City of Riverside Public Works Department

Update of the Integrated Master Plan for the Wastewater Collection and Treatment Facilities

VOLUME 4: WASTEWATER TREATMENT SYSTEMS

CHAPTER 11: CAPITAL PROJECT STUDIES

APPENDIX 11A: DIGESTER NO. 5 – FOOD WASTE EVALUATION

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Carollo Project No. 10495A00

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Section 1

PROJECT OBJECTIVE

This project is part of the City's effort to comply with California's organic waste diversion regulations. The purpose of this report is to evaluate the structural integrity of the Digester No. 5 for future use as a food waste digester. Findings and recommendations for digester upgrades, repairs and additional controls for digester feeding and operation are included in the evaluation. A preliminary layout for a food waste receiving station is provided. The detailed layout and specific equipment type and sizing will be determined during the design.

Section 2

BACKGROUND

The City of Riverside Public Works Department operates a comprehensive wastewater treatment and disposal system that serves most of the City, as well as the CSDs of Jurupa, Rubidoux, and Edgemont, and the community of Highgrove. Treatment of the wastewater occurs at the 28 mgd RWQCP, where influent flows undergo preliminary, primary, secondary, and tertiary treatment, followed by disinfection using sodium hypochlorite, and dechlorination using sodium bisulfite. A limited volume of the final effluent is reclaimed for non-potable reuse and the remainder is discharged to Reach 3 of the Santa Ana River. The RWQCP is currently treating about 28 mgd.

The RWQCP completed a major expansion in 2017. The expansion was to include the demolition of Digester No. 5 (formerly Digester No. 3). However, the City decided to halt the demolition and instead study the feasibility of using this digester for anaerobic digestion of food waste substrates, also known as Anaerobic Digestible Materials. The findings of that evaluation are the focus of this report.

The following areas were included in the evaluation of Digester No. 5:

- Its structural integrity, and the estimated cost of any needed repairs or upgrades to make it suitable for operation as a food waste digester.
- Determination of whether additional digester mixing equipment is needed, and or process controls and instrumentation.
- Determination of a potential location for a food waste receiving station.
- The impact of additional digested solids production on the solids dewatering system.
- The impact of additional biogas production on the existing gas fare system.

An independent study by Global Green undertaken for the City in October 2018 has determined that approximately 100 tons per day of food waste will need to be re-directed from City landfills to the RWQCP for treatment. This information was used as a basis for determining the required capacity of the food waste receiving station, as well as the potential impacts on the solids dewatering equipment and the potential biogas production.

Section 3

EXISTING FACILITIES

3.1 FOG Receiving and Rendering (Co-Digestion) Facility

As part of the recent expansion project, a new FOG receiving station was constructed. It is equipped with pumps and a basket strainer, and the details are included here for completeness. This system would introduce FOG to the plant biosolids (thickened primary solids and WAS) as a way to enhance biogas production. This system is totally independent to the proposed food waste processing in Digester No. 5.

The existing FOG Receiving and Rendering Station (FOG facility) is capable of receiving, processing and transferring 60,000 gal of grease per day to the Sludge Blending Facility. The FOG facility is designed to grind and remove larger solids. The FOG is discharged to below-grade hoppers for subsequent pumping to the SBTs. The co-digestion facility includes a FOG (septage) receiving station, a pumped recirculation mixing system, heat exchangers, and a FOG transfer pump.

3.1.1 FOG Receiving Station

The receiving station is a packaged system that includes camlock connections for the trucks that deliver the FOG to the RWQCP, rock traps, in-line solids grinders, receiving tanks, screening and washing systems, inclined augers, and compactors. It has two bays so FOG can be received from two trucks at the same time. Table 1 summarizes the design criteria for the FOG receiving station.

Table 1 FOG Receiving Station Design Criteria[1]

Description	Value
FOG Receiving System	
Overall System Capacity	60,000 gpd
FOG Receiving Bays	
Number	2
Number of FOG Deliveries[2]	8 for 5,500 gal Trucks 10 for 3,500 Trucks
Time to Empty Truck	60 min for 5,500 Trucks 53 for 3,500 gal Trucks
Quick Coupling Diameter	4 inches
Number of Rock Traps	2

Table 1 FOG Receiving Station Design Criteria[1] (continued)

Description	Value
Inline Solids Grinder	
Number	2
Line Size	4 inch
Motor Horsepower	5 hp
FOG Screens	
Number	2
Screening Capacity[3], each	50 gpm
Auger Motor Horsepower	2 hp
Size of the screen openings	1/4 inch
Discharge Port Size	12 inch
Lateral Rock Transfer Conveyors	
Number	2
Motor Horsepower	2 hp
Inclined Main Rock Screw Conveyor	
Number	1
Motor Horsepower	2 hp

Notes:
(1) Source: RWQCP Phase 1 Expansion Design Criteria.
(2) Per 8-hour day.
(3) Based on clean water.

3.1.2 FOG Receiving Hoppers

Each bay of the FOG receiving station discharges screened FOG to below-grade hoppers. The hoppers have a combined capacity to store a half-day worth of FOG, about 30,000 gal. Each hopper includes a pumped recirculation system and heat exchanger to maintain the FOG in a homogenous and flowable state. Table 2 summarizes the design criteria for the FOG hoppers.

Table 2 FOG Hoppers Design Criteria[1]

Description	Value
Number	2
Capacity, each	15,000 gal
Length	17 ft
Width	10 ft
Side Water Depth	8 ft

Notes:
(1) Source: RWQCP Phase 1 Expansion Design Criteria.

3.1.3 FOG Pumped Recirculation System

The pumped recirculation system for the FOG hoppers is designed to turn over the hopper contents in one hour. Table 3 summarizes the design criteria for the FOG pumped recirculation system mixing pumps.

Table 3 Existing FOG Pumped Recirculation System Mixing Pump(1)

Description	Value
Number	2 (1 per Heat Exchanger)
Type	Constant Speed, Chopper
Capacity, each	125 gpm
Total Dynamic Head	77 ft
Motor Horsepower	15 hp

Notes:
(1) Source: RWQCP Phase 1 Expansion Design Criteria.

3.1.4 Heat Exchangers

The FOG is heated to maintain flow and facilitate pumping. Each FOG hopper includes a heat exchanger to maintain the temperature at 100 degrees F to 110 degrees F. Table 4 summarizes the design criteria for the FOG heat exchangers.

Table 4 Existing FOG Heat Exchanger(1)

Description	Value
Heat Exchangers	
Number	2 Duty (1 per hopper)
Type	Spiral Plate Counter-Current lows
Design Temperature Rise	30 degrees F
Heat Exchange, Total	1.375 MMBtu/hr
Volumetric Flow Rate – Hot Water	150 gpm
Volumetric Flow Rate – FOG	125 gpm
Hot Water Secondary Loop Pump	
Number	2 Duty (1 per Heat Exchanger)
Type	Constant Speed, Centrifugal
Capacity	150 gpm
Total Discharge Head	45 ft
Motor Horsepower	5 hp

Notes:
(1) Source: RWQCP Phase 1 Expansion Design Criteria.

3.1.5 FOG Transfer Pumps

The FOG transfer pumps feed FOG from the hopper to the SBTs, where it is combined with incoming thickened primary and WAS. Table 5 summarizes the design criteria for the FOG transfer pumps.

Table 5 FOG Transfer Pump Design Criteria(1)

Description	Value
Number	2 (1 per hopper)
Type	Constant Speed, Progressive Cavity
Capacity, each	167 gpm
Discharge Pressure	33 psi
Motor Horsepower	30 hp

Notes:
Abbreviations: psi – pounds per square inch.
(1) Source: RWQCP Phase 1 Expansion Design Criteria.

3.2 Anaerobic Digestion System

In the digestion system, the blended solids from primary treatment, the dissolved air flotation thickeners, and FOG receiving station are processed in the absence of air. This reduces the solids volume, stabilizes the sludge, and produces methane gas that can be used in the existing fuel cells for the generation of electrical power and heat, or in boilers for digester heating. The biosolids and FOG digestion system consists of anaerobic Digester Nos. 1, 2, 3 and 4 (Digesters 3 and 4 are new), linear motion mixers, standby pumped recirculation systems, digester heating recirculation pumps, heat exchangers, foam spray pumps, and sludge transfer pumps.

3.2.1 Anaerobic Digester No. 5

Digester No. 5 (formerly Digester No. 3) is a spare digester that is not needed for biosolids digestion. It was constructed in 1982 and as mentioned it was originally to be demolished as part of the recent expansion project. It is a 75-ft diameter digester with a capacity of 1.1 MG. Table 6 summarizes the design criteria for the anaerobic digester. The City is evaluating whether Digester No. 5 can be used as a standalone food waste digester. This would require a new food waste receiving station, which would be piped to feed substrate directly to Digester No. 5.

Table 6 Anaerobic Digester No. 5(1)

Description	Value
Digester No. 5 (Standby)	
Number	1
Cover Type	Gas Cover Dome
Diameter, each	75 ft
Side Water Depth (Total)	32 ft(2)
Bottom Cone Slope, Horizontal to Vertical	4
Bottom Cone Depth	11.25 ft
Cover Dome Height	10 ft
Total Volume	1.150 MG

Notes:
(1) Source: RWQCP Phase 1 Expansion Design Criteria.
(2) See comments later following seismic evaluation.

3.2.2 Digester No. 5 Mixing System

The goal of digester mixing systems is to provide high turnover of the digester contents, to minimize deposition of grit, and to break up scum. Effective digester mixing is widely acknowledged to be a critical factor in achieving good anaerobic digestion, both in terms of volatiles reduction and process stability. Linear motion mixers were provided in the new Digesters Nos. 3 and 4 and retrofitted to digesters Nos. 1 and 2. The linear motion mixers utilize oscillating ring-shaped impellers to provide near isotropic mixing while minimizing turbulence intensity and vorticity associated with rotary type mechanical mixers. Digester No. 5 is mixed using a pumped recirculation system using one chopper pump as shown on Figure 1. The information on this system is included in Table 7.

Table 7 Digester No. 5 Mixing System Design Criteria

Description	Value
Digester No. 5 Mixing System	
Number of Pumps	1
Type	Constant Speed, Chopper
Capacity, each	6,670 gpm
Total Dynamic Head	41 ft
Pump Speed	750 rpm
Motor Horsepower	50 hp
Digester Tank Turnover Time	2.6 hr
Maximum solids content for pump mixing	15 percent

Figure 1 Existing Hydraulic Mixing System for Digester No. 5

Section 4

NEW FOOD WASTE RECEIVING STATION

If Digester No. 5 is converted to a standalone food waste digester then a new food waste receiving station will be required. In this section the Food Waste receiving station options and overall layout are analyzed and presented. The operating principle is discussed along with the advantages and disadvantage of the corresponding screening technology. In addition, the design criteria necessary to meet the need to accept 15-20 truckloads per day is presented, together with a potential site location and capital cost estimate for each technology. Detailed cost estimates are located in Attachment C.

Food Waste slurry will be processed off-site in hammer mills or grinders which are equipped with screens of 5-10 mm. In order to remove the remaining contamination such as plastics, metal and glass, screening of the waste material during unloading of the trucks is recommended. The typical screen size for the receiving station could be up to 5 mm, but preferably 2 mm. The City decided to have a third party provide the pre-screening services off-site so that they are required to deliver the AMD and bioslurry material based on specific quality requirements.

The following sections describe the conceptual layout for the receiving tanks and equipment.

4.1 Receiving Facility Equipment and Storage Tanks

The necessary equipment for this facility includes slurry receiving tanks, tank mixing pumps, slurry metering pumps, and odor control. With an anticipated slurry flow rate of 40,000 gpd, it is recommended to install three 30,000 gal receiving tanks, equating to 2 days of storage above ground and additional equalization is available when using the SBTs. This will provide flexibility when offloading the trucks and dosing the digesters over weekends. Glass lined ductile iron and plug valves are recommended for slurry piping and valving.

The receiving tanks will be installed above grade, assuming a slurry total solids concentration of 10-15 percent. A complete equipment list with recommended manufacturers, sizing, and power requirements is summarized in Table 8.

Table 8 Slurry Receiving Facility Equipment List

Equipment	Equipment/ Material Type	Recommended Manufacturer(s)	Size	Quantity	Power, each, hp
Rock Trap/Grinder	Muffin Monster	JWC Environmental	275 gpm	3	3
Equalization Tank(1)(2)	FRP	Xerxes, Augusta, Enduro	30,000 gal	3	-
Tank Mixing Pump	Chopper Pump	Flygt(3), Vaughan(4)	200 gpm	3	15-45
Slurry Metering Pump	Rotary Lobe	Böerger(5)	30 gpm	3	10(6)

Table 8 Slurry Receiving Facility Equipment List (continued)

Equipment	Equipment/ Material Type	Recommended Manufacturer(s)	Size	Quantity	Power, each, hp
Heat Exchanger	Tube-in-tube	Walker Process Equipment	Sized to maintain temperature of 80 degrees. F	3	-
Odor Control	Carbon Canister	Evoqua, Environmental Solutions, Calgon Carbon	50 cfm	2	-

Notes:
(1) Sized to provide 2 days of storage at design throughput.
(2) If above ground, tanks should be insulated.
(3) For below grade tank mixing.
(4) For above grade tank mixing.
(5) Standardizing on Böerger rotary lobe pumps for similar applications.
(6) VFDs are recommended for the slurry metering pumps to provide consistent slurry feed to the digester.

Due to the significant odors anticipated from the food waste slurry, odor control is vital to treat the tank headspace. For this application, a carbon canister with coconut shell-based material was shown to adequately treat the odors to an H_2S concentration of less than 1 ppm.

Biofilters are located near the Dewatering Building and Headworks Building to treat existing odors produced onsite. It is likely these biofilters do not have the capacity to treat the food waste odors without pretreatment. A carbon canister, followed by one of the existing biofilters as a polishing step is recommended for this application. Carbon canisters and biofilters are used at food waste processing facilities around the country including Los Angeles Sanitation District, Johnson County's Middle Basin Plant, the City of Gresham Wastewater Treatment Plant, IEUA, and East Bay Municipal Utility District.

A process flow diagram of the slurry receiving facility is shown on Figure 2.

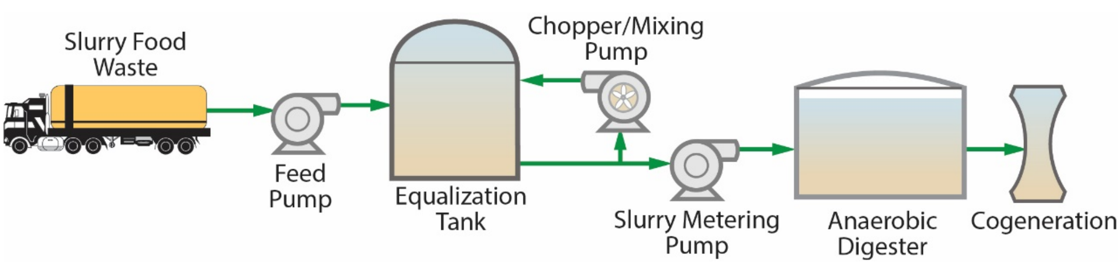


Figure 2 Food Waste Slurry Receiving Facility

4.2 Conceptual Site Layout

A conceptual layout of the food waste slurry receiving facility is presented on Figure 3. The layout includes rock trap/grinders to remove impurities in the slurry prior to the two receiving tanks. There are two mixing pumps used to mix each tank and two transfer pumps to dose the slurry to the digesters. Two heat exchangers will provide heat and the carbon canister will service the headspace from both tanks. The pumps and heat exchangers are recommended to be located indoors to serve as protection from the elements and for ease of operations and maintenance. The rock trap/grinders, tanks, and carbon canister can be located outdoors.

The new facility should be provided with heating, ventilation, and air conditioning systems meeting 2016 NFPA 820 standards for wastewater facilities and 2015 Mechanical Code requirements. While the slurry receiving facility is not intended to convey sewage, the food waste slurry will generate off gases. Per NFPA 820, the receiving tanks will be considered classified which requires a three ft distance between the tanks and any non-classified equipment. The building is unclassified unless it is placed directly above a below grade storage tank.

4.2.1 Site Location and Tank Sizing

The footprint of a new standalone facility was determined based on the need to received and hold 100 tons per day of bioslurry. The bioslurry will be pre-processed at a Material Recovery Facility, where the food waste solids will be processed, decontaminated, and diluted to 10 percent solids concentration to generate a pumpable bioslurry. The trucked volume will be around 40,000 gpd depending on water content. The facility will need to be 52 ft by 35 ft in order to accommodate three 30,000 gal bioslurry storage tanks, the mixing pumps, the screening system, and utilities. Figure 3 shows the dimensions, potential location south of the Digester No. 5 and east of the FOG receiving station.

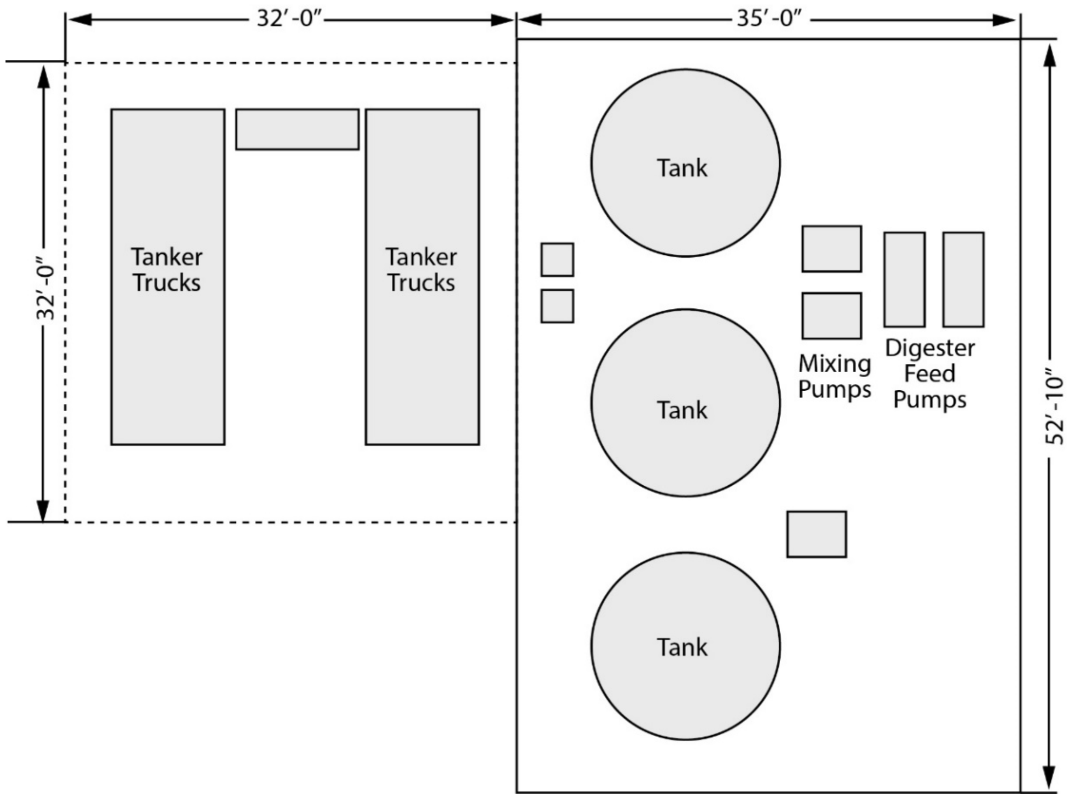


Figure 3 Food Waste Receiving Facility Conceptual Site Layout and Rendering

Several locations for the food waste slurry receiving facility were evaluated, including a modification to the existing FOG station. The first location using the existing FOG receiving station is shown on Figure 4 and is located south of the Digester No. 5. This option would utilize two existing parallel receiving bays which have 1/4-inch screening systems and two 15,000 gallon hoppers. This option would require the addition of two 30,000 gallon holding tanks while using one of the existing below ground sludge blending tanks for additional storage and to feed the sludge digesters. An additional above ground pipeline would be added to feed the food waste to Digester No. 5.

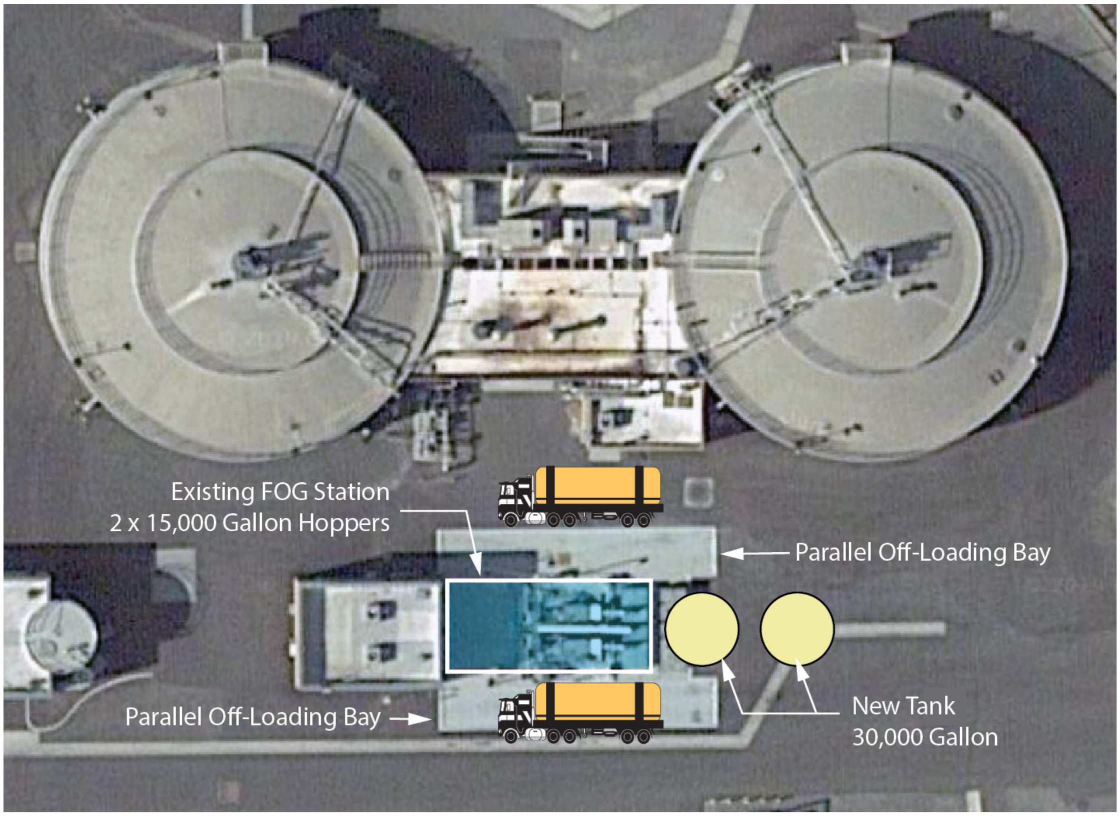


Figure 4 Food Waste Receiving Using the Modified FOG Station Option No. 1

Another option that was considered, would be to retrofit the old cogeneration building, which provides an enclosed area of 79 ft by 67 ft, which would be beneficial for odor containment. Figure 5 and Figure 6 show this location and layout of four receiving tanks and pumping equipment including an odor control system. These two potential layout alternatives can be evaluated in more detail, along with other options, during the preliminary design phase of the project.

Figure 5 Future Food Waste Receiving Station Option No. 2

Table 9 presents a summary of the preliminary design criteria for a new food waste receiving station including storage tanks and bioslurry pumping, similar to that depicted on Figure 6. The preliminary capital cost estimate for such a system is $1.3 M and a detailed cost breakdown is provided in Attachment C.

Table 9 Design Criteria for Receiving Station and Screening and Estimated Costs

Element	Receiving Station Tanks, and Mixing Pumps	Bioslurry Screening
Footprint (sq ft)	3,000	100
Operational Reliability (-)	High	High
Solids Concentration (%)	10-15	10-15
Horsepower (hp)	20	10
Maintenance Requirement (-)	Low	Low
Operator Attention Requirements (-)	Low	Low
Equipment Cost Estimate ($)	$521,800	-
Total Equipment Costs ($)		$521,800
Total Estimated Project Costs ($)		$1,324,623

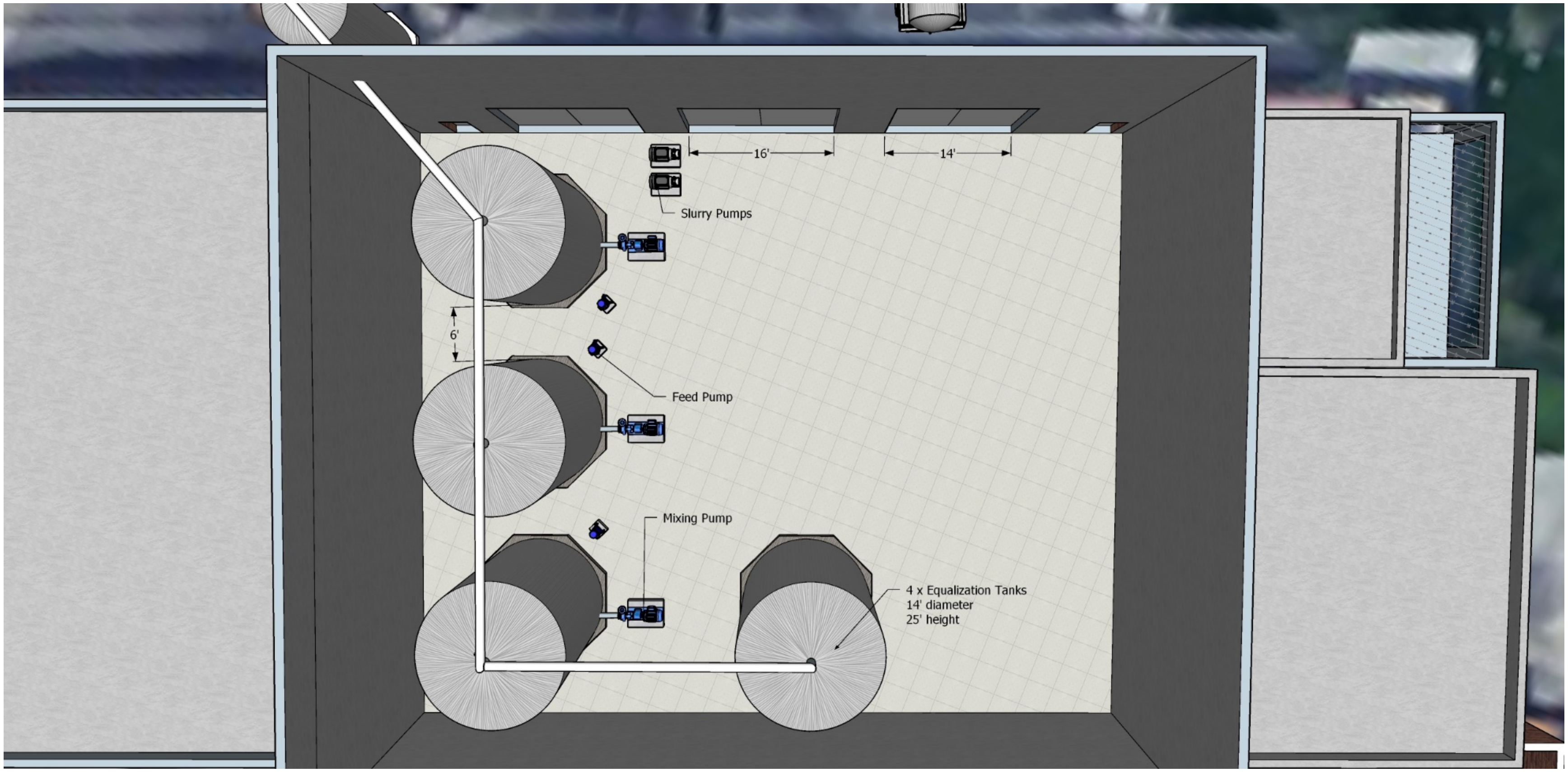


Figure 6 Rendering for Future Food Waste Receiving Station Option 2

Section 5

ASSESSMENT OF DIGESTER NO. 5

This section discusses the structural and process/mechanical assessment of Digester No. 5 and its potential to be used as a food waste digester, together with the costs associated with any upgrades/modifications/refurbishment needed.

