Silicon Valley Clean Water

Headworks Facility
Project Planning Report

Task Order 2016-04

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Table of Contents

List of Figures

List of Tables

Appendices

Executive Summary

ES.1 Document Purpose

This planning report presents the current thinking regarding the Headworks Facility Project (Project), which is one of several projects included in an overall Capital Improvements Program (CIP) being executed by Silicon Valley Clean Water (SVCW). Information provided here is conceptual in nature and is provided for information only mostly as background. SVCW staff and consultants have developed many ideas regarding the CIP projects and these ideas are described in the various planning reports. The intent is to describe the projects developed for and as generally presented in the Environmental Impact Report (EIR). It is not meant to be a preliminary or final design and it is not intended to be prescriptive to a progressive design build entity. A progressive design build entity will review this information as background and then work collaboratively with SVCW to develop additional alternative concepts, preliminary design, a final design, and then construct the Project. Alternative concepts may be developed that vary from the concepts contained in the planning reports. These new concepts will be considered and evaluated as alternatives. If the final project varies significantly from the concepts shown in these planning reports, additional California Environmental Quality Act (CEQA) review may be required. The level and timing of this possible CEQA review will be considered as the concepts are evaluated.

ES.2 Project Background

SVCW is implementing a CIP to improve the reliability of their conveyance system and waste water treatment plant (WWTP). The CIP includes rehabilitation and repurposing of several collection system pump stations and installation of the following new facilities:

- Gravity Pipeline to replace the existing 54-inch force main that conveys wastewater to the treatment plant
- Receiving Lift Station (RLS) located on the treatment plant site at the end of the new Gravity Pipeline
- Headworks Facility to remove screenings and grit from influent wastewater
- Influent Connector Pipes to convey flow from the Headworks Facility to the primary clarifiers
- Odor control facilities to treat foul air venting from the RLS and Headworks Facility, referred to as the Front of Plant (FoP) Odor Control Facilities
- Odor control facilities to treat foul air venting from a Gravity Pipeline drop shaft structure, referred to as the San Carlos Odor Control (SCOC) Facility.
- Flow Diversion Structure (FDS) to be used to equalize flows to the plant during dry weather conditions (This would be a future project if desired).

- Civil Improvements for the FoP area to accommodate the new RLS, Headworks Facility, and FDS
- Nutrient Removal Facilities, including new aeration basins and secondary clarifiers, to remove nitrogen and phosphorus from outgoing wastewater in preparation for new regulations (This would be a future project when required).
- Stormwater Treatment Planters and a Stormwater Pump Station to handle stormwater in the FoP area
- Belmont Force Main Rehabilitation to line the existing force main that conveys wastewater flow from the City of Belmont to the SVCW WWTP
- San Carlos Pump Station (SCPS) Site Improvements
- Redwood City Pump Station Replacement and Menlo Park Pump Station Rehabilitation to improve the existing conveyance system.

ES.3 Project Objectives

The main purpose of the Headworks Facility is to remove large solids, rags, grit, or other debris from the sewage entering the treatment plant. Prior to installation of the existing interim screening facility, there was no mechanism for removing this material and it would accumulate in various treatment processes throughout the plant. Operation and Maintenance (O&M) staff had to remove this material manually. The manual removal was both time consuming, expensive, and places plant personnel in confined spaces and difficult work environments, and requires process interruptions to facilitate tank cleaning and pump access.

The existing screening facility, constructed in 2016, has improved the plant's ability to remove this material and has reduced the O&M associated with removing this material. However, this facility was intended to operate as an interim facility until the new, more robust Headworks Facility could be installed.

The new Headworks Facility will provide a robust and efficient means for removing screenings from the influent sewage. The new Headworks Facility will also include an odor control system (the FoP Odor Control Facility), which is currently not included as part of the existing preliminary treatment system. In addition, the new Headworks Facility will include a grit removal system to replace the existing hydrocyclones, which the WWTP is currently using to remove grit from the primary sludge. The existing hydrocyclones remove some of the grit, but testing has shown that a significant portion of the grit is not removed by the hydrocyclones. Therefore, the new grit removal system included in the new Headworks Facility will replace the hydrocyclones with a more efficient system.

Grit, which consists of sand, gravel, and other heavy solid material is abrasive and contributes to the wear of pumps, piping, and other equipment. Grit can also settle within treatment processes. The settled grit reduces the volumetric capacity of the processes and requires significant labor to remove. Therefore, the addition of grit removal to the preliminary treatment facilities will be a significant benefit.

ES.4 Project Location

The new Headworks and FoP Odor Control Facilities will be constructed in the area currently occupied by a 10-acre ornamental pond, located to the west of the existing WWTP within SVCW's property boundary. A preliminary geotechnical investigation found that the soils underlying the Headworks Facility project area consist of very thick deposits of Young Bay Mud (YBM) underlain by Old Bay Clay (OBC). Based on these observations, the Headworks Facility will need to be constructed on deep piles, like the construction of the existing WWTP.

ES.5 Headworks Facility Description

A conceptual site plan of the Headworks Facility and FoP Odor Control Facility is shown in Figure ES-1. The Gravity Pipeline, RLS, and the ICP are also shown in the figure. After the facilities shown in Figure ES-1 are constructed, raw sewage will be conveyed through the Gravity Pipeline to the RLS, which will pump it up to the new Headworks Facility. The raw sewage will flow by gravity through the Headworks Facility and the ICP to the existing WWTP.

A process flow diagram of the proposed Headworks Facility is shown in Figure ES-2. As shown, the proposed Headworks facility will consist of the following main process areas:

- Influent junction structure, referred to as Distribution Structure 1, which will collect influent flows and any return flows, and convey the flows to the screen channels
- Screens, which will remove screenable material from the influent wastewater
- Screenings conveyance equipment, which will convey screenings captured by the screens to the screenings processing equipment
- Screenings processing equipment, which will dewater and remove organic material from the screenings
- Screenings bins, which will collect the processed screenings and store them until they can be hauled offsite
- Grit separators, which will remove grit from the influent wastewater
- Grit processing equipment, which will dewater and remove organic material from the grit collected by the grit separators
- Grit bins, which will collect processed grit and store it until it can be hauled offsite
- Effluent distribution structure, referred to as Distribution Structure 2, which will receive flow from the grit basins and distribute it to downstream processes
- A possible future Flow Diversion Structure, which would be used to equalize dry weather flows going to the primary clarifiers

Figures ES-3 and ES-4 show a three-dimensional conceptual layout of the proposed Headworks Facility. Design criteria for the facilities shown are presented in Table ES-1.

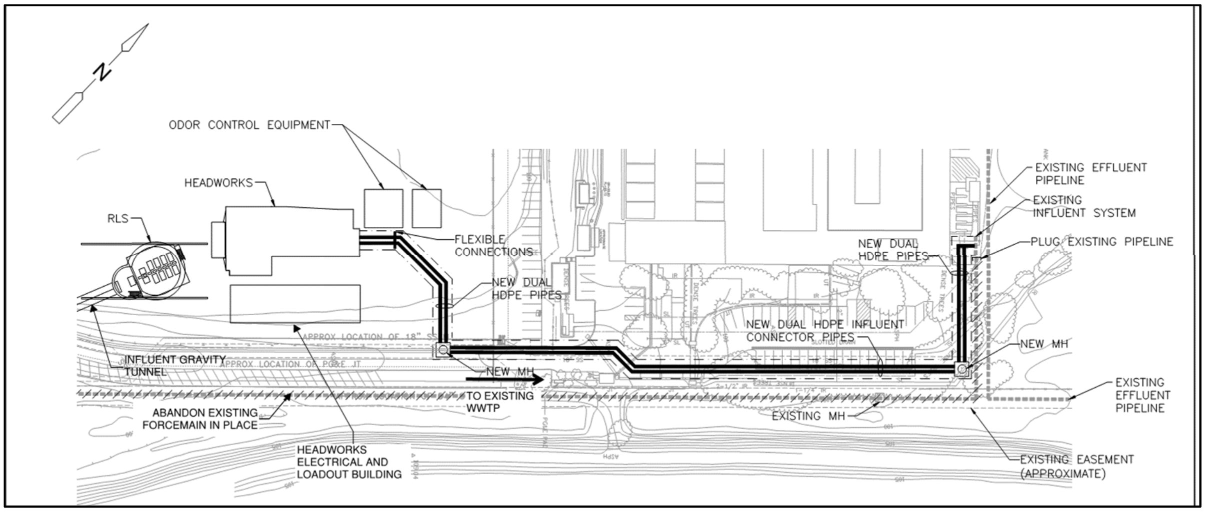

Figure ES-1
SVCW Proposed Conveyance System and Preliminary Treatment Improvements

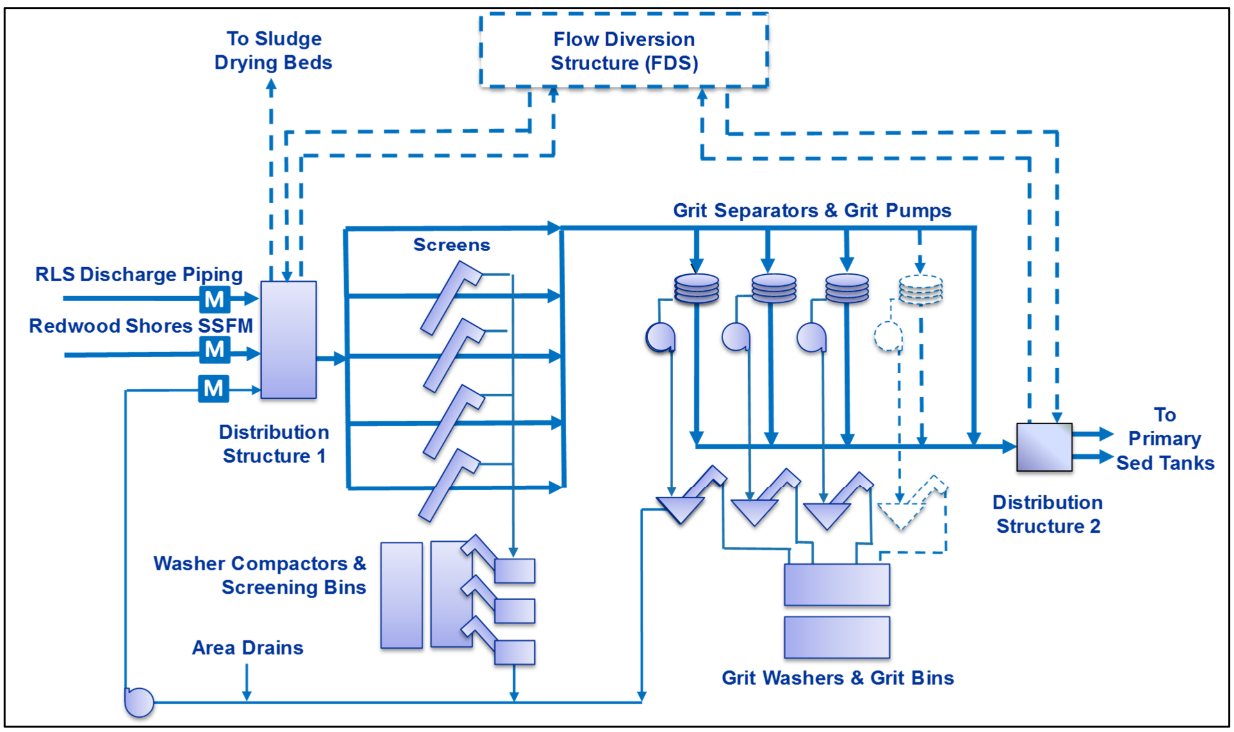

Figure ES-2
Proposed Headworks Facility Process Flow Diagram.

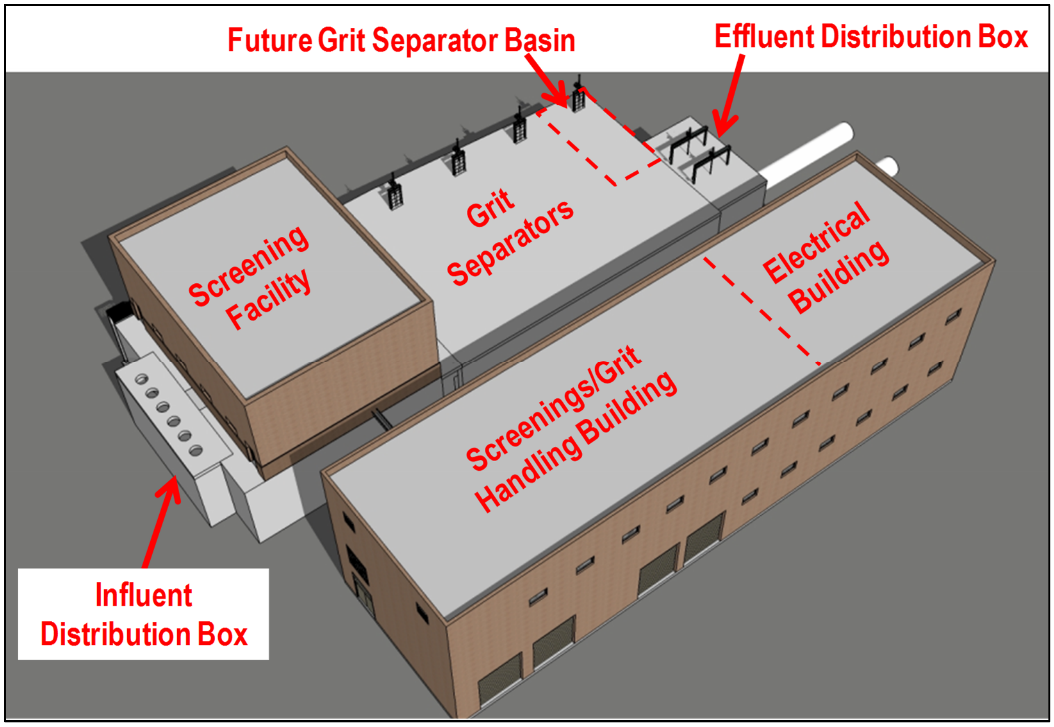

Figure ES-3
Headworks Facility Isometric

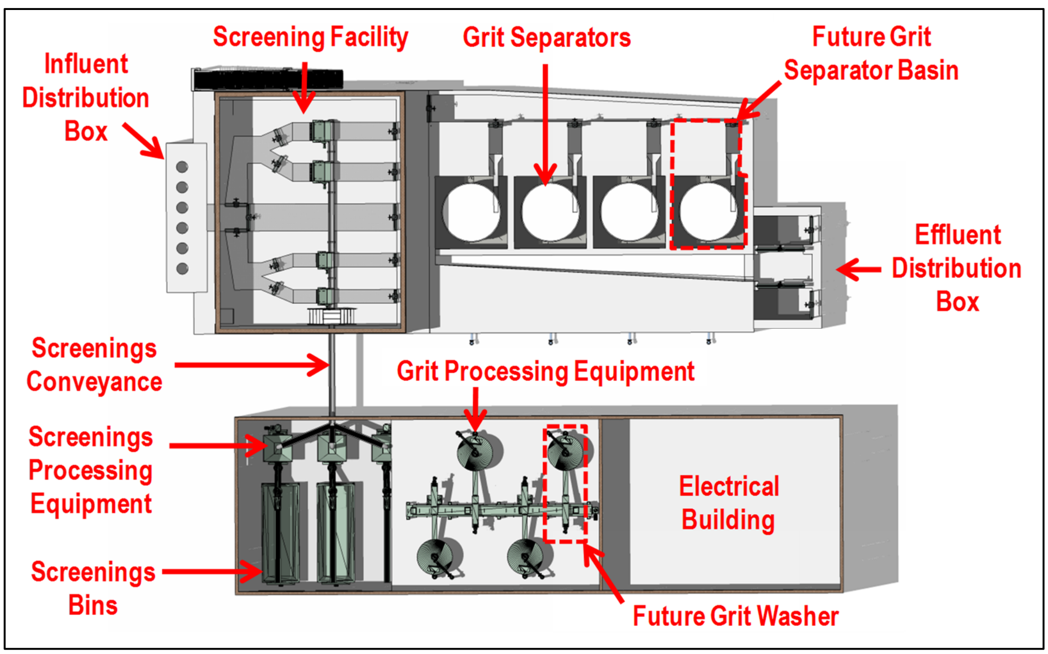

Figure ES-4
Headworks Facility Plan View

Table ES-1 Proposed Headworks Facility Design Criteria

Parameter	Unit	Value
Wet Screen Channels		
Number of Channels	-	2
Dimensions	ft	4 wide x 8 deep
Screen Type	-	3/8-inch Multi-Rake
Channel Velocity	ft/sec	2-4
Dry Weather Screen Channels		
Number of Channels	-	2
Dimensions	ft	3 wide x 6.5 deep
Screen Type	-	3/8-inch Multi-Rake
Channel Velocity	ft/sec	2-4
Screen Bypass Channel		
Number of Channels	-	1
Dimensions	ft	6 wide X 8 deep
Channel Velocity	ft/sec	$\leq$ 5
Wet Screenings Production		
Screenings Capture, avg	ft3/MG	8
Screenings Density	lb/ft3	45
Volumetric Load, average per day	yd^3/day	5
Mass Load, average per day	wet tons/day	3
Screenings Conveyance		
Type	-	Sluice
No. of Units	-	1 duty
Target Solids Concentration	%	1
Sluice Water Feed Rate	gpm	50
Washer Compactor		
Type	-	Batch Mode
Number of Units	-	2 duty, 1 standby
Volume Reduction	%	60
Mass Reduction	%	50
COD Reduction	%	N/A
Processed Screenings		
Volumetric Load, average per day	yd^3/day	2
Mass Load, average per day	ton/day	1.4
Screenings Bin		
Number of Units	-	1 duty, 1 standby
Bin Volume Capacity	yd^3	10
Bin Weight Capacity	tons	8
Volumetric Storage Time	day	5
Mass Storage Time	day	6
Appurtenant Equipment	-	1 Dumpster-conveyor/bin

Table ES-1 Proposed Headworks Facility Design Criteria (continued)

Parameter	Unit	Value
Grit Separators		
Type	-	Headcells
Number of Units[1]	-	3
Tray Diameter	ft	12
Number of Trays	-	12
Target Settling Velocity		
Peak Hour Wet Weather Flow (PHWWF)	ft/min	1.8
Average Day Dry Weather Flow (ADDWF)	ft/min	1.4
SES Cutpoint		
Peak Hour Wet Weather Flow (PHWWF)	µm	110
Average Day Dry Weather Flow (ADDWF)	µm	95
Grit Capture		
Peak Hour Wet Weather Flow (PHWWF)	%	>95
Average Day Dry Weather Flow (ADDWF)	%	55
Grit Pumps		
Type	-	Recessed Impeller/Solids Handling
Number of Units[1]	-	3
Flow	gpm	400
Static Head	ft	27
Grit Loads[1]		
Raw Grit Concentration, Average		
Dry Weather	lb/MG	22
Wet Weather	lb/MG	76
Raw Grit Loads – Entering Gravity Tunnel		
Average Dry Weather Day	ton/d	0.2
Max Wet Weather Day	ton/d	3
Raw Grit Loads – Entering Headworks		
Peak Hour, Dry Weather Draining Event	ton/hr	0.1 – 1.4
Peak Hour, Wet Weather Draining Event	ton/hr	0.1 – 3.0
Grit Washer		
Number of Units[1]		1 Washer per Basin
Flow Capacity per Unit	gpm	400
Grit Load capacity per Unit	lbs/hr	2,500 – 3,000
Effluent Grit Water Content, Max	%	3
Effluent Grit Volatile Solids Content, Max	%	10
Grit Bins		
Number of Units		1 duty, 1 standby
Volume Capacity	yd^3	10
Bin Weight Capacity	tons	8

Table ES-1 Proposed Headworks Facility Design Criteria (continued)

Parameter	Unit	Value
Grit Bins		
Volumetric Loading Rate	yd3/day	2
Mass Loading Rate	tons/day	4
Volumetric Storage Time	day	5
Mass Storage Time	day	2

[1]Grit loads based on results of grit sampling and operation of Gravity Pipeline (see Section 3.6.7).

ES.6 FoP Odor Control Facility Description

The FoP Odor Control Facility will be used to treat odorous air from the following sources:

- Gravity Pipeline
- RLS Wet Well
- Screening Influent Channels
- Screen Channels
- Screening Effluent Channels
- Grit Influent Channels
- Grit Separators
- Grit Effluent Channels
- Screenings and Grit Handling Building

Odorous air will be collected from these sources and routed through ductwork to the FoP Odor Control Facility.

The design criteria for the FoP Odor Control Facility are summarized in Table ES-2. A process flow diagram of the facility is shown in Figure ES-5 and a conceptual layout of the facility is shown in Figure ES-6. As shown, the facility will consist of two multi-stage chemical scrubbers and the required chemical storage and metering equipment. The facility will be located adjacent to the Headworks, as shown in Figure ES-1.

