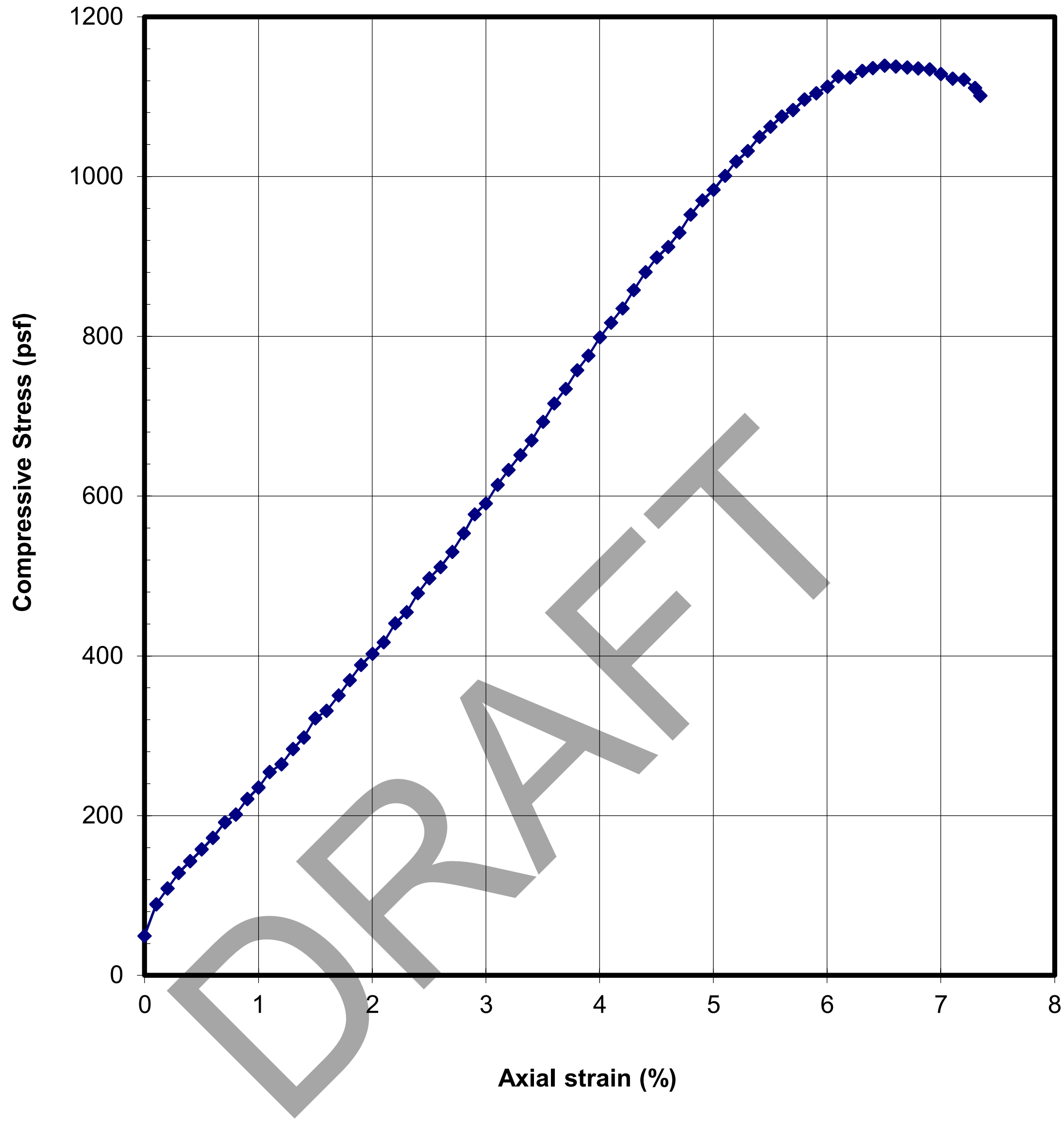
CITY OF SANTA ROSA
R-17 WATER TANK EVALUATION

UNCONFINED COMPRESSION TEST

B. HILLEBRANDT SOILS TESTING, INC

Date: 07/06/16 | Project No. BA024 | Figure

Attachment 2



Sampler Type: Mod Cal		Shear Strength:	570 psf
Diameter (in): 2.39	Height (in): 5.1	Strain at Failure:	6.5%
Moisture Content:	55 %	Confining Pressure:	n/a
Dry Density:	69 pcf	Strain Rate:	1%/min
Source:	B-1 at 15.5 feet		
Description:	Reddish brown clayey, sandy SILT		

CITY OF SANTA ROSA
R-17 WATER TANK EVALUATION

UNCONFINED COMPRESSION TEST

B. HILLEBRANDT SOILS TESTING, INC

Date: 07/06/16	Project No. BA024	Figure

California State Certified Laboratory No. 2153

Attachment 2

CERCO analytical
1100 Willow Pass Court, Suite A
Concord, CA 94520-1006
925 462 2771 Fax. 925 462 2775
www.cercoanalytical.com

1 July, 2016

Job No. 1606260
Cust. No. 12925

Mr. Ali Salehian
Group Delta
1970 Broadway, Suite 1100
Oakland, CA 94612

Subject: Project No.: BA024
Project Name: Santa Rosa Tanks
Corrosivity Analysis – ASTM Test Methods

Dear Mr. Salehian:

Pursuant to your request, CERCO Analytical has analyzed the soil samples submitted on June 29, 2016. Based on the analytical results, this brief corrosivity evaluation is enclosed for your consideration.

Based upon the resistivity measurements, sample 001 is classified as "moderately corrosive", sample 002 is classified as "mildly corrosive" and sample 003 is classified as "corrosive". All buried iron, steel, cast iron, ductile iron, galvanized steel and dielectric coated steel or iron should be properly protected against corrosion depending upon the critical nature of the structure. All buried metallic pressure piping such as ductile iron firewater pipelines should be protected against corrosion.

The chloride ion concentrations range from none detected to 16 mg/kg. Because the chloride ion concentrations are less than 300 mg/kg, they are determined to be insufficient to attack steel embedded in a concrete mortar coating.

The sulfate ion concentrations range from none detected to 140 mg/kg and are determined to be insufficient to damage reinforced concrete structures and cement mortar-coated steel at these locations.

The pH of the soils range from 5.10 to 7.83. Any soils with a pH of <6.0 is considered to be corrosive to buried iron, steel, mortar-coated steel and reinforced concrete structures. Therefore, corrosion prevention measures need to be considered for structures to be placed in this acidic soil.

The redox potentials range from 420 to 450-mV which is indicative of aerobic soil conditions.

This corrosivity evaluation is based on general corrosion engineering standards and is non-specific in nature. For specific long-term corrosion control design recommendations or consultation, please call *JDH Corrosion Consultants, Inc. at (925) 927-6630.*

Very truly yours,
CERCO ANALYTICAL, INC.

J. Darby Howard, Jr., P.E.
President

JDH/jdl
Enclosure

Attachment 2

California State Certified Laboratory No. 2153

CERCO analytical
1100 Willow Pass Court, Suite A
Concord, CA 94520-1006
925 462 2771 Fax. 925 462 2775
www.cercoanalytical.com

Client: Group Delta
Client's Project No.: BA024
Client's Project Name: Santa Rosa Tanks
Date Sampled: 06/16 & 17/16
Date Received: 29-Jun-2016
Matrix: Soil
Authorization: Signed Chain of Custody

Date of Report: 1-Jul-2016

DRAFT

Job/Sample No.	Sample I.D.	Redox (mV)	pH	Conductivity (umhos/cm)*	Resistivity (100% Saturation) (ohms-cm)	Sulfide (mg/kg)*	Chloride (mg/kg)*	Sulfate (mg/kg)*
1606260-001	R-9A, Boring B-2 Sample S-1 @ 2.5'-4'	450	7.83	-	2,100	-	N.D.	22
1606260-002	R-16, Boring B-3 Sample R-2-2 @ 4'-4.5'	420	5.10	-	10,000	-	N.D.	N.D.
1606260-003	R-17, Boring B-2 Sample B-1 @ 1'-2.5'	430	7.53	-	1,900	-	16	140

	Redox	pH	Conductivity	Resistivity	Sulfide	Chloride	Sulfate
Method:	ASTM D1498	ASTM D4972	ASTM G57	ASTM G57	ASTM D4658M	ASTM D4327	ASTM D4327
Reporting Limit:	-	-	-	-	50	15	15
Date Analyzed:	30-Jun-2016	30-Jun-2016	-	30-Jun-2016	-	30-Jun-2016	30-Jun-2016

* Results Reported on "As Received" Basis

N.D. - None Detected

Cheryl McMillen
Laboratory Director

<u>Quality Control Summary</u> - All laboratory quality control parameters were found to be within established limits

APPENDIX E

Sampson Gumpertz & Heger Structural Evaluation

REGISTERED PROFESSIONAL ENGINEER
GAYLE S. JOHNSON
No. C36658
CIVIL
STATE OF CALIFORNIA

7/10/2017

Seismic Evaluation

Water Tanks R-17, R-16, and R-9A
Santa Rosa, CA

July 2017

SGH Project 167525

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

Attachment 2

PREPARED FOR:

West Yost Associates, Inc.
2020 Research Park Dr #100
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PREPARED BY:

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Appendix B – Structural Calculations – R-16
Appendix C – Structural Calculations – R-9A

1. INTRODUCTION

Simpson Gumpertz & Heger Inc. (SGH) is pleased to provide you with this report summarizing our seismic analysis of three water tanks, R-17, R-16, and R-9A, owned by the City of Santa Rosa. This report and the attached calculations present our findings and conclusions.

1.1 Background

West Yost Associates, Inc. (West Yost) has been contracted by the City of Santa Rosa to perform evaluations of the existing water tanks and tank sites. West Yost has subcontracted SGH to perform the seismic analysis of the following tanks:

- R-17: Newgate Court, Santa Rosa, CA
- R-16: Fountain Grove Parkway, Santa Rosa, CA
- R-9A: Annadel Heights Drive, Santa Rosa, CA

The primary purpose of the seismic evaluations is to determine whether the tanks meet current code requirements that would be applicable for the design of a new tank and to provide mitigation concepts to address structural deficiencies identified in the analysis.

1.2 SGH Scope of Work

As defined in our subcontract agreement, SGH has performed the following tasks as part of this investigation:

- Define the seismic input for the current building code as provided by the geotechnical engineer.
- Model the tank information in our tank design spreadsheets.
- Perform seismic calculations for the tanks using AWWA D100-11 and the 2012 International Building Code (IBC).
- Evaluate tank stability, sloshing wave height, anchorage ratio, and other parameters that define overall ability to withstand seismic loads in the tank's as-designed condition under current code design load conditions.
- Determine foundation loads due to seismic loads on the unanchored tank under the current code design load conditions.
- Determine foundation compliance with the current building code.

- Provide comments and/or recommendations on feasibility of potential rehabilitation measure such as raising tank wall heights, reducing fill height, or anchoring the tank.
- Prepare a report summarizing the tasks above, including a set of calculations stamped by a California Registered Civil or Structural Engineer.

The SGH Scope of Work specifically excluded rehabilitation design and the creation of drawings or sketches of rehabilitation options.

2. TANK INFORMATION

Table 1 provides a summary of key information for each tank, based on photos and drawings provided by West Yost and observations from the initial site visit on 30 March 2016.

Table 1 - Basic Tank Properties

	R-17	R-16	R-9A
Year Erected	1994	1994	1977
Design Code	AWWA D100-84 Appendix C	AWWA D100-84 Appendix C	AWWA D100-73 Appendix C
Fabricator & Erector	Trusco Tank Inc.	Trusco Tank Inc.	Chicago Bridge & Iron (CB&I)
Tank Type	Welded steel, ground supported	Welded steel, ground supported	Welded steel, ground supported
Nominal Capacity	750,000 gallons	250,000 gallons	2,000,000 gallons
Nominal Diameter	47 ft	36 ft	92 ft
Top Capacity Level (TCL)	57 ft-10 in.	34 ft	40 ft (see Note 1)
Nominal Shell Height	59 ft	35 ft	42 ft
Anchorage	Anchored w/ bolts	Anchored w/ bolts	Self-anchored
Foundation Type	Concrete Ringwall	Concrete Ringwall	Concrete Ringwall
Roof Type	Cone shaped steel plate w/ steel rafters, center support column, and knuckle	Cone shaped steel plate w/ steel rafters, center support column, and knuckle	Steel plate w/ knuckle, (5) radial columns plus (1) center column

1. The original TCL of R-9A was 40 ft. However, an evaluation of the tank was performed in 2004 which recommended lowering the max fill height to 13 ft. Since we have not found any evidence indicating whether the new fill height was actually implemented, we performed calculations using both the 40 ft and 13 ft fill heights.

2.1 Information Provided by West Yost

West Yost provided a collection of various documents to aid in our evaluation including drawings, geotechnical reports, past structural evaluations, permit calculations, forwarded e-mails, etc. We have relied on the following documents for data used in our tank analyses:

- "City of Santa Rosa Water Master Plan Update," prepared by West Yost Associates on August 2014, 228 pages.
- Original Civil and MEP drawings for tanks R-16 and R-17, and their respective pump houses, created by Carlile / Associates, dated April 1993, 36 sheets.
- Document with filename "Reservoir Misc01.pdf," dated 23 September 2004 containing pumping information for tanks R-16 and R-17, source and date unknown.

- Document with filename “Stations Misc01.pdf” containing pumping information for tanks R-16 and R-17, source unknown.
- E-mail 17 March 20 from Jeff Wanlass to Gayle Johnson with forwarded information from JDH Corrosion Consultants, Inc. regarding measured tank wall thicknesses.

Documents pertinent only to individual tanks are summarized in Sections 4.1, 5.1, and 6.1.

2.2 Information Gathered in Field

An SGH Senior Principal, Gayle Johnson, conducted an initial site visit on 30 March 2016, along with several West Yost team members and other project subconsultants. Mr. Johnson traveled to the three tank sites, made visual observations of the tank and foundation conditions, took photos of the tanks and components which were accessible from ground level, and made relevant rough measurements where possible such as bottom plate thickness, anchor bolt diameters, number of anchors, etc.

3. BASIS FOR ANALYSIS

3.1 Design Criteria

SGH evaluated the existing tanks based on the requirements for a new tank according to the provisions of the following standards:

- American Society of Civil Engineers, "Minimum Design Loads for Buildings and Other Structures," 3rd printing (ASCE 7-10)
- American Water Works Association, "Welded Carbon Steel Tanks for Water Storage" (AWWA D100-11)
- American Concrete Institute, "Building Code Requirements for Structural Concrete" (ACI 318-11)

3.2 Seismic Hazards Data

Group Delta Consultants provided values for the design level earthquake used in each tank evaluation, corresponding to the ASCE 7-10 design level earthquake. Table 2 presents the seismic parameters.

Table 2 - Seismic Parameters

	R-17	R-16	R-9A
Seismic Design Category	D	D	D
Seismic Importance Factor (see note 1)	1.5	1.5	1.5
Spectral Resp. Accel. 5% Damped, at Short Period (S_s)	2.202 g	2.170 g	2.081 g
Spectral Resp. Accel. 5% Damped, at One Second (S_1)	0.911 g	0.895 g	0.853 g
Site Class	C	C	C
Design Spectral Resp. Accel. 5% Damped, at Short Period (S_{DS})	1.468 g	1.446 g	1.387 g
Design Spectral Resp. Accel. 5% Damped, at One Second (S_{D1})	0.789 g	0.776 g	0.739 g
Long Period Transition Period (T_L)	8 sec	8 sec	8 sec

1. Seismic Importance Factor was not provided by Group Delta but was chosen based on Seismic Use Group. See Section 3.3.

3.3 General Assumption and Limitations

In some instances, West Yost was not able to provide data for the tank components. Unless a reasonable assumption could be made, we did not evaluate these components. However, where information on the tank, tank components, or footing was not available but was still needed in order to carry out other analyses, we assumed typical values or made best estimate approximations. Assumptions and limitations specific to each tank are listed in Sections 4.2, 5.2, and 6.2 of this report.

Seismic Importance factor is equal to 1.5 based on Seismic Use Group III, as defined in AWWA D100-11 Section 13.2. Seismic Use Group III includes tanks deemed "essential to the life, health, and safety of the public, including post-earthquake fire suppression."

As indicated in Table 5-4 of the 2014 City of Santa Rosa Water Master Plan, all three tanks are required to provide minimum operational, fire, and emergency flow capacities. As such, we considered these tanks Seismic Use Group III and used a Seismic Importance Factor of 1.5 in our analyses.

4. TANK R-17

4.1 Referenced Information

In addition to those listed in Section 2.1 of this report, SGH also used the following information provided by West Yost:

- Original construction permit submittal calculations and drawings for Tank R-17, prepared by Trusco Tank Inc., dated 1993 to 1995, 181 pages.
- Geotechnical investigation report for Tank R-17, prepared by Kleinfelder, Inc., dated 26 November 1992, 26 pages.

4.2 Assumptions and Limitations

- Based on the permit calculations prepared by Trusco, the original designer used a corrosion allowance of 0 in. Our calculations also assume 0 in. for the corrosion allowance.
- We obtained design shell course thicknesses from the permit calculations prepared by Trusco as well as measured thicknesses from JDH Corrosion Consultants, Inc. Since the measured thicknesses were only slightly larger than those indicated in the permit calculations, our calculations conservatively assume the smaller value given in the permit calculations.
- We found conflicting information on the foundation dimensions between the civil drawings created by Carlile / Associates and the permit drawings prepared by Trusco. While the civil drawings show a 3 ft deep by 2 ft wide concrete ringwall footing, the permit drawings indicate a 4 ft deep by 12 ft wide ringwall. Based on our field observations of the footing, we believe the footing is consistent with the 4 ft by 12 ft dimensions shown in the permit drawings.
- Splice length of top #6 reinforcement bars in ringwall is assumed long enough to develop yield strength per ACI 318-11.

4.3 Structural Analysis Findings

Tank R-17 in its current condition does not comply with requirements of AWWA D.100-11, using the ASCE 7-10 seismic parameters provided by Group Delta.

We have identified the following primary tank deficiencies:

- Tank Ringwall Stability
    - At the current fill height of 57 ft-10 in., the tank ringwall uplifts due to the overturning forces. Industry practice is to design the tank such that the ringwall maintains positive soil bearing pressure during the design level event.

- Tank Wall Stress
  - Shell compression stresses in the tank wall are exceeded at Courses 2, 3, 4, and 5 for the design seismic loads.
- Freeboard and Sloshing
  - The calculated wave height during a design level earthquake exceeds the available freeboard when filled to the current TCL. The steel roof plate, the rafter beams, and their bolted connections do not have adequate strength to resist the sloshing loads exerted on the roof.
- Interior Column
  - The interior column supporting the roof does not have enough strength to resist the lateral force of water during a design seismic event.
- Ringwall Foundation
  - The ringwall does not have sufficient hoop steel to resist the twist moment generated during a design seismic event.
- Anchorage
  - The concrete breakout strength of the anchors is exceeded during a design level seismic event, even when accounting for supplemental tension

Detailed results of the analyses are provided in the structural calculations in Appendix A.

4.4 Discussion of Analysis Results

The permit submittal package for the tank included the original design calculations performed by Trusco in 1995. We have not performed a complete design review of those calculations; however, we have performed limited comparisons in order to identify the bases for several of our conclusions regarding lack of conformance to current code versus the original 1995 design. Key differences include the following:

- The code-required seismic accelerations have increased significantly since 1995. The horizontal design acceleration for impulsive loads, which is the most significant load, has increased approximately 25 percent since 1995, from 0.42g to 0.54g. The design acceleration for convective loads, associated with sloshing of water, has increased 700 percent, from 0.03g to 0.21g.
- The requirements for calculating sloshing loads on the roof have changed considerably since 1995. Trusco calculated a sloshing wave height using AWWA D-100 (edition not specified) of 1.65 ft. Using the 2011 version of AWWA D-100, the calculated sloshing wave height is 7.03 ft. We have used the sloshing wave height derived from formulas in ASCE 7-10, which is the governing document for the California Building Code. That height is 8.86 ft. The formulas used within AWWA D-100 have changed considerably over the years. In the 1995 calculations, they reduce the wave height by an R_w factor

of 4.5, The R_w factor, now called “R” in the later versions of the code, is used in structural design to reduce seismic design forces to recognize nonlinear behavior and ductility in structures, but was included in the sloshing height formula at that time.

- It appears that Trusco made major calculation errors in determining the overturning moment in the upper courses of the tank wall. Figure 4-1 shows the overturning moment along the height of the tank, at the base of each course, from the Trusco design calculations and the SGH calculations. While the difference in values at the base can be attributed to changes in the code requirements, Trusco’s calculations along the height simplified the impulsive load as a point load at the center of gravity of the tank rather than as a distributed load. As a result, they did not include any seismic impulsive load in the shell design for the upper courses above the center of gravity. AWWA D100-11, Section A.13.5.4.2.2 suggests a linear reduction in the overturning moment from the base to the roof, which is what we assumed in our calculations. The net result is that Courses 2 through 5 were undersized in the original design, and Courses 3 to 5 in particular are highly overstressed for shell compressive stresses when using the current code, by a factor ranging from 1.9 to 3.2.

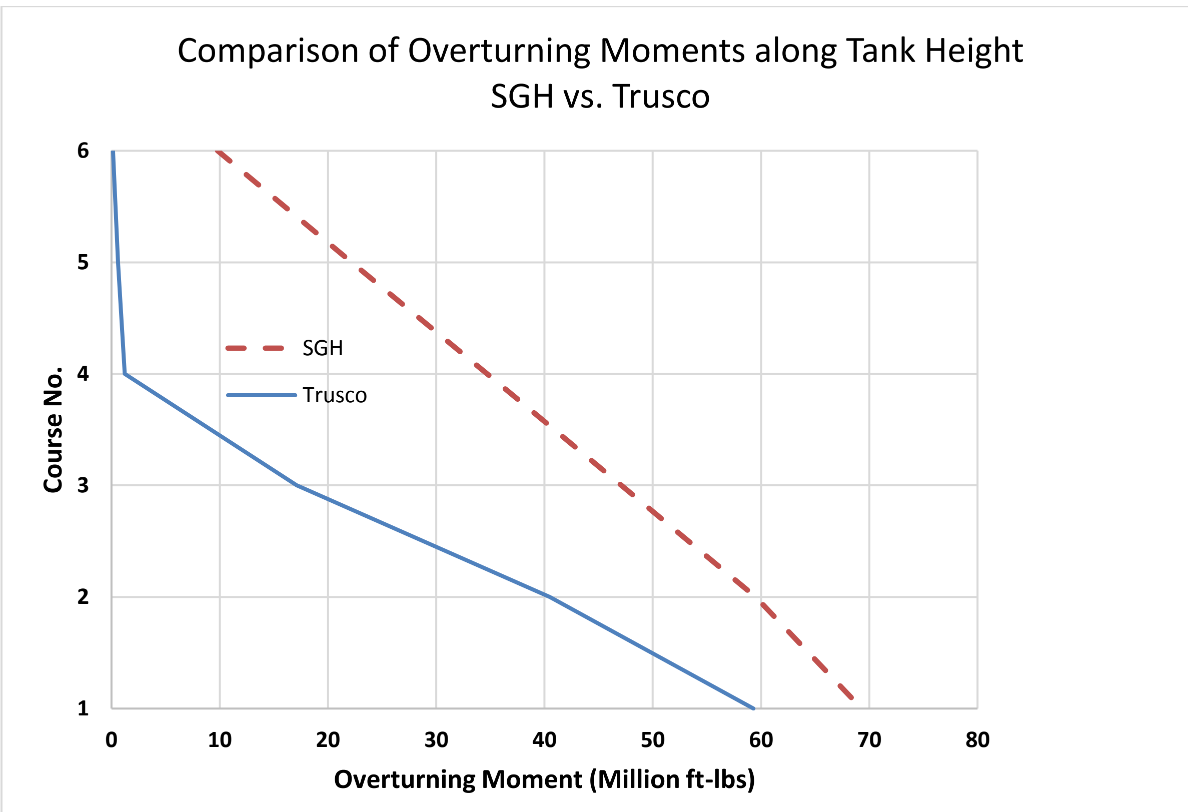

Figure 4-1: Comparison of loads along tank height as calculated by Trusco in original design vs. calculations by SGH using current code. Trusco calculation errors resulted in underdesign of upper courses.

- The calculated deficiencies in the tank anchorage concrete capacity are likely the result of increased loads combined with changes since 1995 in the concrete design code ACI 318.

4.5 Mitigation Concepts

SGH has identified several mitigation concepts to meet current code requirements. Please note that this investigation was intended to be conceptual in nature, and does not address every combination of solutions and does not fully address cost, constructability, or other key issues. We also do not include comparisons to the option of the construction of a new tank. This also applies to the mitigation concepts we developed for Tank R-16 and Tank R-9A.

- Replace / strengthen column, strengthen shell, strengthen/replace roof, strengthen anchorage
  - In order to avoid any reduction in fill height and tank storage capacity, all of the above mentioned tank components will require significant strengthening or replacement in order to comply with current code requirements.
- Reduce maximum fill height only
  - Our analysis indicates if the maximum fill height is reduced to approximately 13 ft, no other changes are necessary for the existing tank to meet code requirements. In this case, the maximum storage capacity decreases from 0.75 million gallons (MG) to approximately 0.17 MG. The controlling design condition is the strength of the interior column.
- Reduce maximum fill height and replace/strengthen column
  - If the interior column is strengthened or replaced with a stronger section, the maximum fill height can be reduced to 34 ft with no other necessary alterations to the existing tank. In this case, the maximum storage capacity decreases from 0.75 MG to approximately 0.45 MG. The controlling design condition is compression of Course 4.
- Reduce maximum fill height, replace/strengthen column, and strengthen shell
  - If both the interior column and Course 4 of the shell are strengthened, the maximum fill height can be reduced to 42 ft with no other necessary alterations to the existing tank. In this case, the maximum storage capacity decreases from 0.75 MG to approximately 0.57 MG. The controlling design condition is compression of Courses 3 and 5.
  - If Courses 3 and 5 were additionally strengthened, the fill height can be reduced to 45 ft, corresponding to a storage capacity of 0.58 MG. The controlling design condition is tension breakout of the anchors from the concrete foundation.
- Redefine service requirements
  - If the service requirements for R-17 can be redefined such that the currently serviced facilities are not dependent on this tank for essential or emergency purposes, the Seismic Use Group (SUG) can be reassigned to a less critical category. This would allow us to reduce the Importance Factor from 1.50 to

1.25 (SUG II) or 1.0 (SUG I), resulting in a decrease of the required loads used in this analysis. Note that this course of action may still require strengthening of some of the tank components as discussed above.

4.6 Additional Discussion of Mitigation Concepts

When evaluating the importance of tank upgrades, the City of Santa Rosa may wish to consider options that do not include complete conformance to current building codes. Should that be a possibility, we provide additional observations related to the possible consequences of damage that the City may choose to consider when evaluating upgrade options.

- Our experience and knowledge of historic tank performance in earthquakes indicates that the consequences of the different “overstress” conditions discussed above are not the same. For example, the damage to tank roof systems from sloshing has been known for many years, but has evolved in the building codes within the last 10 to 20 years. We believe this is a significant effect that is likely to directly impact tank survivability and functionality following a major earthquake.

- Significant overstress in the tank shell could lead to tank damage that could compromise the tank integrity. In this case, the overstress is worse in the upper courses due to design errors by Trusco.

  Historically, the more common damage scenario has been in self-anchored (unanchored) tanks at the bottom course, such as “elephant’s foot buckling” and damage to welds to the bottom plate, that have compromised tank integrity. Anchored tanks in general have performed much better in past earthquakes. However, the underdesign of the upper courses would be less likely to be mitigated by tank anchorage.

- The tank anchorage and concrete capacity issues noted are not as likely to result in direct damage to the tank wall that would compromise tank integrity.

- The ringwall overstress and uplift issues are also not as likely to directly result in damage to the tank wall that would compromise tank integrity.

5. TANK R-16

5.1 Referenced Information

With the exception of those data listed in Section 2.1 of this report, the City of Santa Rosa and West Yost were unable to provide any further information on Tank R-16.