5.1 Structural Assessments

5.1.1 External Visual Assessment of Digester No. 5

This section summarizes the findings of a site visit to Digester No. 5 and external inspection made on Thursday, March 8, 2018. The site visit began around 9:00 a.m. and ended at 11:00 a.m. Pacific Standard Time. The air temperature was about 65 degrees F and the air was calm. The exterior of the digester is shown on Figure 7 (side view) and Figure 8 (top view).

The digester was filled with about 32 ft of water and the mixers were turned on. The air space below the dome was isolated and the gas pressure monitor varied from about 6.9 to 7.0 inches of water column and was relatively steady throughout the inspection.

In general, the exterior of the concrete walls appeared to be in fair condition with several active weeping leaks. The concrete was discolored throughout and evidence of previous crack repairs (see Figure 9) was observed, especially at the exterior wall ledge where loose surface mortar repair material was prevalent. The length of the leaking cracks was estimated and noted for future use (see Figure 10) in preparing rehabilitation drawings to form the basis for concrete crack injection of the wall. In total the length of leaking cracks was estimated to be about 90 ft. When repairing these cracks, the length of repair would be expected to double as sealing efforts often result in moving the leak to other cracks or away from the sealed length in repaired cracks.

Figure 7 Exterior Concrete Condition of Digester No. 5

Figure 8 Roof View of Digester No. 5

5.1.2 Gas Leak Detection of Digester No. 5

At the same site visit for the exterior visual assessment of Digester No. 5, the existing steel dome was also observed from the exterior and tested for gas leakage. The inspection began at the perimeter of the dome just south of the stair landing and continued around the dome in a counter-clockwise pattern, spiraling towards the center. A soapy water solution was applied with a plastic spray bottle to the surface of the dome at areas with surface defects, rust stains, discoloration, and at the perimeter that is covered with sealant. No major gas leaks were detected using this method. A minute gas leak was detected with a short-lived, yet consistent, gas bubble formation for about 30 seconds at the east side of the dome at a small corroded spot about 8 ft in from the perimeter. The perimeter edge of the dome (interface between the concrete wall and the dome edge) was coated with a foam sealant material. Some cracks, tears, and a patch were observed at a few locations (Figure 9), but no gas leakage was detected with the soapy water solution test.

Figure 9 Concrete Crack Repairs at Digester No. 5

The external surface of the steel dome appeared to be in good condition with localized minor surface corrosion with associated coating failure along the circumferential and radial panel joints (Figure 10 and Figure 11). Most of the observed steel corrosion was limited to the outer three panels. The dome had numerous penetrations of various sizes, but these appeared to be flanged and gasketed. A few locations, where rusting of the flange bolts was observed, were tested for gas leakage using the soapy water solution test, but no detectable leaks were identified.

Other observations included the following:

- The operator for the effluent gate at the overflow box was inoperable and the gate was stuck in the open position.
- A condensate pipe at the overflow box was severely corroded.
- The guardrail at the top landing of the stair and overflow box is missing a metal kick plate. Small boards were wire tied to the guardrail posts to serve as a temporary kick plate.

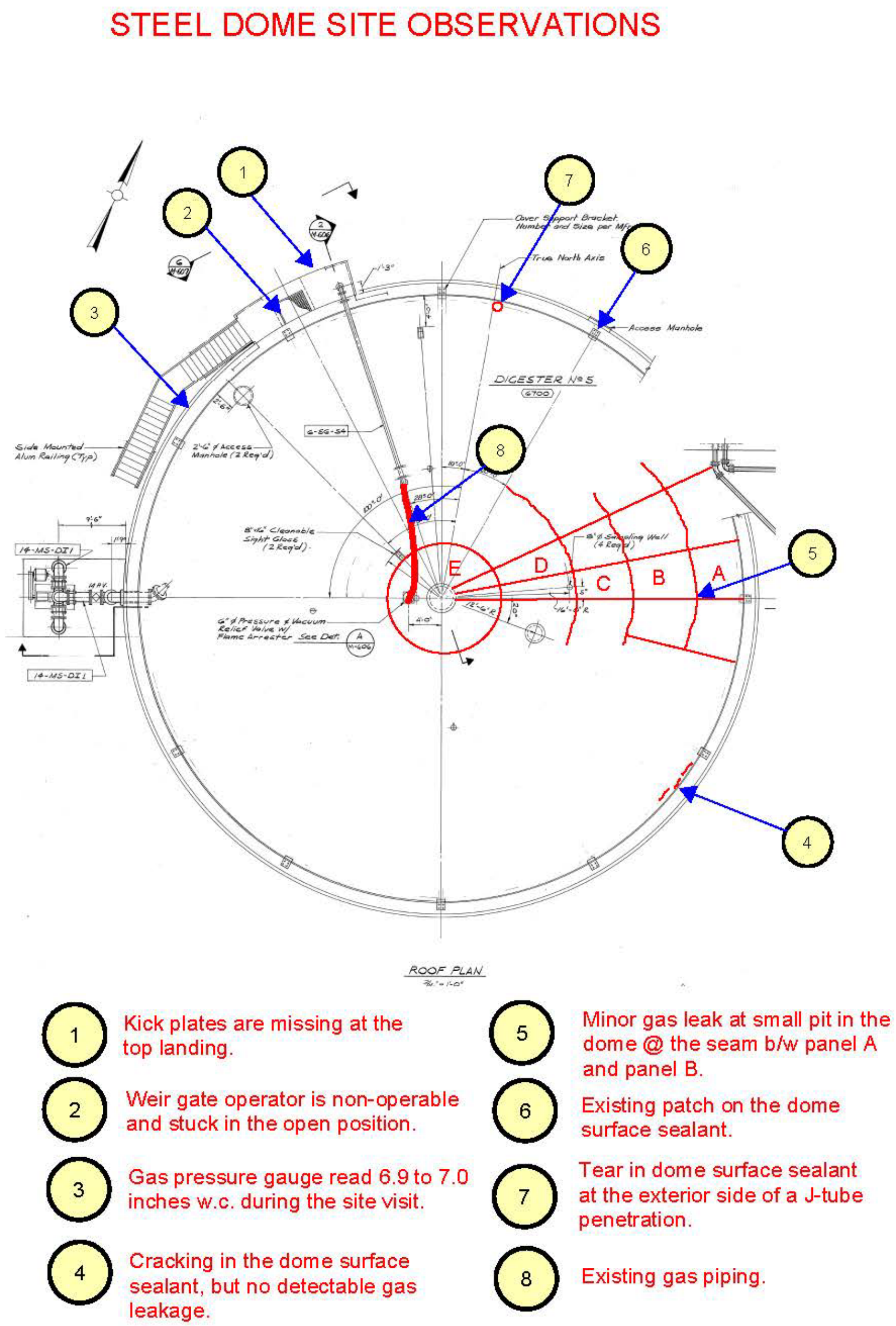


Figure 10 Steel Dome Site Observations

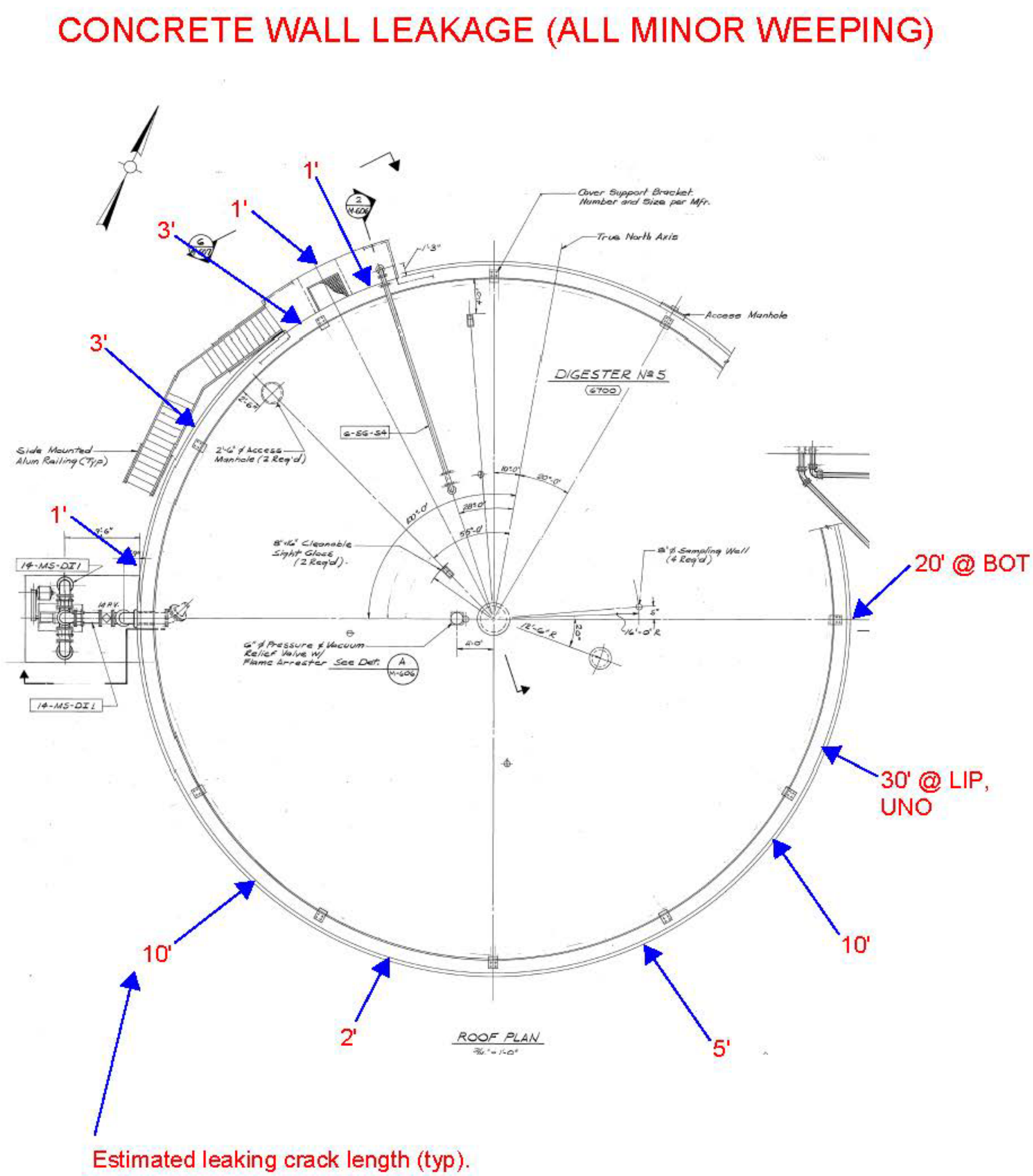


Figure 11 Concrete Wall Leakage (All Minor Weeping)

5.1.3 Internal Visual Assessment of Digester No. 5

The interior of Digester No. 5 was drained for an interior visual assessment; however, the digester could not be fully drained and the water level was stabilized to the invert of the access manway. Also, grit build-up in the bottom of the digester is considered to be substantial with several ft of depth estimated as the level of grit build-up at the southwest side of the digester was visibly higher than the water level. Therefore, entry into the digester was not possible. To provide a visual assessment of the digester interior, a drone inspection was made on November 13, 2018. The drone was successful at capturing high-definition video of the interior concrete wall, dome skirt, dome framing, and the dome plate membrane. Approximately 42 minutes of video footage was captured by the drone, which was professionally operated by Nick Harwood of the Mistras Group. Refer to Figure 12, Figure 13, and Figure 14 for interior views of the digester wall, dome skirt, and dome framing, respectively. The drone is protected by a fiberglass cage, which is visible in Figures 12 through 14.

It appears that the outer sections of the dome have been submerged during the previous digester operation based on the stains that are visible on the dome beams.

Based on a review of the drone video footage, the following observations of the digester interior were made:

- Overall, the coating on the steel members appears to be fair to poor condition at many locations in the outer half of the dome where rust staining occurs frequently. The existing coating appears to be in good to fair condition towards the center half of the dome interior. Discoloration of the coating is prevalent throughout the interior surfaces of the dome.
- It appears that the outer sections of the dome have been submerged during the previous operation of the digester based on the visible stains on the webs of the dome beams and the collection of dried sludge on the bottom flange of the dome beams. Refer to Attachment A – Photos 1 and 2.
- The connection of the dome beams to the dome skirt columns are heavily soiled with dried sludge. It is difficult to ascertain the condition of the steel members and connections, but no obvious signs of delaminating steel or section loss were seen. It is assumed that the members and connections have sustained moderate corrosion, but are likely in a repairable condition. Refer to Attachment A – Photos 3 and 4.
- The dome skirt appears to be in good condition overall, but heavily soiled with sludge and discolored. The bottom seal of the dome skirt is comprised of a stainless steel closure angle that is anchored to the digester wall with stainless steel anchors. The top of the closure angle is caked with dried sludge. About half the length of the perimeter skirt appears to project beyond the stainless steel angle leg towards the inside of the digester and there appears to be moderate to severe corrosion at the exposed ends of the dome skirt. The dome is assumed to be hung from above, so repairs/coating can be implemented to prevent further damage, but the deterioration does not appear to impact structural support. Refer to Attachment A – Photos 5 and 6.
- Overall the concrete appears to be in good condition, but heavily soiled with dried sludge and discolored. There were no obvious signs of concrete deterioration that warrant structural repairs. Refer to Attachment A – Photos 7 and 8.

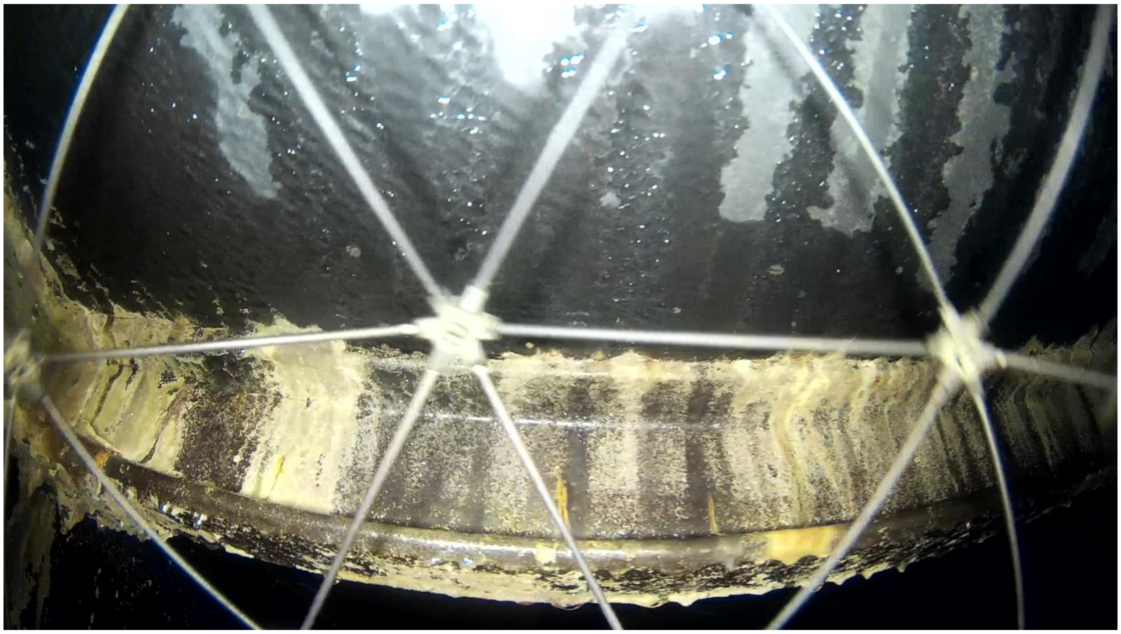


Figure 12 Interior Views of Digester Wall

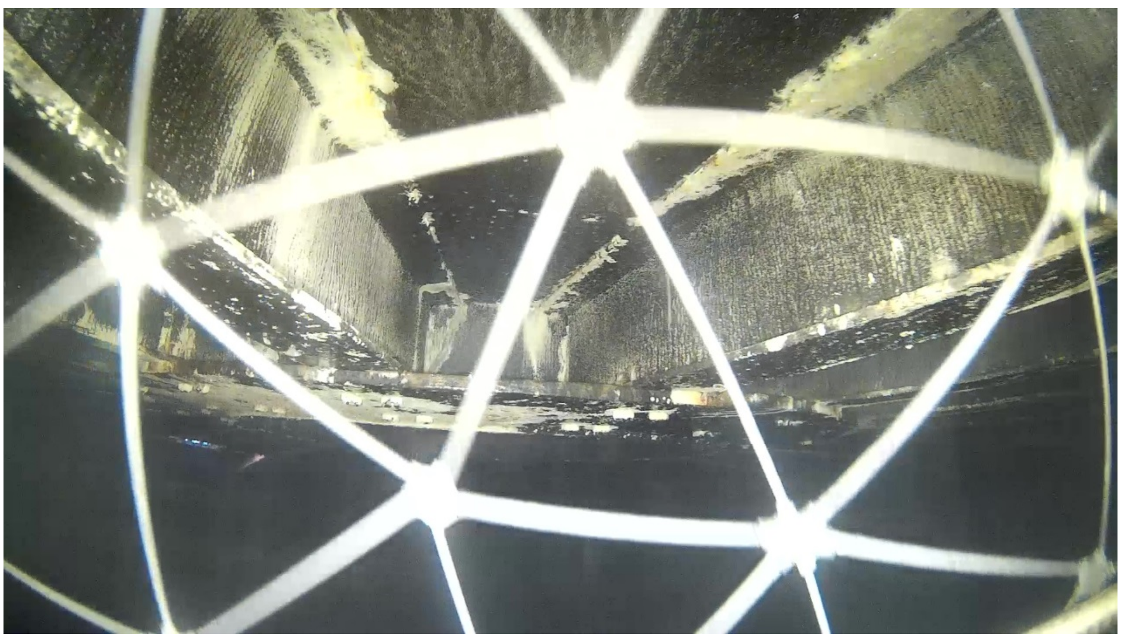


Figure 13 Interior Views of Dome Skirt

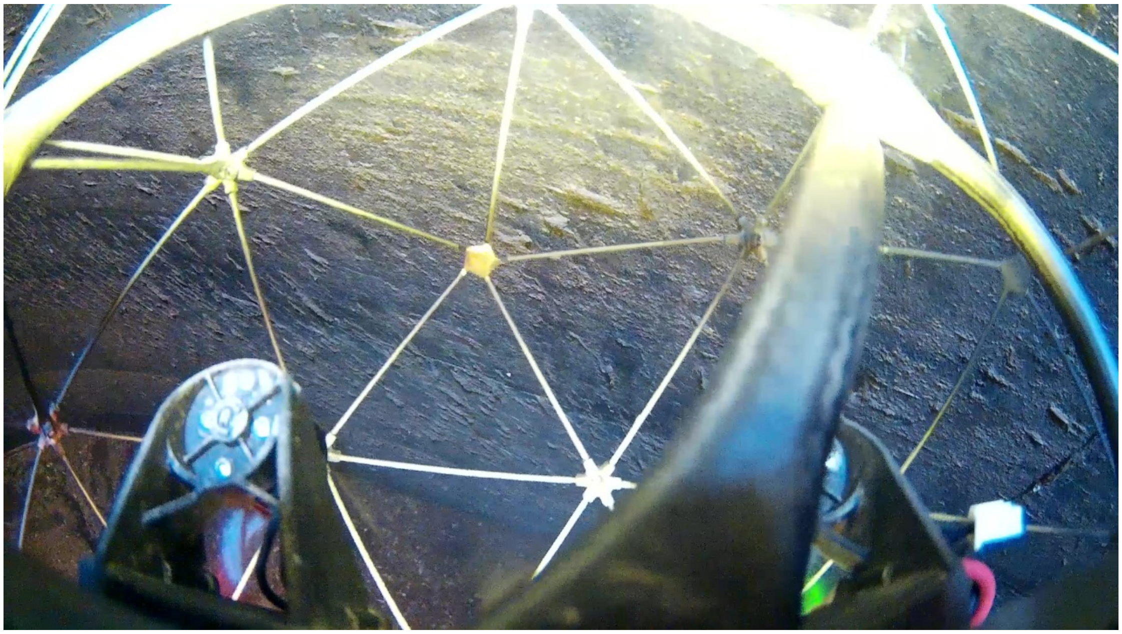


Figure 14 Interior Views of Dome Framing

5.1.4 Seismic Evaluation

Digester No. 5 was part of a primary and secondary replacement project, which was completed around 1982. The digester is a concrete circular tank with an inside diameter of 75 ft and a side wall height of 34.5 ft, steel dome cover, and cone shaped foundation slab sloping down towards the center. The operational high and low water heights are approximately 32 ft and 26 ft, respectively, from the high point elevation of the foundation slab at the side wall. The digester is partially buried on the southwest side to an approximate depth of 15 ft and slopes down to about a few ft above the foundation slab at the opposite side. The overall condition of the digester showed concrete cracks and signs of past leakage. Additional inspection photos of the digester are provided in Attachment A of this report.

The available original design and construction documents were reviewed to perform a seismic evaluation of the digester structure. The goal of this evaluation is to identify potential structural vulnerabilities by estimating the seismic demands and the associated material stresses of the structural members when subjected to those seismic loads, as well as loads due to self-weight, soils, and water. Initially, the evaluation is comprised of data gathering, establishment of a seismic evaluation and acceptance criteria, assumptions regarding material properties, and mathematical analyses of the structural systems and members. The results of this evaluation may serve as a basis for developing mitigation strategies.

5.1.4.1 Data Collection and Review

To obtain data and information necessary for use in the evaluation of the digester, the following documents were reviewed:

- Construction drawings of "Primary-Secondary Replacement Capacity Project for Jurupa and Rubidoux", prepared by CDM, dated December 1979.
- "Technical Memorandum No. 9 - Integrated Digestion System", prepared by CDM, dated March 2010.

5.1.4.2 Evaluation Criteria

Codes and Standards

The seismic evaluation of the digester was performed using ASCE 7-10, ACI 350.3-06, and ACI 350-06. The seismic forces (hydrodynamic forces) were calculated using ASCE 7-10, Chapter 15, in conjunction with ACI 350.3-06. The seismic design spectral accelerations were estimated for both ASCE 7-10 and ASCE 41-13, BSE-1E seismic level, assuming soil site class D. The values that are used in conjunction with ASCE 7-10 and ASCE 41-13 are based on the 2008 seismological data established by the USGS.

The structural material properties could not be found on the available construction documents and were estimated following ASCE 41-13 guidelines. No field-testing was performed to determine the structural properties of any of the existing members.

Gravity Load Evaluation Parameters

Gravity loads acting on the digester are limited to the self-weight of the structure (dead load), potential live loads applied to the roof dome, hydrostatic pressures, and at-rest earth pressure applied to the walls. Table 10 indicates the gravity load parameters used in this evaluation. The value assumed for the roof live load is considered to be the minimum required live load for roof structures.

Table 10 Gravity Load Parameters

Parameter	Value
Roof Live Load	20 psf
Concrete Unit Weight	150 lbs/ft^3
Water Unit Weight	64.27 lbs/ft^3
At-Rest Earth Pressure	60 psf/ft
Operating High Water Height Operating Low Water Height	32 ft 26 ft

Groundwater in the soil was assumed to be below the structure and not included in the structural analyses.

Seismic Load Evaluation Parameters

Table 11 indicates the seismic evaluation parameters used to estimate the seismic loads. The proposed use of the digester will be to process food waste that is delivered to the plant. Digester No. 5 is not anticipated to be a critical facility in the treatment plant. While gas production within the digester may be considered as a hazardous substance, the loads and actions that occur in the upper portion of the tank where methane and H_2S gas reside, are anticipated to be relatively small compared to those loads and actions that occur in the lower portions of the structure. Therefore, the Risk Category for Digester No. 5 has been assumed to be II. This approach is considered to be consistent with the proposed use of the digester and its relative importance to other treatment facilities at the plant. If another use of the digester is to be considered, the findings in this evaluation may need to be revisited.

Table 11 Seismic Parameters

Parameter	Value
Soil Site Class	D
SDS (ASCE 7-10)	1.000 g
SD1 (ASCE 7-10)	0.600 g
SXS (ASCE 41-13, BSE-1E) SX1 (ASCE 41-13, BSE-1E)	0.918 g 0.531 g
TL	8 seconds
Risk Category Importance Factor, I	II 1.00
Seismic Design Category Response Modification Factor, Impulsive	D 2
Response Modification Factor, Convective Soil Dynamic Pressure	1.5 25 H

Seismic Base Shear and Sloshing Wave Height

The hydrodynamic base shear is the combination of impulsive (V_i) and convective (V_c) components. Impulsive forces are those inertial forces associated with the fundamental response to the ground acceleration. Convective forces are those forces that are generated by the longer period sloshing response to earthquake motion. These two components are typically out-of-phase from one another, but both contribute significantly to the total forces that a water-bearing structure might be subjected to. For this evaluation, these two component values were determined as follows:

$V_i = 0.50W_i$ (ASCE 7-10); $V_i = 0.46W_i$ (ASCE 41-13, BSE-1E).