Table ES-2 Proposed FoP Odor Control Facility Conceptual Design Criteria

Item	Value
Scrubber Units	
Number	2
Capacity, ea.[1]	16,200 cfm
Ventilation Fan	
Number	1 per scrubber
Motor Size, ea.	40 hp
Recirculation Pumps	
Number	2 per scrubber
Motor Size, ea.	17.5 hp
Chemical Demand	
25% Sodium Hydroxide (NaOH)	670 gpd
12.5% Sodium Hypochlorite (NaOCl)	130 gpd
Sodium Hydroxide Storage	
Storage Tank Volume	9,000 gal
Days of Storage	13
Sodium Hypochlorite Storage	
Storage Tank Volume	3,000 gal
Days of Storage	23

[1]Scrubber capacity based on maximum possible airflows, which need to be further evaluated during design of the facility

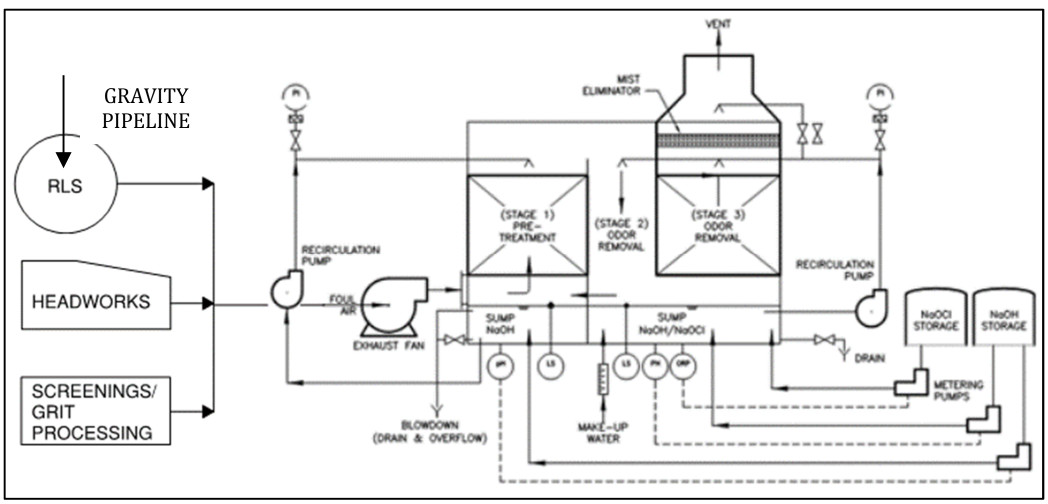

Figure ES-5
FoP Odor Control Facility Process Flow Diagram

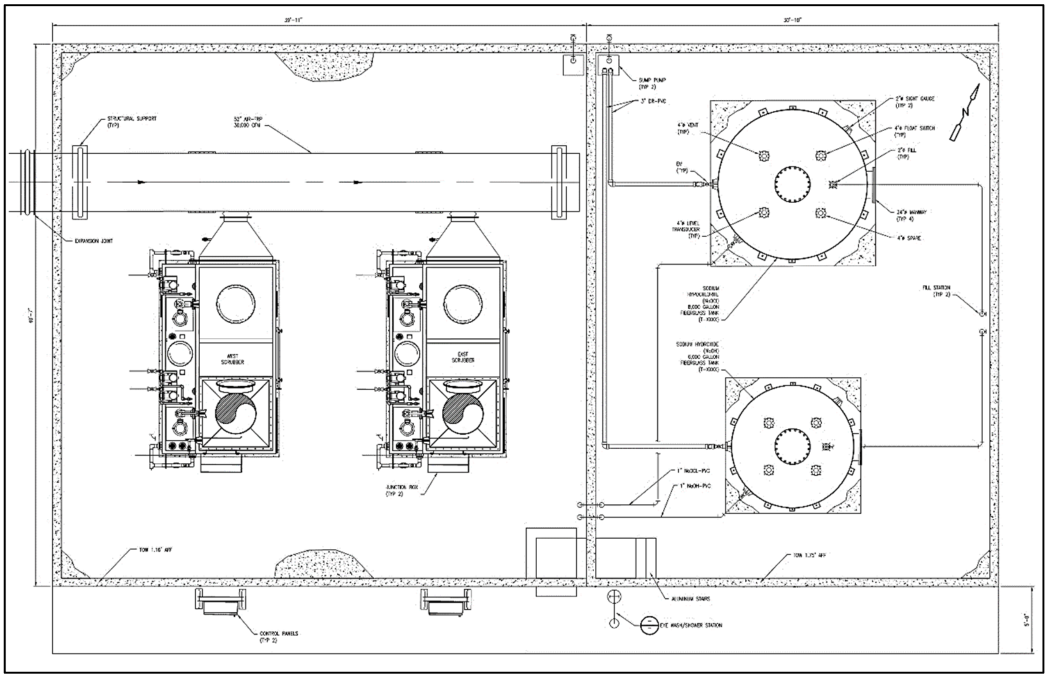

Figure ES-6
FoP Odor Control Facility Conceptual Layout

ES.7 Construction

Construction of the Headworks and FoP Odor Control Facilities could take approximately 27 months. The proposed facilities are located immediately adjacent to and connected to the RLS and ICP. Therefore, the sequencing of construction of these projects will need to be closely coordinated. The final sequencing will be dependent of the project delivery method selected for implementing the CIP projects (design-build or design-bid-build) and the way the projects are grouped together into construction contracts. If the Headworks and FoP Odor Control Facilities are implemented using a design-bid-build approach under a contract that does not include construction of the RLS an ICP, in either procurement process, SVCW may consider constructing and starting up the facilities before the RLS and ICP projects are complete.

ES.8 Life Cycle Cost

A 50-Year Life Cycle Cost (LCC) was calculated for the Headworks and FoP Odor Control Facility. The LCC is for a 50-year period from 2016 to 2066. The LCC for the Headworks and FoP Odor Control Facilities includes the following components:

- Capital Costs
- Annual O&M Costs, including
  - Labor
  - Power

- Chemicals

- Periodic Equipment Rehabilitation and Replacement Costs

The cost for each of the components listed above were developed for each year over a 50-year period between 2016 and 2066. The Net Present Value (NPV) of the cash flow over that 50-year period was then calculated for all the cost components. The LCC is summarized in Table ES-3 below.

Table ES-3 Total Life Cycle Costs

	Cost
Capital Cost (2019 Dollars)[1]	
Base Market Fluctuation	$58 million
Low Market Fluctuation	$59 million
High Market Fluctuation	$65 million
NPV of Annual O&M and Rehabilitation & Replacement Costs (2022 Dollars)	
Labor	$11 million
Power	$14 million
Chemicals	$23 million
Debris Handling	$4 million
Rehabilitation & Replacement	$5 million
50-Year Life Cycle Cost (LCC) (2022 Dollars)	**$115 - $122 million**

[1] Capital Cost reflects the Raw Construction Cost ($31,400,000 in 2016 Dollars) with Project Contingency, Soft Costs, Market Fluctuations, and Escalation applied to the raw cost.

ES.9 Outstanding Issues to Carry into Design

Outstanding issues that need to be considered during detailed design include:

- The way the various elements of the CIP are grouped together into discrete projects needs to be considered in developing an approach for driving the foundation piles around the RLS, Headworks Facility, and FoP Odor Control Facility.

- Additional grit sampling is recommended to better characterize the grit in the plant influent during wet weather events.

- The final determination on whether the Gravity Pipeline will be used for wet weather storage or dry weather diurnal equalization needs to be considered in developing final peak grit load design criteria.

- The way the tunnel will be drained after storage events needs to be considered in developing final peak grit load design criteria.

- The need for a building over the screens should be re-evaluated during detailed design. The building adds significant cost to the project and increases the amount of foul air that needs to be treated by the FoP Odor Control Facility.

- The high-water elevation in the Influent Mix Box should be re-evaluated during detailed design. The high-water elevation assumed in this report is based on peak flows being conveyed over the overflow weir in the existing screening facility when the screens are off-line. There is a possibility that peak flows could be bypassed around the screens using the ILS pumps when the screens are offline. This approach would significantly reduce the high-water elevation in the Influent Mix Box, resulting in a lowering of the Headworks Facility by several feet.

- Design criteria for the FoP Odor Control Facility, including airflows and odor characteristics, should be further evaluated during the design phase of the project. Factors that may impact the design criteria include operation of the Gravity Pipeline, t, characteristics of the sewage entering the Gravity Pipeline, and the potential dosing of chemicals to influent sewage to control odors and corrosion.

Section 1

Introduction and Background

1.1 Introduction

This report presents the status of the Headworks Facility Project (Project), which is one of several projects included in an overall Capital Improvements Program (CIP) being executed by Silicon Valley Clean Water (SVCW). An overview of the existing facilities, the CIP, the Project, and any relevant background information are presented in this section. Further detail regarding existing conditions and the design, construction, operation, maintenance, and environmental impacts of the Headworks Facility are discussed in subsequent sections of this report. Additional background information for the project planning reports being created as part of the CIP may be found in Appendix A appended to the end of this report.

1.2 Overview of Existing Facilities

The SVCW wastewater treatment plant (WWTP) is a regional facility that treats sewage from the West Bay Sanitary District, the City of Redwood, the City of San Carlos, the City of Belmont, and portions of unincorporated San Mateo County. The treatment plant is located at 1400 Radio Road in Redwood City, California. The facility receives sewage via four main pump stations and a network of force main conveyance pipes. A location and vicinity map of the SVCW WWTP and collection system is provided in Figure 1-1. These facilities are described in greater detail in the following sections.

Figure 1-1
Location and Vicinity Map

1.2.1 Existing Collection System

Figure 1-2 below shows a schematic of the collection system that conveys wastewater to the SVCW WWTP. As shown, there is a 54-inch force main which receives flow from the four main collection system pump stations and delivers it to the plant. The Belmont Pump station and the San Carlos Pump Station discharge flow into the 54-inch force main via a 24-inch and 48-inch pipes, respectively. The combined flow from the Redwood City and the Menlo Park Pump Stations are discharged into the 54-inch force main via a 48-inch pipe. The pump stations receive flow from their respective service areas via gravity conveyance piping. The locations of the four main collection system pump stations and the collection system force mains are shown in Figure 1-1.

Not shown in Figures 1-1 and 1-2 is the Redwood Shores Pump Station and its force main. This pump station receives flow from the Redwood Shores community and pumps it to the SVCW WWTP via an 18-inch pipe. The 18-inch pipe connects to the 54-inch force main directly upstream of the existing headworks facility, as described in Section 1.2.2 below.

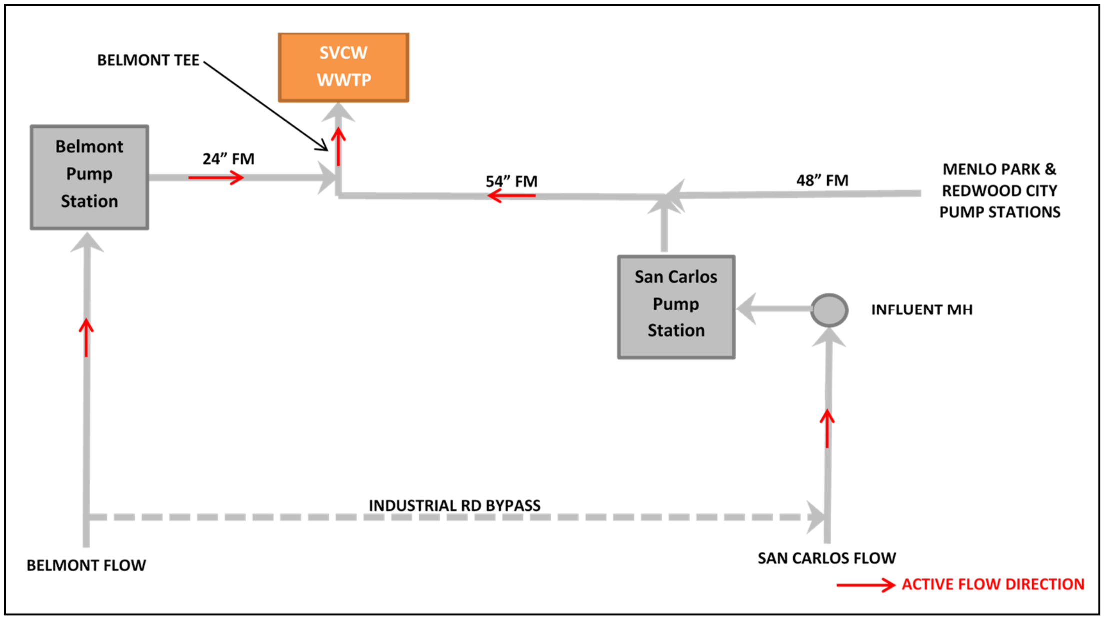

Figure 1-2
Existing Conveyance System and WWTP

1.2.2 Existing Wastewater Treatment Plant

The SVCW WWTP was originally designed in 1977. The existing liquid treatment stream at the treatment plan includes preliminary treatment consisting of a screening facility; primary treatment consisting of primary clarifiers; secondary treatment consisting of fixed film reactors, aeration basins, and secondary clarifiers; and tertiary treatment consisting of dual media filters and disinfection facilities. Solids treatment processes at the SVCW WWTP consist of gravity thickening, gravity belt thickening and anaerobic digestion and sludge dewatering (through either a rotary fan presses, a centrifuge or sludge drying beds). Most of the treated effluent is discharged through a deep-water outfall into the lower San Francisco Bay. A portion of the final effluent is reused by the City of Redwood's recycled water program. Dewatered and/or dried biosolids are disposed of via a contract hauler to varied locations.

A site layout of the existing SVCW WWTP showing the location of the process units described above is provided in Figure 1-3. The preliminary treatment facilities, which are the immediate focus of the CIP, are described in greater detail in Section 1.2.3.

Figure 1-3
Existing Facility Site Plan

1.2.3 Existing Preliminary Treatment Facilities

Figures 1-4 and 1-5 below show the current configuration of the preliminary treatment facilities and related influent conveyance piping at the SVCW WWTP. The facilities include a 54-inch reinforced concrete force main, an Influent Lift Station (ILS), an Influent Mix Box, and a Bar Screen Facility. The 54-inch forcemain enters the WWTP from the west, running along the south side of the site past the primary clarifiers. After passing the primary clarifiers, the forcemain turns north and runs past the ILS pumps, whose suction pipes are connected to the 54-inch forcemain. The forcemain then terminates at the Influent Mix Box. The 18-inch Redwood Shores forcemain connects to the 54-inch forcemain just upstream of the Influent Mix Box

The interim Bar Screen Facility is located downstream of the Influent Mix Box. The bar screen facility consists of two Duperon® multi-rake bar screens with 3/8-inch bar spacing, which discharge screenings to a single washer compactor and dumpster. The facility also has a bypass channel which allows flow from the Influent Mix Box to be routed around the bar screens directly to the primary clarifiers.

Under dry weather conditions, raw sewage is conveyed through the 54-inch force main, past the suction pipes for the ILS pumps, directly to the existing Influent Mix Box. The Influent Mix Box then directs flow to either the Bar Screen Facility or the Primary Settling Tanks. Flow is normally sent to the Bar Screen Facility, but can be diverted to the Primary Settling Tanks when the Bar Screen Facility needs to be shut down for maintenance or other reasons.

Under wet weather conditions, the ILS pumps are used to pump sewage from the 54-inch forcemain directly to the Primary Settling Tanks. The system is operated in this manner to limit the pressure in the existing 54-inch forcemain to 16 psig at the Redwood City Pump Station. Operators aim to keep pressure under 16 psig by managing flows in the forcemain during wet weather events because higher pressures may result in forcemain failure. However, the pressure that will result in forcemain failure is currently unknown and the pressure in the forcemain has increased above 16 psig in the past without resulting in pipe failure.

It should be noted that the bar screen facility was intended to operate as a pilot and interim facility until the new Headworks Facility could be installed. It is anticipated when the new Headworks Facility is brought online, the existing screening facility will be converted to a second stage screening facility by removing the existing screens and replacing them with fine screens. The existing screens will be relocated to the new Headworks Facility and reused, if possible.

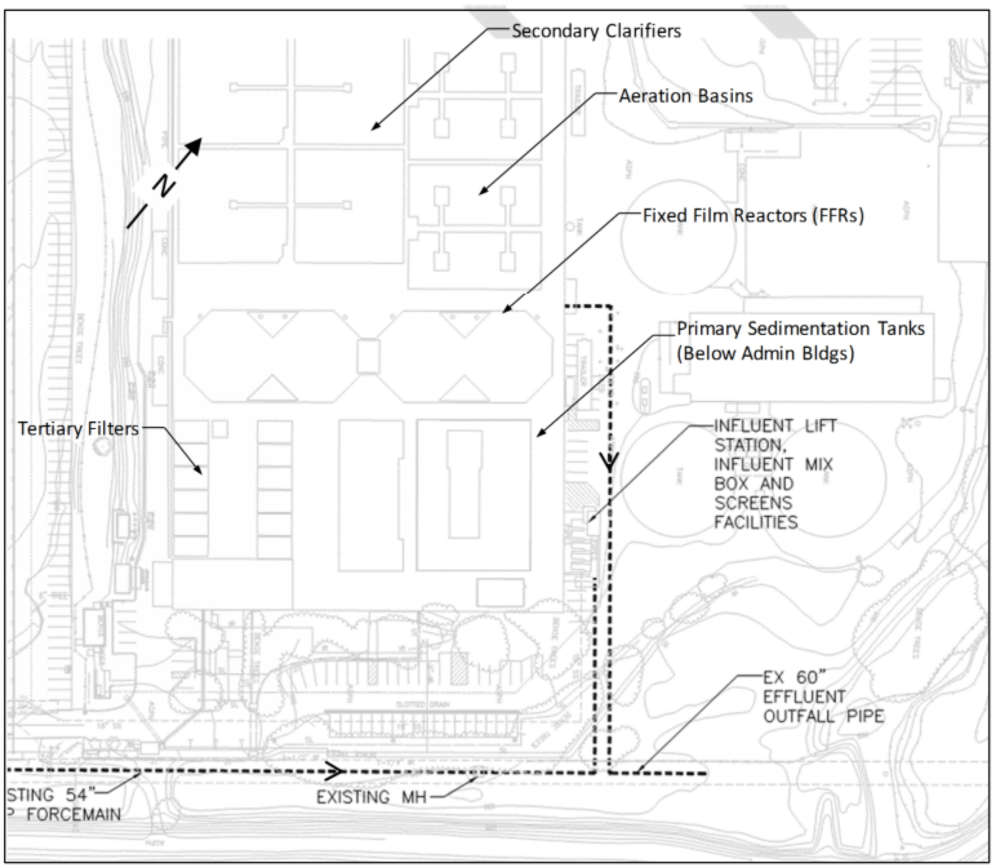

Figure 1-4
Existing Collection System Site Plan

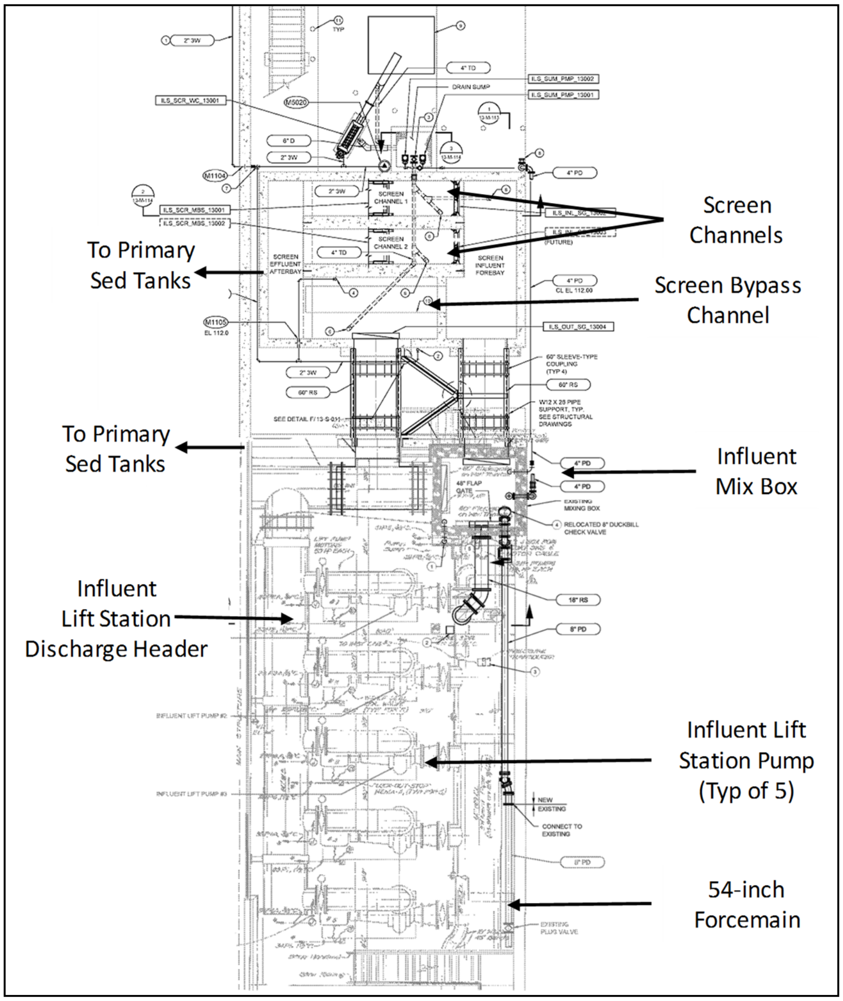

Figure 1-5
Existing Headworks Facility Mechanical Plan

1.3 CIP Overview

1.3.1 Improvements Proposed in the CIP

SVCW is implementing a CIP to improve the reliability of their conveyance system and WWTP. The CIP includes rehabilitation and repurposing of several collection system pump stations and installation of the following new facilities:

- Gravity Pipeline to replace the existing 54-inch force main that conveys wastewater to the treatment plant
- Receiving Lift Station (RLS) located on the treatment plant site at the end of the new Gravity Pipeline
- Headworks Facility to remove screenings and grit from influent wastewater
- Influent Connector Pipes (ICP) to convey flow from the Headworks Facility to the primary clarifiers

- Odor control facilities to treat foul air venting from the RLS and Headworks Facility, referred to as the Front of Plant (FoP) Odor Control Facilities
- Odor control facilities to treat foul air venting from a Gravity Pipeline drop shaft structure, referred to as the San Carlos Odor Control (SCOC) Facility
- Flow Diversion Structure (FDS) to be used to equalize flows to the plant during dry weather conditions (This would be a future project if desired).
- Civil Improvements for the FoP area to accommodate the new RLS, Headworks Facility, and FDS
- Future Nutrient Removal Facilities, including aeration basins and secondary clarifiers, to remove nitrogen and phosphorus from outgoing wastewater in preparation for new regulations (This would be a future project when required)
- Stormwater Treatment Planters and a Stormwater Pump Station to handle stormwater in the FoP area
- Belmont Force Main Rehabilitation to line the existing force main that conveys wastewater flow from the City of Belmont to the SVCW WWTP
- San Carlos Pump Station (SCPS) Site Improvements
- Redwood City Pump Station Replacement and Menlo Park Pump Station Rehabilitation to improve the existing conveyance system

A schematic of the proposed conveyance system modifications is shown in Figure 1-6. A site plan showing the location of the proposed new facilities at the treatment plant site is provided in Figure 1-7.