5.2 Assumptions and Limitations

- The designer of Tank R-17 intended the design to have 0 in. of corrosion allowance. Since R-16 was designed in the same year and by the same designer, our calculations also assume 0 in. of corrosion allowance.
- Since no other information on the tank shell was available, our calculations assume the course thicknesses are equal to the measured thicknesses provided by JDH Corrosion Consultants, Inc.
- Height of each of the four shell courses are assumed equal.
- Joint weld efficiency coefficient, E_{weld}, assumed 0.85.
- Weight of roof approximated based on scalar ratio of tank diameter from Tank R-17.
- Anchor bolt diameter, location, spacing, and concrete cover approximated based on rough measurements and photos taken from site visit.
- Ringwall footing dimensions were approximated based on a scalar ratio of the ringwall supporting R-17, resulting in a 3 ft deep by 8 ft wide footing. This was done for the sole purpose of providing soil bearing demands for Group Delta. However, we did not evaluate the ringwall foundation itself or the anchorage into the foundation due to the lack of available information.
- We did not evaluate the interior column as material and geometric properties were not provided.
- We did not evaluate the tank roof as no information on the roof framing was provided.
- We did not evaluate the anchor chairs as detailed structural information was not available.

5.3 Structural Analysis Findings

Tank R-16 in its current condition does not comply with requirements of AWWA D.100-11, using the ASCE 7-10 seismic parameters provided by Group Delta.

We have identified the following primary tank deficiencies, when applying the assumptions discussed above:

- Tank Ringwall Stability

    - At the current fill height of 34 ft, the tank ringwall uplifts due to the overturning forces. Industry practice is to design the tank such that the ringwall maintains positive soil bearing pressure during the design level event.

- Tank Wall Stress

    - Calculations show that shell compression stresses in the tank wall are exceeded at Courses 2 and 3 for the design seismic loads.

- Freeboard and Sloshing

    - With the current fill height of 34 ft, the available freeboard is inadequate for sloshing of the tank contents.

    - The loads on the roof produced by the sloshing wave overstress the roof framing of Tank R-17. While we did not analyze the roof of R-16, we would expect that similar problems exist for this tank since both tanks were designed by the same company and constructed at the same time.

- Interior Column

    - The column supporting the roof of R-17 is inadequate for combined axial and bending due to gravity loads and lateral water loads from seismic. We expect the column supporting the roof of R-16 is also inadequate.

- Ringwall Foundation

    - The ringwall foundation of R-17 has inadequate reinforcement to resist twist moments induced by lateral seismic loading. We expect that the ringwall of R-16 also exhibits similar deficiencies.

- Anchorage

    - The anchors of R-17 do not have adequate embedment into the foundation or sufficient supplemental tension reinforcement to resist concrete breakout. We expect the same issues for the anchors of R-16.

Detailed results of the analysis are provided in the attached structural calculations.

5.4 Mitigation Concepts

- Replace / strengthen column, strengthen shell, strengthen/replace roof, strengthen anchorage

    - Although many of these components were not explicitly evaluated due to lack of data, based on the results of the analysis of Tank R-17, designed at the same time by the same company, we expect that all of the above mentioned tank components will require significant strengthening or replacement in order to comply with current code requirements without reducing fill height and tank storage capacity.

- Reduce maximum fill height only

    - Our analysis indicates that the tank can be filled to a maximum height of 27 ft without overstressing the tank shell during a design level seismic event. In this case, the maximum storage capacity decreases from 0.25 million gallons (MG) to approximately 0.20 MG.
    Note that this mitigation concept does not account for the demands on the interior column, the foundation, or the tank anchorage since we did not evaluate these components. It is likely that these other components will also require strengthening based on our findings from R-17. Lowering the maximum fill height to 27 ft would, however, satisfy freeboard requirements and limit the sloshing waves from impacting the tank roof.

- Redefine service requirements

    - If the service requirements for R-16 can be redefined such that the currently serviced facilities are not dependent on this tank for essential or emergency purposes, the Seismic Use Group (SUG) can be reassigned to a less critical category. This would allow us to reduce the Importance Factor from 1.50 to 1.25 (SUG II) or 1.0 (SUG I), resulting in a decrease of the required loads used in this analysis. Note that this course of action may still require strengthening of some of the tank components as discussed above.

5.5 Additional Discussion

Due to the lack of detailed data on Tank R-16, we were not able to evaluate the tank or develop mitigation concepts in more detail. However, given that the tank was designed at the same time as Tank R-17 by the same company, we expect that our findings and discussion would be similar to that presented for Tank R-17 in Section 4.

6. TANK R-9A

6.1 Referenced Information

In addition to those listed in Section 2.1 of this report, SGH also used the following information provided by West Yost:

- Original Civil and MEP drawings for tank R-9A, created by Mitchell & Heryford on November 1976, 8 sheets.
- Report titled “Steel Tank Seismic Summary of Fifteen Steel Tanks,” prepared by Harper & Associates Engineering, Inc. on December 1998, 31 pages.
- Report titled “Reservoir Seismic Upgrade and Improvement Program Report: Bennett Valley R9-A Reservoir,” prepared by Brelje & Race, November 2003, 12 pages.
- Report titled “Structural Evaluation of Existing Tank at Reservoir R-9A,” prepared by Peoples Associates, dated 12 March 2004, 18 pages.

6.2 Assumptions and Limitations

- Signage posted on the side of the tank indicates a volumetric capacity of 20 MG which corresponds to a fill height of approximately 40 ft (Photo 11). However, an evaluation performed by Peoples Associates in 2004 recommended a reduced fill height of 13 ft. Since we have not found any evidence indicating whether the new fill height was actually implemented, we performed calculations using both 40 ft and 13 ft fill heights.
- Joint weld efficiency coefficient, E_{weld}, assumed to be 0.85 as seen in 2004 calculations performed by Peoples Associates.
- Depth of soil at the toe of footing varies along the perimeter of tank. Foundation calculations are based on the minimum 12 in. of earth shown on drawing No. 4 of 8 by Mitchell & Heryford.
- We did not evaluate the bottom annulus plate since there was no information provided on the width of the bottom annulus.
- We did not evaluate the interior columns as material and geometric properties were not provided.
- We did not evaluate the tank roof as no information on the roof framing was provided.

6.3 Structural Analysis Findings

Tank R-9A in its current condition does not comply with requirements of AWWA D.100-11, using the ASCE 7-10 seismic parameters provided by Group Delta.

We have identified the following primary tank deficiencies:

- Tank Wall Stress
  - For a fill height of 40 ft, shell Courses 1, 2, 3, and 4 do not satisfy the minimum thickness requirements outlined in AWWA D100-11 Section 3.7 for hoop tension.
  - Shell courses are adequate for a max fill height of 13 ft.
- Foundation
  - For a fill height of 40 ft, the ringwall does not have sufficient steel to resist the twist moment or hoop tension generated during a design seismic event.
  - For a fill height of 13 ft, the same deficiencies are found in the ringwall. It should be noted that the 2004 evaluation performed by Peoples Associates only examined pure hoop tension produced by the overburden pressures on the soil contained within the ringwall. Our calculations show that the ringwall does not have sufficient strength to resist bending caused by the twist moments, even at a lowered fill height of 13 ft.
- Bearing pressures
  - As indicated in Section 6.0 of the Geotechnical Investigation performed by Group Delta Consultants, the soil bearing capacity of Tank R-9A is inadequate when filled to its current TCL of 40 ft.
  - Soil bearing capacity is adequate for a fill height of 13 ft.
- Freeboard and sloshing
  - With the original design fill height of 40 ft, the available freeboard is inadequate for sloshing of the tank contents.
  - We did not have roof structural data to allow us to evaluate the capacity of roof components. However, given the changes in tank design codes since 1977, and in particular to the calculation of sloshing wave heights, we believe it is highly unlikely that the roof has been designed for sloshing loads anywhere close to those required by current code, and the roof will require significant strengthening or replacement.
- Attached piping
  - Flexibility of attached piping is a particular concern for unanchored tanks that has been codified in recent editions of building codes. Section 13.6 and Table 30 of AWWA D100-11 specifies that piping must be able to accommodate uplift displacements of 4 in. for the specific calculated parameters for this tank. We did not calculate the uplift capacity of the piping attached to this tank. However, based on our experience, we believe it is highly unlikely that the attached piping will have adequate flexibility for the required displacement demand.

- Soil bearing capacity is adequate for a fill height of 13 ft.

Detailed results of the analysis are provided in the attached structural calculations.

6.4 Mitigation Concepts

Our calculations show that the ringwall foundation does not have adequate strength capacity to withstand the design seismic loads, even when the tank is emptied. Therefore, all mitigation concepts outlined below will also need to be accompanied by strengthening or replacement of the foundation.

- Anchor tank, strengthen foundation, strengthen shell and roof as necessary
  - Adding anchorage to the tank would improve the tank performance and may help avoid or reduce strengthening of the shell. Although we have not evaluated the roof due to lack of any detailed structural data, we expect that the framing will be insufficient due to the sloshing wave heights and lack of freeboard, and that significant strengthening or replacement of the roof will be required to conform to current code requirements without reducing the fill height and tank capacity (assuming the tank is still being used at its design fill height of 40 ft).
- Strengthen foundation and reduce maximum fill height
  - In addition to strengthening the foundation, the fill height may be reduced to 24 ft without overstressing the tank shell. In this case, the maximum storage capacity decreases from 2 million gallons (MG) to approximately 1.2 MG. Note that this mitigation concept does not account for the demands on the interior columns which we did not evaluate due to lack of design data. Lowering the maximum fill height to 24 ft would, however, satisfy freeboard requirements and limit the sloshing waves from impacting the tank roof.
- Redefine service requirements
  - If the service requirements for R-9A can be redefined such that the currently serviced facilities are not dependent on this tank for essential or emergency purposes, the Seismic Use Group (SUG) can be reassigned to a less critical category. This would allow us to reduce the Importance Factor from 1.50 to 1.25 (SUG II) or 1.0 (SUG I), resulting in a decrease of the required loads used in this analysis. Note that this course of action may still require strengthening of some of the tank components as discussed above.
- Add piping flexibility
  - The piping shown in Photo 15 can be reconfigured to provide flexibility to withstand the required 4 in. of uplift.

6.5 Additional Discussion of Mitigation Concepts

Similar to our previous discussion related to Tank R-17, when evaluating the importance of tank upgrades, the City of Santa Rosa may wish to consider options that do not include complete conformance to current building codes. Should that be a possibility, we provide additional observations related to the possible consequences of damage that the City may choose to consider when evaluating upgrade options.

- Our experience and knowledge of historic tank performance in earthquakes indicates that the consequences of the different “overstress” conditions discussed above are not the same. For example, the damage to tank roof systems from sloshing has been known for many years, but has evolved in the building codes within the last 10 to 20 years. We believe this is a significant effect that is likely to directly impact tank survivability and functionality following a major earthquake.

- The response of self-anchored (unanchored) tanks in earthquakes is highly nonlinear and much more complex than implied by design standards. The overturning loads cause a portion of the tank baseplate to uplift from the foundation. This uplift itself may not cause serious damage, but the deformations and additional stresses, as well as the impact from load reversal and resulting compressive stresses in the tank wall often result in buckling of the tank wall, also known as “elephant’s foot buckling”. The deformation can damage the weld between the wall and bottom plate, leading to loss of tank integrity. This is a common and well documented failure mode in past earthquakes.

- The potential piping damage that results from uplift of an unanchored tank is one of the most prevalent causes of loss of contents from storage tanks during earthquakes, and has occurred even in more moderate earthquakes, when other damage to the tank walls has not occurred.

- The ringwall overstress and uplift issues are not as likely to directly result in damage to the tank wall that would compromise tank integrity.

7. SUMMARY

SGH has evaluated Tanks R-17, R-16, and R-9A and determined that the existing tanks do not satisfy the current code requirements of AWWA D100-11. Deficiencies have been identified in the tank shells, roofs, columns, ringwall foundations, and attached piping.

We investigated several mitigation concepts in order to bring the above tanks within code compliance. This includes reduction of the maximum fill height, strengthening tank components, redefining the intended service requirements, and combinations of these.

We recognize that upgrade to complete code compliance may not be economically feasible and the City may choose to consider lesser degrees of compliance. If this is the case, we have provided some discussion of likelihood and potential consequences of various types of damage associated with code compliance issues identified that the City may wish to consider.

Photos

Photo 1

Tank R-17

Elevation

Photo 2

Tank R-17

Tank Placard

Photo 3

Tank R-17

Anchorage and Ringwall

Photo 4

Tank R-17

Anchorage and Ringwall

Photo 5

Tank R-16

Elevation

Photo 6

Tank R-16

Tank Placard

Photo 7

Tank R-16

Anchorage

Photo 8

Tank R-16

Anchorage and Ringwall

Photo 9

Tank R-16

Tank Bottom

Photo 10

Tank R-9A

Elevation

Photo 11

Tank R-9A

Tank Placard

Photo 12

Tank R-9A

Ringwall

Photo 13

Tank R-9A

Ringwall

Photo 14

Tank R-9A

Elevation

Photo 15

Tank R-9A

Attached Piping

Appendix A
Structural Calculations R-17

Attachment 2

Structural Calculations – Tank R-17

City of Santa Rosa Water Tanks Seismic Evaluation
Santa Rosa, CA

07 July 2017

SGH Project 167525

SIMPSON GUMPERTZ & HEGER

Engineering of Structures and Building Enclosures

Attachment 2

PREPARED FOR:

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Davis, CA

PREPARED BY:

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Oakland, CA 94607
Tel: 510.457.4600
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SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

SHEET NO. i

PROJECT NO. 167525.00 - ROSA

DATE 16 June 2017

CLIENT West Yost Associates

BY BLP

SUBJECT Structural Calculations – Tank R-17

CHECKED BY

INDEX TO CALCULATIONS:

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SUMMARY SHEET

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COLUMN (GRAVITY ONLY)

SHELL HYDROSTATIC HOOP TENSION

SHELL STRESS (GRAVITY + SEISMIC)

COLUMN (GRAVITY + SEISMIC)

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SOIL BEARING

UPLIFT

TWIST ANALYSIS

HOOP STEEL TENSION

LAP SPLICE LENGTH OF HOOP STEEL

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ANCHORAGE A1 – A3

ANCHOR TENSION & SHEAR

CONCRETE BREAKOUT IN TENSION

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SHEET NO. ii
PROJECT NO. 167525.00 - ROSA
DATE 16 June 2017
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CLIENT West Yost Associates
SUBJECT Structural Calculations – Tank R-17

INDEX TO CALCULATIONS:

ANCHOR CHAIRS AC1 – AC3

TOP PLATE
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ROOF ANALYSIS RF1 – RF2

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ROOF PLATE
RAFTER TO ROOF WELD
RAFTER BENDING & SHEAR
RAFTER CONNECTION TO SHELL

MITIGATION CONCEPTS MC1 – MC4

MC 1 – REDUCE FILL HEIGHT ONLY
MC 2 – REDUCE FILL HEIGHT, STRENGTHEN COLUMN
MC 3 – REDUCE FILL HEIGHT, STRENGTHEN COLUMN & SHELL COURSE 4
MC 4 – REDUCE FILL HEIGHT, STRENGTHEN COLUMN & SHELL COURSES 3, 4, 5

PROJECT DESCRIPTION:

West Yost Associates, Inc. (West Yost) has been contracted by the City of Santa Rosa to perform evaluations of the existing water tanks and tank sites. West Yost has subcontracted SGH to perform the structural analysis of the existing tanks, located at:

- R-17: Newgate Court, Santa Rosa, CA
- R-16: Fountain Grove Parkway, Santa Rosa, CA
- R-9A: Annadel Heights Drive, Santa Rosa, CA

The primary purpose of the structural evaluations is to determine whether the tanks meet current code requirements that would be applicable for the design of a new tank and to provide mitigation concepts to address structural deficiencies identified in the analysis.

SUMMARY

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

CLIENT	West Yost Associates	SHEET NO.	
		PROJECT NO.	167525.00 - ROSA
		DATE	26 May 2016
		BY	PHF
SUBJECT	Summary	CHECKED BY	

Note: All values are D/C ratios U.O.N.

Tank Height, Ht (ft)	55.75		
Fill Height, H (ft)	57.83	max TCL (ft) =	57.83
Importance Factor	1.50		
Anchorage	Anchored		
Eweld	1.00		

Course	Thickness (in)	Material	Static Hoop Tension	Static Compression	Min. Thickness?	Seismic Hoop Tension	Seismic Compression
1	0.750	A36	0.49	0.02	Adequate	0.11	0.55
2	0.500	A36	0.63	0.04	Adequate	0.16	1.23
3	0.366	A36	0.69	0.05	Adequate	0.20	1.94
4	0.250	A572-70	0.63	0.09	Adequate	0.22	3.18
5	0.250	A36	0.50	0.07	Adequate	0.20	2.04
6	0.250	A36	0.25	0.04	Adequate	0.13	0.92

Freeboard Required (ft)	8.86	
Available Freeboard (ft)	1.17	*Inadequate freeboard, calculate sloshing loads on roof*

Roof

Column - Static Compression	0.25
Column - Seismic P & M	1.25
Bending of Roof Plate	2.44
Strength of Rafter to Roof Weld	0.02
Rafter Beam Bending	7.96
Rafter Beam Shear	1.72
Rafter Channel Bolted Connx	2.70

Foundation

Soil Bearing (Gravity)	0.54	
Soil Bearing (Gravity + Seismic)	0.93	
Bearing Pressure at Uplift End (psf)	-844	*Insufficient uplift resistance! Ringwall will lift off of soil*
Positive Bending of Ringwall	0.86	
Negative Bending of Ringwall	1.36	
Hoop Steel (Positive Bending)	0.59	
Hoop Steel (Negative Bending)	0.19	

Anchorage

Tank Sliding Resistance	0.82	No Shear Demand on Anchors
Anchor Steel, Tension & Shear	0.56	
Concrete Breakout in Tension	1.73	
Conc. Breakout in Tension w/ Reinf.	1.55	
Anchor Pull-out	0.57	
Side Face Blowout in Tension	0.22	

INPUT PARAMETERS

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

SHEET NO.	
PROJECT NO.	167525.00 - ROSA
DATE	10 May 2016
BY	BLP
CHECKED BY	PHF 2016.05.26

CLIENT West Yost Associates

SUBJECT Welded Steel Tank Properties & Seismic Parameters

Tank & Foundation Properties

Except where noted, tank properties were obtained from original permit calcs and drawings perpared by Trusco Tank Inc. (1994)

NAME	R-17	Specific name of this tank
D	47.000	Nominal tank diameter, measured to the inside of the wall (ft)
Ht	55.750	Total shell height excluding knuckle (ft) as defined in AWWA D.100-11 13.5.2
H	57.830	Fill Height (ft) (note: Maximum fill height is aka MOL and TCL)
t	0.750	Thickness of bottom course (in)
tb	0.250	Thickness of bottom plate (in)
G	1.000	Specific gravity of tank contents
Roof	Steel Rafters w/ Roof Plate	Roof type
Anchorage	Anchored	Self-anchored or Anchored
Fnd Type	Ringwall	
CA =	0.0000	Corrosion Allowance (in)

Material Properties Of Tank

Fty	36,000	Minimum yield strength of bottom course (psi)
Fby	36,000	Minimum yield strength of bottom plate (psi)
E_{mod}	29,000,000	Elastic modulus (psi)
Weld Type	Single-groove butt joint with suitable backing strip or equivalent means to ensure complete joint penetration	
E_{weld}	1	Weld Joint Efficiency in Tension (ref. AWWA D100-11 Table 15)

Seismic Parameters Per ASCE 7-10 Spectra

Seismic parameters obtained from Group Delta Consultants.

S_s	2.202	MCE spectral response acceleration at short periods
F_a	1.000	Site coefficient
S_{MS}	2.202	Adjusted spectral response acceleration for short periods
S_1	0.911	MCE spectral response acceleration at 1.0 sec period
F_v	1.300	Site coefficient
S_{M1}	1.184	Adjusted spectral response acceleration at 1.0 sec period
S_{DS}	1.468	Design spectral response acceleration at short periods
S_{D1}	0.790	Design spectral response acceleration at 1.0 sec period
Ts	0.54	=Sd1/Sds (s)
T_L	8	Long-period transition period (s)
I_E	1.50	Seismic Importance Factor (Risk Cat. IV - ASCE 7-10 / Seismic Use Group III - AWWA D100-11)

General Notes

1. Tank nomenclature, equation and section references are from AWWA D100-11 unless otherwise noted.
2. [shaded cell] indicates a cell with a manually inputed value.

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

CLIENT	West Yost Associates
SUBJECT	Weight Calculations for Tank Shell Courses
SHEET NO.	
PROJECT NO.	167525.00 - ROSA
DATE	10 May 2016
BY	BLP
CHECKED BY	PHF 2016.05.26

Shell Data

D	47.000	Nominal tank diameter (ft)
Ht	55.750	Total tank height (ft)
t	0.750	Thickness of bottom course (in)

Shell Geometry and Weight

Shell course thicknesses obtained from original permit calculations prepared by Trusco Tank Inc. (1994) and from field measurements provided by JDH Corrosion Consultants. Where thicknesses were similar but only slightly differ, the lesser value was conservatively used.

Course	Yield Strength (psi)	(1) Elevation of Top of Course (ft.)	(2) Course Height (ft.)	(3) Plate Thickness (in)	(4) CG Elevation (ft.)	(5) Cross Section Area (ft^2)	(6) Total Course Weight (lbs)	(6)*(4) Wt*CG (lbs*ft)	Total weight of courses (lbs)
1	36,000	7.917	7.917	0.750	3.958	9.24	35,846	1.42E+05	129,917
2	36,000	17.833	9.917	0.500	12.875	6.16	29,921	3.85E+05	94,070
3	36,000	27.833	10.000	0.366	22.833	4.50	22,051	5.04E+05	64,149
4	70,000	37.917	10.083	0.250	32.875	3.08	15,205	5.00E+05	42,098
5	36,000	47.833	9.917	0.250	42.875	3.08	14,954	6.41E+05	26,892
6	36,000	55.750	7.917	0.250	51.792	3.08	11,938	6.18E+05	11,938
						0.00			0
						0.00			0
						Σ =	129,917	2.79E+06	

Roof Weight

Steel Rafter Roof

Wr,x	26,336	Total roof weight (lbs) (ref. Permit Submittal pg. 87)

Overall Weights

Ws	129,917	Total weight of tank shell and all appertures (lbs)
Wr	26,336	Total weight of the tank roof (lbs)
	75%	% of roof weight supported by shell wall (= 0 for a floating roof)
Wrs	19,752	Total weight of the tank roof supported by shell
Xs	21.5	Centroid distance from bottom of tank (ft)

AWWA D.100-11 TANK CALCULATIONS

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

SHEET NO.
PROJECT NO. 167525.00 - ROSA
DATE 10 May 2016
BY BLP
CHECKED BY PHF 2016.05.26

CLIENT West Yost Associates
SUBJECT AWWA D.100-11 Calculations

Tank Data

D	47.000	Nominal tank diameter (ft)
Ht	55.750	Total height of the tank shell (ft)
H	57.830	Top capacity limit (ft)
G	1.000	Specific gravity of tank content
t	0.750	Thickness of bottom course (in)
tb	0.250	Thickness of bottom annulus (in)
Fty	36,000	Min. yield strength of all shell courses (psi) *Except for course 4, which is A573-70
Fby	36,000	Min. yield strength of bottom annulus (psi)

Tank Weights

Ws	129,917	Total weight of tank shell and all apperturences (lbs)
Xs	21.5	Height from bottom of tank shell to shell c.g. (ft)
Wr	26,336	Total weight of the tank roof (lbs)
Wrs	19,752	Total weight of the tank roof supported by tank shell in the vertical direction (lbs)

Section 3.4 - Allowable Compressive Stresses for Columns, Struts, and Shells

3.4.3 Shell Compression

Note: Method 1 is used to calculate shell compression F_L.
Note: For Material Class, refer to Table 4.

K = 1.00 AISC effective column length factor

Course	Thickness (in)	R (in)	t/R	Fy (psi)	Material Class	(t/R)c	FL (psi)	C`c	r (in)	L (in)
1	0.75	282.75	0.0026525	36,000	2	0.0035372	6,275	213.57	199.80	95
2	0.5	282.5	0.0017699	36,000	2	0.0035372	3,582	282.66	199.67	119
3	0.3655	282.3655	0.0012944	36,000	2	0.0035372	2,455	341.45	199.60	120
4	0.25	282.25	0.0008857	70,000	2	0.0035372	1,611	421.52	199.54	121
5	0.25	282.25	0.0008857	36,000	2	0.0035372	1,611	421.52	199.54	119
6	0.25	282.25	0.0008857	36,000	2	0.0035372	1,611	421.52	199.54	95

Course	KL/r	Kϕ	Fb (psi)	capacity Fa (psi)	demand fa (psi)	D/C
1	0.48	1.000	6,275	6,275	112	0.02
2	0.60	1.000	3,582	3,582	128	0.04
3	0.60	1.000	2,455	2,455	129	0.05
4	0.61	1.000	1,611	1,611	140	0.09
5	0.60	1.000	1,611	1,611	105	0.07
6	0.48	1.000	1,611	1,611	72	0.04

Section 3.6 - Roofs

See "Roof Analysis" for checks not included herein (e.g. check of roof and roof components).

3.6.1.3 Column Compression

Note: Strength computed per AISC Steel Manual 14th Ed.

	50%	% of roof weight supported by column
Wrc	13,168	Weight of roof supported by column (lbs)
fa	1,341	Compression stress demand (psi)
Dcol	12.75	Column diameter (in)
tcol	0.25	Column wall thickness (in)
Lcol	62	Length of column (ft)
rx	4.43	Minimum radius of gyration of column (in)
KL/r	168	Effective slenderness ratio of column *OK, KL/r < 175*
Ag	9.82	Gross area of column section (in^2)
Fy_col	36000	Yield stress of column (psi)
Fcr / Ω	5,306	Allowable compression stress (psi), AISC Steel Manual Table 4-22
D/C	0.25	

OK, column good for compression.

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Engineering of Structures and Building Enclosures

CLIENT	West Yost Associates	SHEET NO.	
		PROJECT NO.	167525.00 - ROSA
		DATE	10 May 2016
		BY	BLP
SUBJECT	AWWA D.100-11 Calculations	CHECKED BY	PHF 2016.05.26

Section 3.7 - Cylindrical Shell Plates (Hoop Tension)

D =	47.00	Nominal tank diameter (ft)
G =	1.00	Product specific gravity
E_{weld} =	1.00	Weld Joint efficiency in Tension (ref. Table 15)

Course	Thickness (in)	Course Height (in)	Elevation to bottom of course (in)	hp (ft)	s (psi) (ref. Table 34)	Joint Efficiency (ref. Table 15)	Req'd design shell plate thickness (in)	Shell thickness - CA (in)	D/C	Sufficient thickness?
1	0.75	95	0	57.830	19,330	1.00	0.3656	0.75	0.49	Yes
2	0.5	119	95	49.913	19,330	1.00	0.3155	0.5	0.63	Yes
3	0.3655	120	214	39.997	19,330	1.00	0.2529	0.3655	0.69	Yes
4	0.25	121	334	29.997	23,300	1.00	0.1573	0.25	0.63	Yes
5	0.25	119	455	19.913	19,330	1.00	0.1259	0.25	0.50	Yes
6	0.25	95	574	9.997	19,330	1.00	0.0632	0.25	0.25	Yes

Note: Course 4 has double-welded butt joints on all sides, so Eweld = 1.00 per 14.3.1.2
Note: Maximum design tensile stress, s, is determined per Section 14, Table 34.

Section 3.8 - Anchorage
See "Anchorage Calculations" for check of tank anchors and anchor chairs.