$V_c = 0.11W_c$ (ASCE 7-10); $V_c = 0.09W_c$ (ASCE 41-13, BSE-1E).

Where:

Wi = Equivalent weight of impulsive component of the stored liquid.

Wc = Equivalent weight of the convective component of the stored liquid.

Additionally, vertical acceleration due to seismic ground motion will increase the internal hydrostatic lateral pressure on the structure. The vertical acceleration was estimated to be 0.20 gram.

The sloshing action of the water within the structure during an earthquake can generate a maximum wave height inside of the structure. When insufficient freeboard is provided, the water can slosh and surcharge the bottom side of the roof at or near the perimeter of the structure. The surcharge force will be directly proportional to the amount of freeboard deficit. The associated loading to the underside of a roof structure can be substantial and can cause significant damage or collapse, especially if the roof is framed with a lightweight material.

The wave height was determined using the equations and procedures set forth in ASCE 7-10. The sloshing wave height was estimated to be 4.2 ft for the high operating water level.

5.1.4.3 Material Properties

The material properties of the existing concrete and reinforcing steel were assumed per ASCE 41-13, Chapter 10, based on the year of the design and construction. Table 12 summarizes the expected material strength properties used in this evaluation.

Table 12 Material Properties (ASCE 41-13, Chapter 10)

Material	Default Lower-Bound	Factors for Expected Strength	Expected Strength	Reference Tables
Concrete Wall & Slab	$f_c' = 3{,}000\ psi$	1.5	$f_c' = 4{,}500\ psi$	10-1 & 10-2
Reinforcing Steel	$f_y = 40\ ksi$	1.25	$f_y = 50\ ksi$	10-1 & 10-3

5.1.4.4 Analysis Procedure

In general, the load combinations used in the evaluation of the structural members is based on those set forth in ACI 350-06 and ASCE 7-10. The governing load combinations used in this evaluation are presented in Table 13.

Table 13 Governing Load Combinations for Seismic Evaluation(1)

Load Combinations	Type
D+F+H+E	Un-factored seismic load case for foundation bearing pressure.
1.2(D+F)+1.6H+1.4E	Factored seismic load case for structural material strength evaluation.

Notes:
D = Dead Load, L = Live Load, F = Hydrostatic Load, H = Soil Pressure, E = Seismic Load.
(1) The unbalanced soil pressure was assumed to be present under seismic load conditions and additive to the hydrodynamic pressures acting in the same direction.

Seismic loads were determined using Carollo's proprietary in-house structural analysis programs tailored for analysis of water-bearing structures. Additionally, hand calculations and a finite element software program (STAADPro v8i) were used as analysis tools. The following assumptions were applied to the finite element modeling and analysis:

1. Concrete cracked properties using 0.5EI for wall and foundation slab, where E is the elastic modulus for concrete and I is the moment of inertia for the member.
2. Foundation slab subgrade modulus is based on soil bearing pressure of 2,000 psf assuming a 1/2-inch settlement.
3. The analyses were performed for both full fixity and pinned condition between wall and foundation slab. Pinned condition was achieved by releasing rotational stiffness of the wall bottom nodes at the foundation slab in the finite element model.

5.1.5 Findings

The digester concrete wall and foundation slab were evaluated and the corresponding findings are presented herein. The metric used in this evaluation to quantify the degrees of distress of an existing structural component is referred to as the DCR.

$$\text{DCR} = \frac{\text{Load Demand}}{\text{Available Capacity}}$$

DCR values that exceed 1.0 are typically considered to be overstressed. Values that exceed 1.5 are significantly overstressed and may be treated with greater priority in a seismic retrofit. A summary of the DCR values for the subject structure for various liquid levels are set forth in Table 14 and

Table 15 for load demands calculated in accordance with ASCE 7-10 and ASCE 41-13, respectively. The DCR values indicated in the Tables are the maximum values determined from the evaluation. Where a DCR was determined to be less than 1.0, only that condition is reported in the Table.

Table 14 Demand-Capacity Ratio (DCR) (ASCE 7-10 Seismic Level)

Component	Liq Ht=32ft	Liq Ht=26ft	Liq Ht=22ft	Liq Ht=16.5ft
Wall Hoop Tension	< 1.0	< 1.0	< 1.0	< 1.0
Wall Shear, Out-of-Plane	< 1.0	< 1.0	< 1.0	< 1.0
Wall Shear, In-Plane	< 1.0	< 1.0	< 1.0	< 1.0
Wall Bending Moment at Vertical Dowel	1.72	1.25	1.04	0.93
Foundation Slab, Ring Tension	2.85	2.05	1.80	1.54
Foundation Slab, Bending Moment for Bottom Radial Bars	1.74	1.39	1.30	1.21
Foundation Slab, Bending Moment for Top Radial Bars	< 1.0	< 1.0	< 1.0	< 1.0

Table 15 Demand-Capacity Ratio (DCR) (ASCE 41-13, BSE-1E Seismic Level)

Component	Liq Ht=32ft	Liq Ht=26ft	Liq Ht=22ft	Liq Ht=16.5ft
Wall Hoop Tension	< 1.0	< 1.0	< 1.0	< 1.0
Wall Shear, Out-of-Plane	< 1.0	< 1.0	< 1.0	< 1.0
Wall Shear, In-Plane	< 1.0	< 1.0	< 1.0	< 1.0
Wall Bending Moment at Vertical Dowel	1.61	1.19	1.00	0.92
Foundation Slab, Ring Tension	2.65	1.97	1.73	1.50
Foundation Slab, Bending Moment for Bottom Radial Bars	1.63	1.35	1.26	1.19
Foundation Slab, Bending Moment for Top Radial Bars	< 1.0	< 1.0	< 1.0	< 1.0

The findings indicate significant overstress of the wall dowels and foundation slab reinforcing bars near the wall. Mitigation options to address these potential vulnerabilities are presented in next.

5.1.6 Wall Dowels

The digester wall is subject to bending moments at the bottom of the wall due to the applied loads. The DCR for the wall dowels is estimated to be from 1.72 to 1.19, depending on the seismic level, for the current operating water height between 32 ft and 26 ft. This level of overstress is considered to be moderate to severe, depending on the liquid height in the digester. The wall can potentially experience extensive cracking during a major earthquake at these levels of stress.

It is recommended that the operating water height be limited to 22 ft, at which point the DCR is within acceptable limits. Alternatively, the wall can be strengthened by means of an interior shotcrete addition as shown on Figure 15.

5.1.7 Foundation Slab Reinforcing Bars

The foundation slab is subject to ring tension and bending moments from the wall reactions and soil bearing pressure. The DCRs for the slab ring tension (circumferential bars) and bending moment (radial bottom bars) are estimated to be from 2.85 to 1.50 and 1.74 to 1.19, respectively, depending on the seismic level, for the water heights between 32 ft and 16.5 ft. This level of overstress is considered to be moderate to excessive depending on the liquid height in the digester. Extensive cracking is anticipated during a major earthquake at these levels of stress at operating water heights of 32 ft and 26 ft.

It is recommended that the existing slab be thickened and that additional reinforcing bars be provided, which will give additional strength to the slab bending moment capacity and ring tension capacity. Refer to Figure 15.

For the operation at a higher liquid height of 32-ft (high liquid level) the following conditions would apply:

1. Seismic soil bearing pressure of 5,000 psf is expected. This should be verified with the soil engineer for the acceptability.
2. Liquid slushing height of 5.5-ft is expected during seismic which will impart uplift pressure to the lower outer (about 10-ft) ring of the roof dome. Low elevation of the dome is about 2.5-ft above the liquid level:
    a. Dome anchor connection could not be evaluated due to lack of information in the available drawings.
    b. Limit the liquid height to 29-ft or raise the wall height to provide adequate freeboard, or;
    c. Replace or strengthen existing dome to be able to take additional stresses.
3. Thicken the wall and slab by at least 18-in with additional reinforcing bars per attached.

5.1.8 Foundation Slab Soil Bearing Pressure

A summary of the foundation slab soil bearing pressures is presented in Table 16. The slab soil bearing pressure is estimated to vary from 5,026 psf to 3,571 psf, depending on the seismic level, for an operating water height between 32 ft and 26 ft. This level of bearing pressure is considered to be moderate to excessive and may result in additional settlement that can impart additional stresses to the concrete structure. Allowable soil bearing pressure is estimated to be 3,325 psf for the seismic load case, obtained by applying a one-third increase to an assumed allowable soil bearing pressure of 2,500 psf.

It is recommended that the operating water height be limited to no more than 26 ft, at which point the soil bearing pressure is estimated to be slightly higher than the estimated allowable bearing pressure at which the soil would still not be anticipated to have a bearing failure.

Table 16 Foundation Slab Soil Bearing Pressure (Service Level)

Component	Liquid Height=32 ft	Liquid Height=26 ft	Liquid Height=22 ft	Liquid Height=16.5 ft
Fixed Base				
ASCE 7-10	4,666 psf	3,643 psf	3,125 psf	2,534 psf
ASCE 41-13, BSE-1E	4,522 psf	3,571 psf	3,067 psf	2,506 psf
Pinned Base				
ASCE 7-10	5,026 psf	4,018 psf	3,528 psf	3,010 psf
ASCE 41-13, BSE-1E	4,882 psf	3,946 psf	3,470 psf	2,981 psf

5.1.9 Sloshing Wave Height

The sloshing wave height was estimated to be 4.2 ft. Based on the available construction documents, the current freeboard available from high water elevation is approximately 2.5 ft which can result in a net upward force applied to the steel dome. This complication can be resolved by limiting the operating water height as recommended in Sections 3.1 and 3.3. Otherwise, the dome may experience damage to the steel members, dome seal, and dome anchorage at the top of the wall.

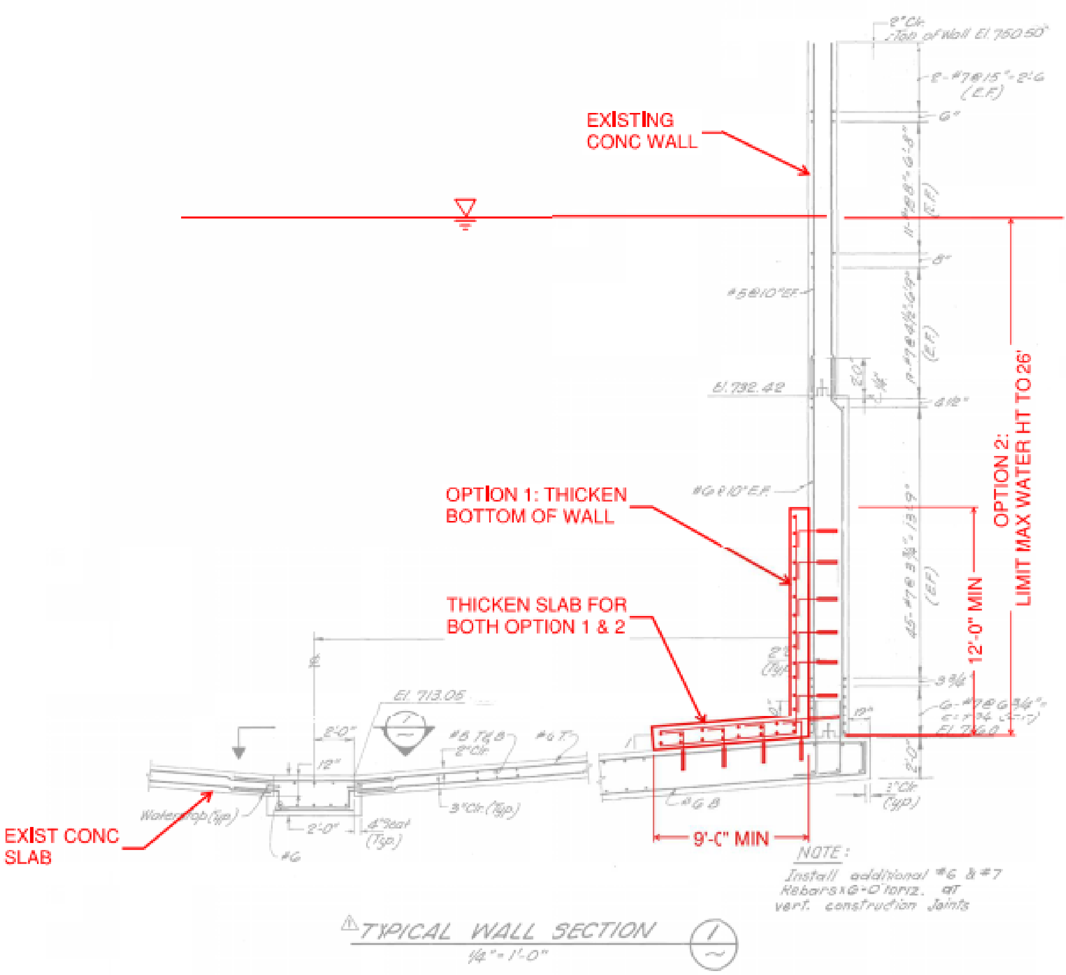


Figure 15 Conceptual Details

5.2 Process/Mechanical Assessment

5.2.1 Digester Mixing

As described in Section 3, only one Vaughn chopper pump is currently available for mixing of Digester No. 5. Since having an installed standby will require major modifications to the piping, it is recommended that an uninstalled spare pump be stored in the warehouse to allow maintenance to switch pumps in a short period in case of failure.

Currently, for pump mixing, sludge is withdrawn from the top of the digester and discharged at the bottom via nozzle. There is a top discharge nozzle to be used for breaking up scum. However, since the digester will be operated at varying levels, changes to the piping inlet configuration should be implemented during tank repairs to move the suction to the bottom and center of the digester and the discharge to the bottom and top along the perimeter of the digester.

The online DG pressure indicator in the DG piping is in good working condition and allows the monitoring and control of the DG pressure (by adjusting the organic loading rate) which will be critical in reducing the risk of DG venting occurrences.

5.2.2 Estimated Solids Production

5.2.2.1 Projected Municipal Solids Production

In order to evaluate the impact of additional food waste biosolids on the overall solids handling system, an evaluation was carried out. Table 17 summarizes the anticipated solids projections (Thickened WAS and primary solids) for the 39.0-mgd ADF condition, which is projected for 2037. These values were developed from the calibrated BioWin model that was calibrated based on data that was gathered when the plant was receiving an ADF of 25 mgd.

Table 17 Solids Projections at 39.0 mgd ADF

Element	Unit	Value
Thickened WAS Production (ADF)(1)		
• Thickened WAS Flow Rate	gpd	83,624
• Solids	ppd	43,938
• Solids Concentration	%	6.3
• VSS	%	85
Thickened WAS Production (Max Month)(2)		
• WAS Flow Rate	gpd	99,511
• Solids	ppd	52,285
• Solids Concentration	%	6.3
• VSS	%	85
Primary Sludge Production		
• PS Flow Rate	gpd	214,000 (2.5%), 119,000 (4.5%)
• Solids	ppd	44,600

Notes:
(1) Results from calibrated BioWin prediction.
(2) Estimated from Mathematical Models.

The Thickened WAS projection for the 39.0-mgd ADF condition was based on the projected WAS production and historical dissolved air flotation thickening performance. More detailed information is located in Volume 4, Chapter 3: Process Design and Reliability Criteria and Volume 5, Chapter 4: Sludge Production and Thickening of the Master Plan. The primary sludge projection information is obtained from Volume 4 Chapter 5: Primary Treatment of the Master Plan.

Based on Table 17, the anticipated maximum monthly solids flowrate for 39-mgd ADF is 313,511 gpd. The required dewatering capacity for 24-hour operation is 218 gpm.

5.2.2.2 Digester No. 5 Capacity and Food Waste Solids Production

The expected additional organics from food waste and the impact on the digester loading rates, and solids generation are described in Table 18. The Solids generation rate will be compared with the existing dewatering capacity for digestate after addition of the organics.

Table 18 Digester Loading Rates and Solids Generation

Parameter	Values
Digester volume (Digester No. 5)	132,469 cu ft
Maximum	990,866 gal
Recommended maximum operating volume	858,750 gal
Diameter	75 ft
Tank height	30 ft
Recommended liquid level	29 ft
Digester No. 5 organic loading rate design criteria	0.20 lbs/cfd
Design solids loading	22,961 ppd
	10 dry tons per day
	100 WTPD (at 10% solids)
Truck loads per day	~6 per day (5,000 gal)
	26,843 gpd
VSR	75 percent
	16,790 ppd
Solids for disposal	5,597 dry ppd
Estimated cake solids concentration	25%
Solids for disposal	13 WTPD
Estimated sludge flowrate to dewatering	26,843 gpd
Biogas generation	251,856 cfd at 15 cu ft per lbs VSR(1)
	175 cfm

Notes:
(1) Food Waste ranged from 11 to 35 cu ft per ton of VS processed. A biogas production rate of 15 cu ft/lbs VSR was used for this estimate.

5.2.3 Dewatering Capacity

The sludge dewatering process capacity was determined based on a screw press peak solids loading rate of 700 lbs per hour per unit and a peak hydraulic loading rate of 55 gpm per unit with six screw presses in service, operating 24 hours per day, 7 days per week. Under these conditions, the available dewatering capacity is 330 gpm, assuming hydraulic loading rate is limiting. With the addition of food waste bioslurry at 26,843 gpd, an average 18.64 gpm of digested sludge would be added to the dewatering units. Based on the excess capacity of the existing system, the additional digested bioslurry is not expected to cause any dewatering capacity issues. However, adjustments to the dewatering polymer dose might be needed.

5.2.4 Estimated Gas Production and Flare

The expected DG production from food waste is presented in Table 19. The DG flow rates will be compared with the existing flaring capacity.

Table 19 Sludge Dewatering System Design Criteria(1)

Dewatering Screw Presses	Value
Number	6
Dewatered Cake Solids Concentration	19 percent
Solids Capture	95 percent
Average Feed Rate	40 gpm

Notes:
(1) Source: 2008 RWQCP Wastewater Collection and Treatment Facilities Integrated Master Plan, and Field Inspection.

5.2.4.1 Digester Gas Generation and Existing Flaring Capacity

Digestion of food waste in Digester No. 5 at a loading rate of 0.20 lbs/ft^3 will allow the treatment of 100 WTPD of food waste based on a 10 percent solids content and assuming that 70 percent of the food waste will be from bioslurry and only 30 percent from ADM. The digester tank volume at an operating level of 29 ft and the lower solids concentration of the Burrtec bioslurry with 6-7 percent solids and a limit of the other food waste material (ADM) of 30 percent due to the higher solids concentration of 20 percent TS and potential foaming concerns. Assuming a 75 percent VSR the calculated DG generation will be approximately 252,000 cfd. This will be verified by the City during a future DG study using COD concentrations and biogas yield test data.

The additional DG generation from food waste digestion will be beneficially used in fuel cells and future biomethane projects. If these systems are out of service or undergoing maintenance, the existing flaring capacity will need to process all DG generated. The existing flaring capacity is designed for 1,445,000 cfd (1003.5 scfm), for a maximum heat release of 52 MMBtu/hr (max). Two flares are installed, Digester Gas Flare No. 1 (Tag # FDG-892-1) and Digester Gas Flare No. 2 (Tag # FDG-892-2).

The current DG flow rate to the existing fuel cell is 300 cfm and the total generation is 400 cfm. The average DG generated in the food waste Digester No. 5 would be approximately 135 scfm, but could be up to about 200 scfm. Thus, the total DG flow to the flare system would be a maximum of about 600 scfm. The projected DG flow is therefore within the existing flare design capacity.

The operation of the new flares is currently unreliable due to mechanical issues related to low feed pressure shut-downs caused by the DG booster blowers. Based on current AQMD permit conditions the flaring of DG over 560 cfm would result in exceedance of the daily SO_x limits, which is 5 ppd, until such time as the City is able to overcome the existing mechanical issues. The DG would have to be scrubbed for H_2S prior to flaring.

5.2.4.2 Digestate Dewatering and Solids Disposal

The upgrade of the dewatering facility with screw presses was discussed above. The additional solids loading from food waste digestion at a digester loading rate of 0.20 lbs/cfd and 75 percent VSR will be 5,597 dry ppd. It is estimated that 13 wt of sludge will be generated from food waste alone and will need to be hauled off-site.

5.2.4.3 Bioslurry Screening

Food Waste slurry will be processed off-site in hammer mills or grinders which are typically equipped with screens of 5 to 10 mm. The contamination of bioslurry can include fibers, plastics, glass, grit, and metal and can account for around 10 percent of the total mass, as shown on Figure 16 shows an example of bioslurry contamination. In order to remove such remaining contamination, screening of the waste material during unloading of the trucks is recommended. The screening onsite is still recommended as a precaution against poor pretreatment by the third party. Unremoved inert materials would accumulate in the digester over time and reduce the available digester volume, and increase the cleaning frequency and associated costs.

Figure 16 Typical Reject from Food Waste Screening: Plastic, Glass, Fiber and Metals

The typical screen size for a food waste receiving station is 6 mm, which is based on pilot tests at Napa Sanitary District with a Huber StrainPress on a FOG solid-liquid separation system, and food waste screening at IEUA RP-5 Solids Handling Facility using a Vincent Screw press.

Based on recent experience at the RWQCP, bucket strainers are not recommended as they get clogged frequently causing a halt in the truck unloading and material handling process.

5.2.5 Instrumentation

Instrumentation to monitor and control the operation of a digester are important components of the system. Digester No. 5 has some existing instrumentation, but some additional equipment is recommended.

5.2.5.1 Instrumentation for Monitoring Digester Operations

Only mechanical drawings for DG piping showing flame arrestors and valves were available for review (CDM drawing set from 1979). Based on the site assessment there are two DG flow meters connected to SCADA (as shown in the process and instrumentation diagram for the new digesters):

- One DG flow meter for the vented gas, which is installed downstream of the pressure relieve valve to monitor any DG going to the carbon canisters in order to monitor venting events for AQMD compliance
- One DG flow meter on the DG collection header and this line is also equipped with a pressure indicator.

5.2.5.2 Digester Feeding and Control of Flow Rate and Organic Loading of the Digester

A consistent organic loading rate to the digester is important to avoid operational challenges and to produce a constant DG flow to the fuel cells or other future beneficial DG uses. The organic loading rate can be expressed as COD or VSS concentrations and flow rates per volume of digester available. In-line COD analyzers based on UVAS technology have been developed and tested in the field for industrial digesters. As part of the recommended instrumentation, HACH UVAS 254 or similar is recommended. A flow meter to monitor instantaneous influent flow rate and totalized flow should be included. This instrument should be connected to the plant's SCADA system.

5.2.5.3 pH Neutralization Needs for Acidic Waste Streams

The organic acids which will be generated in the food waste due to hydrolysis will result in a lower pH of the substrate. The volatile acids will be readily transformed into shorter chain volatile organic compounds for methane formers and will be converted to methane and carbon dioxide. The only substrates which will need pH adjustment are industrial organic liquids such as spent vinegar. Therefore a pH injection and control system for this type of substrate would be recommended. Figure 17 shows a schematic of the proposed control system and instrumentation arrangement for Digester No. 5. Some of the instrumentation is existing and some will be new.

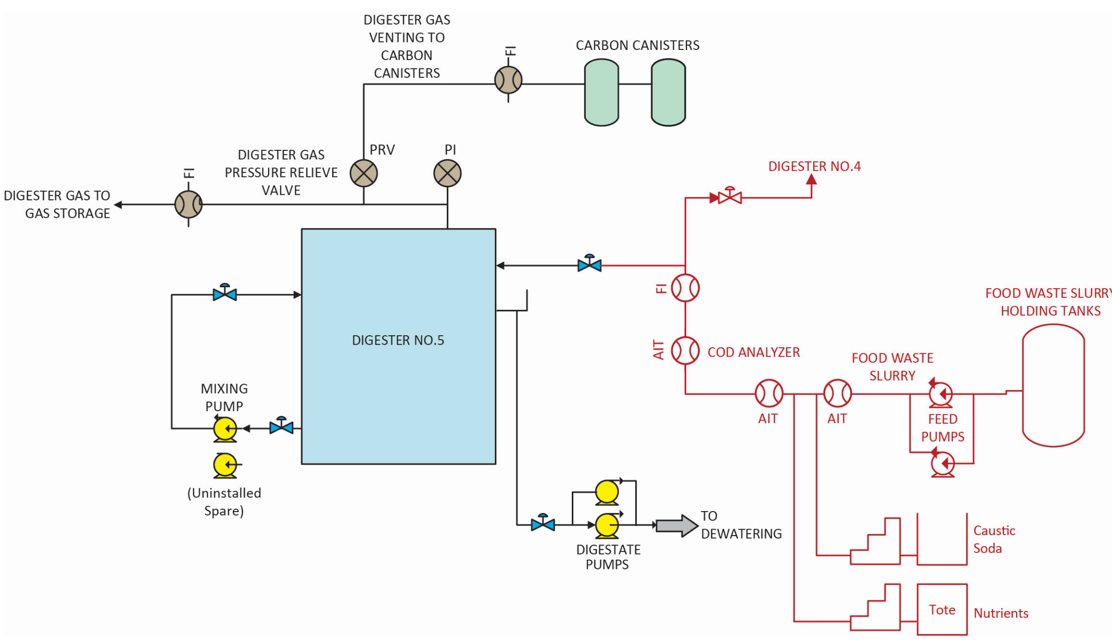


Figure 17 Schematic of Proposed Digester Control System

5.2.5.4 Other Chemical Injection Options (Magox, Micronutrients)

Micronutrients are mostly needed for industrial organic substrates. This will be added on as needed basis and can be set up in a tote with chemical feed pumps set up in the receiving station.

5.3 Digester No. 5 Rehabilitation Cost Estimate

The goal of the evaluation of Digester No. 5 was to identify specific structural and mechanical vulnerabilities for the purpose of improving the overall reliability of the digester for its proposed use as a dedicated food waste digester. The findings presented in this report identify several seismic vulnerabilities that warrant retrofit/rehabilitation of the structure. Mitigation strategies involve limiting operational water height and thickening the foundation slab with additional reinforcing bars. The cost for implementing this alternative will be limited to the amount of effort required to control the water level in the digester and the construction of new slab/wall over the existing members.