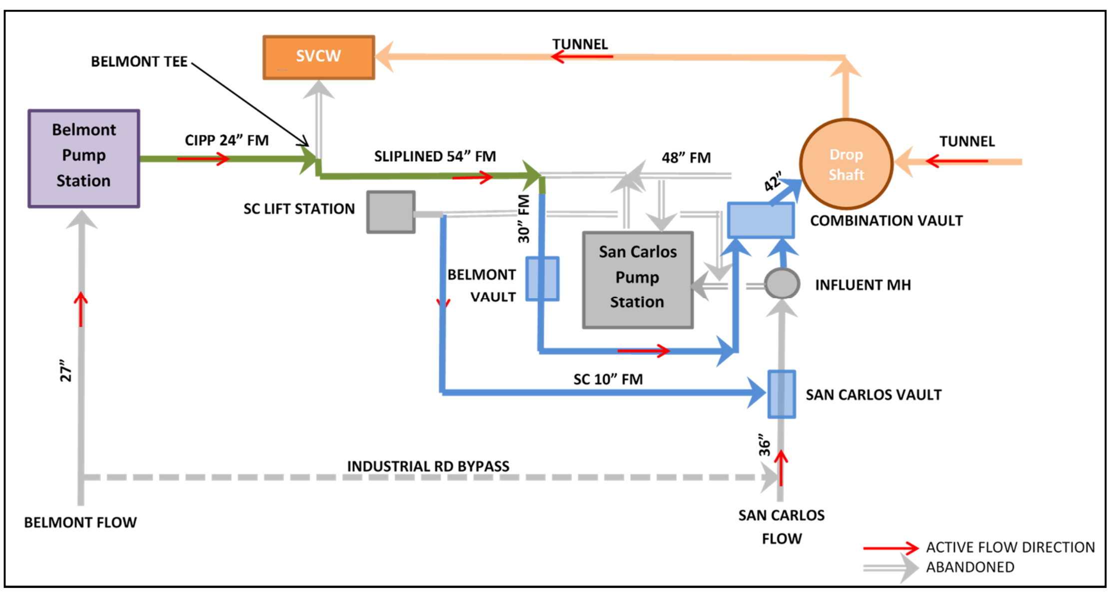

Figure 1-6
Proposed Conveyance System Modification Projects in CIP

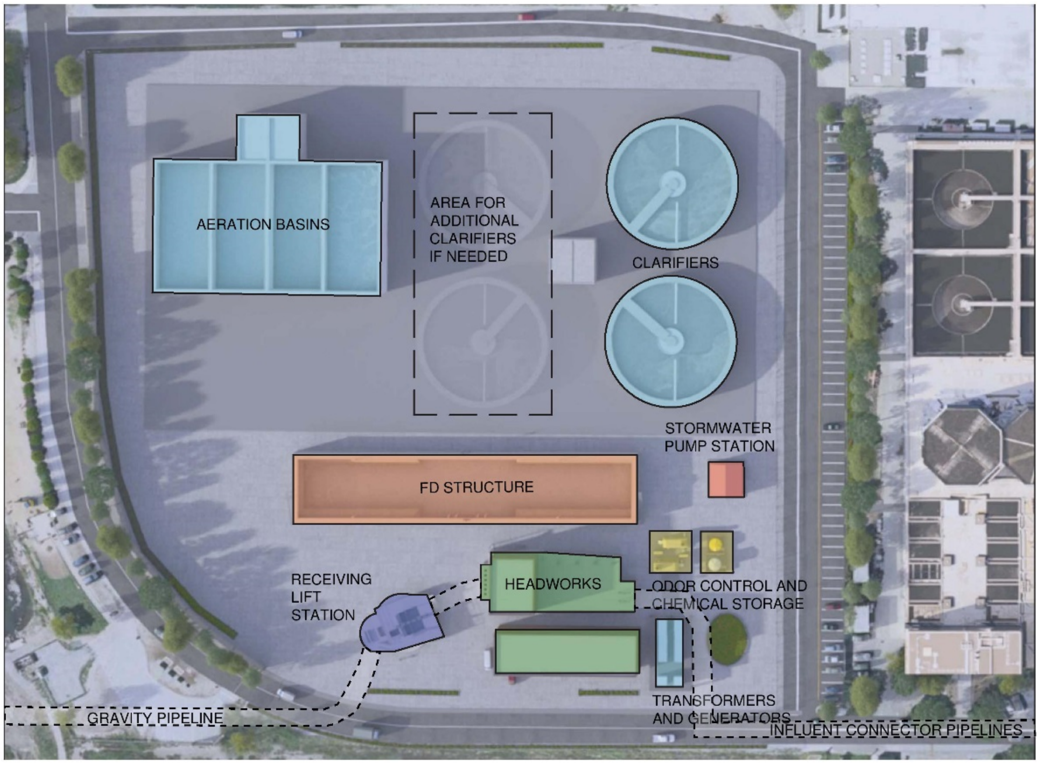

Figure 1-7
Proposed WWTP Facility Projects in CIP

1.3.2 Currently Proposed Improvements

Since the CIP was drafted, SVCW has decided to move forward with only 15 of the 17 proposed projects. At this time, SVCW has chosen not to move forward with the FDS and Nutrient Removal Facilities Projects to equalize flows to the plant during dry weather conditions and to add wastewater treatment processes to the existing WWTP in anticipation of new nitrogen and phosphorus regulations, respectively. The following are the CIP Projects SVCW has chosen to move forward with:

- Gravity Pipeline
- RLS
- Headworks Facility
- ICP
- FoP Odor Control Facilities
- SCOC Facility
- FoP Civil Improvements
- Stormwater Treatment Planters and a Stormwater Pump Station

- Belmont Force Main Rehabilitation
- SCPS Site Improvements
- Redwood City Pump Station replacement and Menlo Park Pump Station Rehabilitation

1.3.3 Delivery Method for CIP Projects

In the initial planning stages of the CIP, SVCW had intended to use a design-bid-build project delivery approach for all the proposed improvements. Under this approach, the CIP improvements would be grouped together in the following projects, each with their own design team and Contractor:

- Gravity Pipeline Project
- Pump Station Modifications Project, which includes the SCPS Site Improvements, Redwood City Pump Station Replacement, and Menlo Park Pump Station Rehabilitation. Final designs could be separated based on work flow.
- RLS Project
- Headworks Facility Project, which includes the Headworks Facility, the FoP Odor Control Facility, and the SCOC Facility
- The Influent Connector Project
- The Civil Site Improvements Project, which includes FoP Civil Improvements and installation of the Storm Water Pump Station

However, SVCW is now considering using a progressive design-build project delivery method for some of the proposed improvements. Under this approach, the proposed improvements would be grouped together and executed as follows:

- The Gravity Pipeline Project, which includes the Gravity Pipeline and piping modifications at the SCPS, may be executed using a design-build delivery method
- The FoP Improvements Project, which includes the RLS, Headworks Facility Project, the FoP Odor Control Facility, and the ICP, would be executed using a design-build delivery method.
- The Civil Site Improvements Project will be executed in two phases. The first phase, which includes initial soil stabilization work, will be executed using a traditional design-bid-build delivery method. The remainder of the work will be executed under the FoP Improvements Project design-build contract.
- The SCOC Facility could be executed under either a Design-Bid-Build or Design-Build project delivery method.

1.4 Headworks Facility Project Objectives and Approach

As discussed in Section 1.3.2, the CIP will include installation of a new Headworks Facility. The main purpose of the Headworks Facility is to remove large solids, rags, grit, or other debris from the sewage entering the treatment plant. Prior to installation of the existing screening facility, there was no mechanism for removing this material and it would accumulate in various treatment processes throughout the plant. O&M staff had to remove this material manually. The manual removal was both time consuming, expensive, and places plant personnel in confined spaces and difficult work environments, and requires process interruptions to facilitate tank cleaning and pump access.

The existing screening facility, constructed in 2016, has improved the plant's ability to remove this material and has reduced the O&M associated with removing this material. However, this facility was intended to operate as a pilot facility until the new, more robust Headworks Facility could be installed.

The new Headworks Facility will provide a robust and efficient means for removing screenings from the influent sewage. The new Headworks Facility will also include an odor control system, which is currently not included as part of the existing preliminary treatment system. In addition, the new Headworks Facility will include a grit removal system to replace the existing hydrocyclones, which the WWTP is currently using to remove grit from the primary sludge. The existing hydrocyclones remove some of the grit, but testing has shown that a significant portion of the grit is not removed by the hydrocyclones. Therefore, the new grit removal system, included in the new Headworks Facility, will replace the hydrocyclones with a more efficient system.

Grit, which consists of sand, gravel, and other heavy solid material is abrasive and contributes to the wear of pumps, piping, and other equipment. Grit can also settle within treatment processes. The settled grit reduces the volumetric capacity of the processes and requires significant labor to remove. Therefore, the addition of grit removal to the preliminary treatment facilities will be a significant benefit.

1.5 Related & Supporting Studies

The layout of the Headworks Facility was developed to a conceptual level as part of the Headworks Facility Project, which was executed under Task Order 2015-05. The following technical memoranda, prepared as part of that project, include design and cost information for various elements of the Headworks Facility:

- Headworks Facility Conceptual Layout TM (December 16, 2016)
- Screening and Screening Handling Evaluation TM (March 7, 2016)
- Grit Removal and Grit Handling TM (March 7, 2016)
- Grit Sampling TM (December 30, 2016)
- Grit Facility Design Criteria Update TM (January 20, 2017)

- FoP Odor Control Facility Strategy TM (January 6, 2017)
- San Carlos Odor Control Facility Strategy TM (January 6, 2017)
- Headworks Facility Opinion of Probable Construction Cost TM (May 6, 2016)
- Headwork Facility Life Cycle Cost TM (August 29, 2016)
- San Carlos Odor Control Facility Opinion of Probable Construction Cost TM (May 6, 2016)
- San Carlos Odor Control Facility Life Cycle Cost TM (August 29, 2016)
- Headworks Facility Early Startup TM (December 13, 2016)

SVCW has also developed a draft Environmental Impact Report (EIR) for the Conveyance System Improvement Project. The EIR, prepared by SVCW, was publicly reviewed for a 45-day public review period beginning on November 29, 2016, and ending on January 13, 2017. The document is anticipated to be finalized once all the responses to the comments from the public review period including the public meeting held on December 14, 2016, at SVCW's Administrative Offices have been addressed and any necessary edits have been incorporated.

Section 2

Existing Conditions

2.1 Project Location Overview

The new Headworks Facility will be constructed in the area currently occupied by a 10-acre ornamental pond, located to the west of the existing WWTP within SVCW's property boundary. In the 1950s, significant levees and fills were placed on the Redwood Shores Peninsula for land development. The ornamental ponds, however, were not filled with engineered fill during original plant construction between 1978 and 1989. Instead, the project area was reportedly used as a construction staging area, as shown by the thin layer of non-engineered fills of highly variable composition and consistency with near-surface buried construction debris. When the ornamental pond is drained, as it will be during construction of the new Headworks Facility, occasional construction debris can be seen on the ground surface. Other key features in the vicinity of the project are the Steinberger Slough to the south and the San Francisco Bay to the east of the existing WWTP.

2.2 Physical Features of Project Location

This section of the report details the topographic, geologic, and hydrologic features of the existing project area.

2.2.1 Topographic Features

The bottom of the ornamental pond where the Headworks Facility will be located is generally flat without much topographic variation. Key elevations are listed below:

- Bottom elevation of the pond is approximately 99 feet on the plant datum
- Berm around the pond is located at an elevation of approximately 103 feet
- Roadway elevation is approximately 103 feet

2.2.2 Geology

A preliminary geotechnical investigation was conducted for the Headworks Facility project area, to determine the physical characteristics of the soil near the proposed Headworks Facility, and FoP Odor Control Facility. The activities performed for the geotechnical investigation, and its main findings, are detailed in the Geotechnical Investigation Technical Memoranda. The activities performed for the geotechnical investigation, and its main findings, are detailed in the Geotechnical Investigation Technical Memoranda (DCM Consulting, Inc. 2017) included in Appendix B. In general, the preliminary geotechnical investigation included the following activities:

- Four soil samples were taken from a test boring (B-101 by GTC Consultants, 2015) drilled to a depth of 121.5 feet at the site of the RLS. The samples were sent to a laboratory and analyzed for moisture content, unit weight, plasticity index, gradation, consolidation, and unconfined compression.

- The laboratory data were used to perform consolidation, settlement, and pile capacity calculations. The results of the calculations are discussed in Section 3.7.
- The thickness of the Young Bay Mud (YBM) under the Headworks Facility was evaluated by reference to 22 cone penetration test (CPT) probes completed in 2015.

Data for all of the above testing is included in the Appendix B to this planning report and the selected design build entity must evaluate and analyze the data and form and confirm its own conclusions. Summaries below were developed for conceptual project description only.

Figure 2-1 shows the boring locations, CPT locations, and contours of the existing YBM based on the CPT results. Red dashed lines represent the elevation of the bottom of the existing YBM layer based on the WWTP datum.

The geotechnical investigations found that the soils underlying the Headworks Facility project area consist of very thick deposits of YBM underlain by Old Bay Clay (OBC). The YBM and OBC present in the project area had the following properties:

YBM

- Thickness below the Headworks Building and Electrical and Loadout Building was 45 to 55 feet
- Thickness below the Odor Control Equipment Buildings was 55 to 75 feet
- Composition was Fat Clay (CH) and Elastic Silt (MH)
- Consistency was very soft, with a standard penetration test blow count of N = 0 to 2
- Moisture content was measured to be between 72 and 105 percent, indicating that in some areas, there is more water than soil solids in a given unit volume of YBM
- Highly compressible with an over consolidation ratio of 1 and a compression index (Cc) of 1.2 to 1.3

OBC

- Thickness below the YBM layer was greater than 80 feet throughout the project area
- Composition was Lean Clay (CL) and Fat Clay (CH) with significant non-cohesive Poorly Graded Sand (SP-SM) interlayered with minor Poorly Graded Gravel (GP), non-cohesive sands and gravels between elevations 5 and 35, ranging from 25 to 30 feet thick
- Consistency was stiff to very stiff clays, with a standard penetration blow count of N = 8 to 24, along with medium dense to dense sands and gravels, with N = 15 to 50
- Average moisture content was measured to be 45 percent in clays and 21 percent in sands
- Less compressible with an over consolidation ratio of approximately 4 and a Cc of 0.25

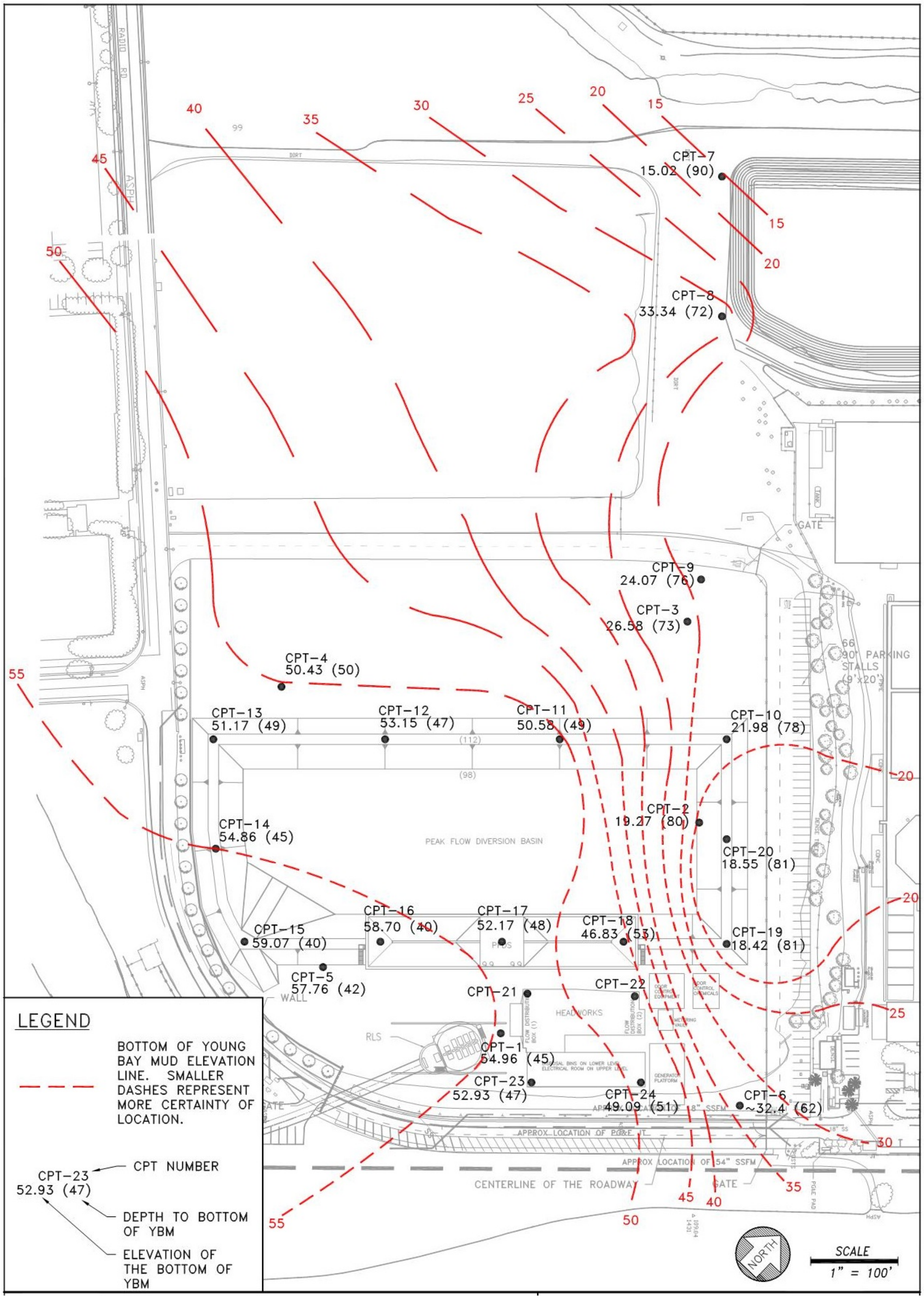

Figure 2-1
Boring Locations, CPT Locations, and Contours of Existing YBM

2.2.3 Surface Water Resources

The ornamental ponds, where the proposed Headworks Facility will be located, are man-made features that have been used since the year 2002 to hold recycled water that is pumped into the ponds from the SVCW Recycled Water Project. Although the ponds are filled periodically with water as part of SVCW operations, they were drained in fall of 2016 to conduct geotechnical evaluations and will remain dry or will be drained upon commencement of the Project.

Additional surface water resources adjacent to the Project site include the Steinberger Slough to the south of the WWTP and the San Francisco Bay to the east of the WWTP, as shown in Figure 3-1 of this report.

The surface water features have the potential to flood the SVCW WWTP site. The design flood elevation for the existing WWTP is 110 feet.

2.2.4 Ground Water Resources

The proposed Headworks Facility overlies the San Mateo Plain groundwater sub-basin, which covers approximately 40 square miles, with a depth ranging from 20 feet to more than 1,250 feet. According to the geotechnical study prepared by Kennedy/Jenks in December 2015, groundwater levels are generally less than ten (10) feet below the ground surface and experience varying degrees of fluctuation coinciding with the tidal stage of the adjacent Steinberger Slough.

2.3 Current and Future Land Uses

The existing ornamental ponds are considered WWTP-related infrastructure. The Headworks Facility Project, along with other CIP improvements in the vicinity of the Headworks Facility, is considered an expansion of the existing WWTP facility and is not considered to be a new land use replacing the ornamental ponds.

2.4 Wastewater Flows

The design flows for the new facilities being installed as part of the CIP, including the Headworks Facility and FoP Odor Control Facility, are summarized in Table 2-1 below.