3.8.9 - Design Loads

Ms =	69,314,885	Design seismic overturning moment at the bottom of the shell (ft-lbs)
Nab =	72	Number of anchors
	2.09	Radial distance between anchors (ft)
eAB =	0.40	Anchor bolt offset from tank inner wall (ft)
Dac =	47.79	Diameter of anchor circle (ft)
W` =	149,669	Dead weight of the structure (corroded condition) available to resist uplift (lbs)
Ps =	78,667	Design uplift force per anchor due to seismic (lbs)

Section 3.10 - Minimum Thickness and Size

Course	Thickness (in)	In Contact with Water?	Required Thickness (in)	Adequacy Check
1	0.75	Yes	0.25	*Adequate*
2	0.5	Yes	0.25	*Adequate*
3	0.3655	Yes	0.25	*Adequate*
4	0.25	Yes	0.25	*Adequate*
5	0.25	Yes	0.25	*Adequate*
6	0.25	Yes	0.25	*Adequate*

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Section 13.2 - Design EQ Ground Motion

13.2.6 - Response Modification Factors (ref. Table 28)

Ri =	3.00	
R_c =	1.50	

13.2.7 - Design Response Spectrum

Sai =	1.47	(g)
Sac =	0.30	(g)

13.2.9.2 - Horizontal Design Accelerations for Ground-Supported Tanks

Ai =	0.524	(g)
Ac =	0.214	(g)

Section 13.5 - Ground-Support Flat Bottom Tanks

13.5.1 - Natural Periods

Tc =	3.96	First mode sloshing wave period (s)
Ti =	0.00	Natural period of the structure (s)

13.5.2 - Design Overturning Moment at the Bottom of the Shell

Wt =	6,259,577	Total weight of the Tank Contents (lbs) (13-27)
Wi =	5,150,540	Effective impulsive weight (lbs)
Wc =	1,169,805	Effective convective weight (lbs)
Xi =	24.50	Height from bottom of shell to centroid of the lateral seismic force applied to Wi (ft)
Xc =	45.30	Height from bottom of shell to centroid of the lateral seismic force applied to Wc (ft)
Ms =	69,314,885	Design overturning moment at the bottom of the shell (ft-lbs)

13.5.3 - Design Shear and Overturning Moment at the Top of the Foundation

Dbp =	48.73	Diameter of bottom plate (ft)
tbp =	0.25	Thickness of bottom plate (in)
Wf =	19,038	Total weight of tank bottom (lbs)
Vf =	2,803,430	Design shear at the top of the foundation due to horizontal design acceleration (lbs)

Fnd Type =	Ringwall	
Ximf =	31.74	Height from shell bot. to centroid of Wi adjusted to incl. the effects of varying bottom pressures (ft)
Xcmf =	45.56	Height from shell bot. to centroid of Wc adjusted to incl. the effects of varying bottom pressures (ft)
Mmf =	69,314,885	Design overturning moment at the top of the foundation (ft-lbs)

13.5.4.1 - Resistance to Overturning

Tank has mechanical anchorage to resist overturning

13.5.4.1.2 - Bottom Annulus Width

Note: If tank is mechanically anchored, the minimum required width, L, does not apply

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13.5.4.2 - Shell Stresses

wrs =	133.8	Roof load acting on shell (plf)
wt =	1,014	Weight of tank shell, apperturances, and portion of roof (plf) (equation 13-41)
CA =	0	Corrosion allowance (in)
ts =	0.75	Actual thickness of bottom shell course less the specified corrosion allowance, if any (in)
σc =	4,560	Longitudinal shell compression (psi), (Eq. 13-39, 13-40)
D =	47.00	Nominal tank diameter (ft)
R =	282.00	Nominal radius of the tank (in)
H =	57.83	MOL, or TCL, or Design Liquid Level (ft)
G =	1.00	Product specific gravity
E_{weld} =	1.00	Weld Joint efficiency in Tension (ref. Table 15)

Course	Thickness (in)	CA (in)	Thickness minus CA (in)	Course Height (in)	Elevation to bottom of tank (in)	s (psi)	Y (ft)
1	0.75	0	0.75	95	0	19,330	57.830
2	0.5	0	0.5	119	119	19,330	47.913
3	0.3655	0	0.3655	120	239	19,330	37.913
4	0.25	0	0.25	121	360	23,300	27.830
5	0.25	0	0.25	119	479	19,330	17.913
6	0.25	0	0.25	95	574	19,330	9.997

Note: "Y" is measured from top of design water level to bottom of course, because that is where course hoop stress is greatest.

	Hoop Tensile Forces & Stresses							
Course	Dynamic impulsive force, Ni (lbs/in)	Dynamic, convective force, Nc (lbs/in)	Static force, Nh (lbs/in)	Static Stress (psi)	Dynamic stress, σ_s (psi)	Total stress (psi)	Allowable stress (psi)	D/C
1	1,610	10	7,067	9,422	2,146	2,891	25,773	0.11
2	1,610	13	5,855	11,710	3,220	4,020	25,773	0.16
3	1,610	25	4,633	12,676	4,405	5,118	25,773	0.20
4	1,533	53	3,401	13,603	6,135	6,742	31,067	0.22
5	1,216	114	2,189	8,756	4,885	5,206	25,773	0.20
6	781	212	1,222	4,886	3,236	3,388	25,773	0.13

OK! Sufficient tensile hoop strength
Note: "dynamic" implies "seismic"
Note: Per 13.5.4.2.4, a 1/3 increase is allowed when calculating the Allowable Tensile Hoop Stress

	Longitudinal Compression Stress									
Course	Allow. Comp. stress σ_a (psi)	$\Delta\sigma_{cr}$ (psi)	Seismic allow. long. shell comp. stress, σ_e (psi)	h_i (ft)	X_{si} - h_i (ft)	1- h_i / H_t (ft)	Overturning Moment (lbs-ft)	w_{ti} (plf)	Longitudinal shell comp. stress, σ_c (psi)	D/C
1	6,275	-	8,364	0.00	21.48	1.00	69,314,885	1,014	4,560	0.55
2	3,582	-	4,775	7.92	20.23	0.86	59,471,964	771	5,851	1.23
3	2,455	-	3,273	17.83	17.44	0.68	47,142,411	568	6,334	1.94
4	1,611	-	2,147	27.83	13.96	0.50	34,709,248	419	6,819	3.18
5	1,611	-	2,147	37.92	8.92	0.32	22,172,475	316	4,373	2.04
6	1,611	-	2,147	47.83	3.96	0.14	9,842,921	215	1,968	0.92

Not OK! Tank compression strength insufficient for seismic forces
Note: σ_a is equal to F_L calculated per 3.4.3.1 (aka Method 1)
Note: Overturning Moment varies linearly from bottom of shell to top, per AWWA D100-11 A.13.5.4.2.2

13.5.4.3 - Vertical Design Acceleration

Av = 0.21 (g)

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13.5.4.4 - Freeboard & Sloshing Wave Height

Hroof =	59.00	Height to bottom of roof for purpose of calculating freeboard and sloshing loads (ft)
Sac =	0.30	Spectral acceleration of convective wave (g)
dwave =	8.86	Sloshing wave height above Fill Height (ft) (ref. ASCE 7-10 (Eq. 15.7-13))
df =	1.17	Freeboard available (ft)
df_reqd =	8.86	Min. freeboard requirement (ref. Table 29) (ft)
	No	Sufficient freeboard available?
	7.69	*ft more freeboard required*

13.5.4.5 - Roof Framing and Columns

See "Roof Analysis" for check of roof and roof components. Column analysis performed below per AISC Steel Manual 14th Ed.

Compression Strength Per AISC Ch. E

Wrc	13,168	Weight of roof supported by column (lbs), calculated above
	758	Vertical seismic force (lbs) (equal to 0.7*Wrc*(0.4*Av))
$p_{r.live}$	15	Roof live load (psf)
$W_{r.live}$	13,012	Roof live load supported by column (lbs)
Pr	23,495	Compression demand on column (lbs)
		Assume ASD Load combination D + 0.75L + 0.75(0.7E)

Note: Copmpression strength is calculated above (Per AWWA 3.6.1.3)

Ag	9.82	Gross area of column section (in^2)
Fcr	8,860	Citical compression stress (psi), AISC Table 4-22, Fy increased by one-third per AWWA 13.5.4.5
Pcr	86,987	Nominal compression strength (lbf), ref. AISC (E3-1)
Ω	1.67	Strength reduction factor, AISC Chapter E1
Pcr / Ω	52,088	Allowable compression strength (lbf)
Axial D/C	0.45	

Bending Strength Per AISC Ch. F

Lcol	62	Height of column (ft)
w_{lat}	336	Uniformly distributed horizontal force from water on column (plf) Ref. Wozniak and Mitchell 1978, Appendix 2
Mr	84,119	Moment in column from lateral water load (lb-ft). Varies w/ H. Refer to AISC Table 3-23 (5) for Mr
		Assume ASD Load combination D + 0.75L + 0.75(0.7E)
Fy_col	36000	Yield stress of column (psi)
D/t	51	Slenderness ratio
0.07E/Fy	56	Limiting compactness ratio, AISC Table B4.1b
0.31E/Fy	250	Limiting slenderness ratio, AISC Table B4.1b

Column is compact, Mn = FyZx.

Zx	39.07	Plastic section modulus of column section (in^3)
Mn	156,232	Nominal bending strength (lb-ft), Fy increased by one-third per AWWA 13.5.4.5
Ω	1.67	Strength reduction factor, AISC Chapter F1
Mn / Ω	93,552	Allowable bending strength (lb-ft)
Bending D/C	0.90	
D/C	1.25	Interaction formula per AISC (H1-1a) and (H1-1b)

No Good, column inadequate for seismic loads

13.5.4.6 - Sliding Check

μ =	0.58	Coefficient of friction, AWWA A.13.2.8.2
V_{ALLOW} =	3,431,868	Allowable Lateral Shear (lbs)
V_f =	2,803,430	Design shear at the top of the foundation due to horizontal design acceleration (lbs)
VNET =	0	
D/C =	0.82	

Tank has sufficient sliding resistance

Section 13.7 - Foundation Design for Ground-Supported Flat-Bottom Tanks

PT =	41,042	Design Shell Compression Load on the Foundation (plf) (ref. PIP STE03020 p.15 of 81)

RINGWALL ANALYSIS

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SUBJECT Ringwall Calculations

DESIGN BASIS

Specifications:

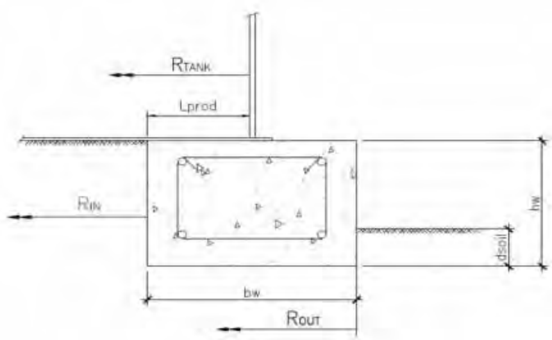
AWWA D100-11
Process Industry Practices PIP STE03020 -- Guidelines for Tank Foundation Designs
ACI 318-11, for calculating ringwall strengths, minimum steel area, lap splice length, shrinkage steel, etc.

MATERIAL PROPERTIES

f`c =	3,000	Concrete compressive strength (psi)
γc =	150	Concrete density (pcf)
fy =	60,000	Rebar yield strength (psi) (ASTM A15 intermediate) (ref. Tank specs, Section 17)
K =	0.50	Coefficient of lateral earth pressure (taken as K_0)
γs =	125	Soil density inside ringwall (pcf)
bnet =	16,000	Ultimate net bearing capacity of the soil (psf) from Group Delta Consultants

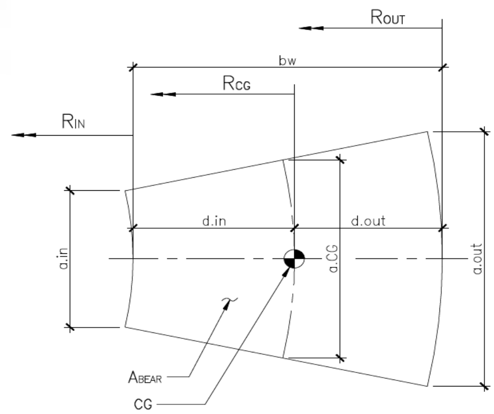
FOUNDATION GEOMETRY & SECTION PROPERTIES

Rtank =	23.50	(ft)
bw =	12	(ft)
hw =	4.5	(ft)
Lprod =	8.00	(ft)
Rout =	27.50	(ft)
Rin =	15.50	(ft)
dsoil =	4.17	(ft)



SECTION VIEW
RINGWALL

dout =	5.44	(ft)
din =	6.56	(ft)
acg =	1.00	(ft)
aout =	1.25	(ft)
ain =	0.70	(ft)
Rcg =	22.06	(ft)
Abear =	11.70	(ft^2)
Rcg_water =	19.77	C.G. of the mass of water that bears over the ringwall, measured from the tank center (ft)
Abear_water =	7.89	Bearing area of water over the ringwall (for unit length of Rcg_water) (ft^2)
Rac =	23.90	Center of anchor bolt ring (ft)



PLAN VIEW
RINGWALL

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LOADS ON THE RINGWALL

wt =	1,014	Self-weight of tank + roof on the base of the shell (plf) (ref. AWWA 13.5.4.2)
Wb =	11,333	Total weight of tank bottom plate bearing on ringwall (lbs)
Ww =	3,537,059	Total water weight bearing on the wall (lbs)
Ms =	69,314,885	Design overturning moment at the bottom of the shell (ft-lbs) (ref. AWWA 13.5.2)

Load Cases

Name	Load Type	Description	Unfactored (at Rcg) (plf)	Unfactored over footing width (psf)	Eccentricity from Rcg (see note 2) (ft)	Location of Force
A	Dead	Shell + Roof weight	1,079.9	90.0	-1.44	Shell
B	Dead	Bottom plate weight	81.8	6.8	2.13	Base PL Center over Wall
C	Dead	Ringwall weight	7,895.0	657.9	0.00	Center of Ringwall
D	Live	Water weight (see note 1)	25,520.8	2,126.7	2.28	Center of Water over Wall
E	EQ	Seismic Bearing (from OTM)	43,724.4	3,643.7	-1.44	Shell
Av	EQ	Vert. Seismic - Shell + Roof	88.8	7.4	-1.44	Shell
Bv	EQ	Vert. Seismic - Bottom PL	6.7	0.6	2.13	Base PL Center over Wall
Cv	EQ	Vert. Seismic - Ringwall	649.0	54.1	0.00	Center of Ringwall
Dv	EQ	Vert. Seismic - Water	2,098.0	174.8	2.28	Center of Water over Wall
F	EQ	Seismic Uplift (from OTM)	-41,858.7	-3,488.2	-1.84	Center of Anchor Ring

Note 1. Water is to be treated as a live load, per AWWA D.100-11 Section 12.1.1
Note 2. If center of load is closer to the tank center than Rcg, value is negative.
Note 3. Vertical seismic acceleration is equal to 0.4*Av per AWWA 13.5.4.3
Note 4. Vertical seismic load from water is included in Load Combo A-3 only since explicitly called for in AWWA 13.7.1
Note 5. Load Case F is only applicable for an Anchored Tank

Unfactored Load Combinations (For Soil Demands & Tank Stability)

Name	Description	Which Side of Tank? (see notes 1 and 3)
A-1	Dead+Live	Bearing
A-2	Dead+Live+EQ	Bearing
A-3	Dead+Live+EQ	Uplift

Factored Load Combinations (For Ringwall Demands)

Name	Description	Which Side of Tank? (see notes 1 and 3)
U-1	1.4Dead	Bearing
U-2	1.2Dead+1.6Live	Bearing
U-3	1.2Dead+1.0Live+1.4EQ	Bearing
U-4	0.9Dead+1.4EQ	Bearing
U-5	1.2Dead+1.0Live+1.4EQ	Uplift
U-6	0.9Dead+1.4EQ	Uplift

Note 1. We use a 1.4 load factor for EQ loads to convert it from ASD to strength design; i.e. AWWA EQ loads include the 0.7 ASD factor
Note 2. The direction of the vertical seismic loads is in accordance with ASCE 7-10 Section 12.4.3
Note 3. For Anchored Tanks, ringwall demands are calculated for 2 locations: where the tank bears AND where it uplifts.

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SOIL BEARING CHECK

Gravity Only (Load Case A-1)

b_{net}	16,000	Ultimate net bearing capacity of the soil (psf)
F.O.S.	3.00	Factor of Safety (gravity only) (ref. 12.3.2)
Capacity	5,333	Allowable bearing pressure (psf)
Demand	2,881	(psf)
D/C	0.540	

OK! Adequate bearing strength

Gravity + Seismic (Load Case A-2)

b_{net}	16,000	Ultimate net bearing capacity of the soil (psf)
F.O.S.	2.25	Factor of Safety (gravity + seismic) (ref. 12.3.2.2)
Capacity	7,111	Allowable bearing pressure (psf)
Demand	6,587	(psf)
D/C	0.926	

OK! Adequate bearing strength

CHECK THAT RINGWALL WILL NOT UPLIFT FROM SOIL

Note1. Positive values indicate downward bearing on the soil, negative values indicate uplift force
Note 2. Load Combo A-3 is used.

Load Case	Soil bearing pressure (psf)	
A, Av, B, Bv	89	steel
C, Cv	604	ringwall
D, Dv	1,952	water
F	-3,488	OTM
SUM	-844	Resultant Bearing Pressure on Soil

Not OK! Insufficient uplift resistance

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TWIST ANALYSIS

Positive Bending of Ringwall (Bottom in Tension)

As.b	19.97	Rebar area at bottom of ringwall (in^2)	(6 - #9 and 11 - #10)
Fy	60,000	(psi)	
f'c	3,000	(psi)	
β_1	0.85	Factor to approximate depth of compression stress block, ACI 318-11 10.2.7.3	
d	47.49	Depth from top of ringwall to bottom rebar (in)	
b	144	Width of ringwall in bending (in)	
c	3.84	Depth to neutral axis (in), assuming tension steel reaches yield	
ε_s	0.0050	Strain in steel (in/in)	
	OK, steel yields before concrte fails.		
ϕ	0.90	Strength reduction factor, ACI 318-11 9.3.2	
ϕMn =	4,121,071	Ringwall design moment strength (lbs*ft)	
Mu =	3,536,702	Maximum moment on ringwall due to twist (lbs*ft)	
	U - 5	Governing Load Combination	
D/C	0.858		
	OK! There is adequate steel present to resist ringwall bending due to twist		
As.b,req'd =	17.05	(in^2)	

Negtive Bending of Ringwall (Top in Tension)

As.t	2.64	Rebar area at top of ringwall (in^2)	(6 - #6)
Fy	60,000	(psi)	
f'c	3,000	(psi)	
β_1	0.85	Factor to approximate depth of compression stress block, ACI 318-11 10.2.7.3	
d	49.75	Depth from bottom of ringwall to top rebar (in)	
b	144	Width of ringwall in bending (in)	
c	0.51	Depth to neutral axis (in), assuming tension steel reaches yield	
ε_s	0.2911	Strain in steel (in/in)	
	OK, steel yields before concrete fails.		
ϕ	0.90	Strength reduction factor, ACI 318-11 9.3.2	
ϕMn =	588,468	Ringwall design moment strength (lbs*ft)	
Mu =	799,614	Maximum moment on ringwall due to twist (lbs*ft)	
	U - 4	Governing Load Combination	
D/C	1.359		
	Not OK! Insufficient steel present to resist ringwall bending due to twist		
As.t,req'd =	3.593	(in^2)	

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HOOP STEEL

P =	3,609	Pressure from water on bottom of tank (psf)
K =	0.5	Coefficient of lateral earth pressure
γs =	125	Soil weight (pcf)
H =	135,658	Hoop tension (lbs)

Check hoop steel during Positive Bending of Ringwall (Bottom in Tension)

As,req'd =	4.02	Required hoop steel (in^2)	
As,top_avail =	2.64	Hoop steel available from top of ringwall, not used by twist (in^2)	
As,bot_avail =	2.92	Hoop steel available from bottom of ringwall, not used by twist (in^2)	
As,other_avail =	1.20	Other hoop steel available, not used by twist (in^2)	(6 - #4)
As,avail =	6.76	Total hoop steel available (in^2)	
D/C	0.595		

OK! There is adequate hoop steel present

Check hoop steel during Negative Bending of Ringwall (Top in Tension)

As,req'd =	4.02	Required hoop steel (in^2)
As,top_avail =	0.00	Hoop steel available from top of ringwall, not used by twist (in^2)
As,bot_avail =	19.97	Hoop steel available from bottom of ringwall, not used by twist (in^2)
As,other_avail =	1.20	Other hoop steel available, not used by twist (in^2)
As,avail =	21.17	Total hoop steel available (in^2)
D/C	0.190	

OK! There is adequate hoop steel present

CHECK LENGTH of LAP SPLICES Per ACI Ch. 12.15 — Verify splices can achieve develop yield of the hoop steel

Note: Conservatively assume Class B splice

Check Bottom Steel: (6 - #9 and 11 - #10)

Fy	60,000	Yield strength of rebar (psi)
λ	1.0	Concrete type factor, normal-weight concrete
ψt	1.0	Reinforcement location factor, ACI 318-11 12.2.4 (a)
ψe	1.0	Reinforcement coating factor, ACI 318-11 12.2.4 (b)
ψt ψe	1.0	Limit on product of ψt*ψe = 1.7
ψs	1.0	Reinforcement size factor, ACI 318-11 12.2.4 (c)
Ktr	0.0	Confining reinforcement factor. Conservatively assume 0

Bar	db (in)	cb (in)	(cb+Ktr) / db	ld (in)	$L_{lap.req}$ (in)	$L_{lap.prov}$ (in)	lap.prov > lap.req?
#9	1.128	4.00	2.50	37.1	48.2	57.0	Yes, lap length ok.
#10	1.270	4.00	2.50	41.7	54.3	57.0	Yes, lap length ok.

Check Top Steel: (6 - #6)

Fy	60,000	Yield strength of rebar (psi)
λ	1.0	Concrete type factor, normal-weight concrete
ψt	1.3	Reinforcement location factor, ACI 318-11 12.2.4 (a)
ψe	1.0	Reinforcement coating factor, ACI 318-11 12.2.4 (b)
ψt ψe	1.3	Limit on product of ψt*ψe = 1.7
ψs	0.8	Reinforcement size factor, ACI 318-11 12.2.4 (c)
Ktr	0.0	Confining reinforcement factor. Conservatively assume 0

Bar	db (in)	cb (in)	(cb+Ktr) / db	ld (in)	$L_{lap.req}$ (in)	$L_{lap.prov}$ (in)	lap.prov > lap.req?
#6	0.750	4.25	2.50	25.6	33.3	Unknown	Presumably OK

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		DATE	10 May 2016
		BY	BLP
SUBJECT	Ringwall Calculations	CHECKED BY	PHF 2016.05.26

MINIMUM STEEL TO RESIST SHRINKAGE AND TEMPERATURE EFFECTS
ref. ACI 318 Ch. 14.3

Horizontal Rebar

ρ_t =	0.0025	Minimum ratio of horizontal reinforcement area to gross concrete area per PIP 5.6.6.1
Ag =	7,776	Gross area of concrete (in^2)
As,req'd =	19.44	Minimum required horizontal wall steel (in^2)
As =	22.61	Horizontal steel present (in^2)
	OK! Sufficient horizontal rebar for shrinkage and temperature effects	

Vertical Rebar

ρ_l =	0.0015	Minimum ratio of vertical reinforcement area to gross concrete area per PIP 5.6.6.1
Ag =	1,684	Gross area of concrete over 1 foot circumferential length (in^2)
As,req'd =	2.53	Minimum required vertical wall steel over 1 foot circumferential length (in^2)
As =	3.24	Vertical steel present in 1 foot circumferential length (in^2) (9 #7's @ 20" spacing)
	OK! Sufficient vertical rebar for shrinkage and temperature effects	

ANCHORAGE

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SHEET NO. ______
PROJECT NO. 167525.00 - ROSA
DATE 10 May 2016
BY BLP
CHECKED BY PHF 2016.05.26

CLIENT West Yost Associates
SUBJECT Anchorage Calculations

Design Basis

Specifications: AWWA D.100-11: Welded Carbon Steel Tanks for Water Storage
ACI 318-11

Tank Data

D	47.00	Nominal tank diameter (ft)
Ht	55.75	Total height of the tank shell (ft)
H	57.83	Maximum design liquid level (ft)
t	0.75	Thickness of bottom shell (in)

Seismic Demands

Ms	69,314,885	Total overturning moment (ft-lbs)
Vf	2,803,430	Total base shear (lbs)

Uplift Force on Anchors

P_S	78,667	Uplift force per anchor due to seismic (lbs)	*AWWA D100-11 Eq. 3-42*

Shear Force on Anchors

V_{NET}	0	Net shear demand at top of foundation not resisted by friction (lbs), per AWWA 3.8.7.1
V_s	0	Shear force per anchor due to seismic (lbs)

Check Anchors for Tension and Shear Due To Seismic Forces

Nab	72	Number of anchor bolts	
db	2.50	Bolt diameter (in)	*Satisfies AWWA recommended minimum diameter of 1 inch*
Ab	4.91	Bolt gross area (in^2)	
	A36	Bolt material	
Fnt	28,800	Bolt Allowable tensile strength (psi), per AWWA 3.8.4.3 and 3.3.3.2 (for seismic loads only)	
ts	16,026	Tensile stress per anchor (psi)	
vs	0	Shear stress per anchor (psi)	
D/C	0.56	Equal to (ts + vs)/Fnt per 3.3.2	

OK. Anchors adequate for tension/shear due to seismic

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DATE 10 May 2016
BY BLP
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CLIENT West Yost Associates
SUBJECT Anchorage Calculations

Anchor Layout

D_{ac}	47.79	Diameter of anchor circle (ft)
N_{ab}	72	Number of anchors
s	25.02	C-C spacing of anchors (in)
s_{max}	120	Maximum anchor spacing per AWWA D.100-11 3.8.1.2 (in)

Anchor spacing ok.

h_{ef}	40.00	Anchor embedment (in)	
h_{ef}'	40.00	Adjusted effective anchor embedment (in)	*ACI 318-11 D.5.2.3*
bw	12	Width of ringwall (ft)	

Edge Distances			Ca < $1.5h_{ef}$?	Ca_{ef} (in)
Ca1o	40.00	Edge distance to outside edge of ringwall (in)	Y	40.00
Ca1i	104.00	Edge distance to inside edge of ringwall (in)	N	60.00
Ca2	12.51	Half distance between anchors (in)	Y	12.51

Concrete Breakout Strength In Tension Per D.5.2

f'c	3,000	Concrete compressive strength (psi)	
A_{NC}	2,502	Projected concrete breakout area (in^2)	
A_{NCo}	14,400	Full prism concrete breakout area (in^2)	*ACI 318-11 (D-5)*
kc	24	For cast-in anchor	*ACI 318-11 D.5.2.2*
λa	1.00	For normal-weight concrete	*ACI 318-11 D.3.6*
ψ_{edN}	0.90	Edge distance adjustment factor	*ACI 318-11 Eq. D-9, D-10*
ψ_{cN}	1.25	For cast-in anchor	*ACI 318-11 D.5.2.6*
ψ_{cpN}	1.00	For cast-in anchor	*ACI 318-11 D.5.2.7*

Note: No need to include $\psi_{ec,N}$ per (D-8) because we are looking at a single anchor bolt.