Table 20 presents a summary of the cost estimate to rehabilitation Digester No. 5 for use as a food waste digester. The digesters effective holding volume with the liquid height limited to 29 ft will be 858,750 gal.

Table 20 Estimated Cost to Rehabilitate Digester No. 5

Description	Estimated Cost
Structural Modifications	
Internal Walls rehabilitation	$199,862
Seismic Retrofits	$254,609
Mechanical	
Uninstalled Standby Mixing Pump	$95,000
Instrumentation and Valves	$50,000
Sub-total	**$784,471**
Electrical	$85,000
Mechanical, pipe, supports, etc.	$100,000
Total Direct Cost	**$784,471**
Contingency - 30%	$235,341
General Conditions, Contractor Overhead, Profit and Risk - 25%	$254,953
Escalation to Mid-Point (3.5 % per year for 3 years, 10.5%)	$133,850
Sales tax	$123,254
Total Estimated Construction Cost	**$1,531,870**
Engineering 10%	$459,561
Estimated Project Cost	**$1,991,430**

More detailed estimates of the cost are located in Attachment C.

Section 6

SUMMARY AND RECOMMENDATIONS

Based on the evaluation of the existing Digester No. 5 presented in this report, the following conclusions and recommendations are made.

1. Digester No. 5 is generally in good condition and could be rehabilitated to be converted to a standalone food waste digester.
2. Rehabilitation of Digester No. 5 will involve both structural and mechanical work. Structural work includes both internal coating of the digester as well as wall strengthening to bring the structure up to seismic code. The rehabilitation work is recommended to include:
   a. Epoxy or chemical grout injection to seal approximately 200 linear ft of concrete cracks in the digester wall.
   b. Blast and recoat the interior steel dome surfaces inside of the digester. Exterior rehabilitation of the steel may be limited to localized recoating and resealing of damaged seals at the dome perimeter.
   c. Repair of steel members that have experienced section loss with lap-welded plates as required. It is estimated that the occurrence of these repairs would be infrequent.
   d. Application of a surface-applied waterproofing mortar, such as Xypex Concentrate, that is treated with an anti-microbial agent to provide both concrete protection and waterproofing for the digester wall. This should be applied to the existing wall surface above the new concrete wall addition.
   e. Provide new aluminum guardrail and kick-plate at the top stair landing.
   f. Mechanical work includes a new standby pump mixer, some piping modifications, and additional instrumentation.
3. Due to seismic considerations, the operating level in Digester No. 5 is limited to 29-ft, which results in a working volume of 858,750 gal.
4. A maximum level of 29 ft could be considered with additional concrete reinforcement and this would result in 858,750 gal of operating volume, which is sufficient to treat the bioslurry and some ADM max 30 percent of total food waste at an organic loading rate of 0.2 lbs VSS/cu ft day.
5. Digester No. 5 should be able to treat approximately 100 tons per day of food waste.
6. Initial estimates indicated that approximately 252,000 cfd of additional biogas could be generated from food waste digestion in Digester No. 5. Understanding that different food waste sources generate different amounts of biogas, it is recommended that laboratory testing of various food waste sources be carried out to confirm the potential gas production from the mixture of food waste expected at the RWQCP.
7. It appears that the existing gas flaring capacity will be sufficient to handle the additional biogas anticipated from Digester No. 5, once the mechanical issues for the existing flaring system are addressed.
8. A food waste bioslurry receiving station design was proposed upstream of Digester No. 5. This system is expected to have a project cost of approximately $1.3 million.
9. The estimated cost to rehabilitate Digester No. 5 is approximately $2 million.

Attachment A

EXISTING DIGESTER INSPECTION PHOTOS

Figure A1 Photo 1 and 2, Outer Section of the Dome

Figure A2 Photo 3 and 4, Connection of the Dome Beams to the Dome Skirt Columns

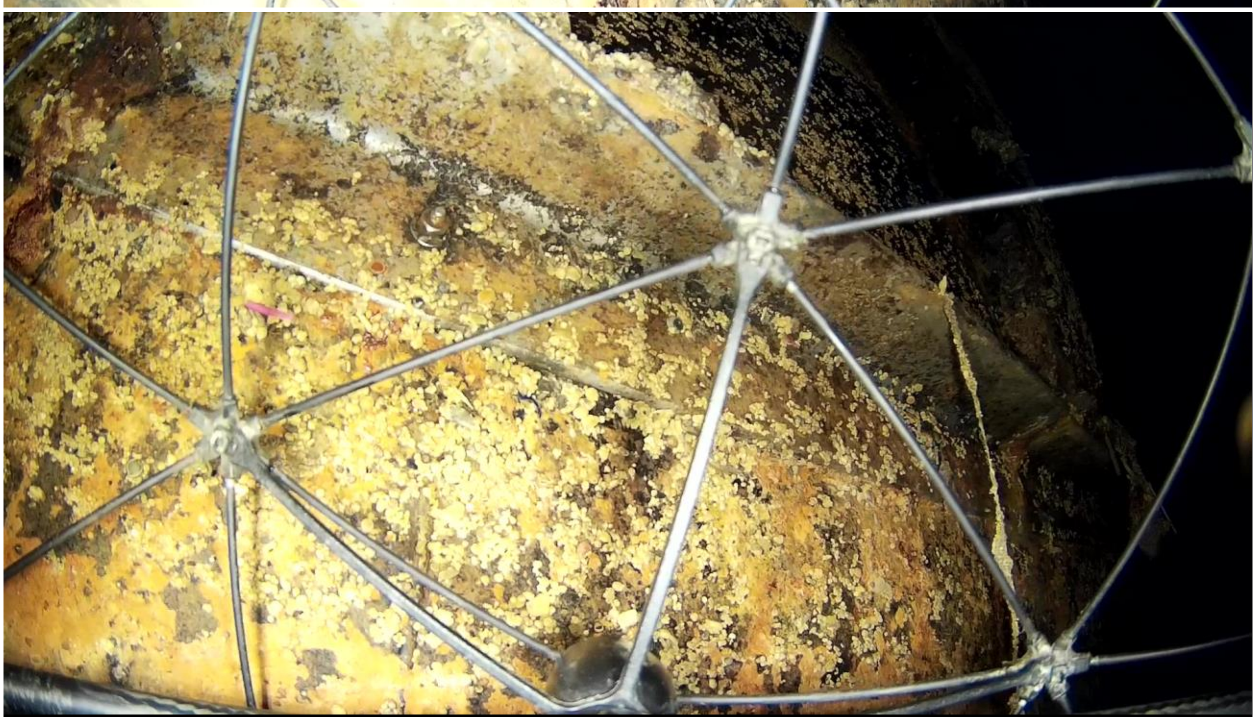
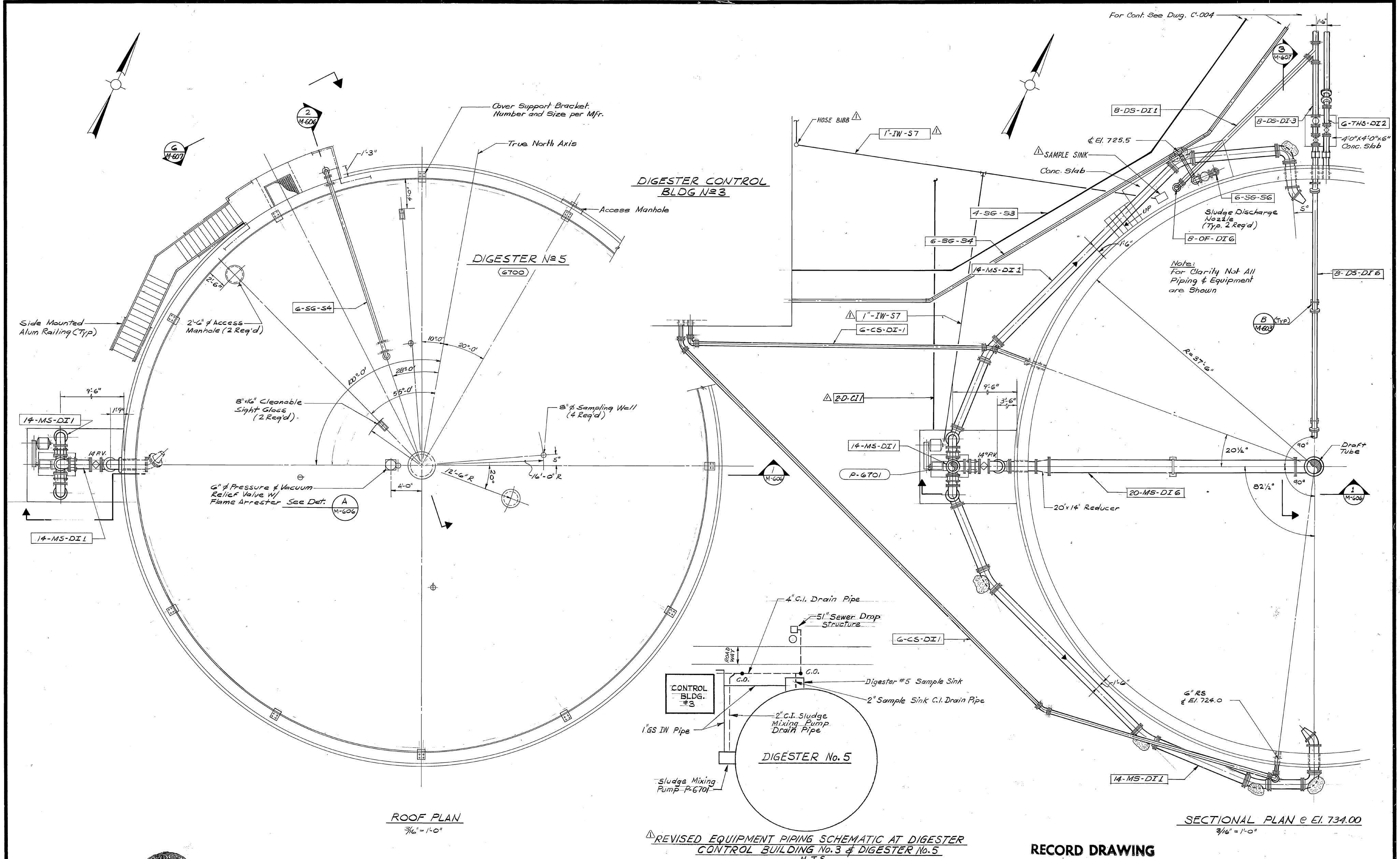


Figure A3 Photo 5 and 6, Dome Skirt

Figure A4 Photo 7 and 8, Concrete

Attachment B

SEISMIC CALCULATIONS



RECORD DRAWING

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environmental engineers, scientists, planners & management consultants

Approved by:	Date	Name
Structural		
Architectural		
Electrical		
Instrumentation		
HVAC		
Project Engineer	12/79	ASR
Project Manager	12/79	DMS

MARK	REVISIONS	APPR	DATE
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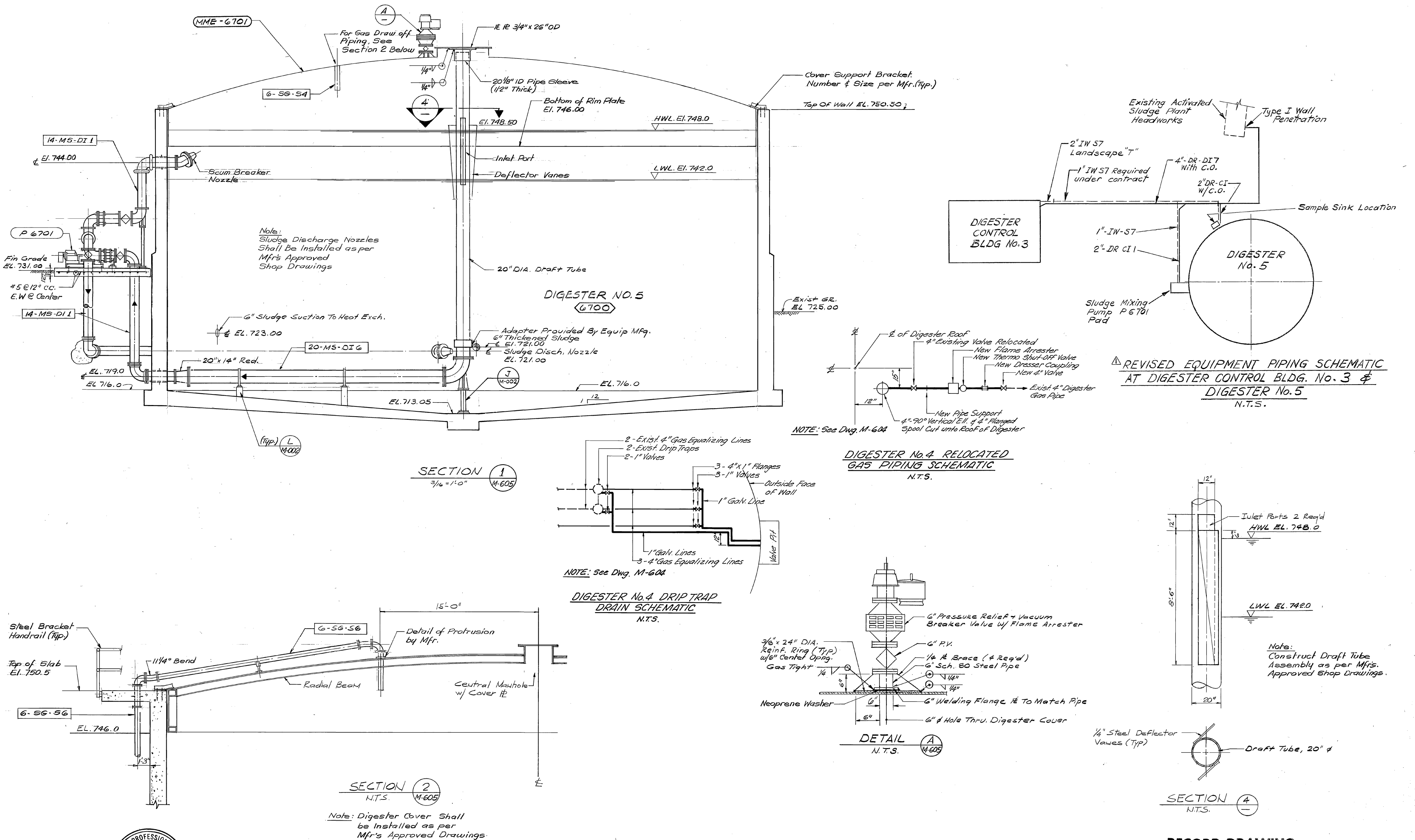
APPROVED BY
PUBLIC WORKS DIRECTOR
DATE 12-28-79

PRIMARY – SECONDARY
REPLACEMENT CAPACITY PROJECT

DIGESTER NO.5
PLAN

HORIZ. SCALE: 3/16"=1'-0" VERT. SCALE: 1" -

ACCOUNT NO.
T-14
SHEET M-605 OF 55
FILE NO. 2012-7-087



REGISTERED PROFESSIONAL ENGINEER CARLOS M. CAMPUZANO NO. 13161 STATE OF CALIFORNIA

RECORD DRAWING

AS BUILT 10-21-82

INDEXED

CAMP DRESSER & McKEE INC.
Southwestern Regional Office
283 South Lake Avenue
Pasadena California 91101

CDM
environmental engineers, scientists, planners & management consultants

Approved by:	Date	Name
Structural		
Architectural		
Electrical		
Instrumentation		
HVAC		
Project Engineer	8/79	ASR
Project Manager	8/79	DMS

MARK	REVISIONS	APPR.	DATE
△	RECORD DRAWING REVISIONS		10-23-81

DESIGNED BY AR/EL DRAWN BY EC CHECKED BY EL

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PUBLIC WORKS DEPARTMENT

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APPROVED BY PUBLIC WORKS DIRECTOR

DATE 12-28-79

PRIMARY - SECONDARY REPLACEMENT CAPACITY PROJECT

DIGESTER NO 5
SECTIONS & DETAILS I

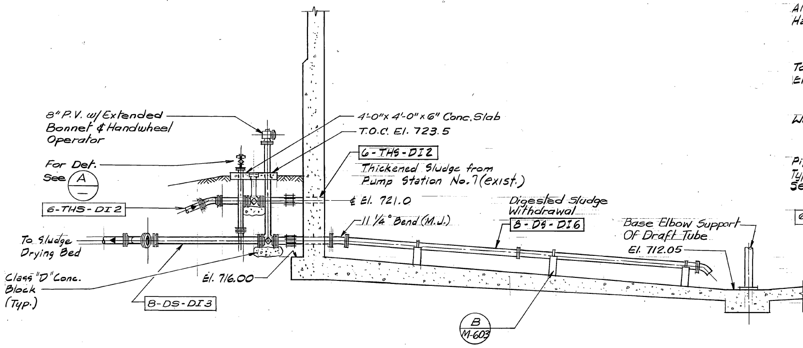
HORIZ. SCALE: AS SHOWN VERT. SCALE: 1" -

ACCOUNT NO.

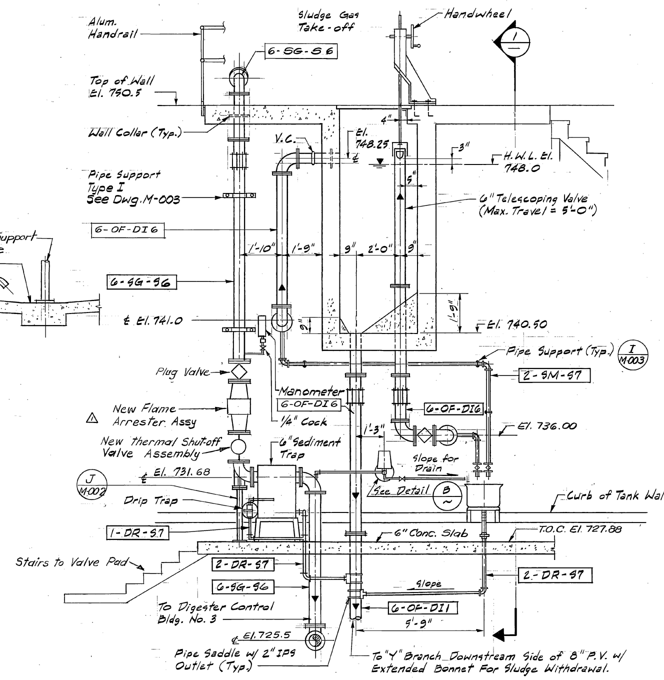
T-14

SHEET M-606 OF 55

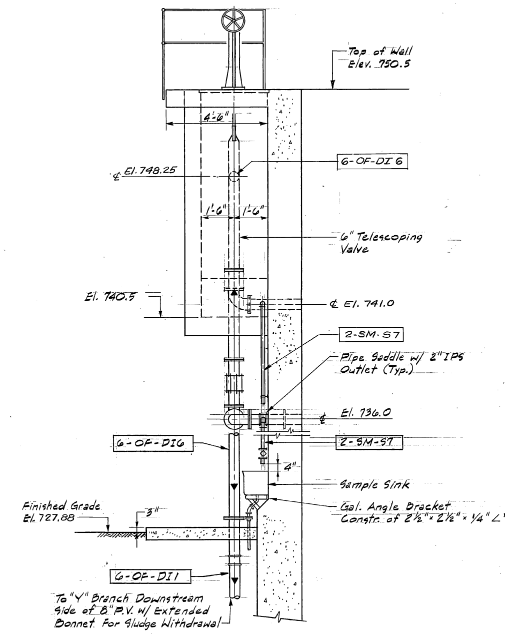
FILE NO. 2012-7-088



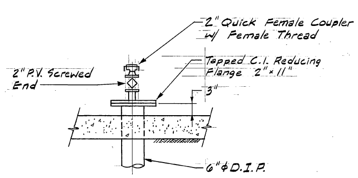
SECTION 3/M605
3/16" = 1'-0"



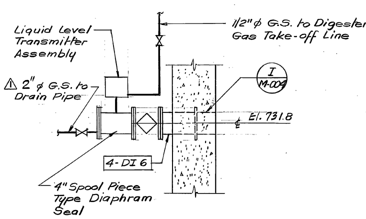
SECTION 6/M605
N.T.S.



SECTION 1/~
3/8" = 1'-0"



DETAIL A/~
N.T.S.



DETAIL B/~
N.T.S.

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Project Manager	8/79	DMS

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*AS BUILT 10-31-82 WF

CITY OF RIVERSIDE
PUBLIC WORKS DEPARTMENT

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PRINCIPAL ENGINEER
PARK DEPARTMENT
TRAFFIC DIVISION
CHIEF P. W. ENGINEER

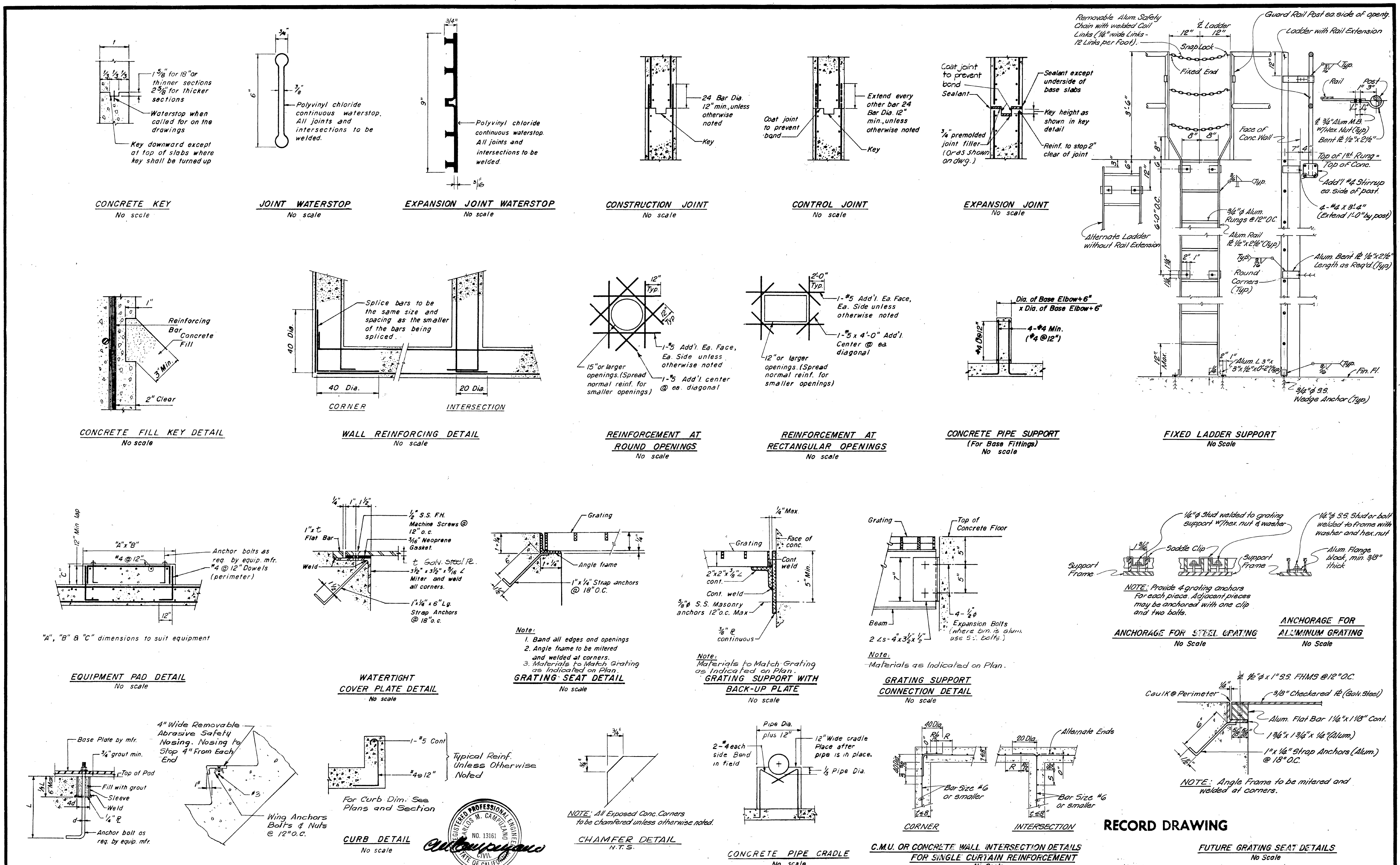
APPROVED BY
PUBLIC WORKS DIRECTOR
DATE 12-28-79

PRIMARY - SECONDARY REPLACEMENT CAPACITY PROJECT

DIGESTER NO. 5
SECTIONS & DETAILS II

HORIZ. SCALE: AS SHOWN VERT. SCALE: 1" =

INDEXED WF
ACCOUNT NO.
T-14
SHEET M-607 OF 55
FILE NO. 2012-7-089



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Architectural		
Electrical		
Instrumentation		
HVAC		
Project Engineer	8/79	ASR
Project Manager	8/79	DMS