Table 2-1 Existing and Buildout (2040) Flows for CIP Facilities

Parameter	2040 Flows (mgd)			
	Gravity Pipeline	RLS	Headworks Facility	ICP
2015 Flows[1]				
Minimum Hour Dry Weather Flow (MHDWF)	2.4	2.4	0	0
Existing Flows				
Average Day Dry Weather Flow (ADDWF)	10.9	10.9	11.8	11.8
Peak Day Dry Weather Flow (PDDWF)	-	-	-	-
Peak Hour Dry Weather Flow (PHDWF)	20.5	20.5	22.5	22.5
Peak Hour Wet Weather Flow (PHWWF)	-	-	-	-
2040 Design Flows				
Minimum Hour Dry Weather Flow (MHDWF)	-	-	-	-

Table 2-1 Existing and Buildout (2040) Flows for CIP Facilities

Parameter	2040 Flows (mgd)			
	Gravity Pipeline	RLS	Headworks Facility	ICP
Average Day Dry Weather Flow (ADDWF)[2]	17.3	17.3	17.9	17.9
Peak Day Dry Weather Flow (PDDWF)[2]	22	22	23	23
Peak Hour Dry Weather Flow (PHDWF)[3,5]	28.9	28.9	33.9	33.9
Peak Hour Wet Weather Flow (PHWWF)[4,5,6]	102.9	75	80	80

[1] 2015 flows based on data provided by SVCW SCADA output from each collection system pump stations

[2] 2040 ADDWF from Table 5-9 of TM1 for Final Plant Capacity Study (Brown and Caldwell, 2013)

[3] 2040 PHDWF from Member Agency Master Plans and CSMP

[4] 2040 PHWWF based on 10-year, 1-hour storm. The flows assume that the storm event peak flows from each Member Agency's collection system reaches the entry point into the collection system at the same time.

[5] The Redwood Shores Pump Station will discharge directly to the new Headworks. Therefore, the PHDWF and PHWWF for the Gravity Pipeline and RLS do not include flows from Redwood Shores Pump Station, but the PHDWF and PHWWF for Headworks Facility and ICP do include flows from Redwood Shores Pump Station

[6] During periods when the flows in the Tunnel exceed the capacity of the RLS, Headworks, and ICP, sewage will be stored in the Gravity Tunnel

2.5 Influent Grit Characteristics

Samples from the SVCW WWTP were collected and analyzed for grit content during several sampling events described in detail in the Grit Sampling TM (CDM Smith, 2016) included in Appendix C. As discussed in that TM, the data from the samples collected from the Influent Mix Box during the period from February 3, 2016, to March 11, 2016, by Black Dog Analytical, LLC, is recommended for use in developing initial pre-design criteria for the Headworks Facility. The data from these samples are summarized in Table 2-2 and Figure 2-2 and 2-3 below. Figure 2-2 shows the distribution of sand equivalent size (SES) of the grit particles in the collected sample. SES is the size of a sand particle that has the same settling velocity as the grit particles in the collected sample. Settling velocity is the velocity at which the grit particles in the collected sample fall to the bottom of a test apparatus. Figure 2-3 shows the distribution of grit particle settling velocities in the collected sample. The selected design build entity should verify grit analysis and consider additional grit sampling and analysis.

It should be noted that the data resulting from the grit sampling performed by SVCW during the period from March 2014 to October 2015, were generally in agreement with the data collected by Black Dog Analytical, LLC. Both sets of data indicated that there is a large fraction of fine grit, in terms of physical particle size, entering the WWTP during dry weather conditions.

Table 2-2 Concentrations of Grit in Influent Wastewater

Sampling Date	Grit Concentration (lbs./MG)
February 3, 2016 (Dry Weather Sample)	4.6
March 5, 2016 (Dry Weather Sample)	11.2
March 11, 2016 (Wet Weather Sample)	38.0

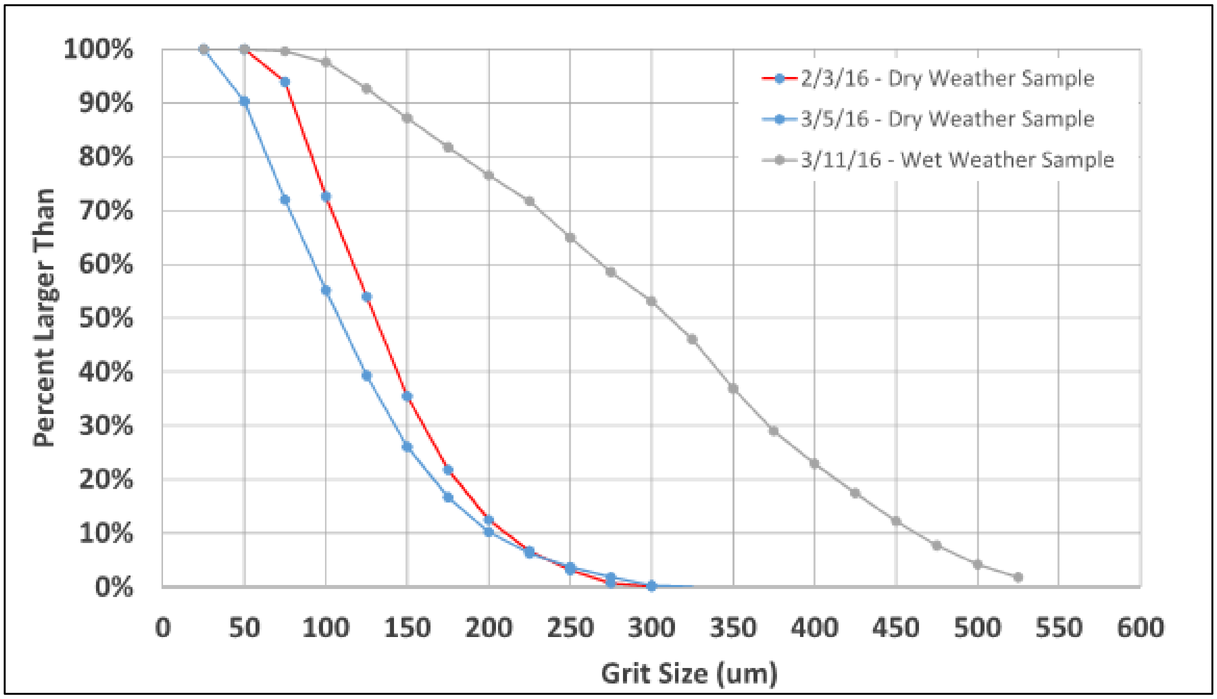

Figure 2-2
Sand Equivalent Size (SES) Distribution of Grit Particles in Influent Samples

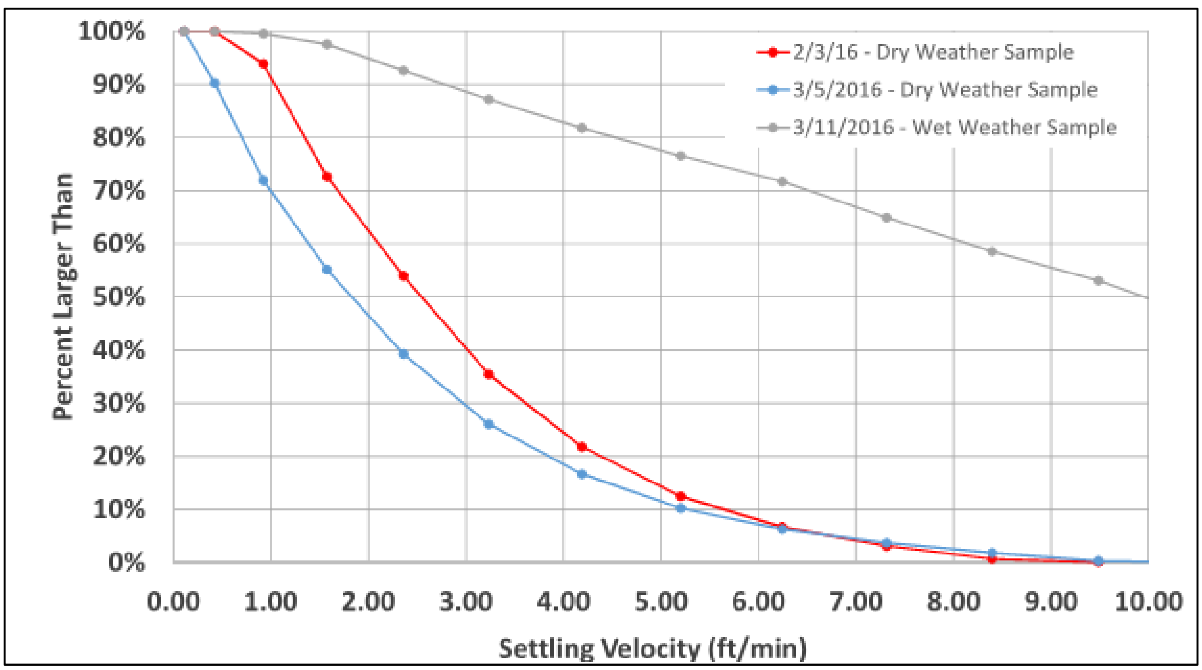

Figure 2-3
Settling Velocity Distribution of Grit Particles in Influent Samples

Section 3

Proposed Headworks Facility

3.1 Site Plan

Figure 3-1 below, shows a conceptual site plan of the RLS, Headworks Facility, FoP Odor Control Facility, and the ICP. After the facilities shown in Figure 3-1 are constructed, raw sewage will be conveyed through the Gravity Pipeline to the RLS, which will pump it up to the new Headworks Facility. The raw sewage will flow through the Headworks Facility and the ICP to the existing WWTP. The existing 54-inch forcemain will no longer be needed, and will be abandoned in place.

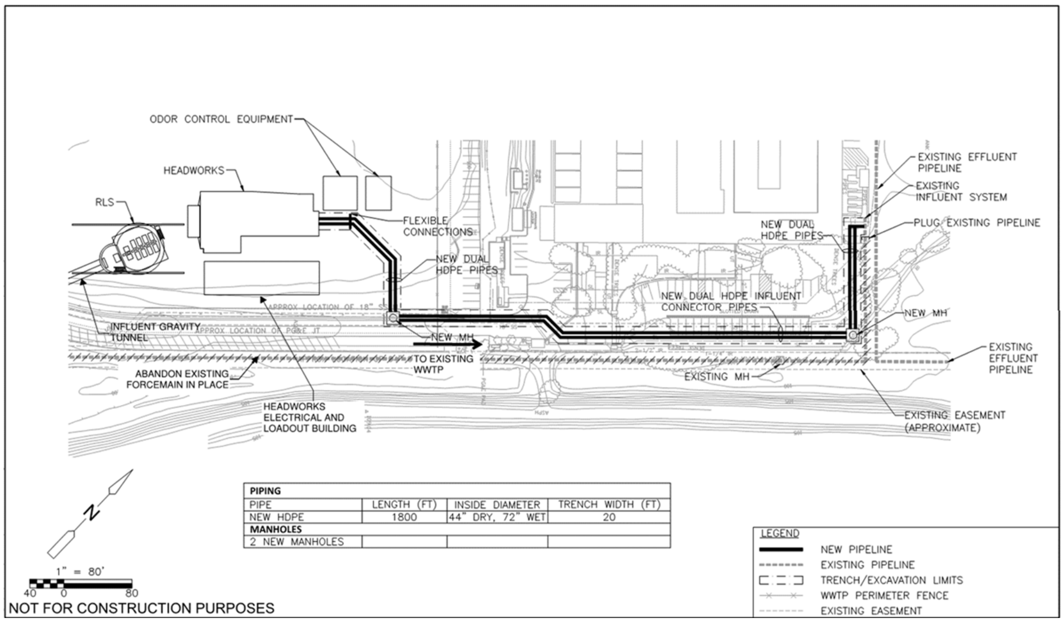

Figure 3-1
SVCW Proposed Conveyance System and Preliminary Treatment Improvements

3.2 Process Flow Diagram

A process flow diagram of the new Headworks Facility is shown in Figure 3-2. This facility will consist of the following main process areas:

- Influent junction structure, referred to as the Distribution Structure 1, which will collect influent flows and any return flows, and convey the flows to the screen channels
- Screens, which will remove screenable material from the influent wastewater
- Screenings conveyance equipment, which will convey screenings captured by the screens to the screenings processing equipment
- Screenings processing equipment, which will dewater and remove organic material from the screenings

- Screenings bins, which will collect the processed screenings and store them until they can be hauled offsite
- Grit separators, which will remove grit from the influent wastewater
- Grit processing equipment, which will dewater and remove organic material from the grit collected by the grit separators
- Grit bins, which will collect processed grit and store it until it can be hauled offsite
- Effluent distribution structure, referred to as the Distribution Structure 2, which will receive flow from the grit basins and distribute it to downstream processes
- A future Flow Diversion Structure, which will be used equalize dry weather flows going to the primary clarifiers

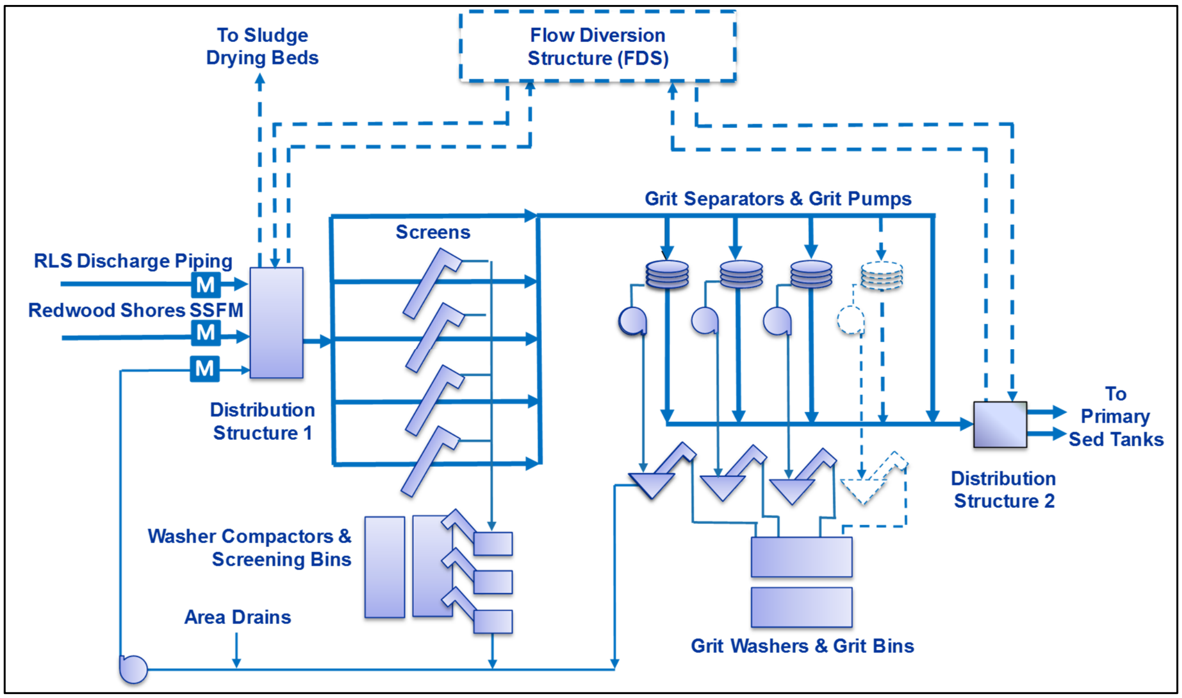

Figure 3-2
Headworks Facility Process Flow Diagram

3.3 Process Equipment Technology Evaluation

Several alternative technologies were considered for each of the main processes shown in Figure 3-2. These technologies were presented, the pros and cons of each technology were discussed, and a preferred technology for each process was recommended during the following workshops:

- Screen and Grit Removal Technology Overview Workshop - August 5, 2015. (See Appendix D)
- Screen Facility Workshop Presentation - December 1, 2015. (See Appendix E)

- Grit Facility Workshop - December 17, 2015. (See Appendix F)

The discussions that occurred at these workshops and final selection of technologies for each process are summarized in the following sections.

3.3.1 Screens

The types of screens considered for the Headworks Facility include:

- Single Rake Bar Screens (Climber Screens)
- Multi-Rake Bar Screens
- Continuous Element Bar Screens
- Continuous Element Perforate Plate Screens (Perf Plate Screens)
- Center Flow Band Screens
- Inclined Cylindrical Screens
- Stair Screens

These options were screened based on their ability to meet the objectives of the project. The screening criteria and results are shown in Table 3-1.

Table 3-1 Screen Technology Evaluation

Criteria	Single Rake Bar Screen	Multi-Rake Bar Screen	Continuous Element Bar Screen	Perf Plate Screens	Center Flow Band Screen	Stair Screen	Inclined Cylindrical Drum Screen
Available in 1/4" and 3/8"?	Yes	Yes	Yes	Yes	Yes	Yes	No
Available with Adequate Capacity?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Installations of Similar Height	No	Yes	Yes	?	Yes	?	No
Adequate Removal	No	Yes	Yes	Yes	Yes	No	No
Proven Experience in US	Yes	Yes	Yes	Yes	No	Yes	No
Meets Overall Objectives?	No	Yes	Yes	Yes	No	No	No

As shown in Table 3-1, the screen types that may meet the objectives of the project and which were selected for further consideration are:

- Multi-Rake Bar Screens
- Continuous Element Bar Screens
- Continuous Element Perforate Plate Screens (Perf Plate Screens)

CDM Smith recommends that continuous element bar screens and perf plate screens be eliminated from further consideration and that the design of the new Headworks Facility be based on a multi-rake bar screen. Continuous element bar screens and per plate screens are good options for fine screening. However, there will be a second stage screening facility with fine screens located downstream of the new Headworks Facility. So, fine screens are not needed at the new Headwork Facility.

There are two main types of multi-rake bar screens: Mahr-Style and Duperon® screens. A summary of differences between the two is listed in Table 3-2. The main difference between these types of screens is that the Mahr-Style screen has a sprocket at the bottom of the screen, which the rake chains ride along. The Duperon® style screen does not have a sprocket at the bottom of the screen. A disadvantage of the bottom sprocket is that it is submerged in wastewater, making it difficult to access it when maintenance needs to be performed on it. A potential advantage of having a bottom sprocket is that it helps hold the rake against the screen. CDM Smith recommends that the selection of the Mahr-style screen versus Duperon screen be deferred until the preliminary design phase of the project, since it does not have a significant impact on the conceptual layout or cost estimate being prepared as part of this Project. For the purposes of the conceptual layout and cost estimate, CDM Smith recommends assuming Mahr-Style screens since they have a slightly higher cost.

Table 3-2 Mahr-Style and Duperon Comparisons

Parameter	Duperon®	Mahr-Style
Bottom Sprocket	No	Yes
Rake Teeth	Partial Penetration	Full Penetration
Cost	15% less	15% more

3.3.2 Screenings Conveyance

The following technologies can be used to convey screenings from the screens to screenings processing equipment:

- Sluices
- Conveyor Belts
- Shafted Screws
- Shaftless Screws.

The pros and cons associated with each of these technologies are summarized in Table 3-3, below. CDM Smith recommends assuming sluices for development of the conceptual layout and costs, based on the pros and cons listed in Table 3-3. Final selection of the screening conveyance technology should be made during preliminary design.

Table 3-3 Pros and Cons of Screenings Conveyance Equipment

Method of Conveyance	Pros	Cons
Sluicing	▪ Prewashes screenings ▪ Few moving parts - Most reliable ▪ Can put in rock trap and magnets ▪ Very long runs possible ▪ Inexpensive	▪ Uses water ▪ Reduces WC capacity
Conveyor Belts	▪ High capacity ▪ No water needed – adds to WC (Washer/Compactor) capacity ▪ Simple to repair ▪ Very long runs possible ▪ Inexpensive	▪ Messy ▪ Hard to contain debris and odors ▪ Flow splitting messy
Shafted Screws	▪ Easy to enclose ▪ Positive movement ▪ Accommodate some rise ▪ No water needed – adds to WC capacity	▪ Limited to runs less than 30 ft. +/- ▪ Bearings in trough catch debris
Shaftless Screws	▪ Easy to enclose ▪ Positive movement ▪ No water needed – adds to WC capacity ▪ Screws segmented to facilitate removal	▪ Must be nearly flat to prevent role back

3.3.3 Screenings Processing

There are two main technologies that should be considered for processing the screenings generated at the new Headworks Facility, including:

- Batch Mode Washer/Compactors
- Flow Through Washer/Compactors

In a flow through washer/compactor, screenings are received in a hopper and fall, and a screw on the bottom of the hopper pushes the screenings through the discharge chute. The point where the screenings are pushed into the discharge chute is referred to as the compaction zone. In the compaction zone, water is squeezed out and drains through a screen located under the screw. Clean water is also sprayed into the compaction zone to help wash organic material off of the screening.

In a batch mode washer/compactor screenings are also received in a hopper and are pushed through a discharge chute with a screw. However, the washing procedure is different. In a batch mode washer/compactor the hopper slowly fills with screenings and when the hopper gets filled the washer/compactors stops accepting screenings and enters a washing mode. During the washing mode, an impeller mixes the contents of the hopper, cleaning the organic material off the screenings, much like a washing machine. When the washing mode is completed, water drains through the bottom of the washer/compactor and the screenings are pushed through the discharge chute by a screw.

A comparison of batch mode and flow through washer/compactors is summarized in Table 3-4 below. The main benefit of the batch-mode washer/compactor is that it produces much cleaner and drier screenings, however has a lower capacity. Because of this lower capacity, the batch mode washer/compactor is not suitable for use with a sluice.

Table 3-4 Washer/Compactor Batch Mode vs Flow Through Mode

Batch Mode	Flow Through Mode
Lower Capacity 42 ft^3/hr	High Capacity 420 ft^3/hr
Higher Chemical Oxygen Demand Reduction	Lower Chemical Oxygen Demand Reduction
Not Compatible with sluicing	Compatible with sluicing
Expelled material is dryer	Wetter/Heavier material expelled
Equipment set up/construction are the same. Operational programming differs.	