Nb	332,554	Basic conc. breakout strength of single anchor (lbs)	*ACI 318-11 Eq. D-6*
Ncb	65,013	Nominal conc. breakout strength of single anchor (lbs)	*ACI 318-11 Eq. D-3*
ϕ	0.70	Strength reduction factor	*ACI 318-11 D.4.3 c*
ϕNcb	45,509	Conc. breakout strength (lbs)	
P_S	78,667	Demand (lbs)	
D/C	1.73		

Concrete no good for concrete breakout

Tension Strength of Supplemental Reinforcement for Conc. Breakout Per D.5.2.9

Bar	Size	Ab (in^2)	Fy (ksi)	Ldh,req (in)	Ld,top (in)	Ld,bot (in)	N_N (lbs)
1	#7	0.60	60	20	23.31	24.69	36,000
2	#7	0.60	60	20	30.31	17.69	31,838
Development Length Table (Ref. ACI 12.2.3)						Σ =	67837.5

ϕ	0.75	Strength reduction factor	*ACI 318-11 D.5.2.9*
ϕN_N	50,878	Design strength of supplemental reinforcement (lbs)	
P_S	78,667	Demand (lbs)	
D/C	1.55		

Supplemental steel no good for concrete breakout

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		BY	BLP
		CHECKED BY	PHF 2016.05.26

Pull-out Strength of Anchor Bolts Per D.5.3

f`c	3,000	Concrete compressive strength (psi)	
db	2.50	Bolt diameter (in)	
A_{brg}	8.17	Bearing area of anchor head (in^2)	*Refer to AISC DG1 Table 3.2*
N_p	196,080	Pullout strength of single headed bolt (lbs)	
ϕ	0.70	Strength reduction factor	*ACI 318-11 D.4.3 c*
ϕN_p	137,256	Design pullout strength of single anchor bolt (lbs)	
P_S	78,667	Demand (lbs)	
D/C	0.57		
	Anchors OK for Pull-out		

Side-Face Blowout Strength of Anchor In Tension Per D.5.4

*No need to check side-face blowout since hef < 2.5*min(ca1o,ca1i) per ACI 318-11 D.5.4.1.*

ANCHOR CHAIRS

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SHEET NO.
PROJECT NO. 167525.00 - ROSA
DATE 10 May 2016
BY BLP
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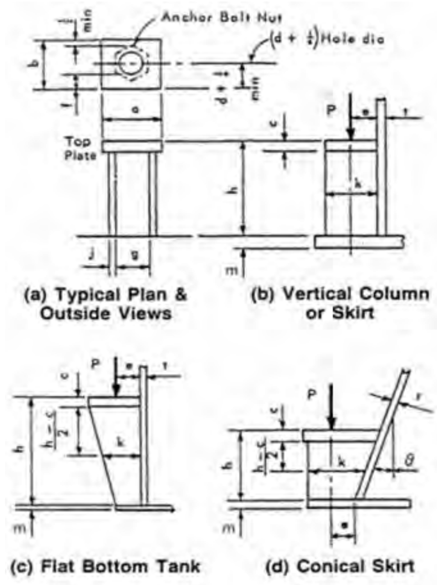
CLIENT West Yost Associates
SUBJECT Anchorage Chair Calculations

Design Basis
Specifications: AISI T-192 Vol.2, Part VII



(a) Typical Plan & Outside Views (b) Vertical Column or Skirt
(c) Flat Bottom Tank (d) Conical Skirt

Anchor Properties

dbolt	2.50	Anchor bolt diameter (in)
Ab	4.91	Bolt gross area (in^2)
Fnt	28800	Bolt Allowable tensile strength (psi), per AWWA 3.8.4.3 and 3.3.3.2 (for seismic loads only)
Ta	141372	Allowable bolt load (lbs)

Chair Steel Properties

Fy	36000	Yield strength of chair steel (ksi)
	2	Material Class per AWWA D.100-11 Table 4

Anchor Chair Seismic Demand

1.5 * Ps	118.00	1.5 x Anchor load (kips)
	141.37	Bolt capacity (kips)
P	118.00	Chair design load (kips) (minimum of loads above per AISI T-192 pg. 49)

Size Top Plate

g 8 5/8 Distance between vertical plates (in)
g, pref = 3.500 *g,pref = dbolt+1* *practical geometric limit, AISI T-192, pg.49*
g = 8.625

f 2 3/4 Distance from outside of top plate to the edge of the hole (in)
fmin,1 = 1.375 *AISI T-192, pg. 49*
fmin,2 = 1.5 *AISI T-192, Figure 7-1(a)*
f = 2.75
Bolt edge distance OK

c 3 1/4 Top plate thickness (in)
c,req = 2.53 *c,req = SQRT(P*(0.375*g-0.22*dbolt)/(Sa*f))*
AISI T-192 Eq. 7-2
c = 3.25
Top plate thickness OK

Sa 18.00 Allowable stress in the top plate for bending (ksi) *AWWA D100-11, Table 7*

Stp 10.91 Bending stress on top plate (ksi) *AISI T-192 Eq. 7-1*

The top plate is OK

R	282.00	Nominal shell radius (in)
t	3/4	Bottom shell plate thickness (in)
e	4	Anchor bolt eccentricity (in)

emin = 2.787 *AISI T-192 pg. 49*
e = 4
Eccentricity of bolt OK

a 13 5/8 Top plate width along shell (in)
amin = 8.25
a = 13.625
Width of top plate OK

m 1/4 Bottom or base plate thickness (in)

Sah	25.00	Maximum recommended allowable shell stress (ksi) *= 25 ksi per API 650 (Note E6.2.3c)*	*AISI T-192 pg. 50*
Z	0.997	Reduction Factor	*AISI T-192 Eq. 7-4*
Sh	8.67	Stress on Shell near top plate (ksi)	*AISI T-192 Eq. 7-3*

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		BY	BLP
		CHECKED BY	PHF 2016.05.26

Chair Height Requirements

Proportioning Requirements:

Bottom plate thinner than 3/8" ? YES

Design for earthquake or wind with speed over 100 mph ? (enter YES/NO) YES

Then, h_{min} = 12.00 *AISI T-192 min recommended, pg. 50*

h_{max} = 40.88 $h_{max} = 3 * a$ *AISI T-192 max recommended, pg. 50*

h 36.00 Height of chair (in)

hreq = 15.22 *AISI T-192 Eq. 7-3 manipulated to solve for h.*

h = 36

Chair height OK

Size Vertical Plates

ktop	7.375	Width of vertical plate at top (in)
kbot	0.5	Width of vertical plate at bottom (in)
k	3 15/16	average plate width (in)
j	1.50	final thickness of the vertical plate (in)

j_{min} = 1.310 *AISI T-192 pg. 50*

j_{req} = 1 3/8

j = 1.5

Thickness of vertical plates OK

Size Vertical Plate to Shell Welds

W_v	1.38	vertical force in the welds (kip/in)	*AISI T-192 Eq. 7-5*
W_h	0.35	horizontal force in the welds (kip/in)	*AISI T-192 Eq. 7-6*
W	1.42	total force (kip/in)	*AISI T-192 Eq. 7-7*
Sa,w	13.60	maximum allowable stress in a fillet weld (ksi)	*AISI T-192, pg. 56 for E60 electrode*

$w1_{min}$ = 0.2500 *= W/(0.707*Sa,w)*

$w1_{max}$ = 0.6875 *= 1/16" less than MIN(shell thickness, vertical plate thickness)*

w1 = 0.313 Weld throat (in)

Weld thickness OK

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SUBJECT Anchorage Chair Calculations
CHECKED BY PHF 2016.05.26

Final Results

P - design load	118.00	kips
t - shell thickness at bottom course	0.7500	inch
m - bottom or base plate thickness	0.2500	inch

Anchor Bolt Chair Dimensions		
a - top plate width along shell	13 5/8	inch
b - top plate depth	4 1/4	inch
c - top-plate thickness	3 1/4	inch
dbolt - anchor bolt diameter	2 1/2	inch
e - anchor bolt eccentricity	4	inch
g - distance between vertical plates	8 5/8	inch
h - total chair height (w/ top plate)	36	inch
j - vertical plate thickness	1 1/2	inch
k - vertical plate width	3 15/16	inch
w1 - chair-tank shell welds	5/16	inch
w2 - chair-chair welds	5/16	inch

ROOF ANALYSIS

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CLIENT	West Yost Associates	SHEET NO.	
SUBJECT	Roof Analysis	PROJECT NO.	167525.00 - ROSA
		DATE	10 May 2016
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ref. Malhorta, "Earthquake Induced Sloshing in Tanks with Insufficient Freeboard" (2006)

Roof Rafter Properties

Rafter	W6x9	
n_{rafter}	22	Number of rafters
s_{rafter}	6.71	Circumferential spacing of rafters at tank perimeter (ft)
θ_{rafter}	4.764	Slope of rafter (deg)
t_{plate}	0.1750	Thickness of roof plate (in)

Vertical Loads on Roof

	Type	Area Load (psf)	Line Load (plf)	Triangular Load (see Note 1) (plf)
Rafter S.W.	D	-	9.00	-
Roof plate S.W.	D	7.15	-	47.96
Live Load	L	15.00	-	100.67

Note 1: Values under "triangular load" represent the peak of the triangle. Load varies linearly to zero at top of the roof.

Wave Height

Sac =	0.299	Spectral acceleration of convective wave (g)
dwave =	8.86	Sloshing wave height above Fill Height (ft) (ref. ASCE 7-10 (Eq. 15.7-13))

Wave Load on Roof

h_{wave}	7.69	Height of unrestricted wave above freeboard (ft)
p_{wave}	479.9	Pressure exerted on roof by wave at shell (psf)

Calculate Wetted Width of Roof Per Malhorta 2006

df / df_reqd	0.132	Ratio of available freeboard / required freeboard. Note our "df_reqd" is the same as Malhorta's "d"
hr	1.07	Height of roof above base of roof (ft)
hr / df_reqd	0.12	Ratio of roof height to required freeboard
L_{r_wet} / R	1.1	Ratio of wetted width to tank radius. Taken from Fig. 6 Malhorta 2006
L_{r_wet}	25.85	Wet roof width (ft), per Malhorta 2006. Equal to "xf" in Malhorta.
Lrafter	18.75	Length of rafter measured along Lr_wet to top of roof (ft)
w_1	3221	Peak of triangular load at end of rafter (plf)
w_2	885	Load at top of rafter (plf)

Use the graph below to determine wetted width of roof, Lr_wet (ref. Malhorta 2006)

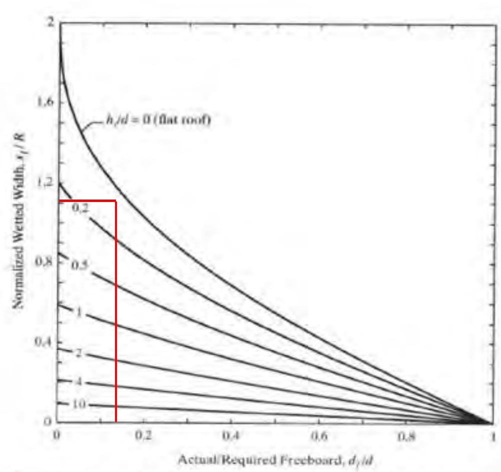
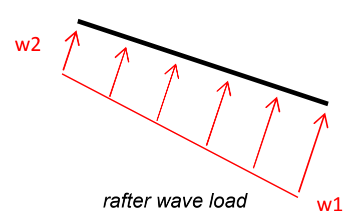


Fig. 6: Cone roof tank. Normalized wetted width of tank roof x_f/R as a function of actual/required freeboard d_f/d and normalized roof height h_r/d



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		BY	BLP
		CHECKED BY	

Bending of Roof Plate

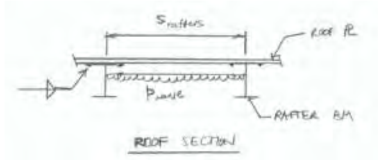
Fy	36000	Yield strength of roof plate (psi)
ΩMn	110	Allowable capacity (lbs*in/in)
Mr	268	Demand (lbs*in/in). Equal to 1/12*w*L^2 b/c roof PL is a continuous beam in circumferential direction.
D/C	2.44	

No Good, roof plate inadequate for bending

Strength of Rafter to Roof Weld

F_{EXX}	70	(ksi)
t_{weld}	0.1875	Fillet throat (in.)
	2	Number of welds (2 for double sided, 1 for single sided)
ΩRn	5.57	Strength of weld (kip/in)
Rw	0.13	Demand (kip/in)
D/C	0.02	

OK, roof plate to rafter weld adequate



Rafter Beam Bending

ΩMn	11.19	Capacity (kip*ft)
Mr	89.1	Demand (kip*ft)
D/C	7.96	

No Good, inadequate bending strength

Rafter Beam Shear

ΩVn	12.97	Capacity (kip)
Vr	22.36	Demand (kip)
D/C	1.72	

No Good, inadequate shear strength

Rafter Beam Demands

M_DL	2.50	kip*ft	V_DL	0.53	kip
M_LL	4.42	kip*ft	V_LL	0.94	kip
M_Wave	-92	kip*ft	V_Wave	-22.90	kip

COMBOS:

DL + LL	6.93	kip*ft	DL + LL	1.48	kip
DL + Wave	89.1	kip*ft	DL + Wave	22.36	kip
Max	89.1	kip*ft	Max	22.36	kip

Rafter Channel Bolted Connection to Shell (Bolt Shear)

ΩRn	8.28	Capacity (kip). (2) 5/8" A307 bolts, single shear. Ref. AISC Table 7-1
R	22.36	Demand (kip). Assume equal to shear in rafter beam
D/C	2.70	

No Good, inadequate shear strength

MITIGATION CONCEPTS

SGH has identified several mitigation concepts to meet current code requirements. Note that concepts involving strengthening or replacement of specific tank elements do not include the design of the upgrade for these elements as this was not included in our scope. For this tank, we investigated the following mitigation concepts:

Mitigation Concept 1

- Reduce Fill Height until all tank checks pass

Mitigation Concept 2

- Strengthen column as needed (e.g. larger section, bracing, etc.)
- Reduce fill height until all tank checks pass other than the column

Mitigation Concept 3

- Strengthen shell course #4 as needed (e.g. thicker shell, strong-backs, etc.)
- Strengthen column as needed
- Reduce fill height until all tank checks pass other than shell course #4 and the column

Mitigation Concept 4

- Strengthen shell course #3, #4, and #5 as needed (e.g. thicker shell, strong-backs, etc.)
- Strengthen column as needed
- Reduce fill height until all tank checks pass other than shell courses #3 – 5 and the column

All mitigation concepts above also address freeboard, roof, ringwall, and anchorage issues identified in our analysis.

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SUBJECT Mitigation Concept 1

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PROJECT NO. 167525.00 - ROSA

DATE 26 May 2016

BY PHF

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Note: All values are D/C ratios U.O.N.

Tank Height, Ht (ft)	55.75
Fill Height, H (ft)	13.00
Importance Factor	1.50
Anchorage	Anchored
Eweld	1.00

max TCL (ft) = 57.83

Course	Thickness (in)	Material	Static Hoop Tension	Static Compression	Min. Thickness?	Seismic Hoop Tension	Seismic Compression
1	0.750	A36	0.11	0.02	Adequate	0.04	0.04
2	0.500	A36	0.06	0.04	Adequate	0.04	0.09
3	0.366	A36	0.00	0.05	Adequate	0.00	0.14
4	0.250	A572-70	0.00	0.09	Adequate	0.00	0.23
5	0.250	A36	0.00	0.07	Adequate	0.00	0.16
6	0.250	A36	0.00	0.04	Adequate	0.00	0.08

Freeboard Required (ft)	7.77	
Available Freeboard (ft)	46.00	*OK! Adequate Freeboard*

Roof

Column - Static Compression	0.25
Column - Seismic P & M	0.96
Bending of Roof Plate	0.00
Strength of Rafter to Roof Weld	0.00
Rafter Beam Bending	0.62
Rafter Beam Shear	0.11
Rafter Channel Bolted Connx	0.18

Foundation

Soil Bearing (Gravity)	0.23	
Soil Bearing (Gravity + Seismic)	0.22	
Bearing Pressure at Uplift End (psf)	951	*OK! Adequate uplift resistance*

Positive Bending of Ringwall	0.10
Negative Bending of Ringwall	0.07
Hoop Steel (Positive Bending)	0.05
Hoop Steel (Negative Bending)	0.05

Anchorage

Tank Sliding Resistance	0.46	No Shear Demand on Anchors
Anchor Steel, Tension & Shear	0.02	
Concrete Breakout in Tension	0.05	
Conc. Breakout in Tension w/ Reinf.	0.04	
Anchor Pull-out	0.02	
Side Face Blowout in Tension	0.01	

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SHEET NO.	
PROJECT NO.	167525.00 - ROSA
DATE	26 May 2016
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CLIENT West Yost Associates

SUBJECT Mitigation Concept 2

Note: All values are D/C ratios U.O.N.

Tank Height, Ht (ft)	55.75
Fill Height, H (ft)	34.00
Importance Factor	1.50
Anchorage	Anchored
Eweld	1.00

max TCL (ft) = 57.83

Course	Thickness (in)	Material	Static Hoop Tension	Static Compression	Min. Thickness?	Seismic Hoop Tension	Seismic Compression
1	0.750	A36	0.29	0.02	Adequate	0.09	0.17
2	0.500	A36	0.33	0.04	Adequate	0.12	0.38
3	0.366	A36	0.28	0.05	Adequate	0.12	0.59
4	0.250	A572-70	0.13	0.09	Adequate	0.06	0.97
5	0.250	A36	0.00	0.07	Adequate	0.00	0.63
6	0.250	A36	0.00	0.04	Adequate	0.00	0.29

Freeboard Required (ft)	8.82	
Available Freeboard (ft)	25.00	*OK! Adequate Freeboard*

Roof

Column - Static Compression	0.25	
~~Column - Seismic P & M~~	~~1.32~~	Ignore if strengthen column
Bending of Roof Plate	0.00	
Strength of Rafter to Roof Weld	0.00	
Rafter Beam Bending	0.62	
Rafter Beam Shear	0.11	
Rafter Channel Bolted Connx	0.18	

Foundation

Soil Bearing (Gravity)	0.38	
Soil Bearing (Gravity + Seismic)	0.45	
Bearing Pressure at Uplift End (psf)	826	*OK! Adequate uplift resistance*
Positive Bending of Ringwall	0.33	
Negative Bending of Ringwall	0.07	
Hoop Steel (Positive Bending)	0.14	
Hoop Steel (Negative Bending)	0.11	

Anchorage

Tank Sliding Resistance	0.71	No Shear Demand on Anchors
Anchor Steel, Tension & Shear	0.15	
Concrete Breakout in Tension	0.47	
Conc. Breakout in Tension w/ Reinf.	0.42	
Anchor Pull-out	0.16	
Side Face Blowout in Tension	0.06	

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

SHEET NO.	
PROJECT NO.	167525.00 - ROSA
DATE	26 May 2016
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CLIENT West Yost Associates

SUBJECT Mitigation Concept 3

Note: All values are D/C ratios U.O.N.

Tank Height, Ht (ft)	55.75
Fill Height, H (ft)	42.00
Importance Factor	1.50
Anchorage	Anchored
Eweld	1.00

max TCL (ft) = 57.83

Course	Thickness (in)	Material	Static Hoop Tension	Static Compression	Min. Thickness?	Seismic Hoop Tension	Seismic Compression
1	0.750	A36	0.35	0.02	Adequate	0.10	0.27
2	0.500	A36	0.43	0.04	Adequate	0.14	0.60
3	0.366	A36	0.42	0.05	Adequate	0.16	0.94
4	0.250	A572-70	0.30	0.09	Adequate	0.13	~~1.55~~
5	0.250	A36	0.10	0.07	Adequate	0.07	1.00
6	0.250	A36	0.00	0.04	Adequate	0.00	0.45

Ignore if strengthen shell course 4

Freeboard Required (ft)	8.85	
Available Freeboard (ft)	17.00	*OK! Adequate Freeboard*

Roof

Column - Static Compression	0.25	
~~Column - Seismic P & M~~	~~1.33~~	Ignore if strengthen column
Bending of Roof Plate	0.00	
Strength of Rafter to Roof Weld	0.00	
Rafter Beam Bending	0.62	
Rafter Beam Shear	0.11	
Rafter Channel Bolted Connx	0.18	

Foundation

Soil Bearing (Gravity)	0.43	
Soil Bearing (Gravity + Seismic)	0.58	
Bearing Pressure at Uplift End (psf)	451	*OK! Adequate uplift resistance*
Positive Bending of Ringwall	0.48	
Negative Bending of Ringwall	0.24	
Hoop Steel (Positive Bending)	0.21	
Hoop Steel (Negative Bending)	0.13	

Anchorage

Tank Sliding Resistance	0.76	No Shear Demand on Anchors
Anchor Steel, Tension & Shear	0.26	
Concrete Breakout in Tension	0.80	
Conc. Breakout in Tension w/ Reinf.	0.72	
Anchor Pull-out	0.27	
Side Face Blowout in Tension	0.10	

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SHEET NO.
PROJECT NO. 167525.00 - ROSA
DATE 26 May 2016
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CLIENT West Yost Associates
SUBJECT Mitigation Concept 4

Note: All values are D/C ratios U.O.N.

Tank Height, Ht (ft)	55.75
Fill Height, H (ft)	45.00
Importance Factor	1.50
Anchorage	Anchored
Eweld	1.00

max TCL (ft) = 57.83

Course	Thickness (in)	Material	Static Hoop Tension	Static Compression	Min. Thickness?	Seismic Hoop Tension	Seismic Compression
1	0.750	A36	0.38	0.02	Adequate	0.10	0.31
2	0.500	A36	0.47	0.04	Adequate	0.14	0.70
3	0.366	A36	0.47	0.05	Adequate	0.17	~~1.10~~
4	0.250	A572-70	0.36	0.09	Adequate	0.15	~~1.81~~
5	0.250	A36	0.18	0.07	Adequate	0.08	~~1.16~~
6	0.250	A36	0.00	0.04	Adequate	0.00	0.53

Ignore if strengthen shell courses 3, 4, and 5

Freeboard Required (ft)	8.85	
Available Freeboard (ft)	14.00	*OK! Adequate Freeboard*

Roof

Column - Static Compression	0.25	
~~Column - Seismic P & M~~	~~1.33~~	Ignore if strengthen column
Bending of Roof Plate	0.00	
Strength of Rafter to Roof Weld	0.00	
Rafter Beam Bending	0.62	
Rafter Beam Shear	0.11	
Rafter Channel Bolted Connx	0.18	

Foundation

Soil Bearing (Gravity)	0.45	
Soil Bearing (Gravity + Seismic)	0.64	
Bearing Pressure at Uplift End (psf)	260	*OK! Adequate uplift resistance*
Positive Bending of Ringwall	0.54	
Negative Bending of Ringwall	0.40	
Hoop Steel (Positive Bending)	0.24	
Hoop Steel (Negative Bending)	0.14	

Anchorage

Tank Sliding Resistance	0.77	No Shear Demand on Anchors
Anchor Steel, Tension & Shear	0.31	
Concrete Breakout in Tension	0.95	
Conc. Breakout in Tension w/ Reinf.	0.85	
Anchor Pull-out	0.31	
Side Face Blowout in Tension	0.12	

Appendix B

Structural Calculations R-16

Attachment 2

Structural Calculations – Tank R-16

City of Santa Rosa Water Tanks Seismic Evaluation
Santa Rosa, CA

07 July 2017

SGH Project 167525

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Engineering of Structures and Building Enclosures

Attachment 2

PREPARED FOR:

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Davis, CA

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Attachment 2

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CLIENT	West Yost Associates	SHEET NO.	i
		PROJECT NO.	167525.00 - ROSA
		DATE	16 June 2017
		BY	BLP
SUBJECT	Structural Calculations – Tank R-16	CHECKED BY	

INDEX TO CALCULATIONS:

CALCULATION INDEX AND PROJECT DESCRIPTION i – ii

SUMMARY S1

SUMMARY SHEET

INPUT PARAMETERS P1 – P2

TANK DATA & SEISMIC PARAMETERS

WEIGHT CALCULATIONS

AWWA D.100-11 TANK CALCULATIONS T1 – T5

SHELL STRESS (GRAVITY ONLY)

COLUMN (GRAVITY ONLY)

SHELL HYDROSTATIC HOOP TENSION

SHELL STRESS (GRAVITY + SEISMIC)

COLUMN (GRAVITY + SEISMIC)

TANK SLIDING

RINGWALL ANALYSIS

(NOT EVALUATED)

ANCHORAGE

(NOT EVALUATED)

ANCHOR CHAIRS

(NOT EVALUATED)

ROOF ANALYSIS

(NOT EVALUATED)

MITIGATION CONCEPTS MC1

MC 1 – REDUCE FILL HEIGHT

PROJECT DESCRIPTION:

West Yost Associates, Inc. (West Yost) has been contracted by the City of Santa Rosa to perform evaluations of the existing water tanks and tank sites. West Yost has subcontracted SGH to perform the structural analysis of the existing tanks, located at:

- R-17: Newgate Court, Santa Rosa, CA
- R-16: Fountain Grove Parkway, Santa Rosa, CA
- R-9A: Annadel Heights Drive, Santa Rosa, CA

The primary purpose of the structural evaluations is to determine whether the tanks meet current code requirements that would be applicable for the design of a new tank and to provide mitigation concepts to address structural deficiencies identified in the analysis.

SUMMARY

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

SHEET NO.
PROJECT NO. 167525.00 - ROSA
DATE 20 July 2016
BY BLP
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CLIENT West Yost Associates
SUBJECT Summary

Note: All values are D/C ratios U.O.N.

Tank Height, Ht (ft)	35.00
Fill Height, H (ft)	34.00
Importance Factor	1.50
Anchorage	Anchored
Eweld	0.85

max TCL (ft) = 34.00

Course	Thickness (in)	Material	Static Hoop Tension	Static Compression	Min. Thickness?	Seismic Hoop Tension	Seismic Compression
1	0.505	A36	0.38	0.02	Adequate	0.10	0.31
2	0.250	A36	0.58	0.06	Adequate	0.19	1.14
3	0.245	A36	0.38	0.05	Adequate	0.16	0.80
4	0.240	A36	0.18	0.04	Adequate	0.09	0.43

Freeboard Required (ft)	7.61	
Available Freeboard (ft)	1.00	*Inadequate freeboard, calculate sloshing loads on roof*

Roof
Column - Static Compression
Column - Seismic P & M
Bending of Roof Plate
Strength of Rafter to Roof Weld
Rafter Beam Bending
Rafter Beam Shear
Rafter Channel Bolted Connx

Foundation
Soil Bearing (Gravity)
Soil Bearing (Gravity + Seismic)
Bearing Pressure at Uplift End (psf)

Positive Bending of Ringwall
Negative Bending of Ringwall
Hoop Steel (Positive Bending)
Hoop Steel (Negative Bending)

Anchorage
Tank Sliding Resistance
Anchor Steel, Tension & Shear
Concrete Breakout in Tension
Conc. Breakout in Tension w/ Reinf.
Anchor Pull-out
Side Face Blowout in Tension

} Not evaluated due to insufficient data

INPUT PARAMETERS

SIMPSON GUMPERTZ & HEGER
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SHEET NO.	
PROJECT NO.	167525.00 - ROSA
DATE	20 July 2016
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CLIENT West Yost Associates

SUBJECT Welded Steel Tank Properties & Seismic Coefficients

Tank & Foundation Properties

Except where noted, tank properties were obtained from the placard posted on the side of the tank. Shell thicknesses were obtained from field measurements performed by JDH Corrions Consultants.

NAME	R-16	Specific name of this tank
D	36.000	Nominal tank diameter, measured to the inside of the wall (ft)
Ht	35.000	Total shell height excluding knuckle (ft) as defined in AWWA D.100-11 13.5.2
H	34.000	Fill Height (ft) (note: Maximum fill height is aka MOL and TCL)
t	0.505	Thickness of bottom course (in)
tb	0.240	Thickness of bottom plate (in)
G	1.000	Specific gravity of tank contents
Roof	Steel Rafters w/ Roof Plate	Roof type
Anchorage	Anchored	Self-anchored or Anchored
Fnd Type	Ringwall	
CA =	0.0000	Corrosion Allowance (in)

Material Properties Of Tank

Fty	36,000	Minimum yield strength of bottom course (psi)
Fby	36,000	Minimum yield strength of bottom plate (psi)
E_{mod}	29,000,000	Elastic modulus (psi)
Weld Type	Single-groove butt joint with suitable backing strip or equivalent means to ensure complete joint penetration	
E_{weld}	0.85	Weld Joint Efficiency in Tension (ref. AWWA D100-11 Table 15)

Seismic Parameters Per ASCE 7-10 Spectra

Seismic parameters obtained from Group Delta Consultants.

S_s	2.170	MCE spectral response acceleration at short periods
F_a	1.000	Site coefficient
S_{MS}	2.170	Adjusted spectral response acceleration for short periods
S_1	0.895	MCE spectral response acceleration at 1.0 sec period
F_v	1.300	Site coefficient
S_{M1}	1.164	Adjusted spectral response acceleration at 1.0 sec period
S_{DS}	1.447	Design spectral response acceleration at short periods
S_{D1}	0.776	Design spectral response acceleration at 1.0 sec period
Ts	0.54	=Sd1/Sds (s)
T_L	8	Long-period transition period (s)
I_E	1.50	Seismic Importance Factor (Risk Cat. IV - ASCE 7-10 / Seismic Use Group III - AWWA D100-11)

General Notes

1. Tank nomenclature, equation and section references are from AWWA D100-11 unless otherwise noted.
2. [shaded cell] indicates a cell with a manually inputed value.

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SHEET NO. ______
PROJECT NO. 167525.00 - ROSA
DATE 20 July 20, 2016
CLIENT West Yost Associates
BY BLP
SUBJECT Weight Calculations for Tank Shell Courses
CHECKED BY SCC

Shell Data

D	36.000	Nominal tank diameter (ft)
Ht	35.000	Total tank height (ft)
t	0.505	Thickness of bottom course (in)

Shell Geometry and Weight
Shell course thicknesses were obtained from field measurements performed by JDH Corrions Consultants.