MARK | REVISIONS | APPR | DATE
DESIGNED BY EL DRAWN BY EC CHECKED BY WP

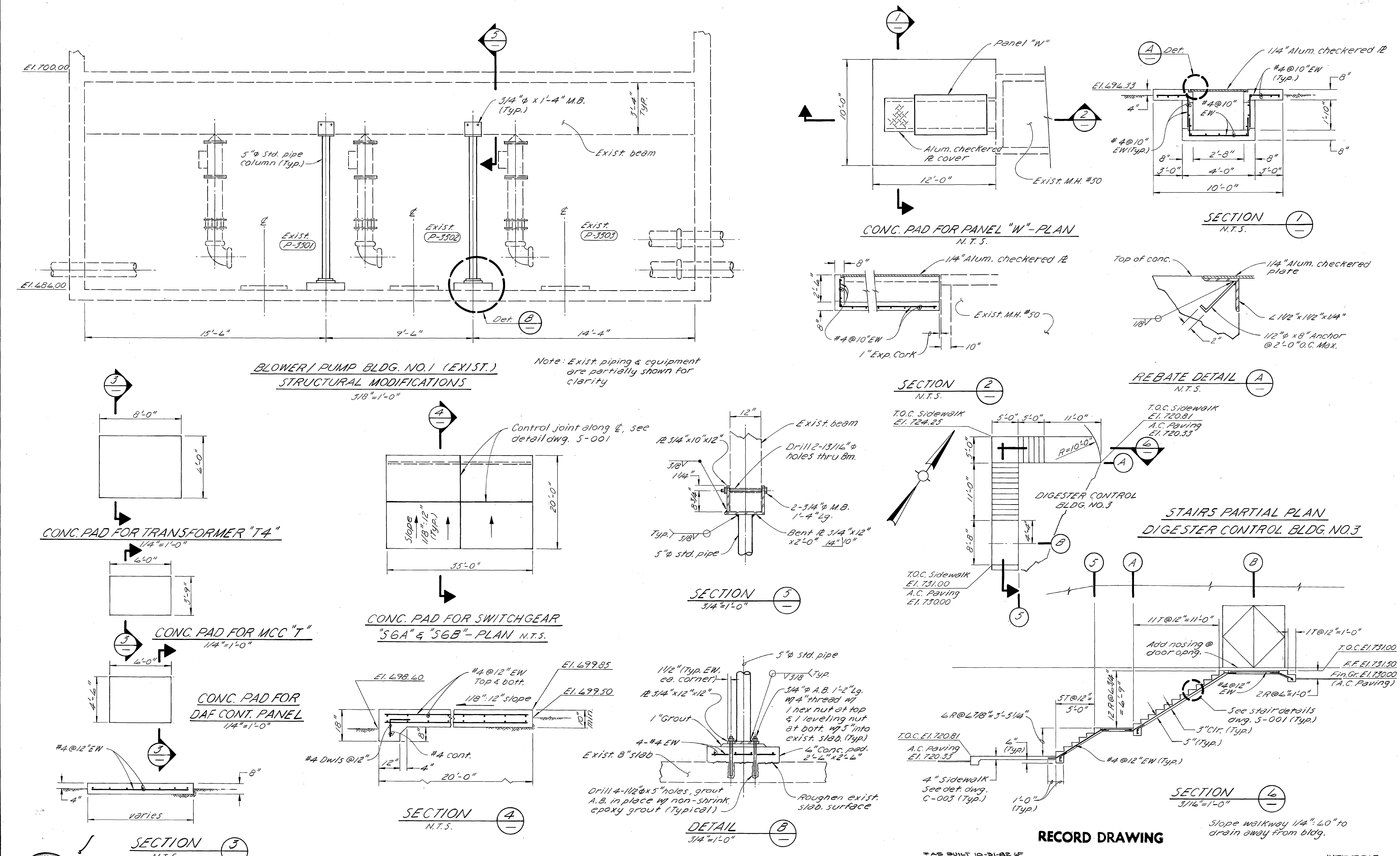
CITY OF RIVERSIDE
PUBLIC WORKS DEPARTMENT
APPROVED BY: PRINCIPAL ENGINEER, PARK DEPARTMENT, TRAFFIC DIVISION, CHIEF P. W. ENGINEER
APPROVED BY
PUBLIC WORKS DIRECTOR
DATE 12-28-79

PRIMARY - SECONDARY
REPLACEMENT CAPACITY PROJECT

STRUCTURAL DETAILS I

HORIZ. SCALE: NO SCALE VERT. SCALE: 1" -

AS BUILT 10-31-82 WP
INDEXED WP
ACCOUNT NO.
T-14
SHEET S-001 OF 18
FILE NO. 2012-7-099



RECORD DRAWING

*AS BUILT 10-31-82 WF

INDEXED WF

ZOLTAN VARGA 27314 CIVIL — REGISTERED PROFESSIONAL ENGINEER — STATE OF CALIFORNIA

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Southwestern Regional Office
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Structural		
Architectural		
Electrical		
Instrumentation		
HVAC		
Project Engineer	12/79	ASR
Project Manager	12/79	DMS

MARK	REVISIONS	APPR.	DATE

DESIGNED BY BW DRAWN BY EL CHECKED BY EC

CITY OF RIVERSIDE
PUBLIC WORKS DEPARTMENT

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APPROVED BY
PUBLIC WORKS DIRECTOR
DATE 12-28-79

PRIMARY - SECONDARY REPLACEMENT CAPACITY PROJECT

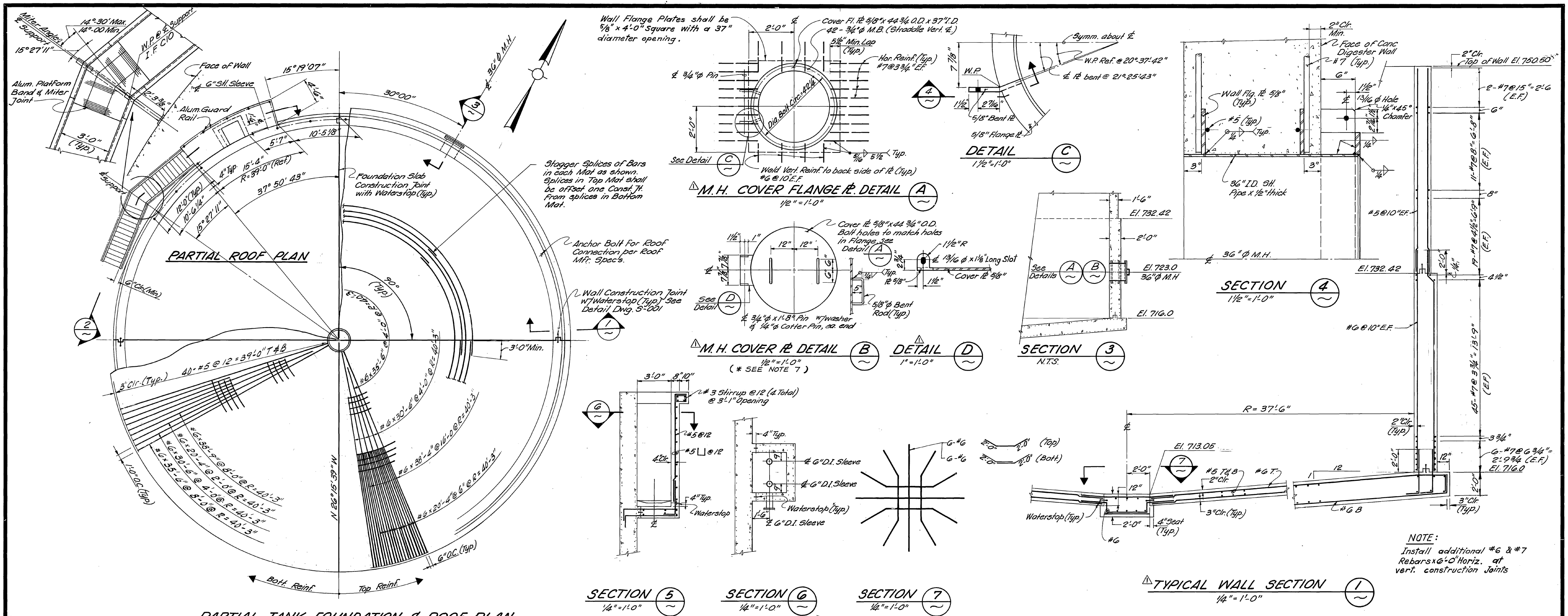
STRUCTURAL MISCELLANEOUS

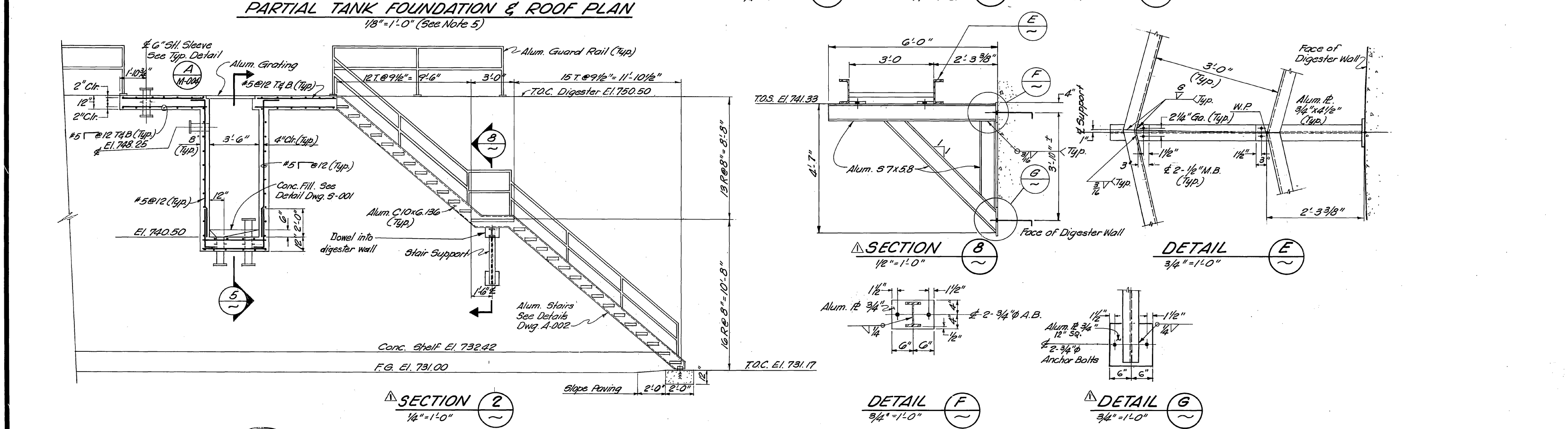
HORIZ. SCALE: AS SHOWN VERT. SCALE: 1" -

ACCOUNT NO.

SHEET S-002 OF 18

FILE NO. 2012-7-100





NOTES: (1-4 Apply to 36" M.H.)

1. 1/8" Long Fiber Asbestos sheet Gasket 41 3/8" O.D. x 36" I.D. between Flange and Cover.
2. All Reinf. cut shall be welded to Wall Flange PL. Actual Reinf. Location may vary from that shown.
3. Welds not shown shall be full penetration groove welds.
4. Hot-dip Galv. M.H. weldment. Galvanizing damaged by Field welding shall be galvanized in field.
5. See Dwg. M-605 for location of Pipe sleeves not shown.
6. Contractor may provide a water tight manhole conforming to AWWA D-100 Specifications. Either MH shown detailed or a Std. AWWA D-100 shall be tested for water tightness before installation.
7. Cover Plate material shall meet AWWA D-100 specification for finish and tolerances to provide a water tight connection with the MH Cover Flange Plate.
8. Digester interior vertical concrete walls & first foot of floor slab painted with 2 coats of coal tar epoxy.

RECORD DRAWING

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Southwestern Regional Office
283 South Lake Avenue
Pasadena California 91101

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Electrical		
Instrumentation		
HVAC		
Project Engineer	8/79	ASD
Project Manager	8/79	DMS

MARK	REVISIONS	APPR.	DATE
⚠	AS BUILT REVISIONS		10-22-81

DESIGNED BY LBG DRAWN BY JTC CHECKED BY EC

* AS BUILT 10-31-82 LF

CITY OF RIVERSIDE
PUBLIC WORKS DEPARTMENT

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APPROVED BY PUBLIC WORKS DIRECTOR
DATE 12-28-79

PRIMARY - SECONDARY
REPLACEMENT CAPACITY PROJECT
DIGESTER NO.5
PLAN & SECTIONS

HORIZ. SCALE: AS SHOWN VERT. SCALE: 1" -

INDEXED LF
ACCOUNT NO.
T-14
SHEET S-601 OF 18
FILE NO. 2012-7-114

Digester Result Summary

f'c = 4500 psi
fy = 50 ksi

ϕ_T = 0.9

WALL HOOP STRESS

Seismic Condition with Fixed Base)

depth from top	wall thick (in)	rebar (in^2/ft)	ϕTn (psi)	High Level Liquid = 32ft $T_{u,ASCE7-10}$ (psi)	$T_{u,BSE-1E}$ (psi)	DCR ASCE 7-10	DCR BSE-1E	Low Level Liquid = 26ft $T_{u,ASCE7-10}$ (psi)	$T_{u,BSE-1E}$ (psi)	DCR ASCE 7-10	DCR BSE-1E
0.00 - 3.00	18	0.96	200	70	64	**0.35**	**0.32**	42	38	**0.21**	**0.19**
3.00 - 10.33	18	1.80	375	267	253	**0.71**	**0.67**	108	102	**0.29**	**0.27**
10.33 - 17.08	18	3.20	667	470	447	**0.71**	**0.67**	292	278	**0.44**	**0.42**
17.08 - 31.28	24	3.84	600	547	521	**0.91**	**0.87**	390	373	**0.65**	**0.62**
31.28 - 34.5	24	2.13	333	205	195	**0.62**	**0.59**	142	136	**0.43**	**0.41**
						OK	***OK***			***OK***	***OK***

Seismic Condition with Pinned Base)

depth from top	wall thick (in)	rebar (in^2/ft)	ϕTn (psi)	High Level Liquid = 32ft $T_{u,ASCE7-10}$ (psi)	$T_{u,BSE-1E}$ (psi)	DCR ASCE 7-10	DCR BSE-1E	Low Level Liquid = 26ft $T_{u,ASCE7-10}$ (psi)	$T_{u,BSE-1E}$ (psi)	DCR ASCE 7-10	DCR BSE-1E
0.00 - 3.00	18	0.96	200	81	74	**0.41**	**0.37**	50	45	**0.25**	**0.23**
3.00 - 10.33	18	1.80	375	274	259	**0.73**	**0.69**	112	106	**0.30**	**0.28**
10.33 - 17.08	18	3.20	667	451	429	**0.68**	**0.64**	279	265	**0.42**	**0.40**
17.08 - 31.28	24	3.84	600	483	461	**0.81**	**0.77**	338	323	**0.56**	**0.54**
31.28 - 34.5	24	2.13	333	126	119	**0.38**	**0.36**	82	78	**0.25**	**0.23**
						OK	***OK***			***OK***	***OK***

Digester Result Summary

FOUNDATION RING STRESS

Seismic Condition

	wall thick (in)	rebar (in^2/ft)	ϕTn (psi)	High Level Liquid = 32ft $T_{u,ASCE7-10}$ (psi)	$T_{u,BSE-1E}$ (psi)	**DCR ASCE 7-10**	**DCR BSE-1E**	Low Level Liquid = 26ft $T_{u,ASCE7-10}$ (psi)	$T_{u,BSE-1E}$ (psi)	**DCR ASCE 7-10**	**DCR BSE-1E**
Fix-Base	24	0.62	97	276	257	**2.85**	**2.65**	180	169	**1.86**	**1.74**
Pin-Base	24	0.62	97	247	235	**2.55**	**2.43**	199	191	**2.05**	**1.97**
						->NG	***->NG***			***->NG***	***->NG***
				Liquid Level = 22ft				Liquid Level = 16.5ft			
Fix-Base	24	0.62	97	133	126	**1.37**	**1.30**	86	82	**0.89**	**0.85**
Pin-Base	24	0.62	97	174	168	**1.80**	**1.73**	149	145	**1.54**	**1.50**
						->NG	***->NG***			***->NG***	***->NG***

FOUNDATION SLAB BEARING PRESSURE (SERVICE LEVEL)

		Fixed-Base q (psi)	**Fixed-Base** q (psf)	**Pinned-Base** q (psi)	**Pinned-Base** q (psf)
(ASCE 7-10)					
High Level Liquid = 32ft	=	32	4,666	35	5,026
Low Level Liquid = 26ft	=	25	3,643	28	4,018
Liquid Level = 22ft	=	22	3,125	25	3,528
Liquid Level = 16.5ft	=	18	2,534	21	3,010
	=				
(BSE-1E)					
High Level Liquid = 32ft	=	31	4,522	34	4,882
Low Level Liquid = 26ft	=	25	3,571	27	3,946
Liquid Level = 22ft	=	21	3,067	24	3,470
Liquid Level = 16.5ft	=	17	2,506	21	2,981

Digester Result Summary

concrete strength, f'_c	= *4,500*	*psi*
reinf bar strength, f_y	= *50,000*	*psi*
Concrete Shear Stress, Vn	= $2*(f'_c)^{0.5}$	
Rebar In-Plane Shear Stress, Vs	= $\rho * f_y$	
Tension Stress, Tn	= $\rho * f_y$	
Strength Reduction Factor for Bending, ϕ_B =	= *0.9*	
Strength Reduction Factor for Shear, ϕ_v =	= *0.75*	

Notes:

t :	*Slab or Wall thickness*
d_b :	*Reinforcing bar diameter*
s :	*Reinforcing bar spacing*
d :	*Distance to flexural reinforcing*
A_s :	*Nominal reinforcing bar area*
ρ :	*Reinforcement bar ratio = A_s / (12 in * d)*
M_n :	*Flexural capacity = $(\rho f_y d^2 * [1-(0.588 \rho f_y / f'_c)]$*

Bar size	*Diameter*	*Bar Area*
# 3	*0.375*	*0.11*
# 4	*0.500*	*0.20*
# 5	*0.625*	*0.31*
# 6	*0.750*	*0.44*
# 7	*0.875*	*0.60*
# 8	*1.000*	*0.79*
# 9	*1.128*	*1.00*
# 10	*1.270*	*1.27*
# 11	*1.410*	*1.56*

OUT-OF-PLANE BENDING MOMENT

	Mu *(kip-ft/ft)*	*t* *(in)*	*bar size*	*bar spacing* *(in)*	*bar cover* *(in)*	d_b (in)	A_s (in^2/ft)	d (in)	ρ	ϕM_n (kip-ft /ft)	***DCR***	
Wall Moment (Fixed-Base)												
(ASCE 7-10)												
High Liquid Level = 32ft	*72.9*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***1.72***	***<-- NG***
Low Liquid Level = 26ft	*53.2*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***1.25***	***<-- NG***
Liquid Level = 22ft	*44.2*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***1.04***	***<-- NG***
Liquid Level = 16.5ft	*39.5*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***0.93***	***OK***
(BSE-1E)												
High Liquid Level = 32ft	*68.5*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***1.61***	***<-- NG***
Low Liquid Level = 26ft	*50.5*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***1.19***	***<-- NG***
Liquid Level = 22ft	*42.3*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***1.00***	***OK***
Liquid Level = 16.5ft	*39.2*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***0.92***	***OK***
Wall Moment (Pinned-Base)												
(ASCE 7-10)												
High Liquid Level = 32ft	*41.9*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***0.99***	***OK***
Low Liquid Level = 26ft	*32.4*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***0.76***	***OK***
Liquid Level = 22ft	*26.3*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***0.62***	***OK***
Liquid Level = 16.5ft	*17.7*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***0.42***	***OK***
(BSE-1E)												
High Liquid Level = 32ft	*39.5*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***0.93***	***OK***
Low Liquid Level = 26ft	*30.6*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***0.72***	***OK***
Liquid Level = 22ft	*24.9*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***0.59***	***OK***
Liquid Level = 16.5ft	*16.6*	*24*	*# 6*	*10*	*2.38*	0.750	0.53	21.63	0.00204	42.42	***0.39***	***OK***

Digester Result Summary

Slab Bars in Radial Dir (Fixed-Base)												
(ASCE 7-10)												
High Liquid Level = 32ft (Bottom)	61.7	24	# 6	12	2.38	0.750	0.44	21.63	0.00170	35.43	1.74	<-- NG
Low Liquid Level = 26ft (Bottom)	49.3	24	# 6	12	2.38	0.750	0.44	21.63	0.00170	35.43	1.39	<-- NG
Liquid Level = 22ft (Bottom)	45.9	24	# 6	12	2.38	0.750	0.44	21.63	0.00170	35.43	1.30	<-- NG
Liquid Level = 16.5ft (Bottom)	42.8	24	# 6	12	2.38	0.750	0.44	21.63	0.00170	35.43	1.21	<-- NG
High Liquid Level = 32ft (Top)	34.3	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.49	OK
Low Liquid Level = 26ft (Top)	22.5	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.32	OK
Liquid Level = 22ft (Top)	17.2	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.25	OK
Liquid Level = 16.5ft (Top))	12.5	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.18	OK
(BSE-1E)												
High Liquid Level = 32ft (Bottom)	57.9	24	# 6	12	2.38	0.750	0.44	21.63	0.00170	35.43	1.63	<-- NG
Low Liquid Level = 26ft (Bottom)	47.7	24	# 6	12	2.38	0.750	0.44	21.63	0.00170	35.43	1.35	<-- NG
Liquid Level = 22ft (Bottom)	44.8	24	# 6	12	2.38	0.750	0.44	21.63	0.00170	35.43	1.26	<-- NG
Liquid Level = 16.5ft (Bottom)	42.2	24	# 6	12	2.38	0.750	0.44	21.63	0.00170	35.43	1.19	<-- NG
High Liquid Level = 32ft (Top)	31.9	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.46	OK
Low Liquid Level = 26ft (Top)	21.0	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.30	OK
Liquid Level = 22ft (Top)	16.3	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.23	OK
Liquid Level = 16.5ft (Top))	12.0	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.17	OK
Slab Bars in Radial Dir (Pinned-Base)												
(ASCE 7-10)												
High Liquid Level = 32ft (Bottom)	9.4	24	# 6	12	2.38	0.750	0.44	21.63	0.00170	35.43	0.26	OK
Low Liquid Level = 26ft (Bottom)	5.5	24	# 6	12	2.38	0.750	0.44	21.63	0.00170	35.43	0.16	OK
Liquid Level = 22ft (Bottom)	4.7											
Liquid Level = 16.5ft (Bottom)	3.9											
High Liquid Level - ASCE 7-10 (Top)	41.4	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.59	OK
Low Liquid Level - ASCE 7-10 (Top)	31.5	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.45	OK
Liquid Level = 22ft (Top)	27.6											
Liquid Level = 16.5ft (Top))	25.0											
(BSE-1E)												
High Liquid Level - BSE-1E (Bottom)	6.9	24	# 6	12	2.38	0.750	0.44	21.63	0.00170	35.43	0.19	OK
Low Liquid Level - BSE-1E (Bottom)	5.4	24	# 6	12	2.38	0.750	0.44	21.63	0.00170	35.43	0.15	OK
Liquid Level = 22ft (Bottom)	4.6											
Liquid Level = 16.5ft (Bottom)	3.9											
High Liquid Level - BSE-1E (Top)	39.0	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.56	OK
Low Liquid Level - BSE-1E (Top)	30.1	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.43	OK
Liquid Level = 22ft (Top)	26.7	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.38	OK
Liquid Level = 16.5ft (Top))	24.6	24	# 6	6	2.38	0.750	0.88	21.63	0.00340	70.06	0.35	OK

Digester Result Summary

OUT-OF-PLANE SHEAR

	$V_{u,max}$ (psi)	V_c (psi)	DCR	
Wall Shear (Fixed-Base)				
(ASCE 7-10)				
High Liquid Level = 32ft	70	101	0.69	OK
Low Liquid Level = 26ft	56	101	0.55	OK
(BSE-1E)				
High Liquid Level = 32ft	65	101	0.64	OK
Low Liquid Level = 26ft	53	101	0.52	OK
Wall Shear (Pinned-Base)				
(ASCE 7-10)				
High Liquid Level = 32ft	58	101	0.57	OK
Low Liquid Level = 26ft	44	101	0.43	OK
(BSE-1E)				
High Liquid Level = 32ft	54	101	0.54	OK
Low Liquid Level = 26ft	41	101	0.41	OK

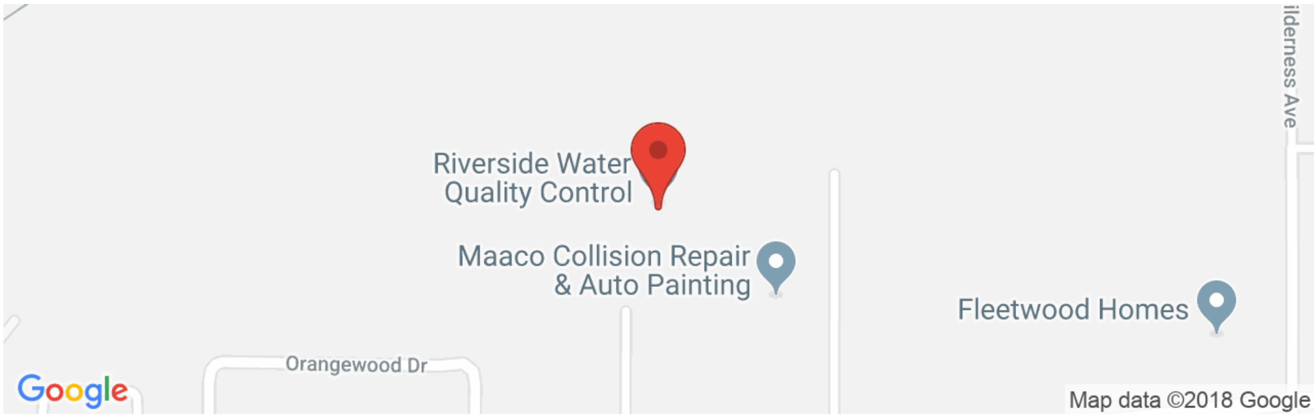
IN-PLANE SHEAR STRESS CHECK

	SXY_{max} (psi)	thick (in)	bar area (in^2)	bar spacing (in)	ρ	V_s (psi)	V_c (psi)	ϕV_n (psi)	DCR	
Fixed Base										
(ASCE 7-10)										
High Liquid Level = 32ft	197	24	2.13	12	0.0074	370	134	378	0.52	OK
Low Liquid Level = 26ft	144	24	2.13	12	0.0074	370	134	378	0.38	OK
(BSE-1E)										
High Liquid Level = 32ft	183	24	2.13	12	0.0074	370	134	378	0.48	OK
Low Liquid Level = 26ft	134	24	2.13	12	0.0074	370	134	378	0.35	OK
Pinned Base										
(ASCE 7-10)										
High Liquid Level = 32ft	243	24	2.13	12	0.0074	370	134	378	0.64	OK
Low Liquid Level = 26ft	177	24	2.13	12	0.0074	370	134	378	0.47	OK
(BSE-1E)										
High Liquid Level = 32ft	225	24	2.13	12	0.0074	370	134	378	0.60	OK
Low Liquid Level = 26ft	165	24	2.13	12	0.0074	370	134	378	0.44	OK