CDM Smith recommends basing the conceptual design and cost estimate on a flow through washer/compactor since they are compatible with a sluice. However, CDM Smith recommends assuming 3 units (2 duty, 1 standby) as part of the conceptual layout. 2 duty units are needed if batch mode washer compactors are selected, because one unit needs to be accepting screenings while another unit is washing screenings. So, assuming 2 duty and 1 standby units would allow batch mode washer/compactors to be incorporated into the design, if desired, during preliminary design.

3.3.4 Screenings Hauling

After screenings have been compacted they will be stored in roll off bins to be transported for landfill disposal. Roll off bins come in a variety of sizes (5, 10, 15, 20, 30 and 40 cubic yards), but are limited to the respective transport truck's gross vehicle weight. The transport trucks currently used by SVCW can carry approximately 8 tons of compacted screenings. Therefore, a 10 yd^3 bin is recommended for storing processed screenings. A larger bin could hold slightly more screenings, but would reach the weight limit before it was completely filled, increasing the likelihood that it would be overfilled. With a 10 yd^3 bin, the bin would fill up before the weight limit was reached.

3.3.5 Grit Separators

The types of grit separators considered for the Headworks Facility include:

- Aerated Grit
- Vortex Grit
- Conical Tray Vortex Separator (commonly referred to as a HeadCell® unit, the brand name of the conical tray vortex separator manufactured by Hydro International)

The screening criteria and results are shown in Table 3-5. HeadCells® have the smallest footprint and the lowest O&M requirements. HeadCell® units have a history of good performance and CDM Smith recommends this process in the conceptual layout of the Headworks Facility.

Table 3-5 Grit Separator Comparison

Criteria	Aerated	Vortex	CTVS
Headloss	<12"	<12"	<12"
Footprint	Largest	Middle	Smallest
Screening Required	Yes	Yes	Yes
Operation and Maintenance	Medium	Low	Low
Number of Installations	Many	Many	140 Total (12+ of Similar Size)
General Concerns	Odor Control Required	Long Approach Channel	Sole Source

3.3.6 Grit Processing

Settled grit is pumped from the HeadCell® units to grit processing equipment, which will clean organic material off the grit and remove excess water from the grit. The following three grit processing technologies were considered for this Project:

- Conventional Cyclone/Grit Classifier
- Cone Washer
- Slurry Cup/Grit Snail

The characteristics of the three types of grit processing equipment are compared in Table 3-6 below. Conventional cyclone/grit classifiers remove very little organic material and water from the grit; this technology was eliminated from further consideration. Cone Washers capture grit as small as 100 µm and remove a high amount of organic material and water from the grit. Slurry Cup/Grit Snails can remove particles as small as 75 µm, but do not remove as much organic material and water from the grit as the Cone Washer. Since the recommended cut point for the HeadCell® units is 100 µm, there is not a need for the grit processing equipment to capture grit as small as 75 µm. Therefore, CDM Smith recommends that the conceptual layout and cost estimate be based on utilization of a cone washer for grit processing.

Table 3-6 Grit Washer/Classifier Comparison

Criteria	Cyclone/Grit Classifier	Cone Washer	Slurry Cup/ Grit Snail
Grit Capture Efficiency	95% of >105µm	95% of >100µm	95% of >75µm
Processed Grit Volatile Solids Conc. (% by Weight)	$\leq$ 25%	$\leq$ 3%	$\leq$ 15%
Processed Grit Water Content (% by Weight)	$\leq$ 50%	$\leq$ 10%	$\leq$ 40%

3.3.7 Grit Loading

After grit has been washed it is conveyed to a dedicated roll off bin for storage prior to off-haul and disposal. For conceptual layout and cost estimating a 10 yd^3 dumpster with an 8 ton weight capacity is recommended.

3.4 Conceptual Layout

Figures 3-3 through 3-6 show the three-dimensional conceptual layout of the new Headworks Facility. The facility would be built as shown with three grit separators and grit washers, with space for a fourth basin and washer to be installed in the future. This will allow the plant to expand for future demands. Design criteria for the facilities shown are presented in Section 3.5 Hydraulic Profile

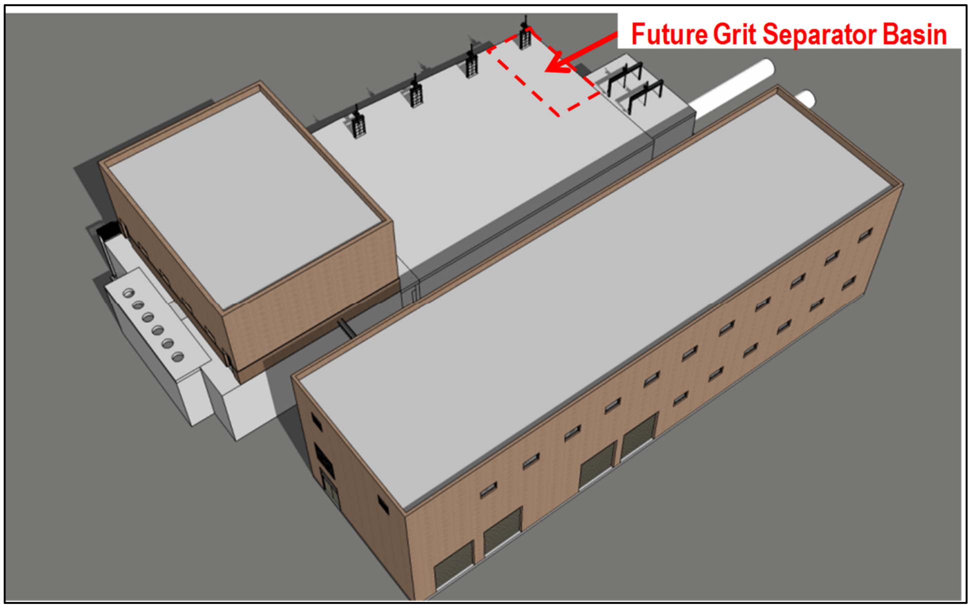

Figure 3-3
Headworks Building-Isometric

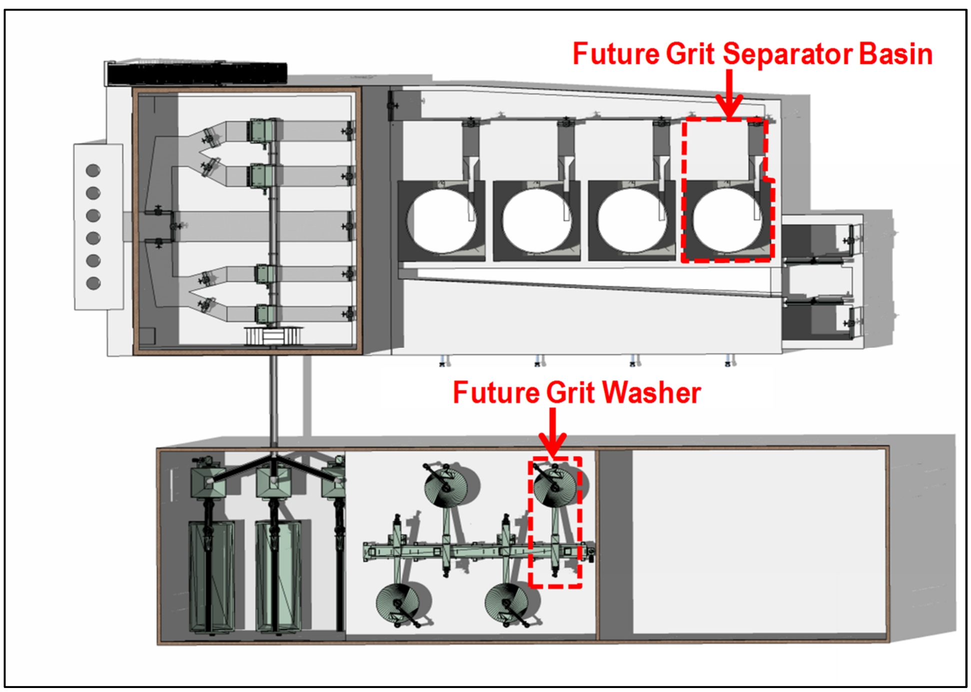

Figure 3-4
Headworks Building Plan View

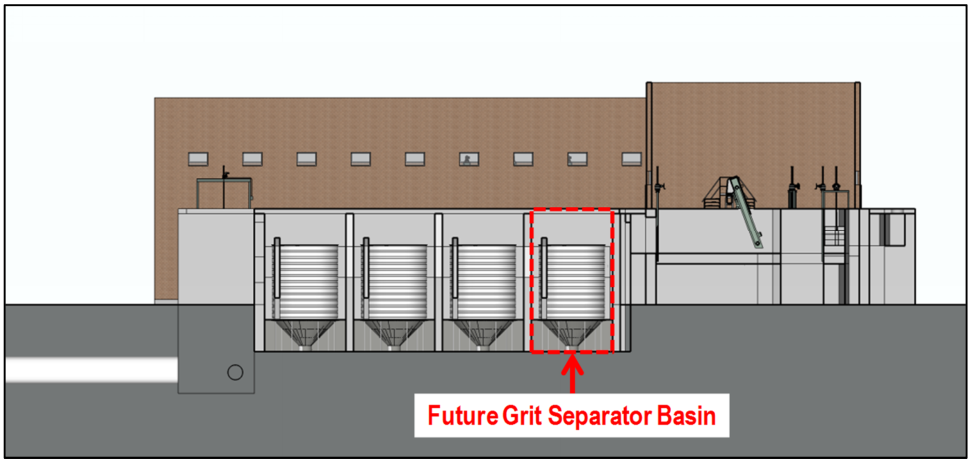

Figure 3-5
Headworks Building North Side Section View

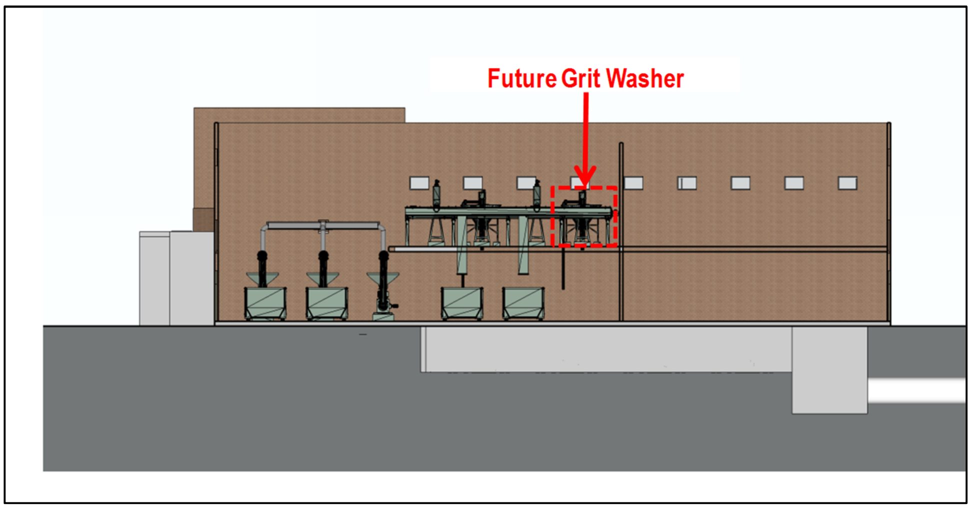

Figure 3-6
Headworks Building South Side Section View

3.5 Hydraulic Profile

The hydraulic profile for the Headworks Facility, in Figure 3-7, shows the water surface elevations in the Headworks Facility at peak hour wet weather flows. The profile was developed based on the scenario where second stage screens are out of service, and all the sewage entering the second stage screening facility flows over the weir in the bypass channel. This assumption needs to be evaluated during the detailed design phase, as there may be other ways of bypassing peak flows around the second stage screening facility. However, the assumed scenario will result in the highest water surface elevations. This assumed scenario results in a water surface elevation of 111 feet in the Influent Mix Box, as shown in Figure 3-7.

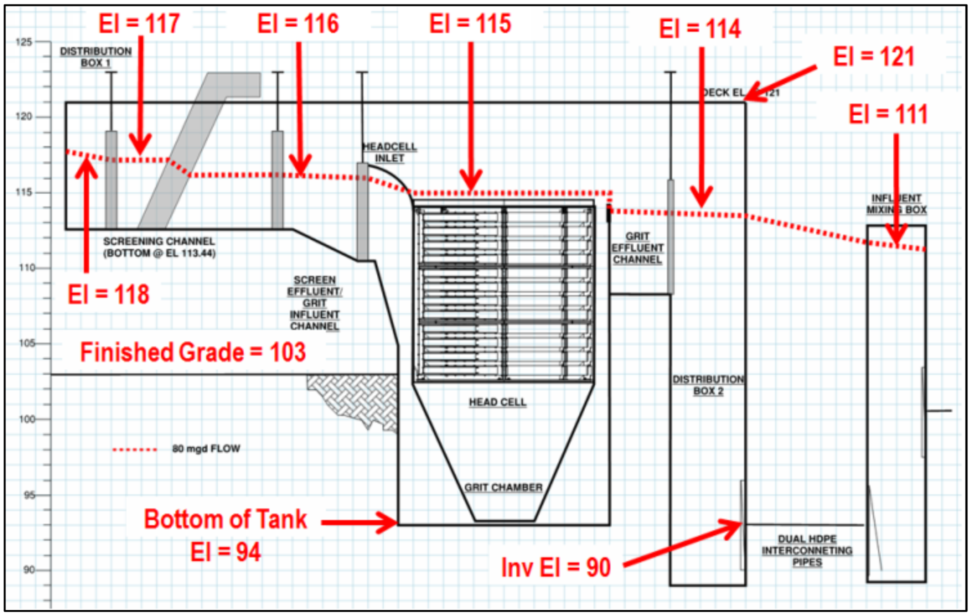

Figure 3-7
Headworks Facility Hydraulic Profile

3.6 Process Design Criteria

The design criteria for each of the main process areas in the new Headworks Facility are summarized in the following sections.

3.6.1 Influent Distribution Structure

The purpose of Distribution Structure 1 is to collect flows from the following sources and direct these flows to the screen channels:

- RLS pump discharge pipes
- 18-inch Redwood Shores Forcemain
- Return flows from Headworks Facility screenings and grit handling equipment
- Nearby site drains

The design of Distribution Structure 1 should meet the following objectives:

- Minimize slow moving and dead water zones to prevent grit and scum/grease build up, while accounting for the instances when during Minimum Hour Dry Weather Flows only one of the RLS pipes might be discharging. During low flows any of the six RLS pipes may be used in a cyclic manner as pumps are turned off and on to reduce individual pump run times.
- Minimize odor generation
- Consist of self-cleaning channels for both grit and floating solids

- Provide the hydraulic capacity to accommodate peak flows up to 80 MGD
- Provide a connection for a future pipe to convey flow from Distribution Structure 1 to the future Flow Diversion Structure
- Provide a connection for a future pipe to convey flow from the future Flow Diversion Structure back to Distribution Structure
- Provide for a connection for a temporary pipe that will convey flow from the existing 54-inch force main to Distribution Structur 1. This pipe will be used in the event that the Headworks Facility is constructed and started up prior to the RLS. More informatio regarding this topic can be found in the Headworks Early Startup TM.
- Allow for discharge of all pipes above the maximum water surface elevation, since there will be no check valves on the RLS pipes

3.6.2 Screening Facility

The conceptual design criteria for the Screening Facility is summarized in Table 3-7. As shown, the facility consists of four screen channels, each equipped with a multi-rake bar screen with 3/8-inch openings, and one bypass channel. Two of the screen channels are 4 feet wide and 8-feet deep and the other two screen channels are 3-feet wide and 6.5-feet deep. The two 3-foot wide channels will be used during dry weather flow conditions. If one of the 3-foot wide channels were out of service, one of the 4-foot wide channels could be brought into service to accommodate dry weather flows. During wet weather conditions, all four screen channels will be in operation. The Screening Facility is configured this way to maintain adequate channel velocities across the full range of flows listed in Table 3-7.

The screen channels will be covered and the screen equipment enclosed to reduce odors. A building will also be provided over the screening equipment and channels. Foul air will be withdrawn from the enclosed channels, equipment, and building and routed through ductworks to FoP Odor Control Facility (see Section 3.6.10). This approach will be further evaluated during design of the facility.

Upon preliminary analysis, it appears that the two existing screens at the existing headworks facility may be reused in the wet weather channels. New screens with smaller openings could then be installed in the channels in the existing screening facility, to allow the facility to act as a second stage screening facility.

Table 3-7 Screening Facility Design Criteria

Parameter	Unit	Value
Wet Weather Channels		
Number of Channels	-	2
Dimensions	ft	4 ft wide x 8 ft deep
Screen Type	-	3/8-inch Multi-Rake
Channel Velocity	ft/sec	2-4
Dry Weather Channels		
Number of Channels	-	2

Table 3-7 Screening Facility Design Criteria

Parameter	Unit	Value
Dimensions	ft	3 ft wide x 6.5 ft deep
Screen Type	-	3/8-inch Multi-Rake
Channel Velocity	ft/sec	2-4
Bypass Channel		
Number of Channels	-	1
Dimensions	ft	6 ft wide X 8 ft deep
Channel Velocity	ft/sec	≤ 5

3.6.3 Screenings Conveyance

Screenings collected by the screens will be conveyed to screening processing equipment located in a building adjacent to the Screening Facility (see Section 3.6.2). The design criteria for the screenings conveyance system is summarized in Table 3-8. As shown, a single sluice will be provided for screenings conveyance. Water will be sprayed into the sluice to convey the screenings down the sluice.

Table 3-8 Screening Conveyance Design Criteria

Parameter	Unit	Value
Type	-	Sluice
No. of Units	-	1 duty
Target Solids Concentration	%	1
Sluice Water Feed Rate	gpm	50

3.6.4 Screenings Processing Equipment

Screenings will be processed to remove excess water and organic material prior to discharging the screenings into dumpsters. The design criteria for the screenings processing equipment is summarized in Table 3-9. As shown, two duty and one standby batch mode washer/compactors will be provided. The washer compactors will be located in a building adjacent to the Screening and Grit Removal Facilities, as shown in Figures 3-3 through 3-6.

Table 3-9 Conceptual Screenings Handling Facility Design Criteria

Criteria	Value	Units
Wet Screenings Production		
Screenings Capture, avg	ft3/MG	8
Screenings Density	lb/ft3	45
Volumetric Load, average per day	yd^3/day	5
Mass Load, average per day	ton/day	3
Washer Compactor		
Type	-	Batch Mode
Number of Units	-	2 duty, 1 standby
Volume Reduction	%	60
Mass Reduction	%	50
COD Reduction	%	N/A

Table 3-9 Conceptual Screenings Handling Facility Design Criteria

Criteria	Value	Units
Processed Screenings		
Volumetric Load, average per day	yd^3/day	2
Mass Load, average per day	ton/day	1.4

3.6.5 Screenings Bins

The screenings processing equipment will discharge the screenings into bins where the screenings will be stored until they can to be transported for landfill disposal. The design criteria for the screenings bins are summarized in Table 3-10. As shown, two 10 yd^3 roll-off dumpsters will be provided for storage of screenings, providing 5 days of storage. The dumpsters will be located adjacent to the screenings processing equipment inside a building, as shown in Figures 3-3 through 3-6. The dumpsters will be mounted on a motorized rail system, which will assist in dumpster change out and improve distribution of screenings within the dumpster.

Table 3-10 Screenings Bins Design Criteria

Criteria	Value	Units
Number of Units	-	1 duty, 1 standby
Bin Volume Capacity	yd^3	10
Bin Weight Capacity	tons	8
Volumetric Storage Time	day	5
Mass Storage Time	day	6
Appurtenant Equipment	-	1 Dumpster-conveyor/bin

3.6.6 Grit Separators

The Headworks Facility grit separator basins are being designed based on Headcell units with twelve 12-foot diameter trays. The number of Headcell units required is dependent on the flow being processed and the desired overflow rate, or target settling velocity. Increasing the number of Headcells will reduce the amount of flow being processed by each unit, which will decrease the overflow rate in that unit and allow grit particles with lower settling velocities to be captured.

Tables 3-11 through 3-13, below show the performance of the Grit Facility at various flows, using various numbers of Headcell units. The information shown in Tables 3-11 through 3-13 was developed as follows:

- The total tray surface area shown in each row was calculated based on the number of Headcells listed for that row assuming each Headcell has twelve 12-foot diameter trays.
- The overflow rate shown in each row was calculated based on the total surface area and influent flow rate listed for that row.
- The minimum settling velocity shown in each row was calculated based on the overflow rate listed for that row. Grit particles with settling velocities higher than the maximum settling velocity would be captured in the grit basin. Grit particle with settling velocities lower than the maximum settling velocity would escape the grit basin.

- The SES cutpoint in each row was calculated based on the minimum setting velocity listed for that row assuming a spherical grit particle with a specific gravity of 2.65.
- The grit capture shown in each row was determined by using the settling velocity and SES distribution data for the raw influent wastewater (see Section 2.5) to determine how much of the influent grit has settling velocities/SES lower than the minimum settling velocity/SES listed for that row.