Course	Yield Strength (psi)	(1) Elevation of Top of Course (ft.)	(2) Course Height (ft.)	(3) Plate Thickness (in)	(4) CG Elevation (ft.)	(5) Cross Section Area (ft^2)	(6) Total Course Weight (lbs)	(6)*(4) Wt*CG (lbs*ft)	Total weight of courses (lbs)
1	36,000	8.750	8.750	0.505	4.375	4.77	20,430	8.94E+04	50,148
2	36,000	17.500	8.750	0.250	13.125	2.36	10,108	1.33E+05	29,717
3	36,000	26.250	8.750	0.245	21.875	2.31	9,906	2.17E+05	19,609
4	36,000	35.000	8.750	0.240	30.625	2.26	9,703	2.97E+05	9,703
5						0.00			0
6						0.00			0
						0.00			0
						0.00			0
						Σ =	50,148	7.36E+05	

Roof Weight

Steel Rafter Roof

Wr,x	20,172	Total roof weight (lbs)

Overall Weights

Ws	50,148	Total weight of tank shell and all apperturences (lbs)
Wr	20,172	Total weight of the tank roof (lbs)
	75%	% of roof weight supported by shell wall (= 0 for a floating roof)
Wrs	15,129	Total weight of the tank roof supported by shell
Xs	14.7	Centroid distance from bottom of tank (ft)

AWWA D.100-11 TANK CALCULATIONS

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

CLIENT	West Yost Associates	SHEET NO.	
SUBJECT	AWWA D.100-11 Calculations	PROJECT NO.	167525.00 - ROSA
		DATE	20 July 2016
		BY	BLP
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Tank Data

D	36.000	Nominal tank diameter (ft)
Ht	35.000	Total height of the tank shell (ft)
H	34.000	Top capacity limit (ft)
G	1.000	Specific gravity of tank content
t	0.505	Thickness of bottom course (in)
tb	0.240	Thickness of bottom annulus (in)
Fty	36,000	Min. yield strength of all shell courses (psi)
Fby	36,000	Min. yield strength of bottom annulus (psi)

Tank Weights

Ws	50,148	Total weight of tank shell and all apperturences (lbs)
Xs	14.7	Height from bottom of tank shell to shell c.g. (ft)
Wr	20,172	Total weight of the tank roof (lbs)
Wrs	15,129	Total weight of the tank roof supported by tank shell in the vertical direction (lbs)

Section 3.4 - Allowable Compressive Stresses for Columns, Struts, and Shells

3.4.3 Shell Compression

Note: Method 1 is used to calculate shell compression F_L.

Note: For Material Class, refer to Table 4.

K = 1.00 AISC effective column length factor

Course	Thickness (in)	R (in)	t/R	Fy (psi)	Material Class	(t/R)c	FL (psi)	C`c	r (in)	L (in)
1	0.505	216.505	0.0023325	36,000	2	0.0035372	5,192	234.78	153.00	105
2	0.25	216.25	0.0011561	36,000	2	0.0035372	2,158	364.16	152.87	105
3	0.245	216.245	0.001133	36,000	2	0.0035372	2,110	368.31	152.87	105
4	0.24	216.24	0.0011099	36,000	2	0.0035372	2,062	372.57	152.86	105

Course	KL/r	Kϕ	Fb (psi)	capacity Fa (psi)	demand fa (psi)	D/C
1	0.69	1.000	5,192	5,192	95	0.02
2	0.69	1.000	2,158	2,158	132	0.06
3	0.69	1.000	2,110	2,110	104	0.05
4	0.69	1.000	2,062	2,062	76	0.04

Section 3.6 - Roofs

See "Roof Analysis" for checks not included herein (e.g. check of roof and roof components).

3.6.1.3 Column Compression

Not evaluated due to insufficient data.

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SUBJECT AWWA D.100-11 Calculations

Section 3.7 - Cylindrical Shell Plates (Hoop Tension)

D =	36.00	Nominal tank diameter (ft)
G =	1.00	Product specific gravity
E_{weld} =	0.85	Weld Joint efficiency in Tension (ref. Table 15)

Course	Thickness (in)	Course Height (in)	Elevation to bottom of course (in)	hp (ft)	s (psi) (ref. Table 34)	Joint Efficiency (ref. Table 15)	Req'd design shell plate thickness (in)	Shell thickness - CA (in)	D/C	Sufficient thickness?
1	0.505	105	0	34.000	19,330	0.85	0.1937	0.505	0.38	Yes
2	0.25	105	105	25.250	19,330	0.85	0.1438	0.25	0.58	Yes
3	0.245	105	210	16.500	19,330	0.85	0.0940	0.245	0.38	Yes
4	0.24	105	315	7.750	19,330	0.85	0.0441	0.24	0.18	Yes

Note: Maximum design tensile stress, s, is determined per Section 14, Table 34.

Section 3.8 - Anchorage
See "Anchorage Calculations" for check of tank anchors and anchor chairs.

3.8.9 - Design Loads

Ms =	12,813,531	Design seismic overturning moment at the bottom of the shell (ft-lbs)
Nab =	28	Number of anchors
	4.12	Radial distance between anchors (ft)
eAB =	0.38	Anchor bolt offset from tank inner wall (ft)
Dac =	36.75	Diameter of anchor circle (ft)
W` =	65,277	Dead weight of the structure (corroded condition) available to resist uplift (lbs)
Ps =	47,666	Design uplift force per anchor due to seismic (lbs)

Section 3.10 - Minimum Thickness and Size

Course	Thickness (in)	In Contact with Water?	Required Thickness (in)	Adequacy Check
1	0.505	Yes	0.1875	*Adequate*
2	0.25	Yes	0.1875	*Adequate*
3	0.245	Yes	0.1875	*Adequate*
4	0.24	Yes	0.1875	*Adequate*

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Section 13.2 - Design EQ Ground Motion

13.2.6 - Response Modification Factors (ref. Table 28)

Ri =	3.00	
R_c =	1.50	

13.2.7 - Design Response Spectrum

Sai =	1.45	(g)
Sac =	0.34	(g)

13.2.9.2 - Horizontal Design Accelerations for Ground-Supported Tanks

Ai =	0.517	(g)
Ac =	0.240	(g)

Section 13.5 - Ground-Support Flat Bottom Tanks

13.5.1 - Natural Periods

Tc =	3.47	First mode sloshing wave period (s)
Ti =	0.00	Natural period of the structure (s)

13.5.2 - Design Overturning Moment at the Bottom of the Shell

Wt =	2,159,136	Total weight of the Tank Contents (lbs) (13-27)
Wi =	1,660,757	Effective impulsive weight (lbs)
Wc =	524,788	Effective convective weight (lbs)
Xi =	13.62	Height from bottom of shell to centroid of the lateral seismic force applied to Wi (ft)
Xc =	24.79	Height from bottom of shell to centroid of the lateral seismic force applied to Wc (ft)
Ms =	12,813,531	Design overturning moment at the bottom of the shell (ft-lbs)

13.5.3 - Design Shear and Overturning Moment at the Top of the Foundation

Dbp =	37.24	Diameter of bottom plate (ft)
tbp =	0.24	Thickness of bottom plate (in)
Wf =	10,674	Total weight of tank bottom (lbs)
Vf =	908,656	Design shear at the top of the foundation due to horizontal design acceleration (lbs)

Fnd Type =	Ringwall	
Ximf =	19.16	Height from shell bot. to centroid of Wi adjusted to incl. the effects of varying bottom pressures (ft)
Xcmf =	25.36	Height from shell bot. to centroid of Wc adjusted to incl. the effects of varying bottom pressures (ft)
Mmf =	12,813,531	Design overturning moment at the top of the foundation (ft-lbs)

13.5.4.1 - Resistance to Overturning
Tank has mechanical anchorage to resist overturning

13.5.4.1.2 - Bottom Annulus Width
Note: If tank is mechanically anchored, the minimum required width, L, does not apply

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13.5.4.2 - Shell Stresses

wrs =	133.8	Roof load acting on shell (plf)
wt =	577	Weight of tank shell, apperturances, and portion of roof (plf) (equation 13-41)
CA =	0	Corrosion allowance (in)
ts =	0.51	Actual thickness of bottom shell course less the specified corrosion allowance, if any (in)
σc =	2,180	Longitudinal shell compression (psi), (Eq. 13-39, 13-40)
D =	36.00	Nominal tank diameter (ft)
R =	216.00	Nominal radius of the tank (in)
H =	34.00	MOL, or TCL, or Design Liquid Level (ft)
G =	1.00	Product specific gravity
E_{weld} =	0.85	Weld Joint efficiency in Tension (ref. Table 15)

Course	Thickness (in)	CA (in)	Thickness minus CA (in)	Course Height (in)	Elevation to bottom of tank (in)	s (psi)	Y (ft)
1	0.505	0	0.505	105	0	19,330	34.000
2	0.25	0	0.25	105	105	19,330	25.250
3	0.245	0	0.245	105	210	19,330	16.500
4	0.24	0	0.24	105	315	19,330	7.750

Note: "Y" is measured from top of design water level to bottom of course, because that is where course hoop stress is greatest.

	Hoop Tensile Forces & Stresses							
Course	Dynamic impulsive force, Ni (lbs/in)	Dynamic, convective force, Nc (lbs/in)	Static force, Nh (lbs/in)	Static Stress (psi)	Dynamic stress, σ_s (psi)	Total stress (psi)	Allowable stress (psi)	D/C
1	931	19	3,182	6,302	1,843	2,242	21,907	0.10
2	924	27	2,363	9,454	3,696	4,162	21,907	0.19
3	787	58	1,544	6,304	3,222	3,465	21,907	0.16
4	456	138	725	3,023	1,986	2,078	21,907	0.09

OK! Sufficient tensile hoop strength
Note: "dynamic" implies "seismic"
Note: Per 13.5.4.2.4, a 1/3 increase is allowed when calculating the Allowable Tensile Hoop Stress

	Longitudinal Compression Stress									
Course	Allow. Comp. stress σ_a (psi)	$\Delta\sigma_{cr}$ (psi)	Seismic allow. long. shell comp. stress, σ_e (psi)	h_i (ft)	X_{si} - h_i (ft)	1- h_i / H_t (ft)	Overturning Moment (lbs-ft)	w_{ti} (plf)	Longitudinal shell comp. stress, σ_c (psi)	D/C
1	5,192	-	6,921	0.00	14.67	1.00	12,813,531	577	2,180	0.31
2	2,158	-	2,877	8.75	13.01	0.75	9,610,148	397	3,289	1.14
3	2,110	-	2,813	17.50	8.70	0.50	6,406,765	307	2,253	0.80
4	2,062	-	2,749	26.25	4.38	0.25	3,203,383	220	1,175	0.43

Not OK! Tank compression strength insufficient for seismic forces
Note: σ_a is equal to F_L calculated per 3.4.3.1 (aka Method 1)
Note: Overturning Moment varies linearly from bottom of shell to top, per AWWA D100-11 A.13.5.4.2.2

13.5.4.3 - Vertical Design Acceleration

Av = 0.20 (g)

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		BY	BLP
SUBJECT	AWWA D.100-11 Calculations	CHECKED BY	SCC

13.5.4.4 - Freeboard & Sloshing Wave Height

Hroof =	35.00	Height to bottom of roof for purpose of calculating freeboard and sloshing loads (ft)
Sac =	0.34	Spectral acceleration of convective wave (g)
dwave =	7.61	Sloshing wave height above Fill Height (ft) (ref. ASCE 7-10 (Eq. 15.7-13))
df =	1.00	Freeboard available (ft)
df_reqd =	7.61	Min. freeboard requirement (ref. Table 29) (ft)
	No	Sufficient freeboard available?
	6.61	*ft more freeboard required*

13.5.4.5 - Roof Framing and Columns

Not evaluated due to insufficient data.

13.5.4.6 - Sliding Check

μ =	0.58	Coefficient of friction, AWWA A.13.2.8.2
V_{ALLOW} =	1,196,910	Allowable Lateral Shear (lbs)
V_f =	908,656	Design shear at the top of the foundation due to horizontal design acceleration (lbs)
VNET =	0	
D/C =	0.76	

Tank has sufficient sliding resistance

Section 13.7 - Foundation Design for Ground-Supported Flat-Bottom Tanks

PT =	13,210	Design Shell Compression Load on the Foundation (plf) (ref. PIP STE03020 p.15 of 81)

RINGWALL ANALYSIS

(NOT EVALUATED DUE TO INSUFFICIENT DATA)

ANCHORAGE

(NOT EVALUATED DUE TO INSUFFICIENT DATA)

ANCHOR CHAIRS

(NOT EVALUATED DUE TO INSUFFICIENT DATA)

ROOF ANALYSIS

(NOT EVALUATED DUE TO INSUFFICIENT DATA)

MITIGATION CONCEPTS

SGH has identified several mitigation concepts to meet current code requirements. Note that concepts involving strengthening or replacement of specific tank elements do not include the design of the upgrade for these elements as this was not included in our scope. For this tank, we investigated the following mitigation concepts:

Mitigation Concept 1

- Reduce Fill Height until all tank checks pass
- Note that this does not include checks for tank components that were not evaluated. Mitigation concept may still require strengthening of these elements.

The mitigation concept above addresses freeboard and shell stress issues identified in our analysis but does not examine stress in the interior columns, ringwall foundation, roof, anchors, or anchor chairs as insufficient data was provided for these components.

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

CLIENT	West Yost Associates	SHEET NO.	
		PROJECT NO.	167525.00 - ROSA
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		BY	BLP
SUBJECT	Mitigation Concept 1	CHECKED BY	

Note: All values are D/C ratios U.O.N.

Tank Height, Ht (ft)	35.00		
Fill Height, H (ft)	27.00	max TCL (ft) =	34.00
Importance Factor	1.50		
Anchorage	Anchored		
Eweld	0.85		

Course	Thickness (in)	Material	Static Hoop Tension	Static Compression	Min. Thickness?	Seismic Hoop Tension	Seismic Compression
1	0.505	A36	0.35	0.02	Adequate	0.11	0.22
2	0.250	A36	0.55	0.06	Adequate	0.22	0.92
3	0.245	A36	0.30	0.05	Adequate	0.14	0.65
4	0.240	A36	0.02	0.04	Adequate	0.07	0.35

Freeboard Required (ft)	7.59	
Available Freeboard (ft)	8.00	*OK! Adequate Freeboard*

Roof
Column - Static Compression
Column - Seismic P & M
Bending of Roof Plate
Strength of Rafter to Roof Weld
Rafter Beam Bending
Rafter Beam Shear
Rafter Channel Bolted Connx

Foundation
Soil Bearing (Gravity)
Soil Bearing (Gravity + Seismic)
Bearing Pressure at Uplift End (psf)

Positive Bending of Ringwall
Negative Bending of Ringwall
Hoop Steel (Positive Bending)
Hoop Steel (Negative Bending)

Anchorage
Tank Sliding Resistance
Anchor Steel, Tension & Shear
Concrete Breakout in Tension
Conc. Breakout in Tension w/ Reinf.
Anchor Pull-out
Side Face Blowout in Tension

} Not evaluated due to insufficient data

Appendix C

Structural Calculations R-9A

Structural Calculations – Tank R-9A

City of Santa Rosa Water Tanks Seismic Evaluation
Santa Rosa, CA

07 July 2017

SGH Project 167525

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

PREPARED FOR:

West Yost Associates
Davis, CA

PREPARED BY:

500 12th Street, Suite 270
Oakland, CA 94607
Tel: 510.457.4600
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SIMPSON GUMPERTZ & HEGER
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SHEET NO. i
PROJECT NO. 167525.00 - ROSA
DATE 16 June 2017
BY BLP
CHECKED BY

CLIENT West Yost Associates
SUBJECT Structural Calculations – Tank R-9A

INDEX TO CALCULATIONS:

CALCULATION INDEX AND PROJECT DESCRIPTION i – ii

SUMMARY S1

SUMMARY SHEET (FILL HEIGHT = 40 ft)

INPUT PARAMETERS P1 – P2

TANK DATA & SEISMIC PARAMETERS
WEIGHT CALCULATIONS

AWWA D.100-11 TANK CALCULATIONS T1 – T5

SHELL STRESS (GRAVITY ONLY)
COLUMN (GRAVITY ONLY)
SHELL HYDROSTATIC HOOP TENSION
SHELL STRESS (GRAVITY + SEISMIC)
COLUMN (GRAVITY + SEISMIC)
TANK SLIDING

RINGWALL ANALYSIS R1 – R6

LOADS ON RINGWALL
SOIL BEARING
UPLIFT
TWIST ANALYSIS
HOOP STEEL TENSION
LAP SPLICE LENGTH OF HOOP STEEL
MINIMUM STEEL FOR SHRINKAGE & TEMP.

ROOF ANALYSIS

(NOT EVALUATED)

ADDITIONAL ANALYSIS A1

SUMMARY SHEET (FILL HEIGHT = 13 ft)

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SHEET NO. ii
PROJECT NO. 167525.00 - ROSA
DATE 16 June 2017
CLIENT West Yost Associates
BY BLP
SUBJECT Structural Calculations – Tank R-9A
CHECKED BY

INDEX TO CALCULATIONS:

MITIGATION CONCEPTS MC1
MC 1 – STRENGTHEN FOUNDATION, REDUCE FILL HEIGHT

PROJECT DESCRIPTION:

West Yost Associates, Inc. (West Yost) has been contracted by the City of Santa Rosa to perform evaluations of the existing water tanks and tank sites. West Yost has subcontracted SGH to perform the structural analysis of the existing tanks, located at:

- R-17: Newgate Court, Santa Rosa, CA
- R-16: Fountain Grove Parkway, Santa Rosa, CA
- R-9A: Annadel Heights Drive, Santa Rosa, CA

The primary purpose of the structural evaluations is to determine whether the tanks meet current code requirements that would be applicable for the design of a new tank and to provide mitigation concepts to address structural deficiencies identified in the analysis.

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Attachment 2

SHEET NO.

PROJECT NO. 167525.00 - ROSA

DATE 16 June 2017

CLIENT West Yost Associates

BY BLP

SUBJECT Structural Calculations – Tank R-9A

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SUMMARY
(FILL HEIGHT = 40 FT)

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CLIENT West Yost Associates
SUBJECT Summary (Fill Height = 40 ft)

SHEET NO.
PROJECT NO. 167525.00 - ROSA
DATE 25 July 2016
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Note: All values are D/C ratios U.O.N.

Tank Height, Ht (ft)	40.00		
Fill Height, H (ft)	40.00	max TCL (ft) =	40.00
Importance Factor	1.50		
Anchorage	Self-anchored		
Eweld	0.85		

Course	Thickness (in)	Material	Static Hoop Tension	Static Compression	Min. Thickness?	Seismic Hoop Tension	Seismic Compression
1	0.525	A36	1.26	0.09	Adequate	0.50	0.41
2	0.440	A36	1.26	0.12	Adequate	0.58	0.50
3	0.330	A36	1.33	0.17	Adequate	0.71	0.75
4	0.264	A36	1.19	0.23	Adequate	0.71	0.88
5	0.250	A36	0.64	0.22	Adequate	0.46	0.55

Freeboard Required (ft)	11.15	
Available Freeboard (ft)	0.00	*Inadequate freeboard, calculate sloshing loads on roof*

Roof
Column - Static Compression
Column - Seismic P & M
Bending of Roof Plate
Strength of Rafter to Roof Weld
Rafter Beam Bending
Rafter Beam Shear
Rafter Channel Bolted Connx

Not evaluated due to insufficient data

Foundation

Soil Bearing (Gravity)	0.54
Soil Bearing (Gravity + Seismic)	2.25
Bearing Pressure at Uplift End (psf)	2714
Positive Bending of Ringwall	0.42
Negative Bending of Ringwall	4.78
Hoop Steel (Positive Bending)	3.98
Hoop Steel (Negative Bending)	6.31

Anchorage

Tank Sliding Resistance	0.59

INPUT PARAMETERS

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

CLIENT	West Yost Associates
SUBJECT	Welded Steel Tank Properties & Seismic Coefficients
SHEET NO.	
PROJECT NO.	167525.00 - ROSA
DATE	25 July 2016
BY	BLP
CHECKED BY	SCC

Tank & Foundation Properties

Except where noted, tank properties were obtained from the placard posted on the side of the tank and from calculations included in an evaluation performed by Peoples Associates (2004).

NAME	R-9A	Specific name of this tank
D	92.000	Nominal tank diameter, measured to the inside of the wall (ft)
Ht	40.000	Total shell height excluding knuckle (ft) as defined in AWWA D.100-11 13.5.2
H	40.000	Fill Height (ft) (note: Maximum fill height is aka MOL and TCL)
t	0.423	Thickness of bottom course (in)
tb	0.375	Thickness of bottom plate (in)
G	1.000	Specific gravity of tank contents
Roof		Roof type
Anchorage	Self-anchored	Self-anchored or Anchored
Fnd Type	Ringwall	
CA =	0.0625	Corrosion Allowance (in)

Material Properties Of Tank

Fty	31,900	Minimum yield strength of bottom course (psi)
Fby	31,900	Minimum yield strength of bottom plate (psi)
E_{mod}	29,000,000	Elastic modulus (psi)
Weld Type	Single-groove butt joint with suitable backing strip or equivalent means to ensure complete joint penetration	
E_{weld}	0.85	Weld Joint Efficiency in Tension (ref. AWWA D100-11 Table 15)

Seismic Parameters Per ASCE 7-10 Spectra

Seismic parameters obtained from Group Delta Consultants.

S_s	2.081	MCE spectral response acceleration at short periods
F_a	1.000	Site coefficient
S_{MS}	2.081	Adjusted spectral response acceleration for short periods
S_1	0.853	MCE spectral response acceleration at 1.0 sec period
F_v	1.300	Site coefficient
S_{M1}	1.109	Adjusted spectral response acceleration at 1.0 sec period
S_{DS}	1.387	Design spectral response acceleration at short periods
S_{D1}	0.739	Design spectral response acceleration at 1.0 sec period
Ts	0.53	=Sd1/Sds (s)
T_L	8	Long-period transition period (s)
I_E	1.50	Seismic Importance Factor (Risk Cat. IV - ASCE 7-10 / Seismic Use Group III - AWWA D100-11)

General Notes

1. Tank nomenclature, equation and section references are from AWWA D100-11 unless otherwise noted.
2. [shaded cell] indicates a cell with a manually inputed value.

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CLIENT	West Yost Associates
SUBJECT	Weight Calculations for Tank Shell Courses
SHEET NO.	
PROJECT NO.	167525.00 - ROSA
DATE	25 July 2016
BY	BLP
CHECKED BY	SCC

Shell Data

D	92.000	Nominal tank diameter (ft)
Ht	40.000	Total tank height (ft)
t	0.423	Thickness of bottom course (in)

Shell Geometry and Weight
Shell course thicknesses obtained from calculations prepared by Peoples Associates (2004) and from field measurements provided by JDH Corrosion Consultants. Where thicknesses were similar but only slightly differ, the lesser value was conservatively used.

Course	Yield Strength (psi)	(1) Elevation of Top of Course (ft.)	(2) Course Height (ft.)	(3) Plate Thickness (in)	(4) CG Elevation (ft.)	(5) Cross Section Area (ft^2)	(6) Total Course Weight (lbs)	(6)*(4) Wt*CG (lbs*ft)	Total weight of courses (lbs)
1	31,900	7.420	7.420	0.525	3.710	12.65	45,996	1.71E+05	168,631
2	31,900	15.500	8.080	0.440	11.460	10.60	41,975	4.81E+05	122,635
3	31,900	23.580	8.080	0.330	19.540	7.95	31,478	6.15E+05	80,660
4	31,900	31.710	8.130	0.264	27.645	6.36	25,337	7.00E+05	49,182
5	31,900	39.790	8.080	0.250	35.750	6.02	23,845	8.52E+05	23,845
						0.00			0
						0.00			0
						0.00			0
						Σ =	168,631	2.82E+06	

Roof Weight

Steel Rafter Roof

Wr,x	186,120	Total roof weight (lbs)	(ref. Peoples Associates calculations 2004)

Overall Weights

Ws	168,631	Total weight of tank shell and all apperturences (lbs)	
Wr	186,120	Total weight of the tank roof (lbs)	
	70.5%	% of roof weight supported by shell wall (= 0 for a floating roof)	
Wrs	131,215	Total weight of the tank roof supported by shell	(ref. Peoples Associates calculations 2004)
Xs	16.7	Centroid distance from bottom of tank (ft)	

AWWA D.100-11 TANK CALCULATIONS

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

SHEET NO.	
PROJECT NO.	167525.00 - ROSA
DATE	25 July 2016
CLIENT	West Yost Associates
BY	BLP
SUBJECT	AWWA D.100-11 Calculations
CHECKED BY	SCC

Tank Data

D	92.000	Nominal tank diameter (ft)
Ht	40.000	Total height of the tank shell (ft)
H	40.000	Top capacity limit (ft)
G	1.000	Specific gravity of tank content
t	0.423	Thickness of bottom course (in)
tb	0.375	Thickness of bottom annulus (in)
Fty	31,900	Min. yield strength of all shell courses (psi)
Fby	31,900	Min. yield strength of bottom annulus (psi)

Tank Weights

Ws	168,631	Total weight of tank shell and all apperturences (lbs)
Xs	16.7	Height from bottom of tank shell to shell c.g. (ft)
Wr	186,120	Total weight of the tank roof (lbs)
Wrs	131,215	Total weight of the tank roof supported by tank shell in the vertical direction (lbs)

Section 3.4 - Allowable Compressive Stresses for Columns, Struts, and Shells

3.4.3 Shell Compression

Note: Method 1 is used to calculate shell compression F_L.

Note: For Material Class, refer to Table 4.

K = 1.00 AISC effective column length factor

Course	Thickness (in)	R (in)	t/R	Fy (psi)	Material Class	(t/R)c	FL (psi)	C`c	r (in)	L (in)
1	0.525	552.525	0.0009502	31,900	1	0.0031088	1,738	405.82	390.60	89.04
2	0.44	552.44	0.0007965	31,900	1	0.0031088	1,438	446.13	390.56	96.96
3	0.33	552.33	0.0005975	31,900	1	0.0031088	1,064	518.60	390.50	96.96
4	0.264	552.264	0.000478	31,900	1	0.0031088	846	581.61	390.46	97.56
5	0.25	552.25	0.0004527	31,900	1	0.0031088	800	598.02	390.46	96.96

Course	KL/r	Kϕ	Fb (psi)	capacity Fa (psi)	demand fa (psi)	D/C
1	0.23	1.000	1,738	1,738	165	0.09
2	0.25	1.000	1,438	1,438	166	0.12
3	0.25	1.000	1,064	1,064	185	0.17
4	0.25	1.000	846	846	197	0.23
5	0.25	1.000	800	800	179	0.22

Section 3.6 - Roofs

See "Roof Analysis" for checks not included herein (e.g. check of roof and roof components).

3.6.1.3 Column Compression

Not evaluated due to insufficient data.

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Section 3.7 - Cylindrical Shell Plates (Hoop Tension)

D = 92.00 Nominal tank diameter (ft)
G = 1.00 Product specific gravity
E_{weld} = 0.85 Weld Joint efficiency in Tension (ref. Table 15)

Course	Thickness (in)	Course Height (in)	Elevation to bottom of course (in)	hp (ft)	s (psi) (ref. Table 34)	Joint Efficiency (ref. Table 15)	Req'd design shell plate thickness (in)	Shell thickness - CA (in)	D/C	Sufficient thickness?
1	0.525	89.04	0	40.000	19,330	0.85	0.5823	0.4625	1.26	No
2	0.44	96.96	89.04	32.580	19,330	0.85	0.4743	0.3775	1.26	No
3	0.33	96.96	186	24.500	19,330	0.85	0.3567	0.2675	1.33	No
4	0.264	97.56	282.96	16.420	19,330	0.85	0.2390	0.2015	1.19	No
5	0.25	96.96	380.52	8.290	19,330	0.85	0.1207	0.1875	0.64	Yes

Note: Maximum design tensile stress, s, is determined per Section 14, Table 34.