Riverside - Digester

5950 Acorn St, Riverside, CA 92504, USA

Latitude, Longitude: 33.962132, -117.45361919999999



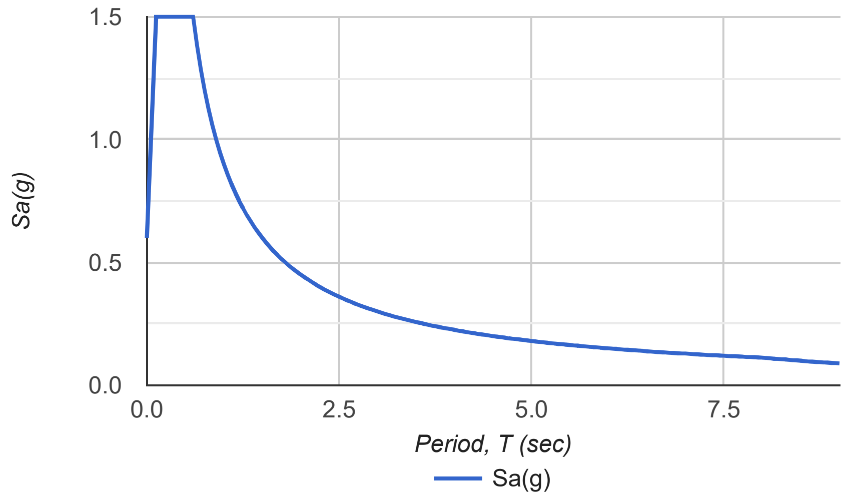
Date	12/5/2018, 10:46:39 AM
Design Code Reference Document	ASCE7-10
Risk Category	IV
Site Class	D - Stiff Soil

Type	Value	Description
S_S	1.5	MCE_R ground motion. (for 0.2 second period)
S_1	0.6	MCE_R ground motion. (for 1.0s period)
S_{MS}	1.5	Site-modified spectral acceleration value
S_{M1}	0.9	Site-modified spectral acceleration value
S_{DS}	1	Numeric seismic design value at 0.2 second SA
S_{D1}	0.6	Numeric seismic design value at 1.0 second SA

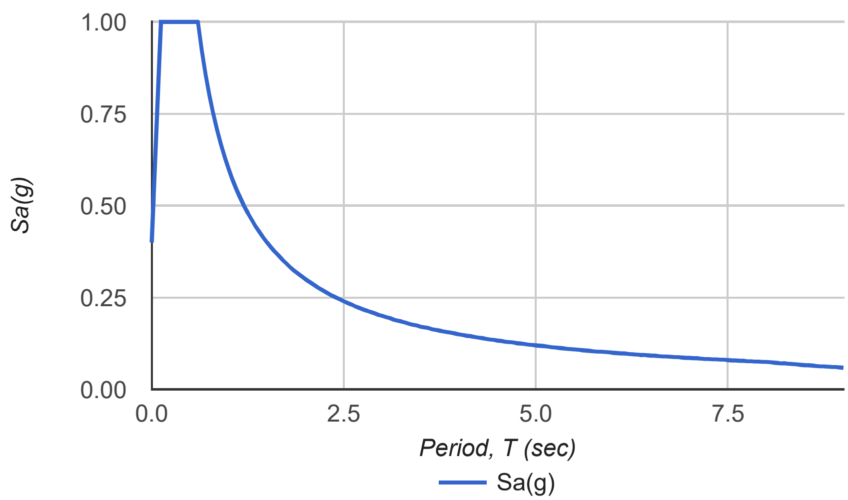
Type	Value	Description
SDC	D	Seismic design category
F_a	1	Site amplification factor at 0.2 second
F_v	1.5	Site amplification factor at 1.0 second
PGA	0.5	MCE_G peak ground acceleration
F_{PGA}	1	Site amplification factor at PGA
PGA_M	0.5	Site modified peak ground acceleration
T_L	8	Long-period transition period in seconds
SsRT	1.821	Probabilistic risk-targeted ground motion. (0.2 second)
SsUH	1.634	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration
SsD	1.5	Factored deterministic acceleration value. (0.2 second)
S1RT	0.695	Probabilistic risk-targeted ground motion. (1.0 second)
S1UH	0.644	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration.
S1D	0.6	Factored deterministic acceleration value. (1.0 second)
PGAd	0.5	Factored deterministic acceleration value. (Peak Ground Acceleration)

Type	Value	Description
C_{RS}	1.114	Mapped value of the risk coefficient at short periods
C_{R1}	1.079	Mapped value of the risk coefficient at a period of 1 s

MCER Response Spectrum



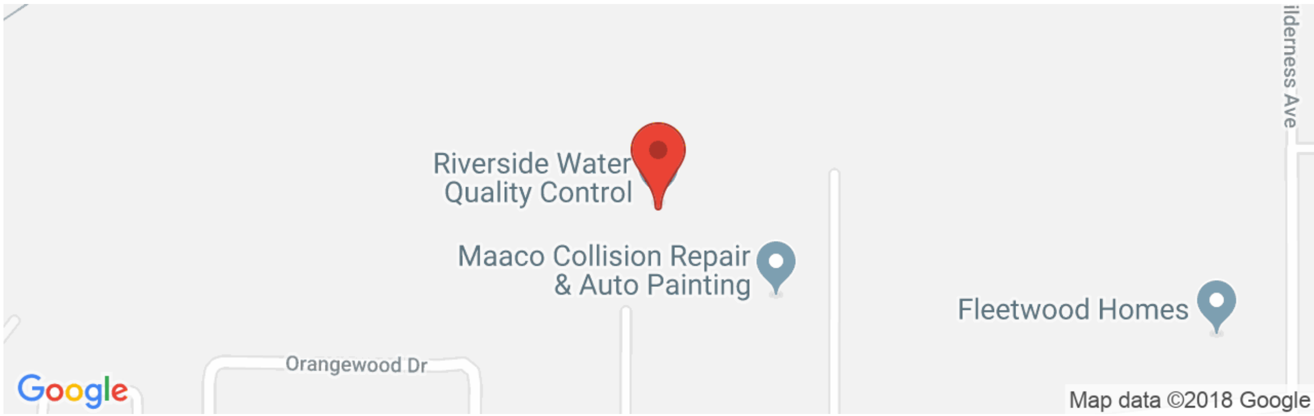
Design Response Spectrum



Riverside - Digester

5950 Acorn St, Riverside, CA 92504, USA

Latitude, Longitude: 33.962132, -117.45361919999999



Date	12/5/2018, 11:11:02 AM
Design Code Reference Document	ASCE41-13
Custom Probability	
Site Class	D - Stiff Soil

Type	Description	Value
Hazard Level		BSE-2N
S_S	spectral response (0.2 s)	1.5
S_1	spectral response (1.0 s)	0.6
S_{XS}	site-modified spectral response (0.2 s)	1.5
S_{X1}	site-modified spectral response (1.0 s)	0.9
F_a	site amplification factor (0.2 s)	1
F_v	site amplification factor (1.0 s)	1.5
ssuh	max direction uniform hazard (0.2 s)	1.634
crs	coefficient of risk (0.2 s)	1.114
ssrt	risk-targeted hazard (0.2 s)	1.821
ssd	deterministic hazard (0.2 s)	1.5
s1uh	max direction uniform hazard (1.0 s)	0.644
cr1	coefficient of risk (1.0 s)	1.079
s1rt	risk-targeted hazard (1.0 s)	0.695
s1d	deterministic hazard (1.0 s)	0.6

Type	Description	Value
Hazard Level		BSE-1N
S_{XS}	site-modified spectral response (0.2 s)	1
S_{X1}	site-modified spectral response (1.0 s)	0.6

Type	Description	Value
Hazard Level		BSE-2E
S_S	spectral response (0.2 s)	1.255
S_1	spectral response (1.0 s)	0.49
S_{XS}	site-modified spectral response (0.2 s)	1.255
S_{X1}	site-modified spectral response (1.0 s)	0.74
f_a	site amplification factor (0.2 s)	1
f_v	site amplification factor (1.0 s)	1.51

Type	Description	Value
Hazard Level		BSE-1E
S_S	spectral response (0.2 s)	0.77
S_1	spectral response (1.0 s)	0.292
S_{XS}	site-modified spectral response (0.2 s)	0.918
S_{X1}	site-modified spectral response (1.0 s)	0.531
F_a	site amplification factor (0.2 s)	1.192
F_v	site amplification factor (1.0 s)	1.815

Type	Description	Value
Hazard Level		T-Sub-L Data
T-Sub-L	Long-period transition period in seconds	8

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BY:	C. Che	**DATE:**	Dec-18	**CLIENT:**	Riverside	**SHEET:**	
CHKD:		**DESCRIPTION:**			Digester Evaluation	**JOB NO:**	10495A.00
DESIGN TASK:					High Liquid; Wall Thick 24"; I=1.0		

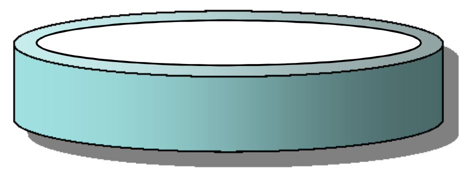
Hydrostatic and Hydrodynamic Seismic Analysis of a Circular Tank per ASCE 7-10 and the 2012 IBC code:

Does groundwater exist in which to consider buoyancy? **No Groundwater**

(Note: Response spectra values shall be strength level.)

tank inside diameter, D =	75	ft
tank inside radius, R =	**37.5**	ft
tank wall thickness, t_w =	**24**	inch
tank wall height to underside of roof =	**34.5**	ft
roof thickness =	**0**	inch
misc roof weights included with seismic =	**0.05**	ksf
liquid height, H_L =	**32**	ft
liquid specific gravity =	**1**	
liquid density, γ_L = (sp.gr.)*γ_w =	0.0624	k/ft^3
acceleration due to gravity, g =	32.17	ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ =	0.00194	$k\text{-}sec^2/ft^4$
concrete strength, f'_c =	**4.5**	ksi
concrete density, γ_c =	0.150	k/ft^3
concrete modulus of elasticity, E_c =	3823.7	ksi
concrete mass density, $\rho_c = \gamma_c / g$ =	0.00466	$k\text{-}sec^2/ft^4$

tank wall mass, W_w =	2503.7	kip
wall c.g. relative to base, h_w =	17.250	ft
tank roof weight =	0.0	kip
total misc roof weight =	245.1	kip
total roof mass, W_r =	245.1	kip
roof c.g. relative to base, h_r =	34.500	ft
liquid mass, $W_L = \pi R^2 * H_L * \gamma_L$ =	8821.6	kip



tank inside diameter, D = 75 ft

Seismic:

Structure Risk Category =	**2**
Importance factor, I =	**1**
Response modification factor, R_i =	**1.874**
Response modification factor, R_c =	**1.609**

(acceleration values from a maximum considered earthquake)

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **1** *g

Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.6** *g

1). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$C_w = 0.09375 + 0.2039\left(\frac{H_L}{D}\right) - 0.1034\left(\frac{H_L}{D}\right)^2 - 0.1253\left(\frac{H_L}{D}\right)^3 + 0.1267\left(\frac{H_L}{D}\right)^4 - 0.03186\left(\frac{H_L}{D}\right)^5 = 0.15594$$

$C_l = C_w * 10*((t_w/12)/R)^{1/2}$ = 0.1559*10*(24/12/37.5)^½ = 0.3601

$\omega_i = C_l * 12/H_L*(E_c/\rho_c)^{1/2}$ = 0.3601*12 / 32*(3823.7 / 0.00466)^½ = 122.2949 rad/sec

impulsive period of oscillation, $T_i = 2\pi / \omega_i$ = 2π / 122.2949 = 0.0514 sec

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 1 g

$$\lambda = \sqrt{3.68\ g\ \tanh\left(3.68\left(\frac{H_L}{D}\right)\right)} =$$ (3.68*32.17*tanh(3.68*(32/75))^½ = 10.4195

convective circular frequency, $\omega_c = \frac{\lambda}{\sqrt{D}}$ = 10.4195 / (75)^½ = 1.2031 rad/sec

convective period of sloshing, $T_c = 2\pi / \omega_c$ = 2π / 1.2031 = 5.2223 sec

Long transition period (from map figure 22-12 ASCE 7), T_L = **8** sec.

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.1723 g

effective mass coeff., $\varepsilon = 0.0151\left(\frac{D}{H_L}\right)^2 - 0.1908\left(\frac{D}{H_L}\right) + 1.021$, but ≤ 1.0 = 0.6568

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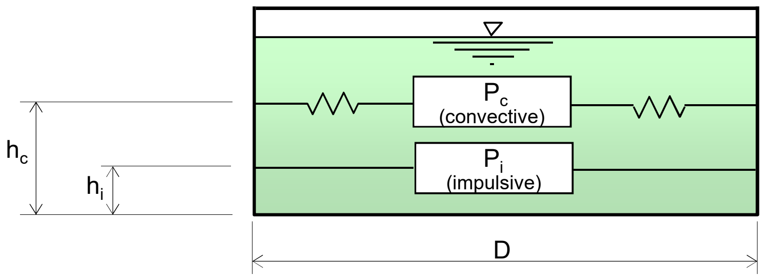
CHKD:		**DESCRIPTION:**			Digester Evaluation	**JOB NO:**	10495A.00
DESIGN TASK:					High Liquid; Wall Thick 24"; I=1.0		



Dynamic Model

$D =$	75	ft
$H_L =$	32	ft
$W_L =$	8821.6	kip
$D / H_L =$	2.34375	
$H_L / D =$	0.42667	

2). lateral fluid impulsive force:

equivalent impulsive mass component, $W_i = W_L \left(\dfrac{\tanh\left(0.866 \dfrac{D}{H_L}\right)}{0.866 \dfrac{D}{H_L}} \right) =$ 4198.8 kip

height above base to the impulsive lateral force, hi (EBP) = HL * 0.375 = 12 ft

hi (IBP) = HL * {{(0.866*D/HL)/(2*tanh(0.866*D/HL))} -1/8 } = 29.616 ft

impulsive force, $P_i = \left(\dfrac{S_{ai}\ I}{R_i} \right) W_i =$ (1 * 1 / 1.874) * 4198.8 = 2240.6 kip

impulsive force moment excluding bottom pressure , $M_{i(EBP)} = P_i * h_{i(EBP)} =$ 2240.6 * 12 = 26887.2 ft-k

impulsive force moment including bottom pressure , $M_{i(IBP)} = P_i * h_{i(IBP)} =$ 2240.6 * 29.616 = 66357.6 ft-k

3). lateral fluid convective force:

equivalent convective mass component, $W_c = W_L \left(0.23 \left(\dfrac{D}{H_L} \right) \tanh\left(3.68 \left(\dfrac{H_L}{D} \right) \right) \right) =$ 4360.9 kip

height above base to convective lateral force, $h_{c\ (EBP)} = H_L \left(1 - \dfrac{\cosh\left(3.68\left(\dfrac{H_L}{D}\right)\right) - 1}{3.68\left(\dfrac{H_L}{D}\right)\sinh\left(3.68\left(\dfrac{H_L}{D}\right)\right)} \right) =$ 18.638 ft

$h_{c(IBP)} = H_L \left(1 - \dfrac{\cosh\left(3.68\left(\dfrac{H_L}{D}\right)\right) - 2.01}{3.68\left(\dfrac{H_L}{D}\right)\sinh\left(3.68\left(\dfrac{H_L}{D}\right)\right)} \right) =$ 27.59 ft

convective force, $P_c = \left(\dfrac{S_{ac}\ I}{R_c} \right) W_c =$ (0.1723 * 1 / 1.609) * 4360.9 = 467.0 kip

convective force moment excluding bottom pressure , $M_{c(EBP)} = P_c * h_{c(EBP)} =$ 467 * 18.638 = 8703.9 ft-k

convective force moment including bottom pressure , $M_{c(IBP)} = P_c * h_{c(IBP)} =$ 467 * 27.59 = 12884.5 ft-k

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4). lateral inertia force of the accelerating wall:

tank wall mass, W_w = 2503.7 kip

wall c.g. relative to base, h_w = 17.250 ft

wall inertia force, $P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_i}\right)W_w =$ (1 * 1 * 0.6568 / 1.874) * 2503.7 = 877.4 kip

wall inertia force moment, $M_w = P_w*h_w$ = 877.4 * 17.25 = 15135.2 ft-k

5). lateral inertia force of the accelerating roof:

total roof mass, W_r = 245.1 kip

roof c.g. relative to base, h_r = 34.5 ft

roof inertia force, $P_r = \left(\frac{S_{ai}\ I}{R_i}\right)W_r =$ (1 * 1 / 1.874) * 245.1 = 130.8 kip

roof inertia force moment, $M_r = P_r*h_r$ = 130.8 * 34.5 = 4512.6 ft-k

6). total base shear:

$$V = \sqrt{(P_i + P_w + P_r)^2 + P_c^2}$$

V = ((2240.6 + 877.4 + 130.8)² + (467)²)^½ = 3282.2 kip

7). total moment at the base excluding bottom pressure (EBP):

$$M_b = \sqrt{(M_i + M_w + M_r)^2 + M_c^2}$$

Mb = ((26887.2 + 15135.2 + 4512.6)² + (8703.9)²)^½ = 47342.0 ft-k

8). total moment at the base including bottom pressure (IBP):

$$M_o = \sqrt{(M_i + M_w + M_r)^2 + M_c{}^2}$$

Mo = ((66357.6 + 15135.2 + 4512.6)² + (12884.5)²)^½ = 86965.2 ft-k

9). maximum wave slosh height displacement: (see ASCE-10, 15.7.6.1 notes c and d)

(Risk Category = 2) I = 1 ,use TL = 4 ,Sd1 = 0.6 ,Tc = 5.2223

S_{ac} = 1.5 * Sd1 * TL / Tc² = 0.132 *g

$d_{(max)} = 0.42\ (\ D\ )(\ S_{ac}\ \ I\ ) =$ 0.42 * (75) * (0.132 * 1) = 4.16 ft

(minimum freeboard see table 15.7-3 of ASCE 7) , d(min) = No minimum req'd

Wave height is greater than the freeboard of 2.5-ft. Check effects of wave spillage.

10). Vertical acceleration:

design horizontal accereration, S_{DS} = 1 *g

period of vibration, $T_v = 2\pi*(\ \gamma_L*D*H_L{}^2 / (24g*t_w*E_c)\ )^{1/2}$ = 0.0517 sec

$Ts = S_{D1} / S_{DS}$ = 0.6 / 1 = 0.6 sec

vertical acceleration (per ACI 350 para 9.4.3), for $T_V \le T_S$ then $C_t = S_{DS}$, for $T_V \succ T_S$ then $C_t = \frac{S_{D1}}{T_V}$

therefore, vertical spectral response acceleration, $S_{av} = C_t$ = 1.0000 *g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

Design vertical acceleration, $\ddot{u} = \frac{S_{av}\ I\ b}{R_i} =$ 1*1*1/1 = 1.0000 g

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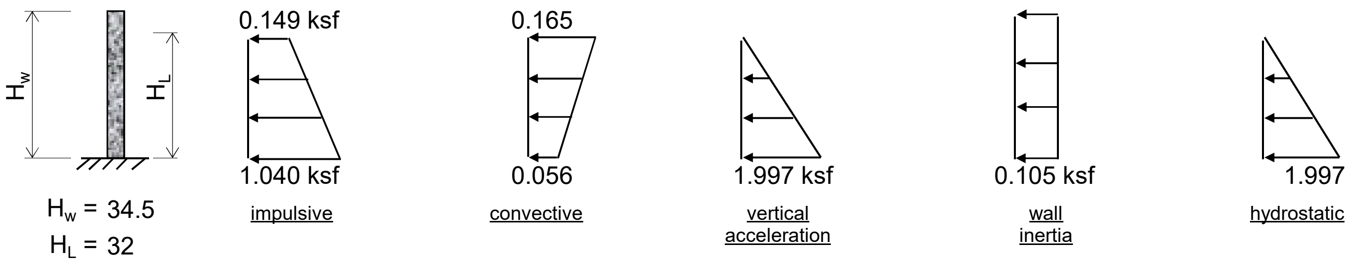
DESIGN TASK:			High Liquid; Wall Thick 24"; I=1.0		

12). vertical pressure distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



impulsive pressure:

$$p_{iy} = \frac{2\left(\frac{P_i}{2}\right)\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{\pi R H_L^2}\cos\theta =$$

use θ = 0°

impulsive force, P_i =	2240.6	kip
h_i =	12	ft
at y = H_L, p_{iy} =	0.149	ksf
at base y = 0, p_{iy} =	1.040	ksf

convective pressure:

$$p_{cy} = \frac{16\left(\frac{P_c}{2}\right)\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{9\pi R H_L^2}\cos\theta =$$

use θ = 0°

convective force, P_c =	467.0	kip
h_c =	18.638	ft
at y = H_L, p_{cy} =	0.165	ksf
at base y = 0, p_{cy} =	0.056	ksf

vertical acceleration pressure:

$$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$$

vertical acceleration, ü =	1	g
at y = H_L, p_{vy} =	0	ksf
at base y = 0, p_{vy} =	1.997	ksf

wall inertia pressure:

$$p_{wy} = \frac{S_{ai}\ I\ \varepsilon\,\gamma_c\ (t_w/12)}{R_i} =$$

p_{wy} =	0.3505	* (γ_c * t_w)
at y = H_w, p_{wy} =	0.105	ksf
at base y = 0, p_{wy} =	0.105	ksf

hydrostatic pressure:

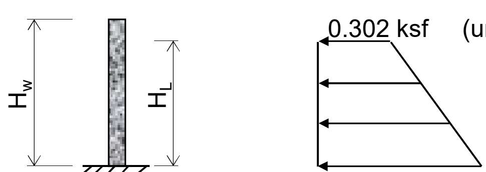
$$q_{hy} = \gamma_L\,(H_L - y) =$$

at y = H_L, q_{hy} =	0	ksf
at base y = 0, q_{hy} =	1.997	ksf

combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$$

at y = H_w, p_y =	0.302	ksf
at base y = 0, p_y =	2.303	ksf



0.302 ksf (unfactored load = 0.302 / 1.4 = 0.216 ksf)

2.303 ksf (unfactored load = 2.303 / 1.4 = 1.645 ksf)

resultant dynamic pressures

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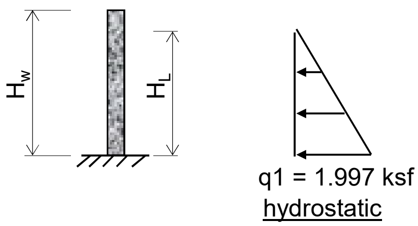
DESIGN TASK:					High Liquid; Wall Thick 24"; I=1.0		

13). load cases:

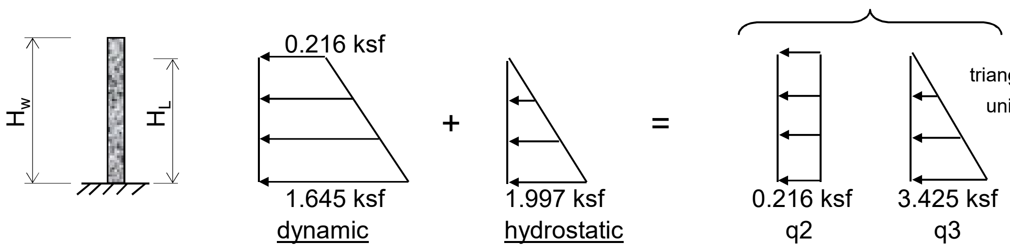
a). hydrostatic water load case:



triangular pressure = 1.997 ksf

b). seismic load case:

equivalent unfactored dynamic + static pressure loadings… equivalent loading (unfactored)



triangular pressure = 3.425 ksf
uniform pressure = 0.216 ksf

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CHKD:		**DESCRIPTION:**			Digester Evaluation	**JOB NO:**	10495A.00
DESIGN TASK:					Low Liquid; Wall Thick 24"; I=1.0		

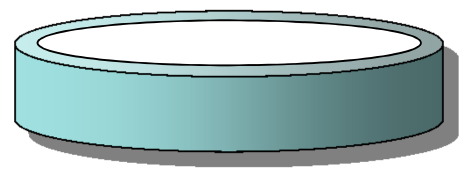
Hydrostatic and Hydrodynamic Seismic Analysis of a Circular Tank per ASCE 7-10 and the 2012 IBC code:

Does groundwater exist in which to consider buoyancy? **No Groundwater**

(Note: Response spectra values shall be strength level.)

tank inside diameter, D =	75	ft
tank inside radius, R =	**37.5**	ft
tank wall thickness, t_w =	**24**	inch
tank wall height to underside of roof =	**34.5**	ft
roof thickness =	**0**	inch
misc roof weights included with seismic =	**0.05**	ksf
liquid height, H_L =	**26**	ft
liquid specific gravity =	**1**	
liquid density, γ_L = (sp.gr.)*γ_w =	0.0624	k/ft^3
acceleration due to gravity, g =	32.17	ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ =	0.00194	$k\text{-}sec^2/ft^4$
concrete strength, f'_c =	**4.5**	ksi
concrete density, γ_c =	0.150	k/ft^3
concrete modulus of elasticity, E_c =	3823.7	ksi
concrete mass density, $\rho_c = \gamma_c / g$ =	0.00466	$k\text{-}sec^2/ft^4$

tank wall mass, W_w =	2503.7	kip
wall c.g. relative to base, h_w =	17.250	ft
tank roof weight =	0.0	kip
total misc roof weight =	245.1	kip
total roof mass, W_r =	245.1	kip
roof c.g. relative to base, h_r =	34.500	ft
liquid mass, $W_L = \pi R^2 * H_L * \gamma_L$ =	7167.5	kip



tank inside diameter, D = 75 ft

Seismic:

Structure Risk Category =	**2**
Importance factor, I =	**1**
Response modification factor, R_i =	**2**
Response modification factor, R_c =	**1.5**

(acceleration values from a maximum considered earthquake)

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **1** *g

Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.6** *g

1). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$C_w = 0.09375 + 0.2039\left(\frac{H_L}{D}\right) - 0.1034\left(\frac{H_L}{D}\right)^2 - 0.1253\left(\frac{H_L}{D}\right)^3 + 0.1267\left(\frac{H_L}{D}\right)^4 - 0.03186\left(\frac{H_L}{D}\right)^5 = 0.14846$$

$C_l = C_w * 10*((t_w/12)/R)^{1/2}$ = 0.1485*10*(24/12/37.5)^½ = 0.3429

$\omega_i = C_l * 12/H_L*(E_c / \rho_c)^{1/2}$ = 0.3429*12 / 26*(3823.7 / 0.00466)^½ = 143.2962 rad/sec

impulsive period of oscillation, $T_i = 2\pi / \omega_i$ = 2π / 143.2962 = 0.0438 sec

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 1 g

$$\lambda = \sqrt{3.68\ g\ \tanh\left(3.68\left(\frac{H_L}{D}\right)\right)} =$$ (3.68*32.17*tanh(3.68*(26/75))^½ = 10.0628

convective circular frequency, $\omega_c = \frac{\lambda}{\sqrt{D}}$ = 10.0628 / (75)^½ = 1.1620 rad/sec

convective period of sloshing, $T_c = 2\pi / \omega_c$ = 2π / 1.162 = 5.4074 sec

Long transition period (from map figure 22-12 ASCE 7), T_L = **8** sec.