Table 3-11 Performance of Grit Separator Basins during Peak Hour Dry Weather Flows (20 mgd)

Headcells	Tray Surface Area	Performance at PDWF (20 mgd)			
		Overflow Rate	Settling Velocity	SES Cutpoint	Grit Capture
1	1,360 ft2	10 gpm/ft2	1.4 ft/min	95 um[1]	55%
2	2,710 ft2	5 gpm/ft2	0.7 ft/min	65 um[1]	80%

[1]Grit handling systems are typically designed for an SES cutpoint of 100um. Therefore, grit particles with an SES < 100um, although captured in the grit separator, will typically flow through the grit handling systems to downstream processes. Therefore, the capture efficiency of the combined grit washer and handling system will be limited to 55 percent during dry weather flows, even though the capture efficiency of the grit separators alone is much higher

Table 3-12 Performance of Grit Separator Basins during Equalized Peak Wet Weather Flows (80 mgd)

Headcells	Tray Surface Area	Performance at PWWF (80 mgd)			
		Overflow Rate	Settling Velocity	SES Cutpoint	Grit Capture
1	1,360 ft2	41 gpm/ft2	5.5 ft/min	205 um	75%
2	2,710 ft2	21 gpm/ft2	2.7 ft/min	135 um	90%
3	4,070 ft2	14 gpm/ft2	1.8 ft/min	110 um	96%
4	5,430 ft2	10 gpm/ft2	1.4 ft/min	95 um[1]	98%
5	6,790 ft2	8 gpm/ft2	1.1 ft/min	80 um[1]	> 99%

[1]Grit handling systems are typically designed for an SES cutpoint of 100um. Therefore, grit particles with an SES < 100um, although captured in the grit separator, will typically flow through the grit handling systems to downstream processes. Therefore, the capture efficiency of the combined grit washer and handling system will be limited to 98 percent, during wet weather flows, even though the capture efficiency of the grit separators alone is much higher.

Table 3-13 Performance of Grit Separator Basins during Un-Equalized Peak Wet Weather Flows (108 mgd)

Headcells	Tray Surface Area	Performance at PWWF (108 mgd)			
		Overflow Rate	Settling Velocity	SES Cutpoint	Grit Capture
1	1,360 ft2	55 gpm/ft2	7.4 ft/min	250 um	65%
2	2,710 ft2	28 gpm/ft2	3.7 ft/min	160 um	85%
3	4,070 ft2	18 gpm/ft2	2.5 ft/min	130 um	92%
4	5,430 ft2	14 gpm/ft2	1.8 ft/min	110 um	96%
5	6,790 ft2	11 gpm/ft2	1.5 ft/min	95 um[1]	98%

[1]Grit handling systems are typically designed for an SES cutpoint of 100um. Therefore, grit particles with an SES < 100um, although captured in the grit separator, will typically flow through the grit handling systems to downstream processes. Therefore, the capture efficiency of the combined grit washer and handling system will be limited to 98 percent during wet weather flows, even though the capture efficiency of the grit separators alone is much higher.

The following observations can be made from the data presented in Tables 3-11 through 3-13:

- Under dry weather conditions, 1 Headcell unit would capture grit with a settling velocity as low as 1.5 feet/minute (95um SES), which constitutes 55 percent of the influent grit.
- Under dry weather conditions, 2 Headcell units would capture grit with a settling velocity as low as 0.7 feet/minute (65 um SES), which constitutes 80 percent of the influent grit.
- This is a significant improvement over the performance of a single Headcell unit in terms of percent grit captured. However, grit processing equipment is typically designed only to retain grit particles with settling velocities above ~1.5 feet/minute (SES > 100 um). Therefore, the additional grit captured by a second Headcell unit would not be fully captured by the grit processing system, and some of the grit would get introduced back into the wastewater. Therefore, a second Headcell unit under dry weather conditions would not significantly improve overall grit capture, without modification to the grit processing system (e.g., additional grit classifiers).
- Under equalized wet weather flows, 1 Headcell would capture grit with a setting velocity as low as 5.5 feet/minute (205 um SES), which constitutes 75 percent of the influent grit.
- Under equalized wet weather flows, 3 Headcells would capture grit with a setting velocity as low as 1.8 feet/minute (110 um SES), which constitutes 96 percent of the influent grit. This is a significant increase in performance versus the performance of one or two Headcell units. Therefore, it is recommended that 3 Headcells be installed for treating wet weather flows.
- Under equalized wet weather flow, the grit capture rate does not increase significantly by increasing the number of Headcells beyond three. Therefore, installing more than three Headcells is not recommended. However, it is recommended that space be provided for a fourth Headcell and additional grit processing facilities if at some point in the future it is determined to be necessary. These additional facilities may be needed if actual grit loads and capture efficiencies do not match the design values.
- Under un-equalized wet weather flows, four Headcells are needed to achieve the same performance as three Headcells under equalized wet weather flows. However, the Grit Facility will likely rarely have to process un-equalized. Therefore, it is not recommended that additional Headcells be installed to process un-equalized wet weather flows.

Based on this analysis, it is recommended that the grit separators be designed based on the design criteria in Table 3-14.

Table 3-14 Grit Separator Design Criteria

Criteria	Value	Units
Type	-	Headcell
Number of Units	-	3
Tray Diameter	ft.	12
Number of Trays	-	12

Table 3-14 Grit Separator Design Criteria

Criteria	Value	Units
Target settling velocity @ PWWF	ft./min	1.8
SES cutpoint at PWWF	µm	110
Grit Capture @ PWWF	%	>95
Target settling velocity @ ADWF	ft./min	1.4
SES cutpoint at ADWF	µm	95
Grit Capture @ ADWF	%	55

Although three Headcells are being currently recommended, consideration should be given to installation of only two Headcells during the next phase of design of the Grit Facility. As shown in Table 3-12, two Headcells would capture up to 90 percent of the influent grit during wet weather conditions, which is a significant portion of the influent grit, and may be an acceptable level of performance for SVCW. Installation of only two Headcells would eliminate some of the capital costs associated with the Grit Facility. However, there would be impacts to the system hydraulics and the grit handling facilities, which may add capital cost to the facility. These impacts should be evaluated further during the next phase of design.

3.6.7 Grit Loads

The design criteria for the grit loads delivered to the Headworks Facility are dependent on the concentration of grit in the raw influent sewage entering the Gravity Pipeline and the manner in which flows are delivered from the Gravity Pipeline into the Headworks Facility. The concentration of grit in the raw influent sewage is presented in Section 2.5. The manner in which flows are processed through the Gravity Pipeline was evaluated in the Grit Migrations TM (See Appendix G). The findings of the Grit Migrations TM and recommended grit load design criteria is discussed in detail below.

Operation of Gravity Pipeline

SVCW may use the Gravity Pipeline for 1) equalizing dry weather diurnal flows to maintain the plant influent flow at 16 million gallons per day (mgd), and/or 2) storing flows during peak wet weather events to keep the influent flow into the plant below 80 mgd. Operation of the Gravity Pipeline during dry weather equalization and wet weather storage events will have an impact on the conveyance of grit down the pipeline to the Headworks Facility. This issue was analyzed in the Grit Migration TM. The findings of the Grit Migrations TM are discussed below. Additional considerations regarding how the findings of the Grit Migrations TMS should be used in developing design criteria for the Grit Facility are also presented below

The Grit Migration TM reported the following grossly simplified findings:

- Grit will settle in the Gravity Pipeline when flow velocities in the pipeline are less than 2 feet per second (ft./s). Grit that has settled in the Gravity Pipeline during low flow velocity conditions will not be re-suspended until the flow velocity in the pipeline increases above 4 ft./s.
- When the Gravity Pipeline is being used for dry weather diurnal equalization, the lower portion of the pipeline will be flowing full. Under these conditions, the flow velocities in

lower portion of pipeline will be below 2 ft./s, causing grit to settle in that portion of the pipeline.

- To flush out grit which has settled in the pipeline during dry weather diurnal equalization, the pipeline should be periodically drained and allowed to flow freely (i.e. not flowing full) during times when the flow into the pipeline is high enough to produce a flow velocity of 4 ft./s. The recommended operation is to allow the pipeline to flow freely for 30 minutes a day during periods of peak dry weather flows, anticipated to be 20 MGD.
- If the pipeline is flushed once a day, as described above, the grit that has accumulated in the Gravity Pipeline, during the 24 hours between flushings, will be conveyed into the Headworks Facility during the 30 min flushing period.
- During a wet weather event, the RLS pumps will match the rate at which flows enter the Gravity Pipeline, up to the maximum capacity of the pumps (i.e., 80 MGD). When the flow entering the pipeline is less than 80 MGD, the pipeline will be free-flowing (i.e. it will not be flowing full). Under these conditions, the flow velocity in the pipeline will be > 2 ft./s and all grit entering the pipeline will be conveyed to the Headworks Facility in real-time, (i.e., no grit is expected to accumulate in the Gravity Pipeline under these conditions).
- When the flow entering the Gravity Pipeline rises above the maximum capacity of the RLS pumps (80 MGD), the rate at which flow is entering the pipeline will exceed the rate at which flow is being extracted from the pipeline, and the lower portion of the Gravity Pipeline will begin to fill up. Under these conditions, the flow velocities in the lower portion of the pipeline will drop below 2 ft./s, causing grit to settle in the pipeline. These conditions are anticipated to occur for a period up to 24 hours.
- After a wet weather event, the Gravity Pipeline will need to be drained to free up the storage volume in the pipeline for the next wet weather event.
- The recommended draining procedure is to drain the pipeline rapidly at the beginning of the draining procedure and then slowly near the end of the draining procedure. This will allow the tunnel to be drained in a relatively short period of time (< 24 hours), but will limit the peak grit load to the Headworks Facility to a manageable level.
- The specific recommended draining procedure is to drain the pipeline at a rate of 55 MGD during the beginning of the procedure. Once the pipeline is drained to the point where only 1,500 feet of the pipeline is flowing full, the draining rate should be reduced to 5 MGD above the rate at which raw sewage is entering the pipeline.
- If the draining procedure outlined above is followed, all the grit that accumulated in the tunnel during the wet weather storage event will be washed to the Headworks Facility during a 3-hour period at the end of the draining process. During this period, the influent rate to the Headworks Facility will be approximately 20 MGD.

The Grit Migration TM made some assumptions regarding design flows, pipeline operations, and grit characteristics, to simplify the fairly complex issues being evaluated in the TM. The authors of the Grit Migration TM, SVCW, and CDM Smith recognize that the operation of the Gravity

Pipeline and the behavior of grit in the pipeline may differ from what is presented in the Grit Migration TM. Therefore, the following considerations should be made in using the findings of the Grit Migration TM to develop design criteria for the Grit Facility:

- Not all grit will settle in the Gravity Pipeline once the flow velocity in the pipeline falls below 2 ft./s. Therefore, even at low flow velocities, some grit will continue to be conveyed to the Headworks Facility.
- Not all grit that has settled in the Gravity Pipeline will be re-suspended once the flow velocity in the pipeline reaches 4 ft./s. Some grit will be re-suspended at a lower velocity and some will be re-suspended at a higher velocity.
- The manner in which the tunnel is periodically flushed during dry weather diurnal equalization operations could differ from the recommendations made in the Grit Migration TM, as follows:
  - The duration of time that the pipeline is allowed to flow freely could be changed. With a very short free flow period, it would take several flushings for grit that has accumulated in the upstream end of the pipeline to reach the Headworks Facility. This would increase the load of grit entering the Headworks Facility during each flushing. As the free flow period is increased, the load of grit to the Headwork Facility will be reduced until the point where the free flow period is long enough to flush all the grit that has accumulated in pipeline to the Headworks Facility.
  - The frequency at which the pipeline is flushed could be changed. If the pipeline is flushed less than once a day, the peak grit load to the Headworks Facility would be increased. If the pipeline is flushed more than once a day, the peak grit load to the Headworks Facility would be decreased.
- The rate at which the Gravity Pipeline is drained after a wet weather storage event storage event could differ from the recommendations made in the Grit Migration TM. Draining the pipeline at a lower rate, during any phase of the draining, will decrease the grit load to the Headworks Facility, but will increase the amount of time it takes to drain the pipeline. Draining the pipeline at a higher rate, during any phase of the draining, will increase the grit load to the Headworks Facility, but will decrease the amount of time it takes to drain the pipeline.

Based on the information discussed above, it is recommended that the following assumptions be made regarding the operation of the Gravity Pipeline and the conveyance of grit to the Headworks Facility:

- 50 percent - 100 percent of the grit in the raw sewage entering the Gravity Pipeline could settle when flow velocities in the pipeline fall below 2 ft./s.
- During dry weather diurnal equalization operations, the Gravity Pipeline could be flushed every 1 – 2 days for a period of 15 – 60 min.

- Grit could accumulate in the Gravity Pipeline for a period of 12 – 36 hours during a wet weather storage event.
- During draining of the Gravity Pipeline after a wet weather storage event, the grit which has accumulated in the pipeline could be conveyed to the Headworks Facility over a 1.5 – 6 hour period.

Recommended Design Criteria

Design grit loads for the Headworks Facility are presented in Table 3-15. The grit loads, which should be further evaluated during design of the project, were developed as follows:

- The data from the grit sampling discussed in Section 2.5 indicated a grit concentration of 11 lb./MG during dry weather conditions and a grit concentration of 38 lb./MG during wet weather conditions. These concentrations are much lower than typical concentrations reported in MOP-8 (i.e., 170 – 790 lb./MG). Also, grit concentrations can vary significantly from day to day. Therefore, it is recommended that a safety factor of two be applied to the grit concentrations reported in Section 2.5, resulting in the grit concentration design criteria shown in Table 3-15.
- The average day grit load entering the Gravity Pipeline shown in Table 3-15, was developed based on the dry weather grit concentration (22 lbs./MG) and the average daily flow (16 mgd). The max wet weather day grit load entering the Gravity Pipeline was based on the wet weather grit concentration (76 lbs./MG) and the peak wet weather flow (80 mgd).
- The peak hour grit load entering the Headworks Facility during dry weather was developed based on the following:
    - 0.1 – 0.35 tons of grit could accumulate in the Gravity Pipeline between dry weather flushings. This is based on a minimum of 50 percent of the grit in the raw sewage accumulating over a 1-day period and a maximum of 100 percent of the grit in the raw sewage accumulating over a 2-day period.
    - The grit that accumulates in the Gravity Pipeline during dry weather could be flushed to the Headworks Facility during a 15-minute to 60-minute period flushing period.
    - The dry weather flushing operations, described in the two previous bullets, would result in a Headworks Facility influent grit load of 0.1 – 1.4 ton/hour.
- The peak hour grit load entering the Headworks Facility during wet weather was developed based on the following:
    - 0.8 – 4.5 tons of grit could accumulate in the Gravity Pipeline during wet weather storage events. This is based on a minimum of 50 percent of the grit in the raw sewage accumulating over a 12-hour period and a maximum of 100 percent of the grit in the raw sewage accumulating over a 36-hour period.
    - The grit that accumulates in the Gravity Pipeline during wet weather storage events could be conveyed to the Headworks Facility in a 1.5 – 6-hour period during the draining of the pipeline.

- The wet weather operations, described in the previous two bullets, would result in a Headworks Facility influent grit load of 0.1 – 3.0 ton/hr.

Table 3-15 Raw Grit Loads – Entering Gravity Pipeline

Criteria	Value	Units
Raw Grit Concentration, Average		
Dry Weather	lb/MG	22
Wet Weather	lb/MG	76
Raw Grit Loads – Entering Gravity Pipeline		
Average Dry Weather Day	ton/d	0.2
Max Wet Weather Day	ton/d	3
Raw Grit Loads – Entering Headworks		
Peak Hour, Dry Weather Draining Event	ton/hr	0.1 – 1.4
Peak Hour, Wet Weather Draining Event	ton/hr	0.1 – 3.0

3.6.8 Grit Processing Equipment

Grit removed by the grit separators will be processed to remove excess water and organic material prior to discharging the grit into dumpsters. The design criteria for the grit processing equipment is summarized in Table 3-16. As shown, 1 grit washer will be provided for each grit separator. Grit washers will be designed to provide a greater amount of water and organics removal than is typically provided by a standard grit classifier system. The grit washers will be located in the same building as the screenings processing equipment, as shown in Figures 3-3 through 3-6.

Table 3-16 Grit Washer Design Criteria

Criteria	Value	Units
Type	-	Cone Washer
Number of Units	-	1 Washer per Basin
Flow Capacity per Unit	gpm	400
Grit Load capacity per Unit	lbs/hr	2,500 – 3,000
Effluent Grit Water Content, Max	%	3
Effluent Grit Volatile Solids Content, Max	%	10

Former operations staff indicated that there were occasions when up to 20 tons of grit were received at the plant over the course of a single wet weather event. It was also indicated that there was at least one day when up to 60 tons of grit was received at the plant over the course of a single wet weather event. Designing the system based on this information would result in a peak hour grit load of approximately 10 tons/hour, based on 60 tons of grit accumulating in the pipeline during the extreme event and the accumulated grit being conveyed to the Grit Facility in as little as 6 hours.

The design criteria presented above includes three grit washers, each with a maximum grit processing capacity of 1.25 ton/hour, resulting in a total grit processing capacity of 3.75 ton/hour. Therefore, the system could not handle the extreme grit loads described above. Under these conditions, the system would continue to operate and remove some grit from the influent wastewater, but some grit would be conveyed to processes downstream of the grit facility. To avoid this from happening, the grit processing capacity of the system could be increased as follows:

- Grit washers with a capacity of 3 tons/hour could be used, to increase the total grit processing capacity to 9 ton/hour. However, these types of grit washers are limited to an inlet of 250 gpm and need to be equipped with a hydrocyclone, as shown schematically in Figure 3-8, to be able accept the full underflow from the grit separators (400 gpm). This arrangement would require that the height of the building over the grit washers be higher because the hydrocyclones are located on top of the grit washers. The larger-capacity grit washer, the hydrocyclone, and the taller building will increase the capital cost of the Grit Facility. Hydrocyclones are high-wear pieces of equipment and require a high inlet pressure, increasing the energy required to pump grit out of the grit basins. Therefore, this option would also increase the O&M costs associated with the Headworks Facility.

- The grit processing capacity of the Headworks facility could be increased beyond 9 tons/hour by adding additional washers. For example, if 4 grit washers, each with a capacity of 3 tons/hour and each equipped with a hydrocyclone, were used, the total grit processing capacity would be increased to 12 tons/hour. This arrangement would add significant capital and O&M costs to the Headworks Facility.

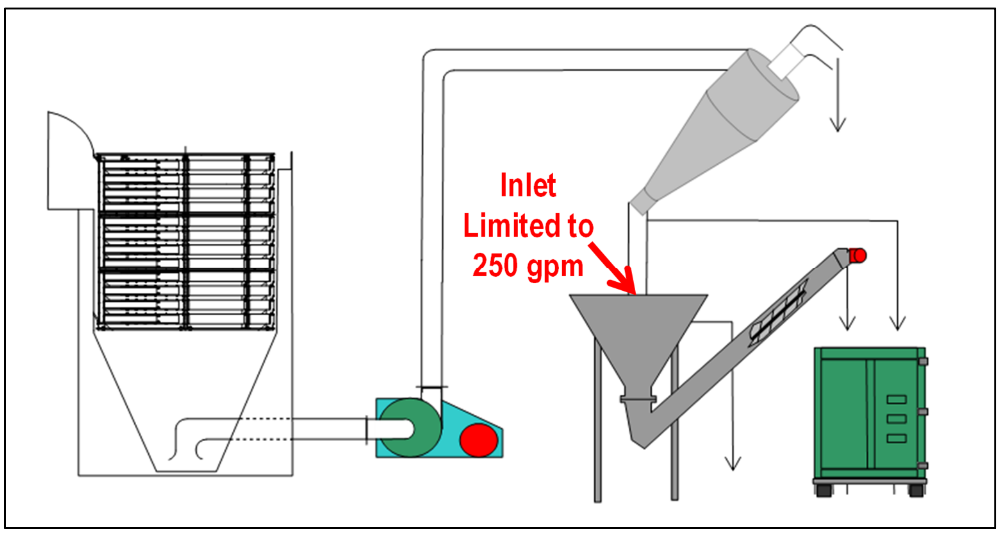

Figure 3-8
Arrangement of Grit Processing Equipment Required for High Grit Loads

It is not recommended that the Headworks Facility be designed to include the modifications described above (i.e. higher capacity grit washers with hydrocyclones or additional grit washers). This recommendation is supported by the following:

- The analysis performed above assumes that the full 60 tons of grit that enters the pipeline during an extreme wet weather event will accumulate in the pipeline. However, grit will not begin accumulating in the pipeline until the flow in the pipeline exceeds the capacity of the RLS pumps, and the pipeline begins filling up. Much of the grit that enters the pipeline during an extreme wet weather event will have passed through the pipeline by this point. This means that much less than 60 tons of grit will accumulate in the pipeline during a storm event and that the analysis above is very conservative.

- During the beginning of an extreme event when flows in the Gravity Pipeline are less than the capacity of the RLS pumps (80 MGD), the grit entering the pipeline will be sent directly to the Headworks Facility, i.e., will not be stored in the pipeline. The rate at which grit will be sent to the Headworks Facility during these periods will be approximately 2.5 ton/hour, assuming the extreme grit loads described above (60 tons/day) are delivered to the plant in a 24-hour period. The grit handling equipment recommended in Section 6 has a total capacity of 3.75 tons/hour, which is ample for the scenario when flows are delivered to the Headworks Facility directly, i.e., without storage in the pipeline.

- As mentioned above, when the Gravity Pipeline is being drained after an extreme event, there is the potential of draining the pipeline in a manner that would overload the recommended grit handling equipment. This could be avoided by modifying the draining procedure to increase the time over which accumulated grit is delivered the Headworks Facility.