Section 3.10 - Minimum Thickness and Size

Course	Thickness (in)	In Contact with Water?	Required Thickness (in)	Adequacy Check
1	0.525	Yes	0.25	*Adequate*
2	0.44	Yes	0.25	*Adequate*
3	0.33	Yes	0.25	*Adequate*
4	0.264	Yes	0.25	*Adequate*
5	0.25	Yes	0.25	*Adequate*

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Engineering of Structures and Building Enclosures

CLIENT West Yost Associates	SHEET NO.
SUBJECT AWWA D.100-11 Calculations	PROJECT NO. 167525.00 - ROSA
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	BY BLP
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Section 13.2 - Design EQ Ground Motion

13.2.6 - Response Modification Factors (ref. Table 28)

Ri =	2.50	
R_c =	1.50	

13.2.7 - Design Response Spectrum

Sai =	1.39	(g)
Sac =	0.19	(g)

13.2.9.2 - Horizontal Design Accelerations for Ground-Supported Tanks

Ai =	0.595	(g)
Ac =	0.137	(g)

Section 13.5 - Ground-Support Flat Bottom Tanks

13.5.1 - Natural Periods

Tc =	5.77	First mode sloshing wave period (s)
Ti =	0.00	Natural period of the structure (s)

13.5.2 - Design Overturning Moment at the Bottom of the Shell

Wt =	16,589,440	Total weight of the Tank Contents (lbs) (AWWA Eq. 13-27)
Wi =	8,024,395	Effective impulsive weight (lbs)
Wc =	8,082,625	Effective convective weight (lbs)
Xi =	15.00	Height from bottom of shell to centroid of the lateral seismic force applied to Wi (ft)
Xc =	23.38	Height from bottom of shell to centroid of the lateral seismic force applied to Wc (ft)
Ms =	81,892,732	Design overturning moment at the bottom of the shell (ft-lbs)

13.5.3 - Design Shear and Overturning Moment at the Top of the Foundation

Dbp =	93.08	Diameter of bottom plate (ft)
tbp =	0.38	Thickness of bottom plate (in)
Wf =	104,185	Total weight of tank bottom (lbs)
Vf =	5,164,671	Design shear at the top of the foundation due to horizontal design acceleration (lbs)
Fnd Type =	Ringwall	
Ximf =	36.34	Height from shell bot. to centroid of Wi adjusted to incl. the effects of varying bottom pressures (ft)
Xcmf =	33.32	Height from shell bot. to centroid of Wc adjusted to incl. the effects of varying bottom pressures (ft)
Mmf =	81,892,732	Design overturning moment at the top of the foundation (ft-lbs)

13.5.4.1 - Resistance to Overturning

tb_design =	0.300	Thickness of bottom annulus used to calculate seismic stability (in)
wL =	2,677	The resisting force of the bottom annulus (plf)
J =	2.662	

Tank is unstable. Modify bottom annulus within limits of tb and L, or provide mechanical anchorage since J>1.54

13.5.4.1.2 - Bottom Annulus Width

Not evaluated due to insufficient data.

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SUBJECT	AWWA D.100-11 Calculations	CHECKED BY	SCC

13.5.4.2 - Shell Stresses

wrs =	454.0	Roof load acting on shell (plf)
wt =	1,037	Weight of tank shell, apperturances, and portion of roof (plf) (equation 13-41)
CA =	0.0625	Corrosion allowance (in)
ts =	0.46	Actual thickness of bottom shell course less the specified corrosion allowance, if any (in)
σc =	2,421	Longitudinal shell compression (psi), (Eq. 13-39, 13-40)
D =	92.00	Nominal tank diameter (ft)
R =	552.00	Nominal radius of the tank (in)
H =	40.00	MOL, or TCL, or Design Liquid Level (ft)
G =	1.00	Product specific gravity
E_{weld} =	0.85	Weld Joint efficiency in Tension (ref. Table 15)

Course	Thickness (in)	CA (in)	Thickness minus CA (in)	Course Height (in)	Elevation to bottom of tank (in)	s (psi)	Y (ft)
1	0.525	0.0625	0.4625	89.04	0	19,330	40.000
2	0.44	0.0625	0.3775	96.96	96.96	19,330	31.920
3	0.33	0.0625	0.2675	96.96	193.92	19,330	23.840
4	0.264	0.0625	0.2015	97.56	291.48	19,330	15.710
5	0.25	0.0625	0.1875	96.96	388.44	19,330	7.630

Note: "Y" is measured from top of design water level to bottom of course, because that is where course hoop stress is greatest.

	Hoop Tensile Forces & Stresses							
Course	Dynamic impulsive force, Ni (lbs/in)	Dynamic, convective force, Nc (lbs/in)	Static force, Nh (lbs/in)	Static Stress (psi)	Dynamic stress, σ_s (psi)	Total stress (psi)	Allowable stress (psi)	D/C
1	4,743	442	9,568	20,688	10,300	11,056	21,907	0.50
2	4,550	465	7,635	20,226	12,115	12,736	21,907	0.58
3	3,969	538	5,703	21,318	14,973	15,535	21,907	0.71
4	2,994	668	3,758	18,649	15,224	15,649	21,907	0.71
5	1,637	867	1,825	9,734	9,880	10,059	21,907	0.46

OK! Sufficient tensile hoop strength
Note: "dynamic" implies "seismic"
Note: Per 13.5.4.2.4, a 1/3 increase is allowed when calculating the Allowable Tensile Hoop Stress

	Longitudinal Compression Stress									
Course	Allow. Comp. stress σ_a (psi)	$\Delta\sigma_{cr}$ (psi)	Seismic allow. long. shell comp. stress, σ_e (psi)	h_i (ft)	X_{si} - h_i (ft)	1- h_i / H_t (ft)	Overturning Moment (lbs-ft)	w_{ti} (plf)	Longitudinal shell comp. stress, σ_c (psi)	D/C
1	1,738	5,346	5,879	0.00	16.72	1.00	81,892,732	1,037	2,421	0.41
2	1,438	4,363	4,825	7.42	14.18	0.81	66,701,630	878	2,424	0.50
3	1,064	3,092	3,479	15.50	11.38	0.61	50,159,299	733	2,596	0.75
4	846	2,329	2,680	23.58	7.99	0.41	33,616,967	624	2,369	0.88
5	800	2,167	2,511	31.71	4.04	0.21	16,972,269	536	1,391	0.55

OK! Sufficient compression strength
Note: σ_a is equal to F_L calculated per 3.4.3.1 (aka Method 1)
Note: Overturning Moment varies linearly from bottom of shell to top, per AWWA D100-11 A.13.5.4.2.2

13.5.4.3 - Vertical Design Acceleration

Av = 0.19 (g)

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CLIENT	West Yost Associates	SHEET NO.	
SUBJECT	AWWA D.100-11 Calculations	PROJECT NO.	167525.00 - ROSA
		DATE	25 July 2016
		BY	BLP
		CHECKED BY	SCC

13.5.4.4 - Freeboard & Sloshing Wave Height

Hroof =	40.00	Height to bottom of roof for purpose of calculating freeboard and sloshing loads (ft)
Sac =	0.19	Spectral acceleration of convective wave (g)
dwave =	11.15	Sloshing wave height above Fill Height (ft) (ref. ASCE 7-10 (Eq. 15.7-13))
df =	0.00	Freeboard available (ft)
df_reqd =	11.15	Min. freeboard requirement (ref. Table 29) (ft)
	No	Sufficient freeboard available?
	11.15	*ft of additional freeboard required.*

13.5.4.5 - Roof Framing and Columns

Not evaluated due to insufficient data.

13.5.4.6 - Sliding Check

μ =	0.58	Coefficient of friction, AWWA A.13.2.8.2
V_{ALLOW} =	8,765,820	Allowable Lateral Shear (lbs)
V_f =	5,164,671	Design shear at the top of the foundation due to horizontal design acceleration (lbs)
VNET =	0	
D/C =	0.59	

Tank has sufficient sliding resistance

Section 13.7 - Foundation Design for Ground-Supported Flat-Bottom Tanks

PT =	13,435	Design Shell Compression Load on the Foundation (plf) (ref. PIP STE03020 p.15 of 81)

RINGWALL ANALYSIS

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Engineering of Structures and Building Enclosures

CLIENT	West Yost Associates	SHEET NO.	
SUBJECT	Ringwall Calculations	PROJECT NO.	167525.00 - ROSA
		DATE	25 July 2016
		BY	BLP
		CHECKED BY	SCC

DESIGN BASIS

Specifications:

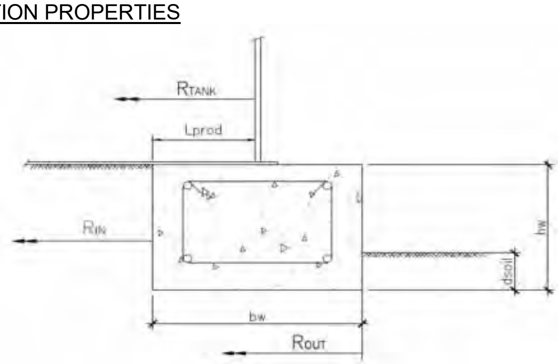
AWWA D100-11
Process Industry Practices PIP STE03020 -- Guidelines for Tank Foundation Designs
ACI 318-11, for calculating ringwall strengths, minimum steel area, lap splice length, shrinkage steel, etc.

MATERIAL PROPERTIES

f`c =	3,000	Concrete compressive strength (psi)
γc =	150	Concrete density (pcf)
fy =	40,000	Rebar yield strength (psi) (ASTM A15 intermediate) (ref. Tank specs, Section 17)
K =	0.50	Coefficient of lateral earth pressure (taken as K_0)
γs =	125	Soil density inside ringwall (pcf)
bnet =	16,500	Ultimate net bearing capacity of the soil (psf) from Group Delta Consultants

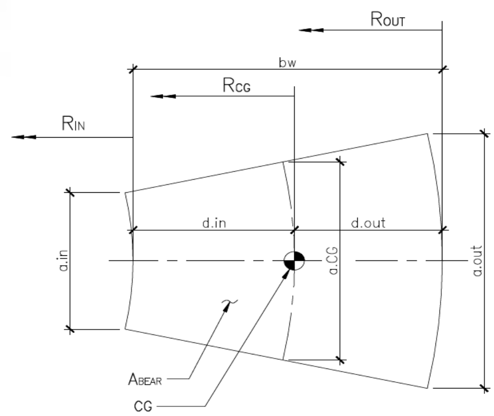
FOUNDATION GEOMETRY & SECTION PROPERTIES

Rtank =	46.00	(ft)
bw =	1	(ft)
hw =	1.50	(ft)
Lprod =	0.67	(ft)
Rout =	46.33	(ft)
Rin =	45.33	(ft)
dsoil =	1.33	(ft)



SECTION VIEW
RINGWALL

dout =	0.50	(ft)
din =	0.50	(ft)
acg =	1.00	(ft)
aout =	1.01	(ft)
ain =	0.99	(ft)
Rcg =	45.84	(ft)
Abear =	1.00	(ft^2)
Rcg_water =	45.67	C.G. of the mass of water that bears over the ringwall, measured from the tank center (ft)
Abear_water =	0.67	Bearing area of water over the ringwall (for unit length of Rcg_water) (ft^2)
Rac =	46.38	Center of anchor bolt ring (ft)



PLAN VIEW
RINGWALL

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

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BY BLP
SUBJECT Ringwall Calculations
CHECKED BY SCC

LOADS ON THE RINGWALL

wt =	1,037	Self-weight of tank + roof on the base of the shell (plf) (ref. AWWA 13.5.4.2)
Wb =	5,322	Total weight of tank bottom plate bearing on ringwall (lbs)
Ww =	477,455	Total water weight bearing on the wall (lbs)
Ms =	81,892,732	Design overturning moment at the bottom of the shell (ft-lbs) (ref. AWWA 13.5.2)

Load Cases

Name	Load Type	Description	Unfactored (at Rcg) (plf)	Unfactored over footing width (psf)	Eccentricity from Rcg (see note 2) (ft)	Location of Force
A	Dead	Shell + Roof weight	1,041.2	1,041.2	-0.16	Shell
B	Dead	Bottom plate weight	18.5	18.5	-0.10	Base PL Center over Wall
C	Dead	Ringwall weight	225.0	225.0	0.00	Center of Ringwall
D	Live	Water weight (see note 1)	1,657.9	1,657.9	0.17	Center of Water over Wall
E	EQ	Seismic Bearing (from OTM)	13,483.2	13,483.2	-0.16	Shell
Av	EQ	Vert. Seismic - Shell + Roof	80.9	80.9	-0.16	Shell
Bv	EQ	Vert. Seismic - Bottom PL	1.4	1.4	-0.10	Base PL Center over Wall
Cv	EQ	Vert. Seismic - Ringwall	17.5	17.5	0.00	Center of Ringwall
Dv	EQ	Vert. Seismic - Water	128.8	128.8	0.17	Center of Water over Wall
F	EQ	Seismic Uplift (from OTM)	0.0	0.0	0.00	Center of Anchor Ring

Note 1. Water is to be treated as a live load, per AWWA D.100-11 Section 12.1.1
Note 2. If center of load is closer to the tank center than Rcg, value is negative.
Note 3. Vertical seismic acceleration is equal to 0.4*Av per AWWA 13.5.4.3
Note 4. Vertical seismic load from water is included in Load Combo A-3 only since explicitly called for in AWWA 13.7.1
Note 5. Load Case F is only applicable for an Anchored Tank

Unfactored Load Combinations (For Soil Demands & Tank Stability)

Name	Description	Which Side of Tank? (see notes 1 and 3)
A-1	Dead+Live	Bearing
A-2	Dead+Live+EQ	Bearing
A-3	Dead+Live+EQ	Uplift

Factored Load Combinations (For Ringwall Demands)

Name	Description	Which Side of Tank? (see notes 1 and 3)
U-1	1.4Dead	Bearing
U-2	1.2Dead+1.6Live	Bearing
U-3	1.2Dead+1.0Live+1.4EQ	Bearing
U-4	0.9Dead+1.4EQ	Bearing
U-5	1.2Dead+1.0Live+1.4EQ	Uplift
U-6	0.9Dead+1.4EQ	Uplift

Note 1. We use a 1.4 load factor for EQ loads to convert it from ASD to strength design; i.e. AWWA EQ loads include the 0.7 ASD factor
Note 2. The direction of the vertical seismic loads is in accordance with ASCE 7-10 Section 12.4.3
Note 3. For Anchored Tanks, ringwall demands are calculated for 2 locations: where the tank bears AND where it uplifts.

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SOIL BEARING CHECK

Gravity Only (Load Case A-1)

b_{net}	16,500	Ultimate net bearing capacity of the soil (psf)
F.O.S.	3.00	Factor of Safety (gravity only) (ref. 12.3.2)
Capacity	5,500	Allowable bearing pressure (psf)
Demand	2,943	(psf)
D/C	0.535	

OK! Adequate bearing strength

Gravity + Seismic (Load Case A-2)

b_{net}	16,500	Ultimate net bearing capacity of the soil (psf)
F.O.S.	2.25	Factor of Safety (gravity + seismic) (ref. 12.3.2.2)
Capacity	7,333	Allowable bearing pressure (psf)
Demand	16,525	(psf)
D/C	2.253	

Not OK! Insufficient bearing strength

CHECK THAT RINGWALL WILL NOT UPLIFT FROM SOIL

Not Applicable Since Tank is Self-Anchored

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TWIST ANALYSIS

Positive Bending of Ringwall (Bottom in Tension)

As.b	0.62	Rebar area at bottom of ringwall (in^2) (2 - #5)
Fy	40,000	(psi)
f'c	3,000	(psi)
β_1	0.85	Factor to approximate depth of compression stress block, ACI 318-11 10.2.7.3
d	14.19	Depth from top of ringwall to bottom rebar (in)
b	12	Width of ringwall in bending (in)
c	0.95	Depth to neutral axis (in), assuming tension steel reaches yield
ε_s	0.0050	Strain in steel (in/in)
	OK, steel yields before concrte fails.	
ϕ	0.90	Strength reduction factor, ACI 318-11 9.3.2
ϕMn =	25,635	Ringwall design moment strength (lbs*ft)
Mu =	10,844	Maximum moment on ringwall due to twist (lbs*ft)
	U - 2	Governing Load Combination
D/C	0.423	
	OK! There is adequate steel present to resist ringwall bending due to twist	
As.b,req'd =	0.26	(in^2)

Negtive Bending of Ringwall (Top in Tension)

As.t	0.62	Rebar area at top of ringwall (in^2) (2 - #5)
Fy	40,000	(psi)
f'c	3,000	(psi)
β_1	0.85	Factor to approximate depth of compression stress block, ACI 318-11 10.2.7.3
d	16.19	Depth from bottom of ringwall to top rebar (in)
b	12	Width of ringwall in bending (in)
c	0.95	Depth to neutral axis (in), assuming tension steel reaches yield
ε_s	0.0479	Strain in steel (in/in)
	OK, steel yields before concrete fails.	
ϕ	0.90	Strength reduction factor, ACI 318-11 9.3.2
ϕMn =	29,360	Ringwall design moment strength (lbs*ft)
Mu =	140,288	Maximum moment on ringwall due to twist (lbs*ft)
	U - 3	Governing Load Combination
D/C	4.778	
	Not OK! Insufficient steel present to resist ringwall bending due to twist	
As.t,req'd =	3.338	(in^2)

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HOOP STEEL

P =	2,496	Pressure from water on bottom of tank (psf)
K =	0.5	Coefficient of lateral earth pressure
γs =	125	Soil weight (pcf)
H =	88,052	Hoop tension (lbs)

Check hoop steel during Positive Bending of Ringwall (Bottom in Tension)

As,req'd =	3.91	Required hoop steel (in^2)
As,top_avail =	0.62	Hoop steel available from top of ringwall, not used by twist (in^2)
As,bot_avail =	0.36	Hoop steel available from bottom of ringwall, not used by twist (in^2)
As,other_avail =		Other hoop steel available, not used by twist (in^2)
As,avail =	0.98	Total hoop steel available (in^2)
D/C	3.984	

Not OK! Insufficient hoop steel

Check hoop steel during Negative Bending of Ringwall (Top in Tension)

As,req'd =	3.91	Required hoop steel (in^2)
As,top_avail =	0.00	Hoop steel available from top of ringwall, not used by twist (in^2)
As,bot_avail =	0.62	Hoop steel available from bottom of ringwall, not used by twist (in^2)
As,other_avail =	0.00	Other hoop steel available, not used by twist (in^2)
As,avail =	0.62	Total hoop steel available (in^2)
D/C	6.312	

Not OK! Insufficient hoop steel

CHECK LENGTH of LAP SPLICES Per ACI Ch. 12.15 — Verify splices can achieve develop yield of the hoop steel

Note: Conservatively assume Class B splice

Check Bottom Steel: (2 - #5)

Fy	40,000	Yield strength of rebar (psi)
λ	1.0	Concrete type factor, normal-weight concrete
ψt	1.0	Reinforcement location factor, ACI 318-11 12.2.4 (a)
ψe	1.0	Reinforcement coating factor, ACI 318-11 12.2.4 (b)
ψt ψe	1.0	Limit on product of ψt*ψe = 1.7
ψs	1.0	Reinforcement size factor, ACI 318-11 12.2.4 (c)
Ktr	0.0	Confining reinforcement factor. Conservatively assume 0

Bar	db (in)	cb (in)	(cb+Ktr) / db	ld (in)	$L_{lap.req}$ (in)	$L_{lap.prov}$ (in)	lap.prov > lap.req?
#5	0.625	2.19	2.50	13.7	17.8	21.0	Yes, lap length ok.

Check Top Steel: (2 - #5)

Fy	40,000	Yield strength of rebar (psi)
λ	1.0	Concrete type factor, normal-weight concrete
ψt	1.3	Reinforcement location factor, ACI 318-11 12.2.4 (a)
ψe	1.0	Reinforcement coating factor, ACI 318-11 12.2.4 (b)
ψt ψe	1.3	Limit on product of ψt*ψe = 1.7
ψs	0.8	Reinforcement size factor, ACI 318-11 12.2.4 (c)
Ktr	0.0	Confining reinforcement factor. Conservatively assume 0

Bar	db (in)	cb (in)	(cb+Ktr) / db	ld (in)	$L_{lap.req}$ (in)	$L_{lap.prov}$ (in)	lap.prov > lap.req?
#5	0.625	2.19	2.50	14.2	18.5	21.0	Yes, lap length ok.

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MINIMUM STEEL TO RESIST SHRINKAGE AND TEMPERATURE EFFECTS
ref. ACI 318 Ch. 14.3

Horizontal Rebar

ρ_t =	0.0025	Minimum ratio of horizontal reinforcement area to gross concrete area per PIP 5.6.6.1
Ag =	216	Gross area of concrete (in^2)
As,req'd =	0.54	Minimum required horizontal wall steel (in^2)
As =	1.24	Horizontal steel present (in^2)
	OK! Sufficient horizontal rebar for shrinkage and temperature effects	

Vertical Rebar

ρ_l =	0.0015	Minimum ratio of vertical reinforcement area to gross concrete area per PIP 5.6.6.1
Ag =	144	Gross area of concrete over 1 foot circumferential length (in^2)
As,req'd =	0.22	Minimum required vertical wall steel over 1 foot circumferential length (in^2)
As =	0.40	Vertical steel present in 1 foot circumferential length (in^2) (#4s @ 12" spacing)
	OK! Sufficient vertical rebar for shrinkage and temperature effects	

ROOF ANALYSIS

(NOT EVALUATED DUE TO INSUFFICIENT DATA)

ADDITIONAL ANALYSIS (FILL HEIGHT = 13 FT)

A previous evaluation of Tank R-9A was performed by Peoples Associates in 2004. This evaluation recommended lowering the maximum fill height from 40 ft to 13 ft. Since we have found no evidence that the new fill height was actually implemented, we have performed calculations for both the 40 ft and 13 ft fill heights. The following page is a summary sheet of all checks performed for the 13 ft fill height.

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CLIENT West Yost Associates
SUBJECT Additional Analysis (Fill Height = 13 ft)

Note: All values are D/C ratios U.O.N.

Tank Height, Ht (ft)	40.00
Fill Height, H (ft)	13.00
Importance Factor	1.50
Anchorage	Self-anchored
Eweld	0.85

max TCL (ft) = 13.00

Course	Thickness (in)	Material	Static Hoop Tension	Static Compression	Min. Thickness?	Seismic Hoop Tension	Seismic Compression
1	0.525	A36	0.41	0.09	Adequate	0.18	0.08
2	0.440	A36	0.22	0.12	Adequate	0.15	0.09
3	0.330	A36	0.00	0.17	Adequate	0.00	0.36
4	0.264	A36	0.00	0.23	Adequate	0.00	0.45
5	0.250	A36	0.00	0.22	Adequate	0.00	0.36

Freeboard Required (ft)	8.01	
Available Freeboard (ft)	27.00	*OK! Adequate Freeboard*

Roof
Column - Static Compression
Column - Seismic P & M
Bending of Roof Plate
Strength of Rafter to Roof Weld
Rafter Beam Bending
Rafter Beam Shear
Rafter Channel Bolted Connx

} Not evaluated due to insufficient data

Foundation

Soil Bearing (Gravity)	0.33
Soil Bearing (Gravity + Seismic)	0.60
Bearing Pressure at Uplift End (psf)	1682
Positive Bending of Ringwall	0.00
Negative Bending of Ringwall	1.11
Hoop Steel (Positive Bending)	1.10
Hoop Steel (Negative Bending)	2.21

Anchorage

Tank Sliding Resistance	0.31

MITIGATION CONCEPTS

SGH has identified several mitigation concepts to meet current code requirements. Note that concepts involving strengthening or replacement of specific tank elements do not include the design of the upgrade for these elements as this was not included in our scope. For this tank, we investigated the following mitigation concepts:

Mitigation Concept 1

- Strengthen ringwall foundation as needed (e.g., larger footing with increased reinforcement)
- Reduce Fill Height until all tank checks pass other than ringwall checks

The mitigation concept above addresses freeboard and shell stress issues identified in our analysis but does not examine stress in the interior columns, the roof, or the bottom annulus plate due to insufficient data.

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CLIENT West Yost Associates
SUBJECT Mitigation Concept 1

Note: All values are D/C ratios U.O.N.

Tank Height, Ht (ft)	40.00
Fill Height, H (ft)	24.00
Importance Factor	1.50
Anchorage	Self-anchored
Eweld	0.85

max TCL (ft) = 40.00

Course	Thickness (in)	Material	Static Hoop Tension	Static Compression	Min. Thickness?	Seismic Hoop Tension	Seismic Compression
1	0.525	A36	0.76	0.09	Adequate	0.32	0.15
2	0.440	A36	0.64	0.12	Adequate	0.34	0.18
3	0.330	A36	0.46	0.17	Adequate	0.32	0.27
4	0.264	A36	0.03	0.23	Adequate	0.00	0.80
5	0.250	A36	0.00	0.22	Adequate	0.00	0.56

Freeboard Required (ft) 10.02
Available Freeboard (ft) 16.00 *OK! Adequate Freeboard*

Roof
Column - Static Compression
Column - Seismic P & M
Bending of Roof Plate
Strength of Rafter to Roof Weld
Rafter Beam Bending
Rafter Beam Shear
Rafter Channel Bolted Connx

} Not evaluated due to insufficient data

Foundation

Soil Bearing (Gravity)	0.41
Soil Bearing (Gravity + Seismic)	0.98
Bearing Pressure at Uplift End (psf)	2102
Positive Bending of Ringwall	0.10
~~Negative Bending of Ringwall~~	~~1.83~~
~~Hoop Steel (Positive Bending)~~	~~2.04~~
~~Hoop Steel (Negative Bending)~~	~~3.88~~

Ignore if strengthen ringwall

Anchorage
Tank Sliding Resistance 0.42 No Shear Demand on Anchors

APPENDIX F

Reservoir Electrical Field Notes

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Appendix F
Reservoir Electrical Evaluation Field Notes

List of Acronyms and Abbreviations

AC	Alternating Current
ATS	Automatic Transfer Switch
CB	Citizens Band
City	City of Santa Rosa
DCU	Digital Concentrator Unit
DSL	Digital Subscriber Line
HP	Horsepower
KVA	Kilo-Volt-Ampere
KW	Kilo-Watt
LED	Light Emitting Diode
LIQ	????
MCC	Motor Control Center
NEMA	National Electrical Manufacturers Association
PLC	Programmable Logic Controller
PSI	Pounds per Square Inch
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
UPS	Uninterrupted Power Supply

Appendix F
Reservoir Electrical Evaluation Field Notes

The following water reservoirs were included in this project:

- **Reservoir R-9A:** located at 4800 Annadel Heights Drive.
- **Reservoir R-16:** located east of Fountaingrove Parkway just south of Hadley Hill Drive.
- **Reservoir R-17:** located behind the City of Santa Rosa Fire Station No. 5 near the corner of Fountaingrove Parkway and Newgate Court.

A visual inspection of the electrical equipment and instrumentation was performed at each pump station site and the field notes are provided below.

1.0 RESERVOIR R-9A

The Reservoir R-9A site is located at 4800 Annadel Heights Drive.

A visual inspection of the electrical equipment and instrumentation was performed at the Reservoir R-9A site. A general listing of equipment and field notes are included and include the following topics:

- Electrical Service
- Generator and ATS
- Instrumentation and Controls

1.1 Electrical Service

The PG&E utility meter pedestal is located down the hill at the entrance to the service road along Annadel Heights Drive. Reservoir R-9A is located on the south-east of the property and Reservoir R-9B is located on the north-west of the property.

The exterior of existing electrical panels appears to be in good shape.

1.2 Generator and ATS

No Standby generator or ATS is located onsite for the tanks.

1.3 Instrumentation and Controls

There are Storage Tank Telemetering Panels (Tesco T-29635) located at each reservoir. Each panel houses the tank instrumentation and RTU. It has a "wet" left instrument side and a "dry" PLC & telemetry side. There is some slight corrosion at the bottom of the wet side of panels for both tanks (see Photos 1 and 2).

Photo 1. Reservoir R-9A Tank Sampling Equipment

Photo 2. Reservoir R-9B Instrument Panel

Each tank is monitored by a L2000 PLC with small form factor LED Operator Interface. Each PLC is provided with a battery backup with battery charger in the event of power failure. The instruments located each the Panels are:

1. Reservoir Level (pressure) transmitter; Rosemount
2. Free Chlorine; US Filter (Wallace & Tiernan) Depolox Basic

High and low alarms will be generated off of the analog instruments.

There are also vault flood switches in each influent valve vault, high hi float switches in Reservoir 9B (future Reservoir 9A), and Reservoir 9B Tank hatch intrusion switch (future Reservoir 9A).