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.1664 g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{D}{H_L}\right)^2 - 0.1908\left(\frac{D}{H_L}\right) + 1.021 \text{ , but } \le 1.0 = 0.5963$$

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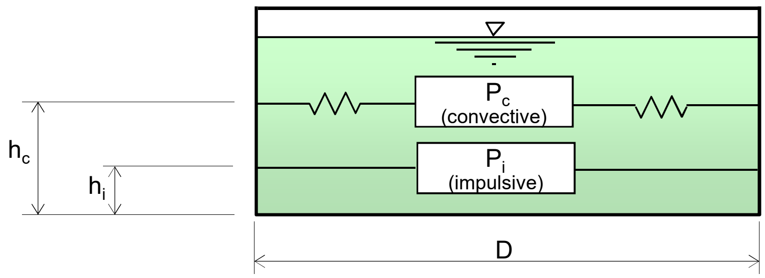
DESIGN TASK:					Low Liquid; Wall Thick 24"; I=1.0		



Dynamic Model

D =	75	ft
H_L =	26	ft
W_L =	7167.5	kip
D / H_L =	2.88462	
H_L / D =	0.34667	

2). lateral fluid impulsive force:

equivalent impulsive mass component, $W_i = W_L \left(\dfrac{\tanh\left(0.866 \dfrac{D}{H_L}\right)}{0.866 \dfrac{D}{H_L}} \right) =$ 2830.7 kip

height above base to the impulsive lateral force, hi (EBP) = HL * 0.375 = 9.75 ft

hi (IBP) = HL * {{(0.866*D/HL)/(2*tanh(0.866*D/HL))} -1/8 } = 29.667 ft

impulsive force, $P_i = \left(\dfrac{S_{ai} \; I}{R_i} \right) W_i =$ (1 * 1 / 2) * 2830.7 = 1415.4 kip

impulsive force moment excluding bottom pressure , $M_{i(EBP)} = P_i{*}h_{i(EBP)}$ = 1415.4 * 9.75 = 13800.2 ft-k

impulsive force moment including bottom pressure , $M_{i(IBP)} = P_i{*}h_{i(IBP)}$ = 1415.4 * 29.667 = 41990.7 ft-k

3). lateral fluid convective force:

equivalent convective mass component, $W_c = W_L \left(0.23 \left(\dfrac{D}{H_L} \right) \tanh\left(3.68 \left(\dfrac{H_L}{D} \right) \right) \right) =$ 4067.5 kip

height above base to convective lateral force, $h_{c\ (EBP)} = H_L \left(1 - \dfrac{\cosh\left(3.68\left(\dfrac{H_L}{D}\right)\right) - 1}{3.68\left(\dfrac{H_L}{D}\right) \sinh\left(3.68\left(\dfrac{H_L}{D}\right)\right)} \right) =$ 14.517 ft

$h_{c(IBP)} = H_L \left(1 - \dfrac{\cosh\left(3.68\left(\dfrac{H_L}{D}\right)\right) - 2.01}{3.68\left(\dfrac{H_L}{D}\right) \sinh\left(3.68\left(\dfrac{H_L}{D}\right)\right)} \right) =$ 26.984 ft

convective force, $P_c = \left(\dfrac{S_{ac} \; I}{R_c} \right) W_c =$ (0.1664 * 1 / 1.5) * 4067.5 = 451.2 kip

convective force moment excluding bottom pressure , $M_{c(EBP)} = P_c{*}h_{c(EBP)}$ = 451.2 * 14.517 = 6550.1 ft-k

convective force moment including bottom pressure , $M_{c(IBP)} = P_c{*}h_{c(IBP)}$ = 451.2 * 26.984 = 12175.2 ft-k

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4). lateral inertia force of the accelerating wall:

tank wall mass, W_w = 2503.7 kip

wall c.g. relative to base, h_w = 17.250 ft

wall inertia force, $P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_i}\right) W_w =$ (1 * 1 * 0.5963 / 2) * 2503.7 = 746.4 kip

wall inertia force moment, $M_w = P_w{*}h_w$ = 746.4 * 17.25 = 12875.4 ft-k

5). lateral inertia force of the accelerating roof:

total roof mass, W_r = 245.1 kip

roof c.g. relative to base, h_r = 34.5 ft

roof inertia force, $P_r = \left(\frac{S_{ai}\ I}{R_i}\right) W_r =$ (1 * 1 / 2) * 245.1 = 122.6 kip

roof inertia force moment, $M_r = P_r{*}h_r$ = 122.6 * 34.5 = 4229.7 ft-k

6). total base shear:

$$V = \sqrt{(P_i + P_w + P_r)^2 + P_c^2}$$

V = ((1415.4 + 746.4 + 122.6)² + (451.2)²)ˆ½ = 2328.5 kip

7). total moment at the base excluding bottom pressure (EBP):

$$M_b = \sqrt{(M_i + M_w + M_r)^2 + M_c^2}$$

Mb = ((13800.2 + 12875.4 + 4229.7)² + (6550.1)²)ˆ½ = 31591.8 ft-k

8). total moment at the base including bottom pressure (IBP):

$$M_o = \sqrt{(M_i + M_w + M_r)^2 + M_c{}^2}$$

Mo = ((41990.7 + 12875.4 + 4229.7)² + (12175.2)²)ˆ½ = 60337.0 ft-k

9). maximum wave slosh height displacement: (see ASCE-10, 15.7.6.1 notes c and d)

(Risk Category = 2) I = 1 ,use TL = 4 ,Sd1 = 0.6 ,Tc = 5.4074

S_{ac} = 1.5 * Sd1 * TL / Tc² = 0.1231 *g

$d_{(max)} = 0.42\ (\ D\ )(\ S_{ac}\ \ I\ ) =$ 0.42 * (75) * (0.1231 * 1) = 3.88 ft

(minimum freeboard see table 15.7-3 of ASCE 7) , d(min) = No minimum req'd

10). Vertical acceleration:

design horizontal accereration, S_{DS} = 1 *g

period of vibration, $T_v = 2\pi{*}(\ \gamma_L{*}D{*}H_L{}^2 / (24g{*}t_w{*}E_c)\ )^{1/2}$ = 0.0420 sec

$Ts = S_{D1} / S_{DS}$ = 0.6 / 1 = 0.6 sec

vertical acceleration (per ACI 350 para 9.4.3), for $T_V \leq T_S$ then $C_t = S_{DS}$, for $T_V \succ T_S$ then $C_t = \frac{S_{D1}}{T_V}$

therefore, vertical spectral response acceleration, $S_{av} = C_t$ = 1.0000 *g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

Design vertical acceleration, $\ddot{u} = \frac{S_{av}\ I\ b}{R_i} =$ 1*1*1/1 = 1.0000 g

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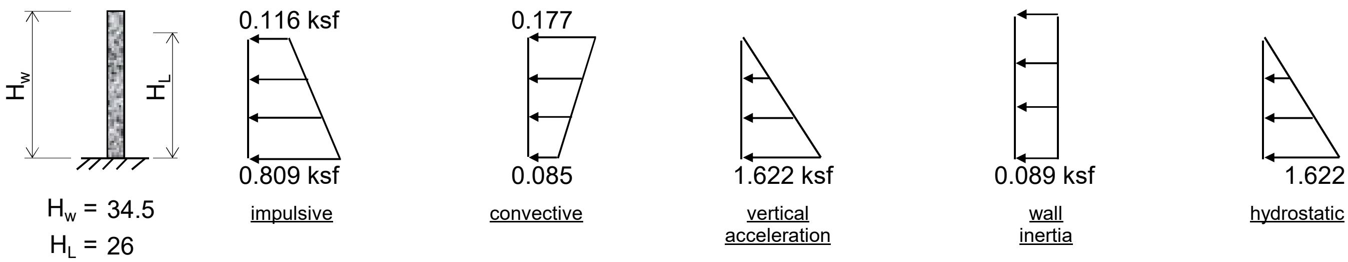
12). vertical pressure distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



impulsive pressure:

$$p_{iy} = \frac{2\left(\frac{P_i}{2}\right)\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{\pi R H_L^2}\cos\theta =$$

use θ = 0°

impulsive force, P_i =	1415.4	kip
h_i =	9.75	ft
at y = H_L, p_{iy} =	0.116	ksf
at base y = 0, p_{iy} =	0.809	ksf

convective pressure:

$$p_{cy} = \frac{16\left(\frac{P_c}{2}\right)\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{9\pi R H_L^2}\cos\theta =$$

use θ = 0°

convective force, P_c =	451.2	kip
h_c =	14.517	ft
at y = H_L, p_{cy} =	0.177	ksf
at base y = 0, p_{cy} =	0.085	ksf

vertical acceleration pressure:

$$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$$

vertical acceleration, ü =	1	g
at y = H_L, p_{vy} =	0	ksf
at base y = 0, p_{vy} =	1.622	ksf

wall inertia pressure:

$$p_{wy} = \frac{S_{ai}\;I\;\varepsilon\,\gamma_c\,(t_w/12)}{R_i} =$$

p_{wy} =	0.2981	* (γ_c * t_w)
at y = H_w, p_{wy} =	0.089	ksf
at base y = 0, p_{wy} =	0.089	ksf

hydrostatic pressure:

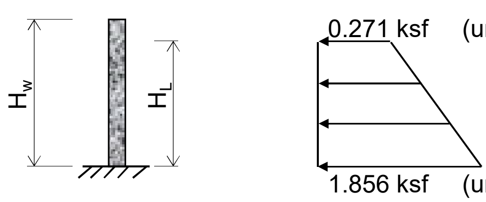
$$q_{hy} = \gamma_L\,(H_L - y) =$$

at y = H_L, q_{hy} =	0	ksf
at base y = 0, q_{hy} =	1.622	ksf

combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$$

at y = H_w, p_y =	0.271	ksf
at base y = 0, p_y =	1.856	ksf



(unfactored load = 0.271 / 1.4 = 0.193 ksf)

(unfactored load = 1.856 / 1.4 = 1.326 ksf)

resultant dynamic pressures

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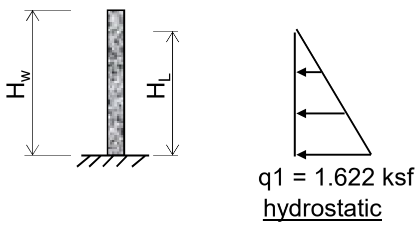
13). load cases:

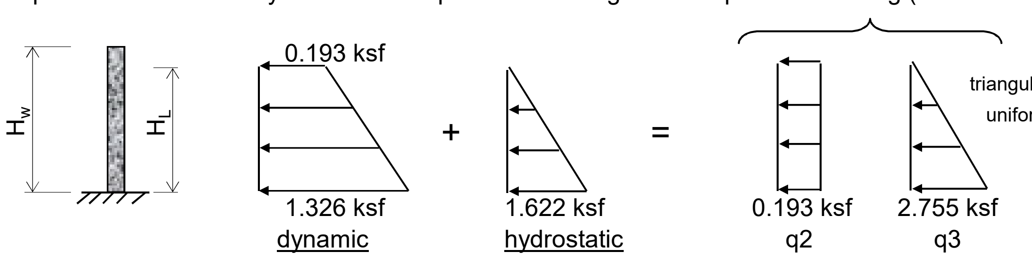
a). hydrostatic water load case:



triangular pressure = 1.622 ksf

b). seismic load case:

equivalent unfactored dynamic + static pressure loadings… equivalent loading (unfactored)



triangular pressure = 2.755 ksf

uniform pressure = 0.193 ksf

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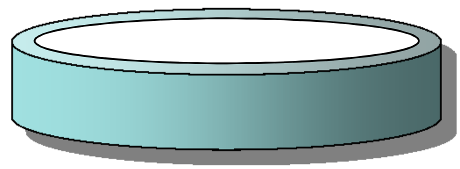
DESIGN TASK:					22ft Liquid; Wall Thick 24"; I=1.0		

Hydrostatic and Hydrodynamic Seismic Analysis of a Circular Tank per ASCE 7-10 and the 2012 IBC code:

Does groundwater exist in which to consider buoyancy? **No Groundwater**

tank inside diameter, D =	75	ft	**(Note: Response spectra values shall be strength level.)**		
tank inside radius, R =	**37.5**	ft	tank wall mass, W_w =	2503.7	kip
tank wall thickness, t_w =	**24**	inch	wall c.g. relative to base, h_w =	17.250	ft
tank wall height to underside of roof =	**34.5**	ft			
roof thickness =	**0**	inch	tank roof weight =	0.0	kip
misc roof weights included with seismic =	**0.05**	ksf	total misc roof weight =	245.1	kip
			total roof mass, W_r =	245.1	kip
liquid height, H_L =	**22**	ft	roof c.g. relative to base, h_r =	34.500	ft
liquid specific gravity =	**1**				
liquid density, γ_L = (sp.gr.)*γ_w =	0.0624	k/ft^3	liquid mass, $W_L = \pi R^2 * H_L * \gamma_L$ =	6064.8	kip
acceleration due to gravity, g =	32.17	ft/sec^2			
liquid mass density, $\rho_L = \gamma_L / g$ =	0.00194	$k\text{-}sec^2/ft^4$			



tank inside diameter, D = 75 ft

concrete strength, f'_c =	**4.5**	ksi
concrete density, γ_c =	0.150	k/ft^3
concrete modulus of elasticity, E_c =	3823.7	ksi
concrete mass density, $\rho_c = \gamma_c / g$ =	0.00466	$k\text{-}sec^2/ft^4$
Seismic:		
Structure Risk Category =	**2**	
Importance factor, I =	**1**	
Response modification factor, R_i =	**2**	
Response modification factor, R_c =	**1.5**	

(acceleration values from a maximum considered earthquake)

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **1** *g

Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.6** *g

1). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$C_w = 0.09375 + 0.2039\left(\frac{H_L}{D}\right) - 0.1034\left(\frac{H_L}{D}\right)^2 - 0.1253\left(\frac{H_L}{D}\right)^3 + 0.1267\left(\frac{H_L}{D}\right)^4 - 0.03186\left(\frac{H_L}{D}\right)^5 = 0.14237$$

$C_l = C_w * 10*((t_w/12)/R)^{1/2}$ = 0.1424*10*(24/12/37.5)^½ = 0.3288

$\omega_i = C_l * 12/H_L*(E_c / \rho_c)^{1/2}$ = 0.3288*12 / 22*(3823.7 / 0.00466)^½ = 162.4040 rad/sec

impulsive period of oscillation, $T_i = 2\pi / \omega_i$ = 2π / 162.404 = 0.0387 sec

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 1 g

$$\lambda = \sqrt{3.68\ g\ \tanh\left(3.68\left(\frac{H_L}{D}\right)\right)} =$$ (3.68*32.17*tanh(3.68*(22/75))^½ = 9.6892

convective circular frequency, $\omega_c = \frac{\lambda}{\sqrt{D}}$ = 9.6892 / (75)^½ = 1.1188 rad/sec

convective period of sloshing, $T_c = 2\pi / \omega_c$ = 2π / 1.1188 = 5.6160 sec

Long transition period (from map figure 22-12 ASCE 7), T_L = **8** sec.

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.1603 g

effective mass coeff., $\varepsilon = 0.0151\left(\frac{D}{H_L}\right)^2 - 0.1908\left(\frac{D}{H_L}\right) + 1.021$, but ≤ 1.0 = 0.5460

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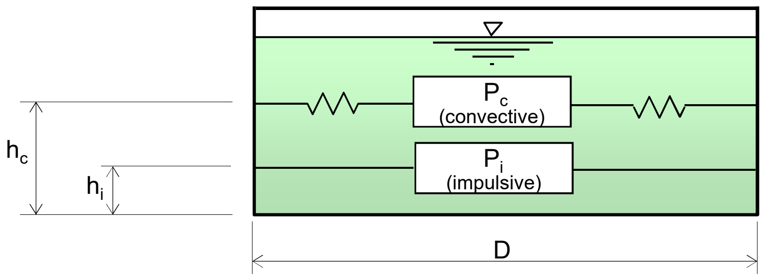

Dynamic Model

$D =$	75	ft
$H_L =$	22	ft
$W_L =$	6064.8	kip
$D / H_L =$	3.40909	
$H_L / D =$	0.29333	

2). lateral fluid impulsive force:

equivalent impulsive mass component, $$W_i = W_L \left(\frac{\tanh\left(0.866 \frac{D}{H_L}\right)}{0.866 \frac{D}{H_L}} \right) =$$ 2043.1 kip

height above base to the impulsive lateral force, hi (EBP) = HL * 0.375 = 8.25 ft

hi (IBP) = HL * {{(0.866*D/HL)/(2*tanh(0.866*D/HL))} -1/8 } = 29.903 ft

impulsive force, $P_i = \left(\frac{S_{ai} \; I}{R_i} \right) W_i =$ (1 * 1 / 2) * 2043.1 = 1021.6 kip

impulsive force moment excluding bottom pressure , $M_{i(EBP)} = P_i * h_{i(EBP)} =$ 1021.6 * 8.25 = 8428.2 ft-k

impulsive force moment including bottom pressure , $M_{i(IBP)} = P_i * h_{i(IBP)} =$ 1021.6 * 29.903 = 30548.9 ft-k

3). lateral fluid convective force:

equivalent convective mass component, $$W_c = W_L \left(0.23 \left(\frac{D}{H_L} \right) \tanh\left(3.68 \left(\frac{H_L}{D} \right) \right) \right) =$$ 3771 kip

height above base to convective lateral force, $$h_{c\ (EBP)} = H_L \left(1 - \frac{\cosh\left(3.68\left(\frac{H_L}{D}\right)\right) - 1}{3.68\left(\frac{H_L}{D}\right) \sinh\left(3.68\left(\frac{H_L}{D}\right)\right)} \right) =$$ 11.957 ft

$$h_{c(IBP)} = H_L \left(1 - \frac{\cosh\left(3.68\left(\frac{H_L}{D}\right)\right) - 2.01}{3.68\left(\frac{H_L}{D}\right) \sinh\left(3.68\left(\frac{H_L}{D}\right)\right)} \right) =$$ 27.771 ft

convective force, $P_c = \left(\frac{S_{ac} \; I}{R_c} \right) W_c =$ (0.1603 * 1 / 1.5) * 3771 = 403.0 kip

convective force moment excluding bottom pressure , $M_{c(EBP)} = P_c * h_{c(EBP)} =$ 403 * 11.957 = 4818.7 ft-k

convective force moment including bottom pressure , $M_{c(IBP)} = P_c * h_{c(IBP)} =$ 403 * 27.771 = 11191.7 ft-k

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4). lateral inertia force of the accelerating wall:

tank wall mass, W_w = 2503.7 kip

wall c.g. relative to base, h_w = 17.250 ft

wall inertia force, $P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_i}\right) W_w =$ (1 * 1 * 0.546 / 2) * 2503.7 = 683.6 kip

wall inertia force moment, $M_w = P_w*h_w$ = 683.6 * 17.25 = 11792.1 ft-k

5). lateral inertia force of the accelerating roof:

total roof mass, W_r = 245.1 kip

roof c.g. relative to base, h_r = 34.5 ft

roof inertia force, $P_r = \left(\frac{S_{ai}\ I}{R_i}\right) W_r =$ (1 * 1 / 2) * 245.1 = 122.6 kip

roof inertia force moment, $M_r = P_r*h_r$ = 122.6 * 34.5 = 4229.7 ft-k

6). total base shear:

$$V = \sqrt{(P_i + P_w + P_r)^2 + P_c^2}$$

V = ((1021.6 + 683.6 + 122.6)² + (403)²)^½ = 1871.7 kip

7). total moment at the base excluding bottom pressure (EBP):

$$M_b = \sqrt{(M_i + M_w + M_r)^2 + M_c^2}$$

Mb = ((8428.2 + 11792.1 + 4229.7)² + (4818.7)²)^½ = 24920.3 ft-k

8). total moment at the base including bottom pressure (IBP):

$$M_o = \sqrt{(M_i + M_w + M_r)^2 + M_c^{\,2}}$$

Mo = ((30548.9 + 11792.1 + 4229.7)² + (11191.7)²)^½ = 47896.6 ft-k

9). maximum wave slosh height displacement: (see ASCE-10, 15.7.6.1 notes c and d)

(Risk Category = 2) I = 1 ,use TL = 4 ,Sd1 = 0.6 ,Tc = 5.616

S_{ac} = 1.5 * Sd1 * TL / Tc² = 0.1141 *g

$d_{(max)} = 0.42\ (\ D\ )(\ S_{ac}\ \ I\ ) =$ 0.42 * (75) * (0.1141 * 1) = 3.59 ft

(minimum freeboard see table 15.7-3 of ASCE 7) , d(min) = No minimum req'd

10). Vertical acceleration:

design horizontal accereration, S_{DS} = 1 *g

period of vibration, $T_v = 2\pi*(\ \gamma_L*D*H_L^{\,2} / (24g*t_w*E_c)\ )^{1/2}$ = 0.0355 sec

Ts = S_{D1} / S_{DS} = 0.6 / 1 = 0.6 sec

vertical acceleration (per ACI 350 para 9.4.3), for $T_V \le T_S$ then $C_t = S_{DS}$, for $T_V \succ T_S$ then $C_t = \frac{S_{D1}}{T_V}$

therefore, vertical spectral response acceleration, $S_{av} = C_t$ = 1.0000 *g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

Design vertical acceleration, $\ddot{u} = \frac{S_{av}\ I\ b}{R_i} =$ 1*1*1/1 = 1.0000 g

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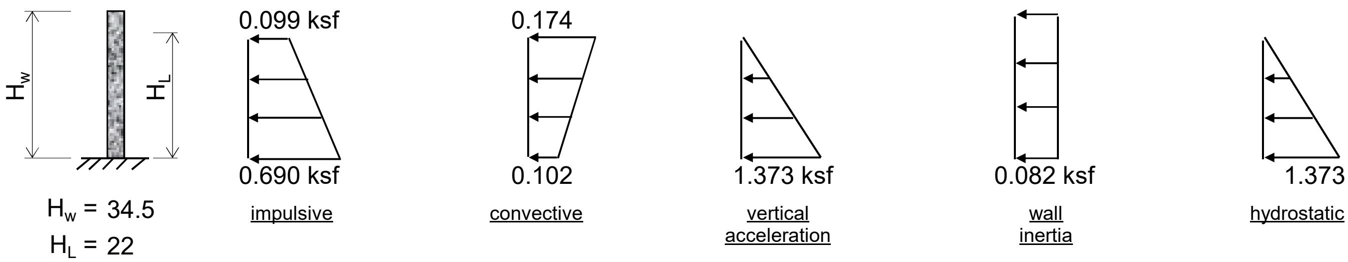
12). vertical pressure distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



H_w = 34.5
H_L = 22

impulsive pressure:

$$p_{iy} = \frac{2\left(\frac{P_i}{2}\right)\left[4H_L - 6h_i - \left(6H_L - 12h_i\right)\left(\frac{y}{H_L}\right)\right]}{\pi R H_L^2}\cos\theta =$$

use θ = 0°

impulsive force, P_i =	1021.6	kip
h_i =	8.25	ft
at y = H_L, p_{iy} =	0.099	ksf
at base y = 0, p_{iy} =	0.690	ksf

convective pressure:

$$p_{cy} = \frac{16\left(\frac{P_c}{2}\right)\left[4H_L - 6h_c - \left(6H_L - 12h_c\right)\left(\frac{y}{H_L}\right)\right]}{9\pi R H_L^2}\cos\theta =$$

use θ = 0°

convective force, P_c =	403.0	kip
h_c =	11.957	ft
at y = H_L, p_{cy} =	0.174	ksf
at base y = 0, p_{cy} =	0.102	ksf

vertical acceleration pressure:

$$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$$

vertical acceleration, ü =	1	g
at y = H_L, p_{vy} =	0	ksf
at base y = 0, p_{vy} =	1.373	ksf

wall inertia pressure:

$$p_{wy} = \frac{S_{ai}\ \ I\ \ \varepsilon\,\gamma_c\ (t_w/12)}{R_i} =$$

p_{wy} =	0.2730	* (γ_c * t_w)
at y = H_w, p_{wy} =	0.082	ksf
at base y = 0, p_{wy} =	0.082	ksf

hydrostatic pressure:

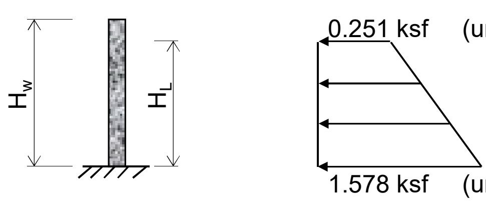
$$q_{hy} = \gamma_L\,(H_L - y) =$$

at y = H_L, q_{hy} =	0	ksf
at base y = 0, q_{hy} =	1.373	ksf

combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{\left(p_{iy} + p_{wy}\right)^2 + p_{cy}^2 + p_{vy}^2} =$$

at y = H_w, p_y =	0.251	ksf
at base y = 0, p_y =	1.578	ksf



(unfactored load = 0.251 / 1.4 = 0.179 ksf)

(unfactored load = 1.578 / 1.4 = 1.127 ksf)

resultant dynamic pressures

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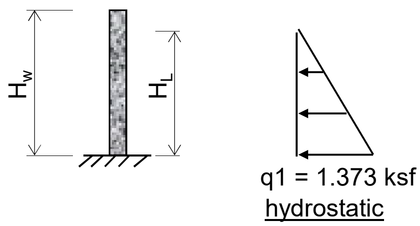
BY:	C. Che	**DATE:**	Dec-18	**CLIENT:**	Riverside	**SHEET:**	
CHKD:		**DESCRIPTION:**			Digester Evaluation	**JOB NO:**	10495A.00
DESIGN TASK:					22ft Liquid; Wall Thick 24"; I=1.0		