- If extreme grit loads to the Headworks Facility during were as high as 10 tons/hour, the grit separator basins and the grit removal pumps are expected to have adequate capacity to process these extreme loads. However, the capacity of the grit washers would be exceeded, resulting in the discharge of grit through the grit washer overflow pipes. During these periods, the overflow from the grit washers could be directed to downstream processes or an off-line storage basin. The grit that is deposited in these locations could be processed after the extreme grit loading event has subsided.

The extreme grit loads, discussed above, are significantly higher than the grit loads determined based on the grit sampling. This could be the result of the grit sampling being performed during a wet weather event, which resulted in an influent flow much lower than the influent flow observed during the extreme events described above. Therefore, it is recommended that additional wet weather sampling be performed during the detailed design of the Headworks Facility to confirm the peak hour grit loads.

3.6.9 Grit Bins

The grit processing equipment will discharge grit into bins where it will be stored until the bins can to be transported for landfill disposal. The design criteria for the grit bins are summarized in Table 3-17. As shown, two 10 yd^3 roll-off dumpsters will be provided for storage of screenings, providing 2 days of storage. The dumpsters will be located adjacent to the screenings processing equipment inside a building, as shown in Figures 3-3 through 3-6. The dumpsters will be mounted on a motorized rail system, which will assist in dumpster change out and improve distribution of grit within the dumpster.

Table 3-17 Grit Bin Design Criteria

Criteria	Value	Units
Number of Units		1 duty, 1 standby
Volume Capacity	yd^3	10
Bin Weight Capacity	tons	8
Volumetric Loading Rate	tons /day	0.2
Mass Loading Rate	tons/day	3
Volumetric Storage Time	day	40
Mass Storage Time	day	2.7

3.6.10 Effluent Distribution Structure

The Effluent Distribution Structure (Distribution Structure 2) will receive flow the grit separators and convey it to downstream processes. Prior to the construction of the FDS, the Distribution Structure 2 will convey flow to the primary clarifiers through one or both of the ICPs. After construction of the FDS, the Distribution Structure 2 will be used to split flow between the primary clarifiers and the FDS depending on flow conditions, as follows:

- Dry weather conditions, Headworks influent flows: < 14 MGD – Under these conditions, all flow from the Headworks Facility will flow into Distribution Structure 2, and then be conveyed directly to the primary clarifiers through one of the two ICPs. Flow will be pumped from the FDS into the Distribution Structure 2, where it will be mixed with flow from the Headworks Facility, to maintain a flow of 14 – 16 MGD going to the primary clarifiers.

- Dry weather conditions, Headworks influent flows: 14 MGD to 16 MGD – Under these conditions all flow from the Headworks Facility will flow into Distribution Structure 2, and then be conveyed directly to the primary clarifiers through one of the two ICPs. No flow will be pumped from the FDS to Distribution Structure 2.

- Wet weather conditions, Headworks influent flows: > 16 MGD to 80 MGD – Under these conditions all flow from the Headworks Facility will flow into Distribution Structure 2, and then be conveyed directly to the primary clarifiers. When the flows rises above the capacity of a single ICP, then both of the ICPs will be utilized. No flow will be pumped from the FDS to Distribution Structure 2.

Distribution Structure 2 shall be designed with the proper pipe connections, flow metering devices, and flow control facilities to accommodate the operations described above.

3.6.11 Power Distribution

The Headworks Facility equipment discussed above will be powered from motor control centers (MCCs) located in an electrical room, which will be on the second floor of the building with the screenings and grit handling equipment. The MCCs will be powered from new 480V feeders from the existing Power Distribution Panel 2 (PDP2), which is located near the existing Fixed Film Reactors (FFRs). The electrical room will be sized so that it is large enough to also house the Variable Frequency Drives (VFDs) for the RLS pumps.

3.7 Foundation Design

As discussed in Section 2.2.3, a preliminary geotechnical investigation was performed to determine the physical characteristics of the soil in the vicinity of the proposed Headworks Facility and FoP Odor Control Facility. The activities performed during the investigation are summarized in Section 2.2.3. The main findings and recommendations of the preliminary geotechnical investigation related to the design of the Headworks Facility and FoP Odor Control Facility (see Section 5.0) are as follows:

- The soil under the proposed Headworks Facility and FoP Odor Control Facility consists of a 45– 75-foot thick layer of YBM (very soft, high water content, and very weak soil), which is underlain by a > 80-foot thick layer of Old Bay Clay (soil with a stiff to very stiff consistency)
- The proposed Headworks Facility and FoP Odor Control Facility will need to be supported on a foundation of piles, driven through the Young Bay Mud into the Old Bay Clay, similar to all other existing process structures at the SVCW WWTP.
- Pile foundations for the proposed Headworks Facilty and FoP Odor Control Facility should consist of 14-inch square, pre-cast, pre-stressed, concrete piles with a net 50 ton capacity, each. The piles should be driven to a minimum of 80 feet below present ground surface where the layer of Young Bay Mud is 45 feet thick and driven to a maximum of 109 feet below present ground surface where the layer of Young Bay Mud is 75 feet thick.
- Four feet of fill will be required to raise the elevation of the ground surface around the Headworks and FoP Odor Control Facilities from the existing elevation of approximately 99 ft to the proposed finished elevation of approximately 103 feet. This fill will be a significant load on the existing Young Bay Mud and will result in consolidation settlement on the order of 1.0 – 1.4 feet after 25 years, 1.3 – 1.7 feet after 50 years, and 2.0 – 2.8 feet on a long term basis. This will result in differential settlement between pile supported structures and non-pile supported structures. Differential settlement will also occur between facilities constructed on new fill and existing facilities constructed on already consolidated soils.

The selected design build entity will be required to analyze the existing data, make recommendations about any desired additional investigations and draw their own geotechnical conclusions.

Section 4

Proposed FoP Odor Control Facility

4.1 General Description

The following facilities have the potential to generate odors, which could be of nuisance to the local community, if not contained and treated. Therefore, the FoP Odor Control Facility will be used to treat odorous air from these facilities:

- Gravity Pipeline
- RLS Wet Well
- Screening Influent Channels
- Screen Channels
- Screening Effluent Channels
- Grit Influent Channels
- Grit Effluent Channels
- Screenings and Grit Handling Building

Odorous air will be collected from these sources and routed through ductwork to the FoP Odor Control Facility. It is assumed that the odors from the future FDS will be treated through chemical addition to the liquid phase of flows to that structure. Therefore, the FoP Odor Control Facility will not need to treat air from the future FDS.

A workshop to discuss alternatives for treating odor from the sources listed above was conducted with SVCW staff on November 11, 2015. The minutes summarizing the discussion that took place at that workshop are included in Appendix H.

4.2 Process Design Criteria

This section summarizes the airflow rates for the various sources of odorous air that will be treated by the FOP Odor Control Facility and the strength of odors in the air.

4.2.1 Odor Characteristics

To quantify and characterize current odors in the wastewater entering the SVCW WWTP, a sampling event was conducted on February 24, 2016, through March 6, 2016. The sampling event was conducted in accordance with the Sampling and Analysis Plan included in Appendix I.

An automated sampler was installed in the Influent Mix Box at a location upstream of the existing bar screens and downstream of where the influent force main discharges into the plant. The automated sampler monitored H_2S concentrations in the vapor space of the influent mix box for the period from February 24, 2016, through March 6, 2016.

On March 2, 2016, liquid and vapor grab samples were collected from the Influent Mix Box. Two vapor samples were collected and sent to a laboratory for analysis of the following:

- Volatile Organic Compounds (VOCs)
- Total Reduced Sulfur (TRS) Compounds

Four liquid grab samples were collected and analyzed on-site for the following:

- Dissolved Sulfide (dS)
- Dissolved Oxygen (DO)
- Oxidation Reduction Potential (ORP)
- pH
- Temperature

The results of the sampling are provided in Appendix J and summarized in Table 4-1.

Table 4-1. Summary of Odor Sampling Results

Sample	Sample Date	H_2S (avg/max) (ppm)	TRS (ppb)	VOCs (ppb)	dS (mg/l)	ORP (mV)	pH	DO (mg/l)	Temp (deg C)
Auto-sampler	2/24/16 – 3/2/16	9/113	-	-	-	-	-	-	-
Auto-sampler	3/2/16 – 3/6/16	11/132	-	-	-	-	-	-	-
Vapor Grab #1	3/2/16	-	130	35.33	-	-	-	-	-
Vapor Grab #2	3/2/16	-	1400	14.49	-	-	-	-	-
Liquid Grab #1	3/2/16	-	-	-	0.4	-261	7.00	-	20.0
Liquid Grab #2	3/2/16	-	-	-	-	-272	7.24	2.1	20.1
Liquid Grab #3	3/2/16	-	-	-	1.3	-270	7.16	1.1	20.1
Liquid Grab #4	3/2/16	-	-	-	1.6	-291	7.16	1.9	20.1

Based on these observations, it is recommended that the FoP Odor Control Facility be designed based on the criteria summarized in Table 4-2, which should be further evaluated during design.

Table 4-2. Chemical Scrubber Design Criteria

Constituent	Vapor Phase Concentration (ppm)
H_2S, avg	10
H_2S, peak	130
TRS, avg	2

4.2.2 Ventilation Rates

Odors generated at the Headworks Facilities will need to be ventilated through a network of fiberglass (FRP) ducts and balancing dampers to the FoP Odor Control Facility. The rate at which these facilities are ventilated is determined based on the following codes:

- National Fire Protection Code 820 (NFPA 820-16)
- Control of Fugitive Emissions and Indoor Air Quality

Using these codes, the ventilation rates from each odor sources has been estimated. The estimated ventilation rates from each source are summarized in Table 4-3 below. The ventilation rates shown in Table 4-3 should be further evaluated during design.

Table 4-3 Odor Control Ventilation Rates

Location	Total Airflow Rate (cfm)
Screening influent Channels	1,000±
Screen Housings	500±
Screening Effluent Channels	1,000±
Grit Influent & Effluent Channels	3,000±
Grit Influent & Effluent Channels	3,000±
Screening Building	5,000±
Screening/Grit Processing	10,000±
RLS	5,000±
TOTAL	**29,000±**

4.3 Odor Control Equipment Technology Evaluation

SVCW's preferred technology for treating odorous air is the chemical scrubber technology. Therefore, the conceptual layout of the FoP Odor Control Facility will be based on this technology. There are several types of chemical scrubbers that can be considered for the FoP Odor Control Facility. An evaluation of the various types of chemical scrubbers and a recommendation on the preferred type is provided below.

4.3.1 Chemical Scrubber Technologies

A chemical scrubber consists of a tower, partially filled with plastic media. Odorous air is forced into the bottom of the tower with an exhaust fan. Liquid chemicals, typically sodium hydroxide and sodium hypochlorite, are sprayed into the top of the stack. The chemicals trickle down through the plastic media to the bottom of the stack, running the opposite direction of the odorous air. As the liquid trickles through the plastic media, it comes in contact with the odorous air. When the odorous air contacts the liquid, the contaminants in the odorous air are transferred into the liquid and are removed from the air. The chemicals in the liquid then oxidize the odorous compounds.

There are three main types of chemical scrubbers:

- Single Stage Packed Tower

- Two Stage Packed Tower
- Low Profile Multi-stage Chemical Scrubber

A process flow diagram of a single stage packed tower chemical scrubber is shown in Figure 4-1. As shown, in this type of scrubber, the odorous air makes a single pass through a tower of media. NaOH and NaOCl are recirculated through the vessel to maintain the pH at 9.5 – 10.0 and the oxidation reduction potential (ORP) at 600 mV. Single stage scrubbers can remove organic sulfur compounds and up to 99 percent of H_2S provided the incoming odorous air has an H_2S concentration less than 25 ppm.

A process flow diagram of a two-stage packed tower chemical scrubber is shown in Figure 4-2. In this type of scrubber, the odorous air passes through two towers of media, or stages, in series. The stages of media are contained in separate towers, with ductwork connecting the two towers. Sodium hydroxide (NaOH) is recirculated through the first stage. NaOH and sodium hypochlorite (NaOCl) are recirculated through the second stage. The first stage typically removes 90 percent of H_2S in the odorous air. The second stage polishes any residual H_2S, but its primary purpose is to remove residual organic sulfur compounds.

A low profile multi-stage chemical scrubber is shown in Figure 4-3. This type of scrubber functions like a dual stage packed tower chemical scrubber. However, in this type of scrubber, the stages of media are contained within a single housing, with baffles separating the stages. This setup has a smaller footprint than the dual stage packed tower arrangement shown in Figure 4-2.

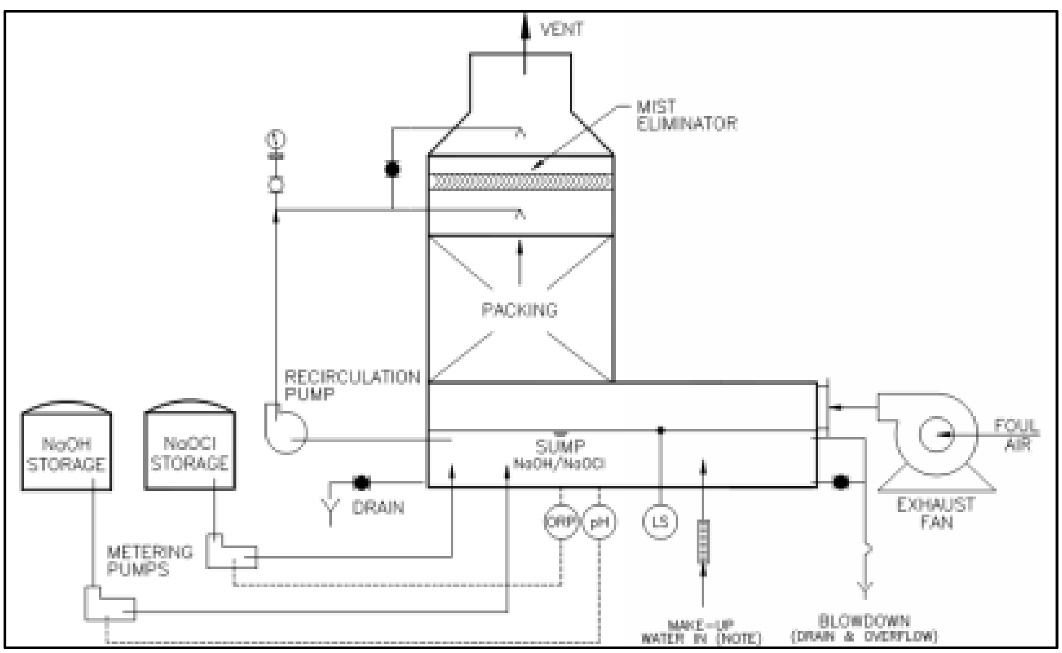

Figure 4-1
Process Flow Diagram for a Single Stage Packed Tower Chemical Scrubber

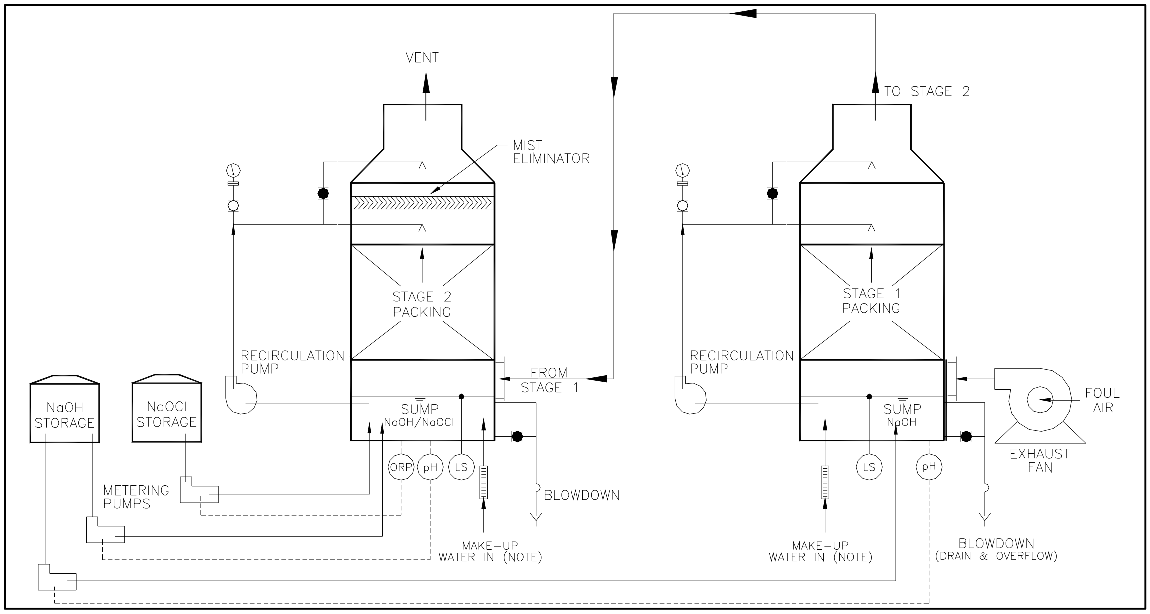

Figure 4-2
Process Flow Diagram for a Two Stage Packed Tower Chemical Scrubber

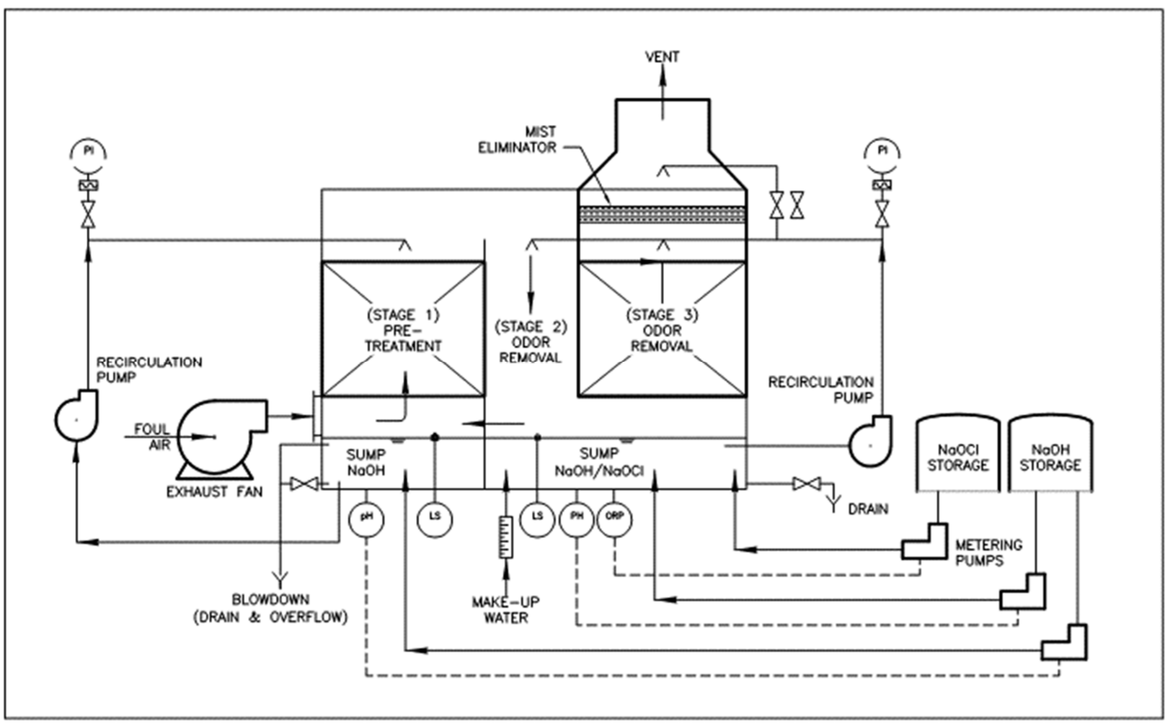

Figure 4-3
Process Flow Diagram for a Low Profile Multi-Stage Chemical Scrubber

4.3.2 Recommended Technology

It is recommended that low profile multi-stage chemical scrubbers be used as the basis for developing the layout of the FoP Odor Control Facility. This recommendation is based on the following:

- Single stage packed tower scrubbers are an effective technology to implement in applications where the H_2S levels in the odorous air are < 25 ppm. However, the H_2S levels for this Project could be as high as 130 ppm. Therefore, single stage packed tower scrubbers are not recommended.
- A two-stage packed tower scrubber can accommodate H_2S levels > 25 ppm. However, this type of scrubber will be taller, will have a larger footprint, and will have a higher capital cost than a low profile multi-stage scrubber.
- A low profile multi-stage scrubber is recommended because it can accommodate H_2S levels > 25 ppm and has the most compact design and lowest overall capital cost.

It should be noted that chemical scrubbers are maintenance intensive, requiring regular oversight and routine cleaning. A service contract should be considered to provide maintenance for pH and ORP sensors, fans, metering pumps, and recirculation pumps. In addition, the system should be acid washed and cleaned, when needed. With proper maintenance, the chemical scrubber system recommended for the FoP Odor Control Facility will provide consistently high performance odor treatment.

4.4 Equipment Sizing

The sizing of the chemical scrubber equipment was determined based on the ventilation rates and odor characteristics presented in Section 4.2. The required equipment sizing is summarized in Table 4-4.

As shown in Table 4-4, the FoP Odor Control Facility would need to consist of two parallel low profile multi-stage scrubbers, rated at 16,200 cfm each. Each scrubber would need to be equipped with one 40 hp ventilation fan and two 17.5 hp recirculation pumps. A brochure for a typical low profile multi-stage chemical scrubber of this size is included in Appendix K.