Reservoir 9A panel also controls the Reservoir 9A influent control valve. Similarly, the Reservoir 9B panel also controls the Reservoir 9B influent control valve. Reservoir 9B panel also houses the short haul modems that transmits the Reservoir 9A & Reservoir 9B level to Pump Station 9; the RTU radio and a lighting panelboard.

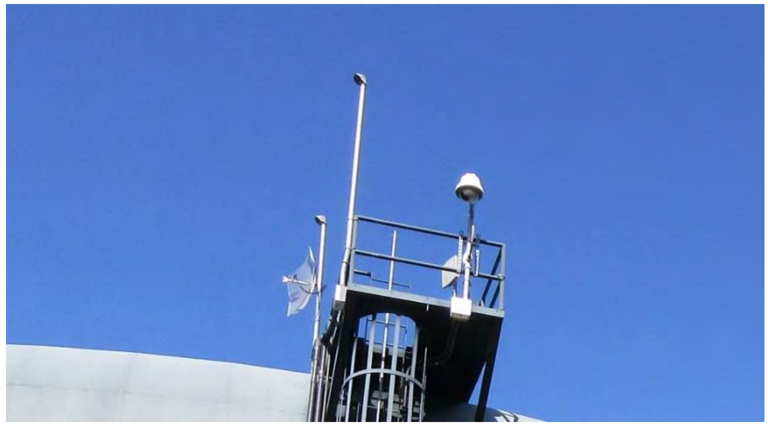
The panelboard circuits are shown in Table 1.

Table 1. Reservoir R-9A Panelboard Circuit Layout

Circuit No.	Circuit Size	Description	Circuit No.	Circuit Size	Description
1	20A/1P	UPS DGH-9H	2	20A/1P	(Blank)
3	20A/1P	Recept DGH-R-9B	4	20A/1P	(Blank)
5	20A/1P	Camera Tank R-9B	6	20A/1P	(Blank)
7	20A/1P	(Blank)	8	20A/1P	(Blank)
9	30A/2P	Irrig Pump	10	20A/1P	Area lights (off)
11	30A/2P	Irrig Pump	12	20A/1P	(Blank)
13	20A/1P	Irrig Time Clock	14	20A/1P	(Blank)
15	20A/1P	(Blank)	16	20A/1P	MOV-902 (off)
17	20A/1P	Vault Sump	18	20A/1P	Vault #2 GFI (off)
19	20A/1P	(Blank)	20	20A/1P	(Blank – on)
21	60A/2P	Main	22	100A/2P	R-9A Disconnect
23	60A/2P	Main	24	100A/2P	R-9A Disconnect

Reservoir 9A has a 900MHz antenna, 400MHz antenna and GHz antenna. There is also a camera mounted to the top of the tank (see Photo 3).

There is a security antenna (flat GHz) and a SCADA antenna (parabolic) on Reservoir 9B. Reservoir 9B's camera is not operational (see Photo 4).

	
Photo 3. Reservoir 9A SCADA Antenna and Security Antenna	**Photo 4. Reservoir 9B Security and SCADA Antennas**

2.0 RESERVOIR R-16

The Reservoir R-16 site is located east of Fountaingrove Parkway just south of Hadley Hill Drive. Pump Station S-17 is also located at the same site.

A visual inspection of the electrical equipment and instrumentation was performed at the Reservoir R-16 site. A general listing of equipment and field notes are included and include the following topics:

- Electrical Service
- Utility Metering
- Pump Control and Building
- Generator and ATS
- Instrumentation and Controls
- Site

2.1 Electrical Service

The site is fed from a PG&E utility transformer (T-6863).

There is a single SCADA antenna located on the roof of the tank. The tank level is communicated to Pump Station S-16 via a modem.

None of the electrical panels have arc flash labels.

2.2 Utility Metering

The power consumption is recorded by a PG&E utility meter (#1009513036) rated for 480V, three-phase at 400A. The meter/main is a NEMA 3R switchboard (Tesco job number T- 16783), rated 35KAIC, and installed approximately in 1996. The utility meter is located on the left above the pull section. The 400A main breaker is located on the right. There are Automatic Transfer Switch (ATS) position indicator lights and a “Press to Test” switch mounted on the switchboard deadfront door. The switchboard is located outside the building wall near the generator exhaust duct.

2.3 Pump Control and Building

There are two rooms in the Control Building; generator room and pump/electrical room. Skylights are located above each 75HP vertical turbine pump for removal. There is a heater in each room for climate control.

The S-17 Pump Station MCC (Tesco T-16783X1) is a seven section 600A horizontal Cutler-Hammer Freedom 2100 (job number 621663355-1) MCC constructed in January of 1996 (right to left).

- Section 1 contain the motor controls for the 75HP Pump S-17-P1. The pump’s soft starter motor controls take up ¾ of the MCC section. The top fourth of the MCC section is a space. This section has 300A vertical section.
- Section 2 contain the motor controls for the 75HP Pump S-17-P2. The pump’s motor controls take up ¾ of the MCC section. Pump 2 motor controls have been replaced with VFD controls. Located above the motor controls is the line monitor and disconnect circuit breaker. This section has a 300A vertical section.
- Section 3 contains the panelboard and transformer. This section has a 300A vertical section. Panelboard “P” is a 120/240V, 1 phase panelboard. Located below the panelboard is a dual circuit breaker cubicle with the 40A/2P Transformer Disconnect and a 70A/2P Panel “P” Disconnect. The 15KVA Transformer is located below the circuit breakers. The panelboard is a 36-circuit single phase panel, shown in Table 2.

Table 2. Reservoir R-16 Panelboard Circuit Layout					
Circuit No.	Circuit Size	Description	Circuit No.	Circuit Size	Description
1	20A	Lights	2	20A	Engine Heater
3	20A	Recept	4	20A	Recept
5	20A	Exh Fan	6	15A	Batt Charger
7	20A	Exh Fan	8	15A	DCU (LIQ 5)
9	30A/2	Spare	10	20A	Tel Recept
11		Spare	12	20A	Recept
13	20A	Spare	14	20A	Telem Cabinet
15	20A	Spare	16	20A	Telem Cabinet
17	20A	Spare	18	20A	Tank Lights
19	20A/2	Spare	20	20A	1.8KVA UPS
21		Spare	22	20A	Spare
Spaces 23-26					

- Section 4 is the Relays and Controls Section. It has miscellaneous alarm lights and the Rosemount flowmeter transmitter.
- Section 5 has the Yokogawa electronic chart recorder mounted to front of the full height MCC section.
- Section 6 is a termination MCC section for wires between the MCC and PLC Control Panel.
- Section 7 contains the PLC control panel with a Tesco Liq 5/30 mounted to the front of the cabinet. There is a blue security button and black Alarm Acknowledge pushbutton mounted below the Liq 5/30. A red “Station 17 in Control when lit” indicating light is mounted above the Liq 5/30. This section contains the Black Box modem. DataRadio, old DSL modem to R17, battery backup and the following selector switches:
  - Switch – Reservoir Select A/B
  - Switch – Operating mode Local / Remote (in local)
  - Switch – AC Power Off / On
  - Switch – Radio Power Off / On
  - Switch – Battery Power Off / On
  - Switch – Mode Pressure / Level (Level)

A telephone termination cabinet is located next to the door between the generator room and the pump/electrical room (see Photo 5). It contains multiple phone lines. There is modem communication between Pump Station S-16 and Reservoir R-16, and Pump Station S-17 and Reservoir R-17 at this site.

Photo 5. Telephone termination cabinet

2.4 Generator and ATS

A Katolight 150KW, 183KVA, 225A (model N179FRZ9, nameplate reads 179KW, 223KVA) @ 480V standby duel fuel (propane / natural gas) generator with a Cummins Engine (model G1A12) provides backup power to the station in the event of a power failure. The standby generator is in the generator room of the control building.

City staff have expressed concerns about the generator's ability to run two pumps. They typically run only one pump. Furthermore, the existing generator is natural gas/propane operated and the City desires to replace with a diesel operated generator.

The generator's main circuit breaker is mounted to the skid. There is a 225A load bank breaker mounted to the side of the generator along with a Crouse-Hines Posi-Lock panel "E0400" series generator receptacle. The Posi-lock panel is used for exercising the generator (see Photo 6).

Photo 6. Posi-lock panel

2.5 Instrumentation and Controls

The Pump Station S-17 Control Panel is located in the MCC line-up.

There are pressure transmitters on both the suction and discharge size of the pumps, along with lo lo suction pressure switch (set at 12 PSI normally) and hi hi discharge pressure switch (set at 90 PSI normally). The pressure transmitters are Bristol Babcock Signature model 2408-10B10B-511; 0-150 and the pressure switches are Allen-Bradley 836T pressure switches (suction-836T-T251J; Discharge 836T-T253JX40). These instruments are located inside the pump/electrical room, between the two pumps, against the wall (see Photo 7).

The pump station discharge flowmeter is located in a vault, outside, near the switchboard.

The Reservoir R-16 Storage Tank Telemetering Panel (Tesco T-29635) houses the tank instrumentation and RTU. It has a "wet" left instrument side and a "dry" PLC & telemetry side. There is no corrosion at the bottom of the wet side of the panel (see Photo 8).

	
Photo 7. Pump Instrument Panel	**Photo 8. Tank Instrument Panel "wet side"**

The R16 tank is monitored by a L2000 PLC with small form factor LED Operator Interface. The PLC is provided with battery backup with battery charger in the event of power failure.

The instruments located in the panel are:

1. Reservoir Level (pressure) transmitter; Rosemount
2. Free Chlorine; US Filter (Wallace & Tiernan) Depolox Basic

The SCADA antenna is located on top of Reservoir 16.

2.6 Site

There are three 25 feet high street lights located around the perimeter of the tank with a pull box next to each light.

The propane tank is located near the utility transformer.

3.0 RESERVOIR R-17

The Reservoir R-17 site is located behind the City of Santa Rosa Fire Station No. 5 near the corner of Fountaingrove Parkway and Newgate Court.

Appendix F
Reservoir Electrical Evaluation Field Notes

City of Santa Rosa

A visual inspection of the electrical equipment and instrumentation was performed at the Reservoir R-17 site. A general listing of equipment and field notes are included and include the following topics:

- Electrical Service
- Utility Metering
- Generator and ATS
- Instrumentation and Controls

3.1 Electrical Service

There are two PG&E utility transformers at the site:

- T-6844 – older, smaller unit located near the telecom panels
- T-39126 – newer, located behind the fire station

This tank is used by two telecom providers to mount their equipment at the top perimeter of the tank. There are panels, separate utility metering and standby generator for the providers' equipment in a segregated fenced off location next to the tank property.

There are multiple electrical panels located around the exterior of the tank (counter clock wise, see Photo 9):

- Old electrical panel with photocell mounted to side of panel
- Tank Utility metering pedestal
- Storage Tank Telemetering Panel (Standard City of Santa Rosa Tank RTU panel)
- City Radio panel (Multiple 5-inch conduit up side of tank)
- Ham Radio Panel
- CB Radio Panel

Photo 9. Electrical panels

3.2 Utility Metering

The power consumption is recorded by a PG&E utility meter (#1008885240) rated for 240/120V, single-phase at 100A, 10KAIC. The meter/main is a NEMA 3R pedestal – (Tesco pedestal type 21-100) installed approximately 1996 (Tesco job number T- 16783X1). The distribution circuit breakers are laid out in Table 3.

Table 3. Reservoir R-17 Panelboard Circuit Layout

Circuit No.	Circuit Size	Description
1	15A/1P	Amateur Radio Repeater Ckt1
2	20A/1P	Amateur Radio Repeater Ckt2
3	20A/1P	Pole Lights
4	20A/1P	Local Operations SCADA Radio Cabinet
5	20A/1P	Telemetry Cabinet PLC Power H-1
6	20A/1P	Telemetry Cabinet Lights, Heater, Recept. Power H-2
7	100A/2P	Service Disconnect

3.3 Generator and ATS

No Standby generator or ATS is located onsite for the tank.

3.4 Instrumentation and Controls

The Storage Tank Telemetering Panel (Tesco T-29635) houses the tank instrumentation and RTU. It has a “wet” left instrument side and a “dry” PLC & telemetry side. There is some slight corrosion at the bottom of the wet side of the panel.

The tank is monitored by a L2000 PLC with small form factor LED Operator Interface. The PLC is provided with battery backup with battery charger in the event of power failure.

The instruments located in the panel are (see Photo 10):

- Reservoir Level (pressure) transmitter; Rosemount
- Free Chlorine; US Filter (Wallace & Tiernan) Depolox Basic

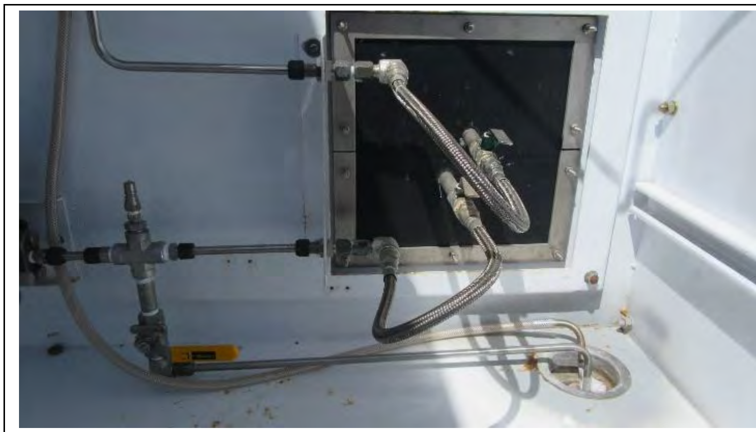


Photo 10. Tank Panel Instrument Panel

High and low alarms will be generated from the analog instruments.

There are three pole lights on site. Area Pole Lighting is fed as follows:

- 1-inch conduit from the Utility metering to pull box
- From pull box, counterclockwise around tank to pole light
- 2-inch conduit from pull box, clockwise around tank to pole light
- 2-inch conduit from pole light, clockwise around tank to last pole light

There is sign of rust on the Reservoir 17 CB radio panel (see Photo 11).

Photo 11. CB Radio Panel

APPENDIX G

Pump Station Electrical Field Notes

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List of Acronyms and Abreviations

AC	Alternating Current
ATS	Automatic Transfer Switch
City	City of Santa Rosa
DCU	Digital Concentrator Unit
DSL	Digital Subscriber Line
HP	Horsepower
KVA	Kilo-Volt-Ampere
KW	Kilo-Watt
LED	Light Emitting Diode
MCC	Motor Control Center
NEMA	National Electrical Manufacturers Association
PID	Proportional Integral Derivative
PLC	Programmable Logic Controller
PSI	Pounds per Square Inch
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
UPS	Uninterrupted Power Supply
URL	Uniform Resource Locator
UT	Ultrasonic Thickness

Appendix G
Pump Station Electrical Evaluation Field Notes

The following pump stations were included in this project:

- **Pump Station S-1:** located on the south side of 280 Fountaingrove Parkway, between Mendocino Avenue and Bicentennial Way.
- **Pump Station S-2:** located on the north side of 1395 Fountaingrove Parkway near Stagecoach Road.
- **Pump Station S-15:** located at 6348 Sonoma Highway.
- **Pump Station S-16:** located off 5401 Montecito Avenue.
- **Pump Station S-17:** located east of Fountaingrove Parkway just south of Hadley Hill Drive.
- **Pump Station S-18:** located on the north side of Fountaingrove Parkway across the street from Reservoir 17.

A visual inspection of the electrical equipment and instrumentation was performed at each pump station site and the field notes are provided below.

1.0 PUMP STATION S-1

The Pump Station S-1 site is located on the south side of 280 Fountaingrove Parkway, between Mendocino Avenue and Bicentennial Way.

A visual inspection of the electrical equipment and instrumentation was performed at the Pump Station S-1 site. A general listing of equipment and field notes are included and include the following topics:

- Electrical Service
- Utility Metering
- Pump Control and Building
- Generator and ATS
- Instrumentation and Controls
- Site

1.1 Electrical Service

The site is fed from a PG&E utility transformer (T-1119).

There is an Arc Flash Label on the main switchboard dated March 20, 2007, but no label on the MCCs Code requires an Arc Flash Study be performed with new labels added every five years.

There is also a cell phone provider building on the property.

1.2 Utility Metering

Power consumption is recorded by a PG&E utility meter (#1010117137) 480V-rated, three-phase at 600A. The switchboard is located outside the building wall near the pump room exhaust duct. The meter/main is a Square D NEMA 3R switchboard, SF #346WR. The utility meter is located on the left above the main circuit breaker (30-inch W). It is a molded case circuit breaker with 600A JJ fuses. The pull section is located on the right (36-inch W). The switchboard is 14 inches deep with a 12-inch deadfront (see Photo 1).

Photo 1. Utility Meter

1.3 Pump Control and Building

The Control Building includes a generator room and pump/electrical room. There is a heater in each room for climate control. On the north side of the building a wall-pack light faces the street.

The Pump Station S-1 MCC (Tesco job number T- 21686) is a ten section 600A horizontal Cutler-Hammer Freedom 2100 (job number 621662881-1) constructed in August 1999 (right to left).

- Section 1 contains the 400-automatic transfer switch. It has the following panel mounted devices:
  - — Indicating light (green) – Normal Connected
  - — Indicating light (amber) – Emergency Connected
  - — Indicating light (red) – Emergency Available
  - — Indicating light (green) – Normal Available
  - — Keyed switch – Normal – Test/Retransfer

- Section 2 contains the motor controls for the 125HP Pump S-1-P1. The pump's soft starter motor controls take up the entire MCC section. This section has a 300A vertical section.
- Section 3 contains the motor controls for the 125HP Pump S-1-P2. The pump's soft starter motor controls take up the entire MCC section. This section has a 300A vertical section.
- Section 4 contains the motor controls for the 125HP Pump S-1-P3. The pump's soft starter motor controls take up the entire MCC section. This section has a 300A vertical section.
- Section 5 contains the motor controls for the 125HP Pump S-1-P4. The pump's soft starter motor controls take up the entire MCC section. This section has a 300A vertical section.
- Section 6 contains the line monitor disconnect, heater disconnect, panelboard and transformer. This section has a 300A vertical section. The line monitor disconnect and heater disconnect are located above the 120/240V 1 phase panelboard. A dual circuit breaker transformer disconnect and a panel disconnect are located below the panelboard. The 9KVA Transformer is located behind the circuit breakers. The panelboard is a 30-circuit single phase panel, as shown in Table 1.

Table 1. Pump Station S-1 Panelboard Circuit Layout

Circuit No.	Circuit Size	Description	Circuit No.	Circuit Size	Description
1	20A	Recept	2	20A	Recept
3	20A	Recept	4	20A	Recept
5	20A	Solenoids	6	15A	Lights – Gen Room
7	20A	Lights Pmp Rm	8	15A	Emerg Lights
9	15A	DCU-Liq 5	10	20A	Exter Lights
11	20A	Controls	12	20A	Battery Charger
13	15A	Exh Fan	14	20A	Recept Gen Rm
15		Space	16	20A	Spare
17	20A	Spare	18	30A	Spare
Spaces 19-30					

- Section 7 is the relays and controls section. It has miscellaneous alarm lights and a Siemens flowmeter transmitter. There are indicating lights and a pushbutton mounted to the front of the panel. The section contains:
  - — Pushbutton (black) – Trouble Reset
  - — Indicating light (red) – Emergency Stop
  - — Indicating light (red) – Line Monitor Trouble
  - — Indicating light (red) – High Discharge Pressure Trouble
  - — Indicating light (red) – Low Suction Pressure Trouble

- Section 8 is a termination MCC section for wires between the MCC and PLC control panel.
- Section 9 has the Yokogawa electronic chart recorder mounted to front of the full height MCC section.
- Section 10 contains the PLC control panel with a Tesco Liq 5/30 mounted to the front of the cabinet. There is a blue security button and black Alarm Acknowledge pushbutton mounted below the Liq 5/30. This section contains the DataRadio to Reservoir R-17 repeater, Black Box modem to 1A/1B, battery backup and the following selector switches:
  - Switch – Reservoir Select A/B
  - Switch – AC Power Off/On
  - Switch – Radio Power Off/On
  - Switch – Battery Power Off/On
  - Switch – Operating Mode Local/Remote

A telephone termination cabinet is located on the wall between the generator room and the pump/electrical room (see Photo 2).

Photo 2. Telephone Termination Cabinet

1.4 Generator and ATS

A Cummins (frame HC I434F1, nameplate reads 300KW, 375KVA) @ 480V standby duel fuel (propane/natural gas) generator provides backup power to the station in the event of a power failure. It is located in the generator room of the control building. Mounted to the generator skid is the main circuit breaker along with a 30A disconnect switch for the generator heater. A 400A load bank breaker and a Crouse-Hines Posi-Lock panel “E0400” series generator receptacle is mounted to the wall. A Posi-lock panel is used for exercising the generator (see Photo 3).

The generator sustained some damage during recent fires; Furthermore, the City prefers to convert existing natural gas/propane fueled generators to diesel fueled generators. Consequently, it is recommended that this generator be replaced.

Photo 3. Generator Posi-lock Panel

1.5 Instrumentation and Controls

The Pump Station S-1 Control Panel is located in the MCC line-up.

There are pressure transmitters located on the suction and discharge sides of the pumps, along with the lo-lo suction pressure switch and hi-hi discharge pressure switch. The pressure transmitters are Yokogawa model EJA-530A, style 52, -EBS4N-02DN/EF1/D1, 0-100 suction 0-200 discharge; and the pressure switches are Allen-Bradley 836T pressure switches (suction-836T-T253J – set at 8.5; Discharge 836T-T254J). These instruments are located inside the pump/electrical room, on the north-east side of the room (see Photo 4).

Photo 4. Pump Instrument Panel

The pump station discharge flowmeter is located in a vault.

The SCADA antenna is mounted to an antenna tower on the west side of the building.

1.6 Site

There are no area lights. There are wall pack lights mounted to the building.

The propane tank is located near the utility transformer.

There is a single SCADA antenna located outside, on the south-west corner of the building, that communicates to the repeater at Reservoir R-17. The Reservoir R-1A and Reservoir R-1B tank levels are received at Pump Station S-1 via a leased line modem.

2.0 PUMP STATION S-2

The Pump Station S-2 site is physically located on the north side of 1395 Fountaingrove Parkway near Stagecoach Road.

Appendix G
Pump Station Electrical Evaluation Field Notes

A visual inspection of the electrical equipment and instrumentation was performed at the Pump Station S-2 site. A general listing of equipment and field notes are included and include the following topics:

- Electrical Service
- Utility Metering
- Pump Control and Building
- Generator and ATS
- Instrumentation and Controls
- Site

2.1 Electrical Service

The site is fed from a PG&E utility transformer (T-1197).

There is an Arc Flash Label on the main switchboard dated 3/20/07, but no label on the MCCs. Code requires an Arc Flash Study be performed with new labels added every 5 years.

2.2 Utility Metering

Power consumption is recorded by a PG&E utility meter (#1006133881) rated for 480V, three-phase at 400A. The switchboard is located outside, on the south-west side of the building. The meter/main is a NEMA 3R switchboard (Tesco job number T- 22947), rated 35KAIC, and installed around 2000. The pull section is on the left and the utility meter is located on the right, above the main 400A fuse disconnect (see Photo 5).

Photo 5. Utility Meter

2.3 Pump Control and Building

The Control Building houses the generator room and pump/electrical room. There is a heater in each room for climate control.

The Pump Station S-2 MCC (Tesco T-22947) is a nine section 600A horizontal Cutler-Hammer Freedom 2100 (right to left). The station sections are:

- Section 0 contains the Automatic Transfer Switch. Additional conduits were installed between the ATS and generator lugs because the generator has not been replaced.
- Section 1 contains the motor controls for the 100HP S-2 Pump S-2-P1. The pump's soft starter motor controls take up the entire MCC section. This section has 300A vertical section.
- Section 2 contains the motor controls for the 100HP S-2 Pump S-2-P2. The pump's motor controls take up the entire MCC section. This section has a 300A vertical section.
- Section 3 contains the motor controls for the 100HP S-2 Pump S-2-P3. The pump's soft starter motor controls take up the entire MCC section. This section has 300A vertical section.
- Section 4 contains the motor controls for the 100HP S-2 Pump S-2-P4. The pump's motor controls take up the entire MCC section. This section has a 300A vertical section.
- Section 5 contains the heater disconnect, supply fan disconnect, line monitor disconnect, panelboard and transformer. This section has a 300A vertical section. The heater and supply fan disconnects are located in a dual circuit breaker cubicle at the top of the MCC section. The line monitor disconnect is located directly above the 120/240V, 1 phase Panelboard "A". A dual circuit breaker 15A/2P Transformer Disconnect and a 40A/2P Panel "A" Disconnect are located below the panelboard. The 9KVA Transformer is located behind the circuit breakers. The panelboard is an 18-circuit single phase panel, as shown in Table 2.

Table 2. Pump Station S-2 Panelboard Circuit Layout

Circuit No.	Circuit Size	Description	Circuit No.	Circuit Size	Description
1	20A	Spare	2	20A	Spare
3	20A	Recept	4	20A	Recept
5	20A	(Blank)	6	15A	Lts Gen Rm
7	20A	Lts – Pump Rm	8	20/2	Gen Jacket Htr
9	15A	DCU-Liq 5	10		
11	20A	120V Ctrl	12	20A	Gen Vent
13	15A	Exhaust Fn	14	20A	Recept Gen Rm
15	60A/2	Supply Fn Ctrl	16	20A	(Blank)
17			18	30A	Exterior Lts

- Section 6 contains the Yokogawa electronic chart recorder, and the following pilot devices mounted to front of the full height MCC section:
  - Indicating light (red) – Emergency Stop
  - Indicating light (red) – Line Monitor Trouble
  - Pushbutton (black) – Trouble Reset
  - Indicating light (red) – High Discharge Pressure Trouble
  - Indicating light (red) – Low Suction Pressure Trouble
- Section 7 is a termination MCC section.
- Section 8 is a termination MCC section for wires between the MCC and PLC Control Panel.
- Section 9 contains the PLC control panel with a Tesco Liq 5/30 mounted to the front of the cabinet. There is a blue security button and black Alarm Acknowledge pushbutton mounted below the Liq 5/30. This section contains the Black Box modem, DataRadio to R2A/2B, old DSL modem to R2A/2B, battery backup and the following selector switches:
  - Switch – Reservoir Select A/B
  - Switch – Operating mode Local/Remote (in local)
  - Switch – AC Power Off/On
  - Switch – Radio Power Off/On
  - Switch – Battery Power Off/On

2.4 Generator and ATS

A Cummins 235KW, 294KVA, 350A @ 480V standby duel fuel (propane/natural gas) generator with a Cummins Engine (model G1A12). The exiting generator failed in February 2017 and has been offline since that time; therefore, the generator needs to be replaced. The standby generator is located in the generator room of the control building.

City staff has reported that the air inlet does not function properly making it difficult to open the generator room door when the generator is running. Furthermore, the automated louvers on the air intake do not appear to function.

The generator's main circuit breaker is mounted to the generator skid.

2.5 Instrumentation and Controls

The Pump Station S-2 Control Panel is located in the MCC line-up.

Pressure transmitters are located on the suction and discharge sides of the pumps, along with lo-lo suction pressure switch and hi-hi discharge pressure switch. The pressure transmitters are Bristol Babcock Signature model 2408-10B-511-110-110; 0-150 and the pressure switches are Square D Class 9015 pressure switches (suction-GDW-21; Discharge GDW). These instruments are located inside the pump/electrical room against the wall, below an abandoned panel (see Photo 6).

Photo 6. Pump Instrument Panel

The Reservoir 1A and 1B Storage Tank Telemetering Panels (Tesco T-29635) house the tank instrumentation and RTU. It has a "wet" instrument side and a "dry" PLC telemetry side which uses the modem to communicate with Pump Station S-1. This panel is clean and operational (see Photo 7).

Photo 7. Tank Instrument Panel "Wet Side"

The R1A & R1B tanks are monitored by L2000 PLCs with small form factor LED Operator Interfaces. Both PLCs have a backup battery and charger in the event of power failure.

The instruments located in each panel are:

1. Reservoir Level (pressure) transmitter; Rosemount
2. Free Chlorine; US Filter (Wallace & Tiernan) Depolox Basic

The SCADA antenna is located on top of Reservoir 1A.

2.6 Site

There are three 30 feet high area (street-type) lights with pull boxes located around the tank perimeter.