13). <u>load cases:</u>

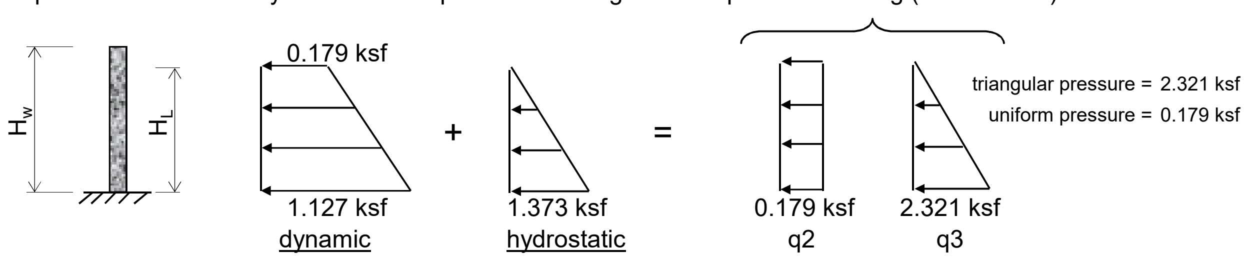
a). hydrostatic water load case:



triangular pressure = 1.373 ksf

b). seismic load case:

equivalent unfactored dynamic + static pressure loadings… equivalent loading (unfactored)



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BY:	C. Che	**DATE:**	Dec-18	**CLIENT:**	Riverside	**SHEET:**	
CHKD:		**DESCRIPTION:**			Digester Evaluation	**JOB NO:**	10495A.00
DESIGN TASK:					16.5ft Liquid; Wall Thick 24"; I=1.0		

Hydrostatic and Hydrodynamic Seismic Analysis of a Circular Tank per ASCE 7-10 and the 2012 IBC code:

Does groundwater exist in which to consider buoyancy? **No Groundwater**

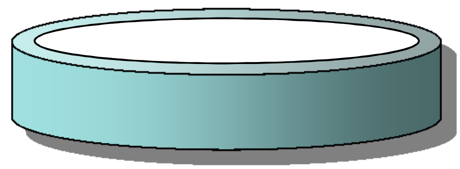
(Note: Response spectra values shall be strength level.)

tank inside diameter, D = 75 ft
tank inside radius, R = **37.5** ft
tank wall thickness, t_w = **24** inch
tank wall height to underside of roof = **34.5** ft
roof thickness = **0** inch
misc roof weights included with seismic = **0.05** ksf

liquid height, H_L = **16.5** ft
liquid specific gravity = **1**
liquid density, $\gamma_L = (\text{sp.gr.})^*\gamma_w$ = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 k-sec^2/ft^4

concrete strength, f'_c = **4.5** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3823.7 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.00466 k-sec^2/ft^4

tank wall mass, W_w = 2503.7 kip
wall c.g. relative to base, h_w = 17.250 ft
tank roof weight = 0.0 kip
total misc roof weight = 245.1 kip
total roof mass, W_r = 245.1 kip
roof c.g. relative to base, h_r = 34.500 ft
liquid mass, $W_L = \pi R^2 * H_L * \gamma_L$ = 4548.6 kip



tank inside diameter, D = 75 ft

Seismic:
Structure Risk Category = **2**
Importance factor, I = **1**
Response modification factor, R_i = **2**
Response modification factor, R_c = **1.5**

(acceleration values from a maximum considered earthquake)

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **1** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.6** *g

1). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$C_w = 0.09375 + 0.2039\left(\frac{H_L}{D}\right) - 0.1034\left(\frac{H_L}{D}\right)^2 - 0.1253\left(\frac{H_L}{D}\right)^3 + 0.1267\left(\frac{H_L}{D}\right)^4 - 0.03186\left(\frac{H_L}{D}\right)^5 = 0.13255$$

$C_l = C_w * 10^*((t_w/12)/R)^{1/2}$ = 0.1325*10*(24/12/37.5)^½ = 0.3061

$\omega_i = C_l * 12/H_L^*(E_c / \rho_c)^{1/2}$ = 0.3061*12 / 16.5*(3823.7 / 0.00466)^½ = 201.6024 rad/sec

impulsive period of oscillation, $T_i = 2\pi / \omega_i$ = 2π / 201.6024 = 0.0312 sec

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 1 g

$$\lambda = \sqrt{3.68\ g\ \tanh\left(3.68\left(\frac{H_L}{D}\right)\right)} =$$ (3.68*32.17*tanh(3.68*(16.5/75)))^½ = 8.9019

convective circular frequency, $\omega_c = \frac{\lambda}{\sqrt{D}}$ = 8.9019 / (75)^½ = 1.0279 rad/sec

convective period of sloshing, $T_c = 2\pi / \omega_c$ = 2π / 1.0279 = 6.1126 sec

Long transition period (from map figure 22-12 ASCE 7), T_L = **8** sec.

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.1472 g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{D}{H_L}\right)^2 - 0.1908\left(\frac{D}{H_L}\right) + 1.021\ , \text{ but } \le 1.0 = 0.4657$$

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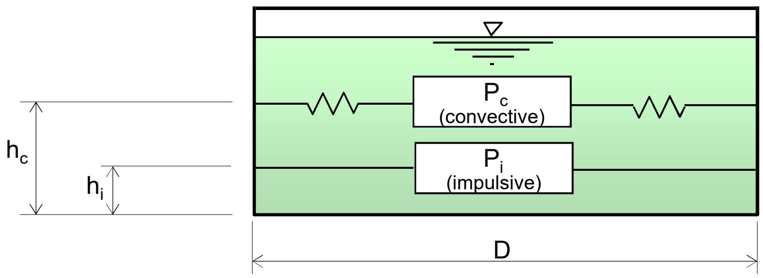
BY:	C. Che	**DATE:**	Dec-18	**CLIENT:**	Riverside	**SHEET:**
CHKD:		**DESCRIPTION:**		Digester Evaluation		**JOB NO:** 10495A.00
DESIGN TASK:		16.5ft Liquid; Wall Thick 24"; I=1.0				



Dynamic Model

$D =$ 75 ft
$H_L =$ 16.5 ft
$W_L =$ 4548.6 kip

$D / H_L =$ 4.54545
$H_L / D =$ 0.22000

2). lateral fluid impulsive force:

equivalent impulsive mass component, $W_i = W_L \left(\frac{\tanh\left(0.866 \frac{D}{H_L}\right)}{0.866 \frac{D}{H_L}} \right) =$ 1154.7 kip

height above base to the impulsive lateral force, hi (EBP) = HL * 0.375 = 6.188 ft

hi (IBP) = HL * {{(0.866*D/HL)/(2*tanh(0.866*D/HL))} -1/8 } = 30.437 ft

impulsive force, $P_i = \left(\frac{S_{ai} \; I}{R_i} \right) W_i =$ (1 * 1 / 2) * 1154.7 = 577.4 kip

impulsive force moment excluding bottom pressure , $M_{i(EBP)} = P_i * h_{i(EBP)} =$ 577.4 * 6.188 = 3573.0 ft-k

impulsive force moment including bottom pressure , $M_{i(IBP)} = P_i * h_{i(IBP)} =$ 577.4 * 30.437 = 17574.3 ft-k

3). lateral fluid convective force:

equivalent convective mass component, $W_c = W_L \left(0.23 \left(\frac{D}{H_L} \right) \tanh\left(3.68 \left(\frac{H_L}{D} \right) \right) \right) =$ 3183.1 kip

height above base to convective lateral force, $h_{c\,(EBP)} = H_L \left(1 - \frac{\cosh\left(3.68\left(\frac{H_L}{D}\right)\right) - 1}{3.68\left(\frac{H_L}{D}\right) \sinh\left(3.68\left(\frac{H_L}{D}\right)\right)} \right) =$ 8.673 ft

$h_{c(IBP)} = H_L \left(1 - \frac{\cosh\left(3.68\left(\frac{H_L}{D}\right)\right) - 2.01}{3.68\left(\frac{H_L}{D}\right) \sinh\left(3.68\left(\frac{H_L}{D}\right)\right)} \right) =$ 31.519 ft

convective force, $P_c = \left(\frac{S_{ac} \; I}{R_c} \right) W_c =$ (0.1472 * 1 / 1.5) * 3183.1 = 312.4 kip

convective force moment excluding bottom pressure , $M_{c(EBP)} = P_c * h_{c(EBP)} =$ 312.4 * 8.673 = 2709.4 ft-k

convective force moment including bottom pressure , $M_{c(IBP)} = P_c * h_{c(IBP)} =$ 312.4 * 31.519 = 9846.5 ft-k

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BY:	C. Che	**DATE:**	Dec-18	**CLIENT:**	Riverside	**SHEET:**	
CHKD:		**DESCRIPTION:**			Digester Evaluation	**JOB NO:**	10495A.00
DESIGN TASK:					16.5ft Liquid; Wall Thick 24"; I=1.0		

4). lateral inertia force of the accelerating wall:

tank wall mass, W_w = 2503.7 kip

wall c.g. relative to base, h_w = 17.250 ft

wall inertia force, $P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_i}\right) W_w =$ (1 * 1 * 0.4657 / 2) * 2503.7 = 583.0 kip

wall inertia force moment, $M_w = P_w{*}h_w$ = 583 * 17.25 = 10056.8 ft-k

5). lateral inertia force of the accelerating roof:

total roof mass, W_r = 245.1 kip

roof c.g. relative to base, h_r = 34.5 ft

roof inertia force, $P_r = \left(\frac{S_{ai}\ I}{R_i}\right) W_r =$ (1 * 1 / 2) * 245.1 = 122.6 kip

roof inertia force moment, $M_r = P_r{*}h_r$ = 122.6 * 34.5 = 4229.7 ft-k

6). total base shear:

$$V = \sqrt{(P_i + P_w + P_r)^2 + P_c^2}$$

V = ((577.4 + 583 + 122.6)² + (312.4)²)^½ = 1320.5 kip

7). total moment at the base excluding bottom pressure (EBP):

$$M_b = \sqrt{(M_i + M_w + M_r)^2 + M_c^2}$$

Mb = ((3573 + 10056.8 + 4229.7)² + (2709.4)²)^½ = 18063.8 ft-k

8). total moment at the base including bottom pressure (IBP):

$$M_o = \sqrt{(M_i + M_w + M_r)^2 + M_c{}^2}$$

Mo = ((17574.3 + 10056.8 + 4229.7)² + (9846.5)²)^½ = 33347.6 ft-k

9). maximum wave slosh height displacement: (see ASCE-10, 15.7.6.1 notes c and d)

(Risk Category = 2) I = 1 ,use TL = 4 ,Sd1 = 0.6 ,Tc = 6.1126

S_{ac} = 1.5 * Sd1 * TL / Tc² = 0.0963 *g

$d_{(max)} = 0.42\ (\ D\ )(\ S_{ac}\ \ I\ ) =$ 0.42 * (75) * (0.0963 * 1) = 3.03 ft

(minimum freeboard see table 15.7-3 of ASCE 7) , d(min) = No minimum req'd

10). Vertical acceleration:

design horizontal accereration, S_{DS} = 1 *g

period of vibration, $T_v = 2\pi{*}(\ \gamma_L{*}D{*}H_L{}^2 / (24g{*}t_w{*}E_c)\ )^{1/2}$ = 0.0266 sec

Ts = S_{D1} / S_{DS} = 0.6 / 1 = 0.6 sec

vertical acceleration (per ACI 350 para 9.4.3), for $T_V \le T_S$ then $C_t = S_{DS}$, for $T_V \succ T_S$ then $C_t = \frac{S_{D1}}{T_V}$

therefore, vertical spectral response acceleration, $S_{av} = C_t$ = 1.0000 *g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

Design vertical acceleration, $\ddot{u} = \frac{S_{av}\ I\ b}{R_i} =$ 1*1*1/1 = 1.0000 g

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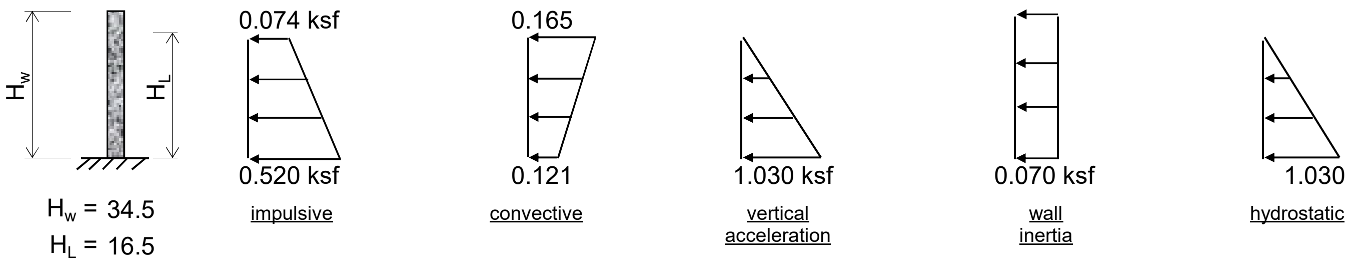
BY:	C. Che	**DATE:**	Dec-18	**CLIENT:**	Riverside	**SHEET:**	
CHKD:		**DESCRIPTION:**			Digester Evaluation	**JOB NO:**	10495A.00
DESIGN TASK:					16.5ft Liquid; Wall Thick 24"; I=1.0		

12). vertical pressure distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



impulsive pressure:

$$p_{iy} = \frac{2\left(\frac{P_i}{2}\right)\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{\pi R H_L^2}\cos\theta =$$

use θ = 0°

impulsive force, P_i =	577.4	kip
h_i =	6.188	ft
at y = H_L, p_{iy} =	0.074	ksf
at base y = 0, p_{iy} =	0.520	ksf

convective pressure:

$$p_{cy} = \frac{16\left(\frac{P_c}{2}\right)\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{9\pi R H_L^2}\cos\theta =$$

use θ = 0°

convective force, P_c =	312.4	kip
h_c =	8.673	ft
at y = H_L, p_{cy} =	0.165	ksf
at base y = 0, p_{cy} =	0.121	ksf

vertical acceleration pressure:

$$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$$

vertical acceleration, ü =	1	g
at y = H_L, p_{vy} =	0	ksf
at base y = 0, p_{vy} =	1.030	ksf

wall inertia pressure:

$$p_{wy} = \frac{S_{ai}\ \ I\ \ \varepsilon\,\gamma_c\ (t_w/12)}{R_i} =$$

p_{wy} =	0.2329	* (γ_c * t_w)
at y = H_w, p_{wy} =	0.070	ksf
at base y = 0, p_{wy} =	0.070	ksf

hydrostatic pressure:

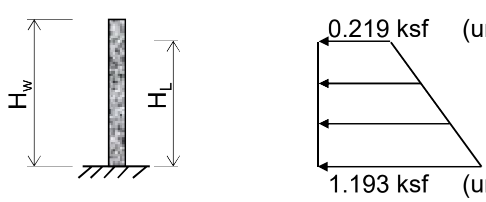
$$q_{hy} = \gamma_L\,(H_L - y) =$$

at y = H_L, q_{hy} =	0	ksf
at base y = 0, q_{hy} =	1.030	ksf

combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$$

at y = H_w, p_y =	0.219	ksf
at base y = 0, p_y =	1.193	ksf



(unfactored load = 0.219 / 1.4 = 0.156 ksf)

(unfactored load = 1.193 / 1.4 = 0.852 ksf)

resultant dynamic pressures

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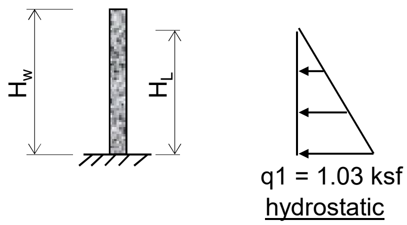
BY:	C. Che	**DATE:**	Dec-18	**CLIENT:**	Riverside	**SHEET:**	
CHKD:		**DESCRIPTION:**			Digester Evaluation	**JOB NO:**	10495A.00
DESIGN TASK:			16.5ft Liquid; Wall Thick 24"; I=1.0				

13). <u>load cases:</u>

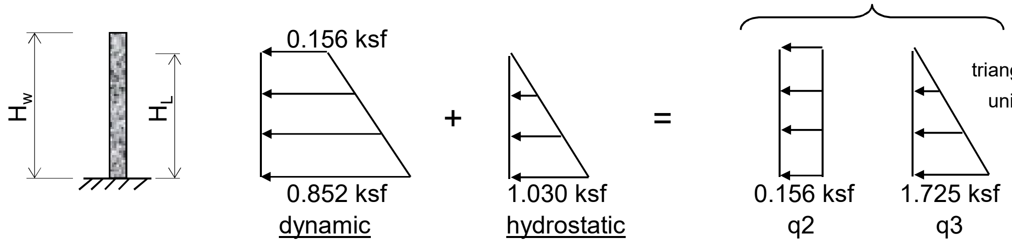
a). hydrostatic water load case:



triangular pressure = 1.030 ksf

b). seismic load case:

equivalent unfactored dynamic + static pressure loadings… equivalent loading (unfactored)



triangular pressure = 1.725 ksf
uniform pressure = 0.156 ksf

Attachment C

DETAILED COST ESTIMATES

Engineers...Working Wonders With Water®

PROJECT SUMMARY

Project:	**Food Waste Evaluation - Digester #5**	**Estimate Class:**	
		PIC:	**GJG**
Client:	**City of Riverside**	**PM:**	**CT**
Location:	**Riverside**	**Date:**	**May 13, 2019**
Zip Code:	**92507**	**By:**	**MAE**
Carollo Job #	**10495A.00**	**Reviewed:**	**CT**

NO.	DESCRIPTION		TOTAL
01	Recoating of digester walls		$199,862
02	Structural retrofit of foundations and digester walls per Figure 1		$254,609
03	Instrumentation and Valves		$50,000
04	Uninstalled stand-by mixing pump		$95,000
	Installation Mechanical, pipe, supports, etc.		$100,000
	Installation Electrical		$85,000
	TOTAL DIRECT COST		**$784,471**
	Contingency	30.0%	$235,341
	Subtotal		**$1,019,812**
	General Conditions and Contractor Overhead, Profit & Risk	25.0%	$254,953
	Subtotal		**$1,274,765**
	Escalation to Mid-Point	10.5%	$133,850
	Subtotal		**$1,408,616**
	Sales Tax	8.8%	$123,254
	Subtotal		**$1,531,870**
	Bid Market Allowance	0.0%	$0
	TOTAL ESTIMATED CONSTRUCTION COST		**$1,531,870**
	Engineering, Legal & Administration Fees	30.0%	$459,561
	TOTAL ESTIMATED PROJECT COST		**$1,991,430**

The cost estimate herein is based on our perception of current conditions at the project location. This estimate reflects our professional opinion

The cost estimate herein is based on our perception of current conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo Engineers have no control over variances in the cost of labor, materials, equipment; nor services provided by others, contractor's means and methods of executing the work or of determining prices, competitive bidding or market conditions, practices or bidding strategies. Carollo Engineers cannot and does not warrant or guarantee that proposals, bids or actual construction costs will not vary from the costs presented as shown.

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Project: Food Waste Evaluation - Digester #5 | **May 13, 2019**
Client: City of Riverside
Location: Riverside | **Estimate Class:**
Carollo Job # 10495A.00

SPEC. DIVISION/ ELEMENT DESCRIPTION	DIV. 00 PROC CTRC	DIV. 01 GEN REQTS	DIV. 02 EXIST COND	DIV. 03 CONC	DIV. 21 FIRE SUPP	DIV. 22 PLUMB	ELEMENT TOTALS	ELEMENT % of Total	TOTAL ESTIMATED CONST COSTS
01 Figure digester retrofits				$213,170			$213,170	**100.00%**	$213,170
Total Direct Cost	**$0**	**$0**	**$0**	**$213,170**	**$0**	**$0**	**$213,170**		**$213,170**
Percent of Total	**0.00%**	**0.00%**	**0.00%**	**100.00%**	**0.00%**	**0.00%**	**100.00%**		

COMMENTS / NOTES

1. Note that the above Divisional costs DO NOT include all of the applicable mark-ups for the total construction or project cost. The far right-hand columns provide the
for each Element and the Total Estimated Construction Costs. However, any other Program Indirect Costs are not included. Refer to the PROJECT SUMMARY for

UNIT COST DEVELOPMENT (UCD)

35

LOCATION FACTOR: 1.065

Date : May 13, 2019

By : MAE

Reviewd: CT

Project: Riverside Digester #5
Client: City of Riverside
Location: Riverside
Carollo Job # 10495A.00

ITEM NO. (Carollo Code)	SPEC. NO.	DESCRIPTION	UNIT	MATERIAL UNIT COST	LABOR UNIT COST	CONST EQUIP UNIT COST	SUB UNIT COST	OTHER UNIT COST	TOTAL DIRECT UNIT COST	RESOURCE/COMMENTS
0330040000	**03_30_00 / 03300**	**CONCRETE WALLS**								
0330040030	03_30_00 / 03300	12" CURVED WALL, 31'-50' DIA, >8' HIGH	CY	$322.94	$694.95	$28.52	$157.00	$0.00	$1,281.63	
0330020000	**03_30_00 / 03300**	**CONCRETE SLABS ON GRADE**								
0330020019	03_30_00 / 03300	12" SLOPED SLAB ON GRADE (TO 30%)	CY	$292.06	$5.88	$26.86	$0.86	$0.00	$346.83	
030000XX000	**03_00_00**	**Non-Inventory Item - Spec 030000**								
030000XX001	03_00_00	Epoxy Bonded Dowel	EA	$55.00					$58.58	Non-Inventory Item - Based on 12" embed with #6 dowel. Per RSMeans
030000XX002	03_00_00	Concrete Surface Prep	SF	$0.25	$14.00	$7.00			$22.63	Non-Inventory Item - assume 2 man team can prep 150 sq.ft. per hour, at $65 per man per hour. Assumes crane and operator required for 2 days to remove any material from roughening process. Assume necessary equipment includes air compressor, spray gun, replacement heads, etc. - this is probably conservative

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QUANTITY TAKEOFF WORKSHEET

Project: Food Waste Evaluation - Digester #5
Client: City of Riverside
Location: Riverside
Zip Code: 92507
Element

Date: May 13, 2019
By : MAE
Reviewed: CT
Format: MASTER FORMAT 50

MF50 / SPEC NO.	DRAWING # / DESCRIPTION	# of PLACES	Resulting UNIT	LENGTH in Feet	WIDTH, HEIGHT or DEPTH	THICKNESS in Feet	DIAMETER in Feet	LBS per LF	TOTAL QTY		NOTES	Item No. (Carollo Code)
	(Leave this row blank)											
03_30_00 / 03300	12" Curved Wall, 31'-50' Dia, >8' High	1	CY	236	14	1			122.37	CY		0330040030
03_30_00 / 03300	12" Sloped Slab On Grade (To 30%)	1	CY			1	46.3		62.36	CY	This is not slab on grade but	0330020019
03_00_00	Epoxy Bonded Dowel	1300	EA						1300	EA	Non-Inventory Item	030000XX001
03_00_00	Concrete Surface Prep	1	SF	235.5	37.5				8831.25	SF	Non-Inventory Item	030000XX002

DETAILED COST ESTIMATE

For Allowances, make sure "Spec No." is entered as TEXT.

Project:	**Food Waste Evaluation - Digester #5**	**Format:**	**MASTER FORMAT 50**
Client:	**City of Riverside**	**Date :**	**May 13, 2019**
Location:	**Riverside**	**By :**	**MAE**
Element:	**Digester repairs**	**Reviewed:**	**CT**

SPEC. NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL	TOTAL	COMMENTS	ITEM NO (Carollo Code)
03_30_00 / 03300	12" Curved Wall, 31'-50' Dia, >8' High	122.37	CY	$1,281.63	$156,833			0330040030
03_30_00 / 03300	12" Sloped Slab On Grade (To 30%)	62.36	CY	$346.83	$21,628			0330020019
03_00_00	Epoxy Bonded Dowel	1300	EA	$58.58	$76,148		Non-Inventory Item	030000XX001
03_00_00	Concrete Surface Prep	8831.25	SF	$22.63	$199,862		Non-Inventory Item	030000XX002

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PROJECT SUMMARY

Project:	**Food Waste Evaluation - Digester #5**	**Estimate Class:**	
		PIC:	**GJG**
Client:	**City of Riverside**	**PM:**	**CT**
Location:	**Riverside**	**Date:**	**January 16, 2019**
Zip Code:	**92507**	**By:**	**MAE**
Carollo Job #	**10495A.00**	**Reviewed:**	**CT**

NO.	DESCRIPTION		TOTAL
1	Food Waste Receiving Station - Equipment		$521,800
1.1	Electrical Installation		$156,540
1.2	Mechanical Installation		$313,080
	TOTAL DIRECT COST		**$521,800**
	Contingency	30.0%	$156,540
	Subtotal		**$678,340**
	General Conditions and Contractor Overhead, Profit & Risk	25.0%	$169,585
	Subtotal		**$847,925**
	Escalation to Mid-Point	10.5%	$89,032
	Subtotal		**$936,957**
	Sales Tax	8.8%	$81,984
	Subtotal		**$1,018,941**
	Bid Market Allowance	0.0%	$0
	TOTAL ESTIMATED CONSTRUCTION COST		**$1,018,941**
	Engineering, Legal & Administration Fees	30.0%	$305,682
	TOTAL ESTIMATED PROJECT COST		**$1,324,623**

The cost estimate herein is based on our perception of current conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo Engineers have no control over variances in the cost of labor, materials, equipment; nor services provided by others, contractor's means and methods of executing the work or of determining prices, competitive bidding or market conditions, practices or bidding strategies. Carollo Engineers cannot and does not warrant or guarantee that proposals, bids or actual construction costs will not vary from the costs presented as shown.

City of Riverside
Food Waste Receiving Facility Equipment List

EQUIPMENT NAME	Recommended Manufacturers	Model Number	Quantity	Size	HP	Unit costs	Costs
Slurry Receiving Facility							
Equalization/Storage Tank	Xerxes	FRP	4	30,000 gal		$ 40,000	$ 160,000
Tank Mixing/Chopper Pump	GasMix		4	200 gpm	45	$ 45,000	
	Landia	Horizontal Chopper Pump		200 gpm	15	$ 20,000	$ 260,000
Food Waste Slurry Metering Pump	Boerger	Rotary Lobe-Blueline AL	4	30 gpm	10	$ 10,000	$ 40,000
Instrumentation: COD analyzer	HACH	UVAS	1			$ 25,000	$ 25,000
Flow meters	various		2			$ 5,000	$ 10,000
Isolation valves	Plug Valve: DeZurik or Milliken	PEF	8	6 in		$ 2,100	$ 16,800
Odor Control	CARBTROL	Carbon canister, 3,000 lbs	1			$ 10,000	$ 10,000
	Calgon Carbon Corp.	Carbon Canister					
Total					73.00		**$ 521,800**