The propane tank will be replaced with a diesel fuel tank.

There is a single SCADA antenna located on the roof of Tank 1A that communicates to Reservoirs 2A and 2B. There are also modems in the control panel that communicates to Reservoirs 2A and 2B.

3.0 PUMP STATION S-15

The Pump Station S-15 site is physically located at 6348 Sonoma Highway.

A visual inspection of the electrical equipment and instrumentation was performed at the Pump Station S-15 site. A general listing of equipment and field notes are included and include the following topics:

- Electrical Service
- Utility Metering
- Pump Control and Building
- Generator and ATS
- Instrumentation and Controls
- Site

3.1 Electrical Service

The site is fed from a PG&E utility transformer (T-6944).

None of the electrical panels have Arc Flash Labels. An Arc Flash study with new labels is required.

3.2 Utility Meter ing

Power consumption is recorded by a PG&E utility meter (#100537913) rated for 480V, three-phase at 200A. The meter/main is a NEMA 3R Circle AW type meter/main (Tesco job number T- 28763), rated 35KAIC and installed around 1996. The 400A main breaker is located to the right of the meter. The meter is located on the west corner of the building (see Photo 8).

Photo 8. Utility Meter

3.3 Pump Co ntr ol an d Bu ilding

The Control Building houses the generator room and pump/electrical room. There are no skylights above the pumps. There is a heater in each room for climate control.

The Pump Station S-15 MCC is an eight section 600A horizontal Cutler-Hammer Freedom 2100 (job number HUSF67991-1) MCC constructed in August 1994 with seven sections (right to left). The sections include:

- Section 1 is a newer (~2013) panel section, housing only the VFDs for Pumps 1 & 2. There are two backpan mounted 10HP rated ABB drives with the faceplates mounted to the front of the section door. This section has a 300A vertical section.

Appendix G
Pump Station Electrical Evaluation Field Notes

- Section 2 contains the motor controls and compressor for pumps P1 & 2. The line monitor is located in the top of the section. There is a spare cubicle and motor controls for the compressor located above the 10HP S-15-P1 & Pump S-15-P2 motor controls. This section has a 300A vertical section.
- Section 3 contains the panelboard and transformer. This section has a 300A vertical section. The transformer feed breaker, located above the panelboard, feeds the line monitor and panelboard. The panelboard is a 120/240V, 1-phase panelboard. The 15KVA Transformer is located below the panelboard. The panelboard is a 36-circuit single phase panel, as shown in Table 3.

Table 3. Pump Station S-15 Panelboard Circuit Layout

Circuit No.	Circuit Size	Description	Circuit No.	Circuit Size	Description
1	20A	Spare in wireway to right	2	20A	(unmarked)
3	20A	Batt Charger	4	20A	(unmarked)
5	20A	Ctrl Pwr	6	20A/2P	Heater
7	20A	Irrg Ctrls	8		Heater
9	20A	SCWA sump pmp	10	20A	Recepts
11	20A	Liq 5	12	20A	Ex Fans
13	15A	Air Comp Rcpt	14	20A	Lights
15	(Blank)		16	20A	Lights Gen
17	(Blank)		18	20A	Extrer Photocelll
19	(Blank)		20	20A	Engin Block Hetaer
Spaces 21-38					
39	(Blank)		40	80A/2P	Main
41	(Blank)		42	80A/2P	Main

- Section 4 contains the motor controls for the 50HP Pump S-15-P3. The pump's VFD motor controls take up ¾ of the MCC section. This section has a 300A vertical section.
- Section 5 contains an empty MCC panel section for wires running between the MCC and PLC Control Panel. It contains a DIN rail, one relay, and a fuse for the chart recorder.
- Section 6 is the relay and controls section. It has miscellaneous alarm lights, the Booster Pump Sensus Act-Pak flowmeter electronic, and Fire Pump Census Act-Pak flowmeter electronics. It has the following pilot devices mounted to front of the full height MCC section:
  - — Pushbutton (black) – Trouble Reset
  - — Indicating light (red) – Emergency Stop
  - — Indicating light (red) – Line Monitor Trouble

- Indicating light (red) – High Discharge Pressure
- Indicating light (red) – Low Suction Pressure
- Indicating light (red) – Station Fire
- Indicating light (red) – Power Quality Fail

- Section 7 is an empty MCC panel section for wires running between the MCC and PLC Control Panel. It contains a DIN rail, one relay, and a fuse for the Yokogawa PID controller mounted to the front of the section.
- Section 8 contains the Yokogawa electronic chart recorder mounted to the full height MCC section and the PLC control panel with a Tesco Liq 5/30 (T-18277x2) mounted to the front cabinet. There is a blue security button and black Alarm Acknowledge pushbutton mounted to the right of the chart recorder. This section contains the DataRadio Integra to R7, battery backup and following selector switches:
  - Switch – AC Power Off/On
  - Switch – Radio Power Off/On
  - Switch – Battery Power Off/On

The City has expressed a wish for an active harmonic filter to be installed at the station, similar to Pump Station PS-3 to address any harmonic issues.

A telephone termination cabinet is located next to the main pump/electrical room door. It contains multiple phone lines for flow and alarm. A Microtel Series 1000 auto-dialer is located on the backpan (see Photo 9).

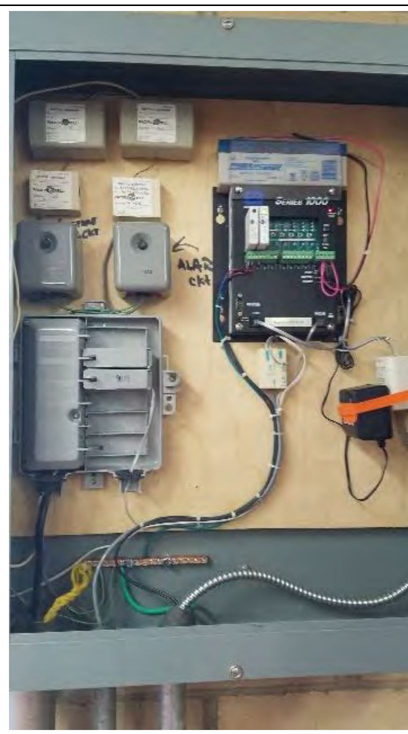

Photo 9. Telephone Termination Cabinet

3.4 Generator and ATS

A Kohler 135KW, 169KVA, 203A generator model 4S13 (Cummins Engine model G855, 25198417) @ 480V standby duel fuel (propane/natural gas) generator provides backup power to the station in the event of a power failure. The standby generator is located in the generator room of the control building. On August 6, 2014, the load bank testing was halted at approximately 48 percent loading due to “extremely hot” exhaust conditions.

The generator’s main circuit breaker is mounted to the generator skid. There is a 200A load bank breaker mounted to the side of the generator along with a Crouse-Hines Posi-Lock panel “E0400” series generator receptacle. The Posi-lock panel is used to exercise the generator (see Photo 10).

To the right of the meter/main is a Westinghouse circuit breaker type NEMA 3R ATS. City staff have expressed concerns about the existing ATS.

Photo 10. Generator Posi-lock Panel

3.5 Instrumentation and Controls

The Pump Station S-15 Control Panel is located in the MCC line-up.

Pressure transmitters are located on the suction and discharge sides of the pumps, along with lo-lo suction pressure switch and hi-hi discharge pressure switch. The pressure transmitters are Bristol Babcock Signature model (suction 2408-10B-511-110-110-A230; 0-100 URL 150PSI; discharge 2408-10B-511-110-100; 0-117, URL 150PSI) and the pressure switches are Allen-Bradley 836T pressure switches (suction-836T-T253J; Discharge 836T- T253J). These instruments are located inside the pump/electrical room, on the north wall, next to the Hydropneumatic tank door (see Photo 11).

Photo 11. Pump Instrument Panel

Next to the Hydropneumatic tank is a US Filter (Wallace & Tiernan) Depolox Basic Free Chlorine analyzer in a galvanized steel enclosure with viewing window. There are signs of corrosion on the panel (see Photo 12).

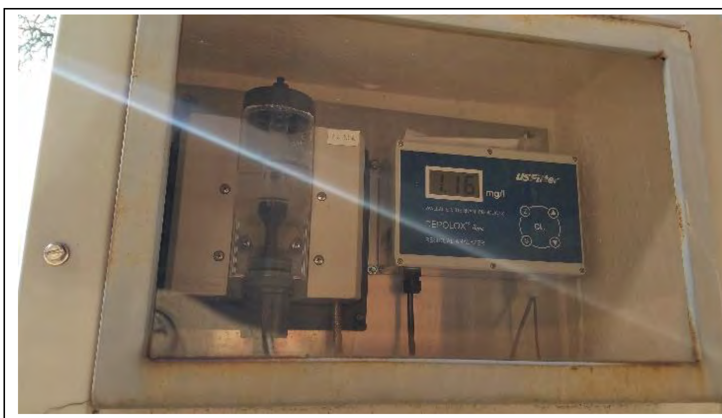

Photo 12. Chlorine Analyzer

3.6 Site

There are no area lights, only wall packs installed on the building.

The propane tank is located to the left of the utility transformer. A future above ground fuel tank may be installed in the dirt area near the utility meter.

There is a single SCADA antenna located on an antenna mast on the northwest side the building communicating to Reservoir 7.

4.0 PUMP STATION S-16

The Pump Station S-16 site is physically located off 5401 Montecito Avenue, accessed by a side street behind houses.

A visual inspection of the electrical equipment and instrumentation was performed at the Pump Station S-16 site. A general listing of equipment and field notes are included and include the following topics:

- Electrical Service
- Utility Metering
- Pump Control and Building
- Generator and ATS
- Instrumentation and Controls
- Site

4.1 Electrical Service

The site is fed from a PG&E utility transformer (T-6806).

There is a single SCADA antenna located on the roof of the tank.

There are arc flash labels on the switchboard.

4.2 Utility Metering

The power consumption is recorded by a PG&E utility meter (#1009504397) rated for 480V, three-phase at 400A. The meter/main is a NEMA 3R switchboard (Tesco job number T- 28763), rated 35KAIC and installed in approximately 1996. The utility meter is located on the left above the pull section. The 400A main breaker is located on the right. There are ATS position indicating lights and a “Press to Test” switch mounted on the switchboard deadfront door. The switchboard is located outside near the generator exhaust duct.

4.3 Pump Control and Building

There are two rooms in the Control Building; generator room and pump/electrical room. Skylights are located above each 75HP vertical turbine pump for removal. There is a heater in each room for climate control.

The Pump Station S-16 MCC is a seven section 600A horizontal Cutler-Hammer Freedom 2100 (job number 621663355-3) MCC constructed in January of 1996 (right to left).

- Section 1 contains the motor controls for the 75HP S-16 Pump S-16-P1. The pump motor controls take up three-quarters of the MCC section. Pump 2 motor controls have been replaced with VFD controls. The top fourth of the MCC section is a space. This section has 300A vertical section.
- Section 2 contains the motor controls for the 75HP S-16 Pump S-16-P2. The pump's soft starter motor controls take up ¾ of the MCC section. Located above the motor controls is the line monitor and disconnect circuit breaker. This section has a 300A vertical section.
- Section 3 contains the panelboard and transformer. This section has a 300A vertical section. Panelboard "P" is a 120/240V, 1 phase panelboard. Located below the panelboard is a dual circuit breaker cubicle with the 40A/2P Transformer Disconnect and a 70A/2P Panel "P" Disconnect. The 15KVA Transformer is located below the circuit breakers. The panelboard is a 36-circuit single phase panel, as shown in Table 4.

Table 4. Pump Station S-16 Panelboard Circuit Layout

Circuit No.	Circuit Size	Description	Circuit No.	Circuit Size	Description
1	20A	Lights	2	20A	Engine Heater
3	20A	Recept	4	20A	Spare
5	20A	Exh Fan	6	15A	Batt Charger
7	20A	Exh Fan	8	15A	DCU (LIQ 5)
9	30A/2	Spare	10	20A	Tel Recept
11	-	Spare	12	20A	Spare
13	20A	Telem Cbt	14	20A	Telem Cabinet
15	20A	Spare	16	20A	Irrigation Controller
17	20A	UPS	18	20A	Tank Lights (pole)
19	20A/2	Spare	20	20A	Recept
21	-	Spare	22	20A	Recept
Spaces 23-36					

- Section 4 is the Relays and Controls Section. It has miscellaneous alarm lights and the Rosemount flowmeter transmitter.
- Section 5 has the Yokogawa electronic chart recorder mounted to front of the full height MCC section
- Section 6 is a termination MCC section for wires between the MCC and PLC Control Panel.
- Section 7 contains the PLC control panel with a Tesco Liq 5/30 mounted to the front of the cabinet. There is a blue security button and black Alarm Acknowledge pushbutton mounted below the Liq 5/30. A red "Station 16 in Control when lit" indicating light is mounted above the Liq 5/30. This section contains the Black Box modem. DataRadio, old DSL modem to R17, battery backup and the following selector switches:
  - Switch – AC Power Off / On
  - Switch – Radio Power Off / On
  - Switch – Battery Power Off / On

A telephone termination cabinet is located next to the door between the generator room and the pump/electrical room. It contains multiple phone lines (see Photo 13).

Photo 13. Telephone Termination Cabinet

4.4 Generator and ATS

A Katolight 150KW, 183KVA, 225A (model N179FRZ4, nameplate reads 179KW, 223KVA) @ 480V standby duel fuel (propane / natural gas) generator provides backup power to the station in the event of a power failure. The standby generator is located in the generator room of the control building. City staff have expressed concerns about the generator's ability to run two pumps. They typically run only one pump.

The generator's main circuit breaker is mounted to the skid. There is a 225A load bank breaker mounted to the side of the generator along with a Crouse-Hines Posi-Lock panel "E0400" series generator receptacle. The Posi-lock panel is used for exercising the generator (see Photo 14).

Photo 14. Generator Posi-lock Panel

4.5 Instrumentation and Controls

The Pump Station S-16 Control Panel is located in the MCC line-up.

There are pressure transmitters on both the suction and discharge size of the pumps, along with lo lo suction pressure switch and hi hi discharge pressure switch. The pressure transmitters are Bristol Babcock Signature model 2408-10B10B-511;0-150 and the pressure switches are Allen Bradley 836T pressure switches (suction-836T-T251J; Discharge 836T-T253JX40). These instruments are located inside the pump/electrical room, between the two pumps, against the wall.

The pump station discharge flowmeter is located in a vault, outside, near the switchboard.

The Reservoir 4B Storage Tank Telemetering Panel (Tesco T-29635) houses the tank instrumentation and RTU. It has a "wet" left instrument side and a "dry" PLC & telemetry side. There is no corrosion at the bottom of the wet side of the panel (see Photo 15).

Photo 15. Reservoir 4B Telemetering Panel

Reservoir R-16 is monitored by a L2000 PLC with small form factor LED Operator Interface. The PLC is provided with battery backup with battery charger in the event of power failure.

The instruments located in the panel are:

1. Reservoir Level (pressure) transmitter; Rosemount
2. Free Chlorine; US Filter (Wallace & Tiernan) Depolox Basic

The SCADA antenna is located on top of Reservoir 4B.

4.6 Site

There are three each 20 feet high area lights with cutoffs located around the perimeter of the site with a pull box next to each light.

The propane tank is located near the utility transformer.

5.0 PUMP STATION S-17

The Pump Station S-17 site is physically located east of Fountaingrove Parkway just south of Hadley Hill Drive.

A visual inspection of the electrical equipment and instrumentation was performed at the Pump Station S-17 site. A general listing of equipment and field notes are included and include the following topics:

- Electrical Service
- Utility Metering
- Pump Control and Building
- Generator and ATS
- Instrumentation and Controls
- Site

5.1 Electrical Service

The site is fed from a PG&E utility transformer (T-6863).

There is a single SCADA antenna located on the roof of the tank. The tank level is communicated to Pump Station S-16 via a modem.

None of the electrical panels have arc flash labels.

5.2 Utility Metering

The power consumption is recorded by a PG&E utility meter (#1009513036) rated for 480V, three-phase at 400A. The meter/main is a NEMA 3R switchboard (Tesco job number T- 16783), rated 35KAIC, and installed approximately in 1996. The utility meter is located on the left above the pull section. The 400A main breaker is located on the right. There are Automatic Transfer Switch (ATS) position indicator lights and a "Press to Test" switch mounted on the switchboard deadfront door. The switchboard is located outside the building wall near the generator exhaust duct.

5.3 Pump Control and Building

There are two rooms in the Control Building; generator room and pump/electrical room. Skylights are located above each 75HP vertical turbine pump for removal. There is a heater in each room for climate control.

The Pump Station S-17 MCC (Tesco T-16783X1) is a seven section 600A horizontal Cutler-Hammer Freedom 2100 (job number 621663355-1) MCC constructed in January of 1996 (right to left).

- Section 1 contain the motor controls for the 75HP S-17 Pump S-17-P1. The pump's soft starter motor controls take up ¾ of the MCC section. The top fourth of the MCC section is a space. This section has 300A vertical section.
- Section 2 contain the motor controls for the 75HP S-17 Pump S-17-P2. The pump's motor controls take up ¾ of the MCC section. Pump 2 motor controls have been replaced with VFD controls. Located above the motor controls is the line monitor and disconnect circuit breaker. This section has a 300A vertical section.
- Section 3 contains the panelboard and transformer. This section has a 300A vertical section. Panelboard "P" is a 120/240V, 1 phase panelboard. Located below the panelboard is a dual circuit breaker cubicle with the 40A/2P Transformer Disconnect and a 70A/2P Panel "P" Disconnect. The 15KVA Transformer is located below the circuit breakers. The panelboard is a 36-circuit single phase panel, shown in Table 5.

Table 5. Pump Station S-17 Panelboard Circuit Layout

Circuit No.	Circuit Size	Description	Circuit No.	Circuit Size	Description
1	20A	Lights	2	20A	Engine Heater
3	20A	Recept	4	20A	Recept
5	20A	Exh Fan	6	15A	Batt Charger
7	20A	Exh Fan	8	15A	DCU (LIQ 5)
9	30A/2	Spare	10	20A	Tel Recept
11		Spare	12	20A	Recept
13	20A	Spare	14	20A	Telem Cabinet
15	20A	Spare	16	20A	Telem Cabinet
17	20A	Spare	18	20A	Tank Lights
19	20A/2	Spare	20	20A	1.8KVA UPS
21		Spare	22	20A	Spare
Spaces 23-26					

- Section 4 is the Relays and Controls Section. It has miscellaneous alarm lights and the Rosemount flowmeter transmitter.
- Section 5 has the Yokogawa electronic chart recorder mounted to front of the full height MCC section.
- Section 6 is a termination MCC section for wires between the MCC and PLC Control Panel.
- Section 7 contains the PLC control panel with a Tesco Liq 5/30 mounted to the front of the cabinet. There is a blue security button and black Alarm Acknowledge pushbutton mounted below the Liq 5/30. A red "Station 17 in Control when lit" indicating light is mounted above the Liq 5/30. This section contains the Black Box modem. DataRadio, old DSL modem to R17, battery backup and the following selector switches:

- Switch – Reservoir Select A/B
- Switch – Operating mode Local / Remote (in local)
- Switch – AC Power Off / On
- Switch – Radio Power Off / On
- Switch – Battery Power Off / On
- Switch – Mode Pressure / Level (Level)

A telephone termination cabinet is located next to the door between the generator room and the pump/electrical room (see Photo 16). It contains multiple phone lines. There is modem communication between Pump Station S-16 and Reservoir R-16, and Pump Station S-17 and Reservoir R-17 at this site.

Photo 16. Telephone termination cabinet

5.4 Generator and ATS

A Katolight 150KW, 183KVA, 225A (model N179FRZ9, nameplate reads 179KW, 223KVA) @ 480V standby duel fuel (propane / natural gas) generator with a Cummins Engine (model G1A12) provides backup power to the station in the event of a power failure. The standby generator is in the generator room of the control building.

City staff have expressed concerns about the generator's ability to run two pumps. They typically run only one pump. Furthermore, the existing generator is natural gas/propane operated and the City desires to replace with a diesel operated generator.

The generator's main circuit breaker is mounted to the skid. There is a 225A load bank breaker mounted to the side of the generator along with a Crouse-Hines Posi-Lock panel "E0400" series generator receptacle. The Posi-lock panel is used for exercising the generator (see Photo 17).

Photo 17. Posi-lock panel

5.5 Instrumentation and Controls

The Pump Station S-17 Control Panel is located in the MCC line-up.

There are pressure transmitters on both the suction and discharge size of the pumps, along with lo lo suction pressure switch (set at 12 PSI normally) and hi hi discharge pressure switch (set at 90 PSI normally). The pressure transmitters are Bristol Babcock Signature model 2408-10B10B-511;0-150 and the pressure switches are Allen-Bradley 836T pressure switches (suction-836T-T251J; Discharge 836T-T253JX40). These instruments are located inside the pump/electrical room, between the two pumps, against the wall (see Photo 18).

The pump station discharge flowmeter is located in a vault, outside, near the switchboard.

The Reservoir R-16 Storage Tank Telemetering Panel (Tesco T-29635) houses the tank instrumentation and RTU. It has a "wet" left instrument side and a "dry" PLC & telemetry side. There is no corrosion at the bottom of the wet side of the panel (see Photo 19).

	
Photo 18. Pump Instrument Panel	**Photo 19. Tank Instrument Panel "wet side"**

The R16 tank is monitored by a L2000 PLC with small form factor LED Operator Interface. The PLC is provided with battery backup with battery charger in the event of power failure.

The instruments located in the panel are:

1. Reservoir Level (pressure) transmitter; Rosemount
2. Free Chlorine; US Filter (Wallace & Tiernan) Depolox Basic

The SCADA antenna is located on top of Reservoir 16.

5.6 Site

There are three 25 feet high street lights located around the perimeter of the tank with a pull box next to each light.

The propane tank is located near the utility transformer.

6.0 PUMP STATION S-18

The Pump Station S-18 site is physically located on the north side of Fountaingrove Parkway across the street from Reservoir R-17.

Appendix G
Pump Station Electrical Evaluation Field Notes

City of Santa Rosa

A visual inspection of the electrical equipment and instrumentation was performed at the Pump Station S-18 site. A general listing of equipment and field notes are included and include the following topics:

- Electrical Service
- Utility Metering
- Pump Control and Building
- Generator and ATS
- Instrumentation and Controls
- Site

6.1 Electrical Service

The site is fed from a PG&E utility transformer (T-6868).

There is a single SCADA antenna located on the roof of the tank. The tank level is communicated to Pump Station S-18 via a modem.

None of the electrical panels have arc flash labels.

6.2 Utility Metering

The power consumption is recorded by a PG&E utility meter (#1006883486) rated for 480V, three-phase at 200A. The meter/main is a NEMA 3R, Circle AW style meter/main with main circuit breaker. The meter is located on the east side of the building next to the Katolight ATS.

6.3 Pump Control and Building

There are two rooms in the Control Building; generator room and pump/electrical room. Skylights are located above each 30HP vertical turbine pump for removal. There is a heater in each room for climate control. On the north side of the building is a wall-pack light facing the tank.

The Pump Station S-18 MCC (Tesco job number T- 16783X1) is a seven section 600A horizontal Cutler-Hammer Freedom 2100 (job number 621663355-2) MCC constructed in January of 1996 (right to left).

- Section 1 contains the motor controls for the 30HP S-18 Pump S-18-P1. The pump's soft starter motor controls take up ¾ of the MCC section. The top fourth of the MCC section is a space. This section has 300A vertical section.
- Section 2 contains the motor controls for the 30HP S-18 Pump S-18-P2. The pump's soft starter motor controls take up ¾ of the MCC section. Located above the motor controls is the line monitor and disconnect circuit breaker. This section has a 300A vertical section.

- Section 3 contains the panelboard and transformer. This section has a 300A vertical section. Panelboard "P" is a 120/240V, 1 phase panelboard. Located below the panelboard is a dual circuit breaker cubicle with the 40A/2P Transformer Disconnect and a 70A/2P Panel "P" Disconnect. The 15KVA Transformer is located below the circuit breakers. The panelboard is a 36-circuit single phase panel shown in Table 6.

Table 6. Pump Station S-18 Panelboard Circuit Layout

Circuit No.	Circuit Size	Description	Circuit No.	Circuit Size	Description
1	20A	Lights	2	20A	Block Heater
3	20A	Recept	4	20A	Batt Chg
5	20A	Exh Fan	6	15A	(Blank)
7	20A	Exh Fan	8	15A	DCU (LIQ 5)
9	30A/2	Tank Panel	10	20A	Tel Recept
11		Tank Panel	12	20A	Spare
13	20A	Spare	13	20A	Recept
15	20A	Spare	16	20A	Spare
17	20A	Spare	18	20A	Tank Lights
19	20A/2	Park's	20	20A	1.8K UPS (gen rm)
21		Shack	22	20A	Spare
Spaces 23-36					

- Section 4 is the Relays and Controls Section. It has miscellaneous alarm lights and the Siemens flowmeter transmitter.
- Section 5 has the Yokogawa electronic chart recorder mounted to front of the full height MCC section
- Section 6 is a termination MCC section for wires between the MCC and PLC Control Panel.
- Section 7 contains the PLC control panel with a Tesco Liq 5/30 mounted to the front of the cabinet. There is a blue security button and black Alarm Acknowledge pushbutton mounted below the Liq 5/30. A red "Station 18 in Control when lit" indicating light is mounted above the Liq 5/30. This section contains the Black Box modem. DataRadio, old DSL modem to Reservoir R-17, battery backup and the following selector switches:
  - Switch – Reservoir Select A/B
  - Switch – Operating mode Local / Remote (in local)
  - Switch – AC Power Off / On
  - Switch – Radio Power Off / On
  - Switch – Battery Power Off / On

A telephone termination cabinet is located next to the door between the generator room and the pump/electrical room. It contains multiple phone lines and an auto-dialer (see Photo 20).

Photo 20. Telephone Termination Cabinet

6.4 Generator and ATS

A Katolight (model N85FR4, nameplate reads 100KW, 125KVA) @ 480V standby duel fuel (propane/natural gas) generator provides backup power to the station in the event of a power failure. The standby generator is located in the generator room of the control building. City staff have expressed concerns about the generator's ability to run two pumps. They typically run only one pump.

The generator's main circuit breaker is mounted to the skid. There is a 225A load bank breaker mounted to the side of the generator along with a Crouse-Hines Posi-Lock panel "E0400" series generator receptacle. The Posi-lock panel is used for exercising the generator (see Photo 21).

Photo 21. Generator Posi-lock Panel

6.5 Instrumentation and Controls

The Pump Station S-18 Control Panel is located in the MCC line-up.

There are pressure transmitters on both the suction and discharge size of the pumps, along with lo lo suction pressure switch and hi hi discharge pressure switch. The pressure transmitters are Bristol Babcock Signature model 2408-10B-511;0-150 and the pressure switches are Allen-Bradley 836T pressure switches (suction-836T-T251J; Discharge 836T-T253JX40). These instruments are located inside the pump/electrical room, between the two pumps, against the wall (see Photo 22).

Appendix G
Pump Station Electrical Evaluation Field Notes

Photo 22. Pump Instrument Panel

The pump station discharge flowmeter is located in a vault.

The temporary Reservoir 3 Storage Tank Telemetering Panel (Tesco T-29635) houses the tank instrumentation and RTU. It is chained to the south side of the building. It has a "wet" left instrument side and a "dry" PLC & telemetry side (see Photo 23).

Photo 23. Telemetering Panel

There are three older panels and pedestals containing the instrumentation and communication for Reservoir R-3 tank. Most of the panels are being used as pull boxes between equipment. There is a pressure transmitter in the larger panel (see Photos 24 and 25).

Photo 24. Reservoir R-3 Instrumentation and Communication Panels

Photo 25. Reservoir R-3 Pressure Transmitter

The Reservoir R-3 tank is monitored by a L2000 PLC with small form factor LED Operator Interface. The PLC is provided with battery backup with battery charger in the event of power failure.

The instruments located in the Panel are:

1. Reservoir Level (pressure) transmitter; Rosemount
2. Free Chlorine; US Filter (Wallace & Tiernan) Depolox Basic

The SCADA antenna is located on top of Reservoir 3.

Appendix G
Pump Station Electrical Evaluation Field Notes

6.6 Site

There are three each 25 feet high street lights located around the perimeter of the tank with a pull box next to each light.

The propane tank is located near the utility transformer.

The tank shack is located on the south-east corner of the tank.