The scrubbers would require approximately 670 gallons per day (gpd) of 25% Sodium Hydroxide and 130 gpd of 12.5% Sodium Hypochlorite. Chemical storage tanks fitted with level sensors, fill ports, and drains would be required to store the chemicals required by the scrubbers. The design criteria for the chemical storage equipment are summarized in Table 4-4. The calculations used to determine the chemical demands are included in Appendix L.

Table 4-4 FoP Odor Control Facility Conceptual Design Criteria

Item	Value
Scrubber Units	
Number	2
Capacity, ea.	16,200 CFM
H_2S average Concentration (ppm)	40
Ventilation Fan	
Number	1 per scrubber
Motor Size, ea.	40 hp
Recirculation Pumps	
Number	2 per scrubber

Motor Size, ea.	17.5 hp
Chemical Demand	
25% Sodium Hydroxide (NaOH)	300 gpd
12.5% Sodium Hypochlorite (NaOCl)	400 gpd
Sodium Hydroxide Storage	
Storage Tank Volume	3,000 gal
Days of Storage	13
Sodium Hypochlorite Storage	
Storage Tank Volume	4,000 gal
Days of Storage	12

4.5 Facility Layout

A conceptual mechanical layout of the FOP Odor Control Facility is shown in Figure 4-4. A more detailed mechanical layout is included in Appendix M. A conceptual site plan showing the FoP Odor Control Facility relative to the new RLS and Headworks Facility is shown in Figure 3-1.

As shown in Figure 4-4, the chemical scrubbers are located on a pad with a curb that is sufficient to provide secondary containment. The chemical storage tanks are located adjacent to the chemical scrubbers with a secondary containment curb around them. Although not shown in Figure 4-4, a canopy should be provided over the chemical storage tanks to keep direct sunlight off the tanks.

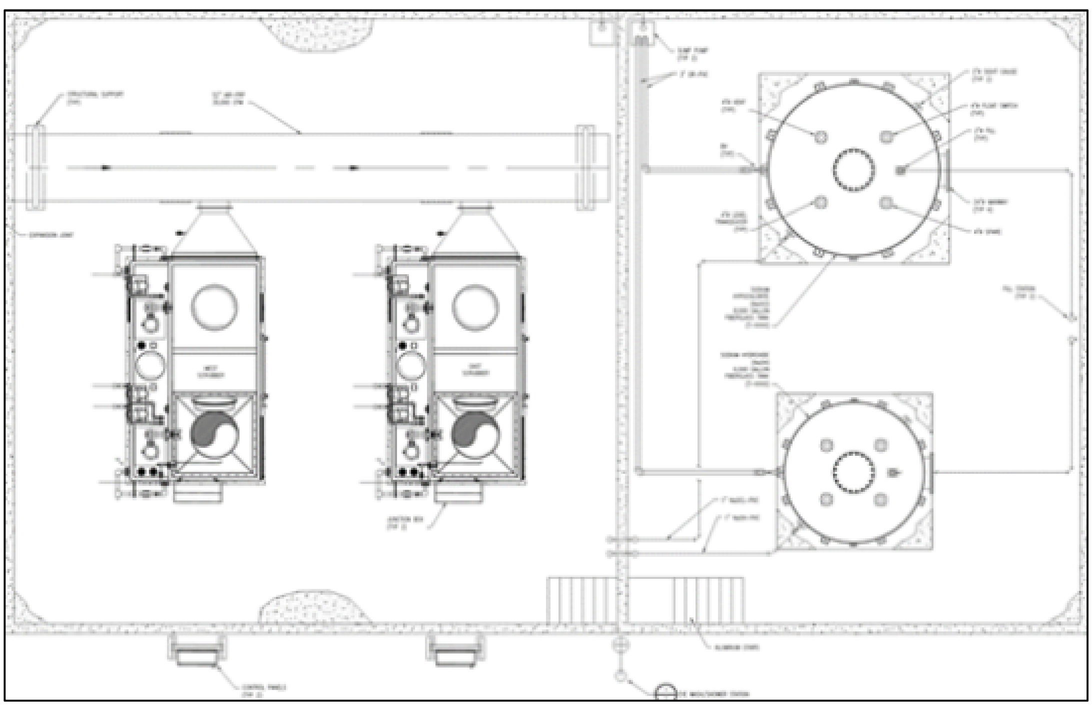

Figure 4-4
FoP Odor Control Facility Conceptual Layout

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Section 5

Detailed Design Considerations

5.1 Civil

5.1.1 Paved Areas

New pavement will need to be installed around the Headworks Facility to provide access for trucks that will be used to deliver and remove the screenings and grit dumpsters located in the Screenings and Grit Handling Equipment. The types of vehicles that are used for moving dumpsters are typically 35 feet long and have a turning radius of 35 feet. A site plan showing how trucks will access the dumpsters in the Screenings and Grit Handling Building, load them, and unload them is provided in Figure 5-1. The paved areas around the Headworks Facility will needs to be designed to allow enough space for the truck maneuvers shown in Figure 5-1.

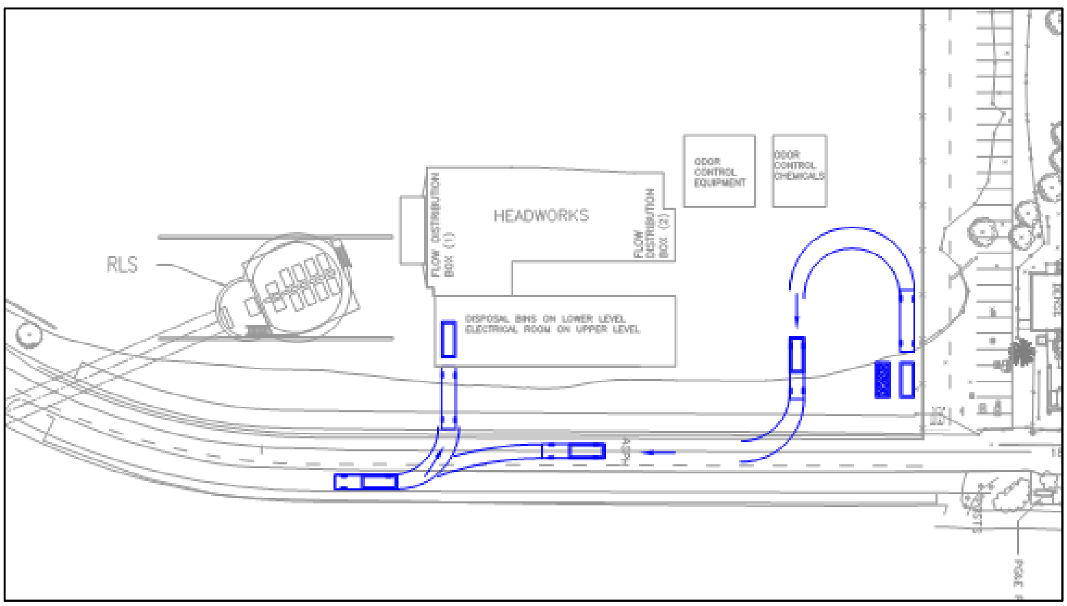

Figure 5-1
Site Plan and Vehicle Turning Radii

The paved areas will also need to be designed in accordance with the following codes and standards:

- *American Association of State Highway Transportation Officials (AASHTO) -A Policy on Geometric Design of Highways and Streets, 6th Edition, 2011 (Green Book.)*
- San Mateo County Green Streets Design Guidebook
- San Mateo County C.3 Stormwater Technical Guidance Manual

5.1.2 Yard Piping

New yard piping installed as part of the Headworks Facility will be designed per the following principles:

- Pipes will be sized based to convey design flows while providing appropriate flow velocities and minimizing headloss and settling.
- Pipe wall thicknesses are determined based on burial depth, trench dimensions, backfill material, traffic loading and insitu soil and groundwater conditions.
- Pipe trenches will be designed with appropriate bedding and backfill materials per local soil conditions.
- Utility design will take into consideration pertinent local, state and federal codes and industry standards.
- Differential settlement may occur between the ground and pile-supported buildings. This should be taken into consideration when designing connections between buried pipes located outside of a building and pipes connected to pile-supported structures.

5.2 Architectural

SVCW's wastewater treatment plant is located across the street from a residential development near the San Francisco Bay. The plant's architectural design should consider views from the local community.

5.3 Structural

The following key items should be considered in the final design of the structures:

- The Headworks and Electrical and Loadout Building is anticipated to require a separation between the structures because they vary in structural height and weight, stiffness, construction material, general layout and configuration, and anticipated behavior in a seismic event. They will be connected by a conveyor that will need to be detailed with connections at either end that can accommodate movement.
- The pipes connecting the RLS to the Headworks distribution structure should be provided with adequate pipe supports and flexible connections to accommodate anticipated differential movement between the structures.
- If odor control equipment is placed on exterior equipment slabs, consider founding the slabs on deep pile foundations.
- Soils on site are potentially corrosive to reinforced concrete, and the design should include means to mitigate these factors. Concrete shall be Type 2 and Type 5 to meet local soil conditions.

The strength, serviceability, quality of materials and design procedures will be in accordance with the codes and standards listed below:

- American Society of Civil Engineers (ASCE), ANSI/ASCE 7-10 – Minimum Design Loads for Buildings and Other Structures
- American Concrete Institute (ACI) Standards:
  - ACI 318-14, Building Code Requirements and Commentary for Reinforced Concrete
  - ACI 350-06, Code Requirements for Environmental Engineering Concrete Structures
  - ACI 350.3-06, Seismic Design of Liquid-Containing Concrete Wastewater Structures
  - ACI 350.1 Tightness Testing
  - ACI 530-13 Building Code for Masonry Structures
  - ACI 350.4 Design Considerations for Environmental Structures (Mechanical Vibration)
- American Institute of Steel Construction (AISC):
  - Manual of Steel Construction, Allowable Stress Design (ASD); Fourteenth edition;
  - AISC 341-10 Seismic Provisions for Steel Buildings, AISC 360-10 Specifications for Steel Buildings
- American Society for Testing and Materials (ASTM) standards
- The Aluminum Association:
  - Aluminum Design Manual (ADM) 2015.
- American Welding Society Structural Steel Welding Code (AWS) D1.1-10 and D1.4-11
- CMAA Crane Manufacturers Association of America – Specification No. 70 and 74 for Cranes

5.4 Mechanical

Mechanical equipment and piping shall be designed in accordance with the following standards:

- American Water Works Association (AWWA) applicable standards
- American National Standards Institute (ANSI) applicable standards
- American Society of Mechanical Engineers (ASME) applicable standards

5.5 Electrical

As the plant is constructed on low-lying land protected by a levee, critical equipment (such as electrical and controls) should be elevated above the flood elevation defined in Section 2.2.3. For example, the backup generator should be located on an elevated pad, with electrical equipment located on the second floor of the new Headworks building. Electrical equipment and instrumentation shall be designed to withstand a marine environment due to the facilities proximity to the San Francisco Bay. Electrical equipment shall also be designed to withstand the hydrogen sulfide (H_2S) and other sewer gases present at the site. The electrical design of the facility shall also conform to the following standards:

- American National Standards Institute (ANSI) standards
- Insulated Cable Engineers Association (ICEA) standards
- Institute of Electrical and Electronics Engineers (IEEE) standards
- International Society of Automation (ISA) standards
- California Electrical Code (CEC), 2016 edition based on National Electrical Code 2014
- California Energy Code 2016
- National Fire Protection Agency (NFPA 70E) Standard for Electrical Safety in the Workplace
- National Fire Protection Agency (NFPA 820) Standard for Fire Protection in Wastewater Treatment and Collection Facilities
- National Electrical Manufacturers Association (NEMA) standards
- Occupational Safety and Health Administration (OSHA) standards
- International Building Code (IBC) 2012, amended by state of California (CBC 2013)
- Acceptance Testing Specifications of Electrical Power Distribution Equipment and Systems, International Electrical Testing Association (NETA)
- National Fire Protection Association (NFPA) 70 (National Electrical Code), 2011 edition
- Underwriters Laboratories, Inc. (UL)
- Pacific Gas and Electric (PG&E)
- American Society for Testing and Materials (ASTM)
- Electrical Testing Laboratories (ETL)
- Illuminating Engineering Society of North America (IESNA)
- National Electrical Installation Standards (NEIS)
- National Electrical Contractor Association (NECA)
- Life Safety Code.
- National Electrical Safety Code.

5.6 Instrumentation and Control

The instrumentation and control systems shall conform to the following standards:

- SVCW Agency Automation – Instrumentation and Controls Standards.
- National Electrical Code (NEC) – Latest Revision of NEC as Amended by the State of California.
- International Society of Automation (ISA) standards
- National Electrical Manufacturers Association (NEMA) standards
- Underwriters Laboratories, Inc. (UL)
- American National Standards Institute (ANSI) standards
- Institute of Electrical and Electronic Engineers (IEEE) standards

5.7 Corrosion Protection

As discussed in Section 5.3, corrosive soils are present onsite. This needs to be considered in selected materials for buried portions of the Headworks Facility. Areas around chemical storage and metering facilities will also be corrosive. Concrete in these areas should be coated to prevent corrosion from vapors and chemical spills.

5.8 Security

The following security features will be included as part of the Headworks Facility

- Access to the plant will be controlled by fencing and gates with keycards. Only approved personal will be allowed to work around the equipment, and visitors will have the check in to the front office before entering the plant.
- New fencing will be installed as part of the Civil Improvements Project.

5.9 Safety

All facilities will be designed to meet Federal and State of California Occupational Health and Safety (USOSHA) and (CalOSHA) standards. Safety design features will include:

- Engineering controls
- Guarding of rotating machinery.
- Venting on chemical storage tanks.
- Chemical containment.
- National Fire Protection Association (NFPA), as well as all federal, state and local fire codes.

5.10 Outstanding Issues

Outstanding issues that need to be considered during detailed design include:

- The final selection of project delivery method and the way the various elements of the CIP are grouped together into discrete projects needs to be considered in developing an approach for driving the foundation piles around the RLS, Headworks Facility, and FoP Odor Control Facility.
- Based on the final selection of project delivery method and the way the various CIP projects are grouped together, consideration could be given to combining some of the facilities into the same structure.
- Additional grit sampling may be required to better characterize the grit in the plant influent during wet weather events. This will allow for a more optimal design of the grit separators and grit processing equipment.
- The method by which the Gravity Pipeline will be used for wet weather storage or dry weather diurnal equalization needs to be considered in developing final peak grit load design criteria.
- The manner in which the tunnel will be drained after storage events needs to be considered in developing final peak grit load design criteria.
- The need for a building over the screens should be re-evaluated during detailed design. The building adds significant cost to the project and increases the amount of foul air that needs to be treated by the FoP Odor Control Facility.
- The high-water elevation in the Influent Mix Box should be re-evaluated during detailed design. The high-water elevation assumed in this report is based on peak flows being conveyed over the overflow weir in the existing screening facility when the screens are off-line. There is a possibility that peak flows could be bypassed around the screens using the ILS pumps when the screens are offline. This approach would significantly reduce the high water elevation in the Influent Mix Box, resulting in a lowering of the Headworks Facility by several feet.
- The design airflows and odor characteristics for the FoP Odor Control Facility should be further evaluated during design of the facility

Section 6
Construction

6.1 Construction Staging

The construction staging areas proposed for all CIP Projects are shown in Figure 6-1. As shown, the staging areas for all projects will occur in the area of the existing ornamental ponds. The soils in this area are not current suitable for supporting equipment and materials that will be stored and moved around in the proposed construction staging areas. These soils will need to be stabilized and fill will need to be imported in order to use these areas for staging. These activities will be performed under a separate project, the Civil Site Improvement Project which is planned to be completed before construction for the headworks project begins.

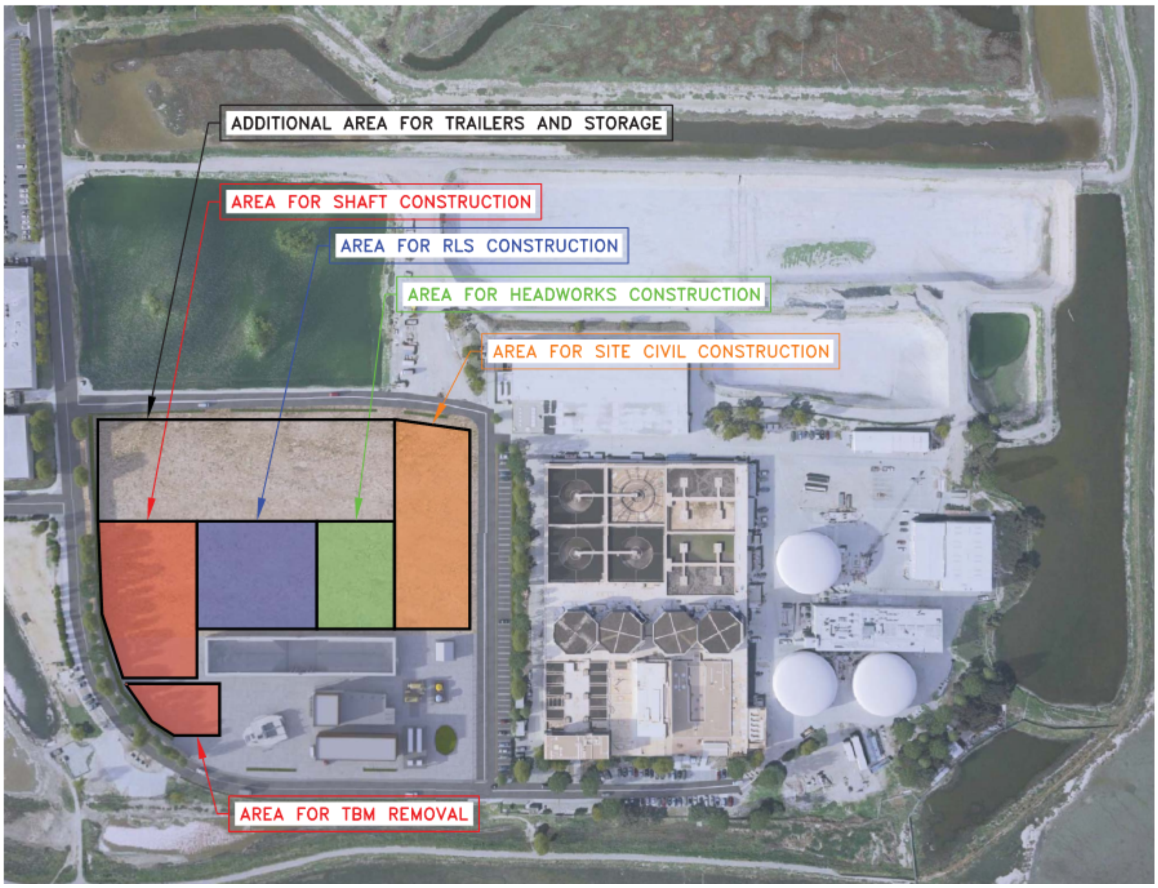

Figure 6-1
CIP Projects Construction Staging Areas

6.2 Construction Sequencing

The proposed Headworks Facility and FoP Odor Control Facility will be located immediately adjacent to the RLS and the ICPs. These facilities will also be physically connected to each other. Therefore, the sequencing of their construction will need to be closely coordinated.

The sequencing of construction of the Headworks Facility, the FoP Odor Control Facility, and adjacent facilities (RLS and ICP) is dependent on the project delivery method that SVCW chooses for executing these CIP projects. Therefore, the construction sequencing under both project delivery methods being considered is described below.

6.2.1 Sequencing Under Design-Build Project Delivery

As discussed in Section 1.3.2, if the CIP projects are executed under a design-build approach, the RLS, the Headworks Facility, and the FoP Odor Control Facility, and the ICPs will be constructed under a single contract. Under this approach, the sequence of construction will be as follows:

- The soils in the proposed staging area and the area around the RLS, Headworks Facility, FoP Odor Control Facility, and western end of the ICPs will be stabilized and fill will be brought into these areas under the Civil Site Improvements Project.
- The RLS shaft will be excavated and used as a receiving shaft for construction of the Gravity Pipeline. This work will be performed under the Gravity Pipeline Project.
- Once the Civil Site Improvements Project and the portion of the Gravity Pipeline that terminates at the RLS shaft are completed, construction of the RLS, Headworks Facility, FoP Odor Control Facility, and ICPs can begin. The sequence of construction of these facilities will be as follows:
  - The concrete RLS shaft will be constructed.
  - The piles needed around the RLS shaft, the Headworks Facility, the FoP Odor Control Facility will be driven. Installation of piles around the RLS shaft have the potential to damage the RLS shaft. However, the RLS shaft will be designed to withstand the force from the nearby pile installation.
  - Excavation for the structures that will extend below existing grade will be performed.
  - Concrete foundations and walls for major structure will be installed, then equipment pads will be poured.
  - Equipment and piping will be installed along with electrical, instrumentation, and control cables.
  - Programming, calibration, and testing will be performed.
  - Startup will occur

6.2.2 Early Headworks Construction Sequencing

As discussed in Section 1.3.2, if the CIP projects are executed under a design-bid-build approach, the Headworks and FoP Odor Control Facilities will be constructed under on one contract, the RLS will be constructed under another contract, and the ICPs will be constructed under a third contract. Under this approach, the Headworks and FoP Odor Control Facilities do not need to be constructed at the same time as the facilities adjacent to them. Therefore, SVCW investigated whether there were any benefits to constructing and starting up the Headworks and FoP Odor

Control Facilities before constructing the adjacent facilities. This approach is referred to as the Headworks Facility Early Startup. A conceptual layout of Headworks Early Startup approach, which allows dry weather flows to be sent to the Headworks Facility before the RLS is constructed, is shown in Figure 6-2.

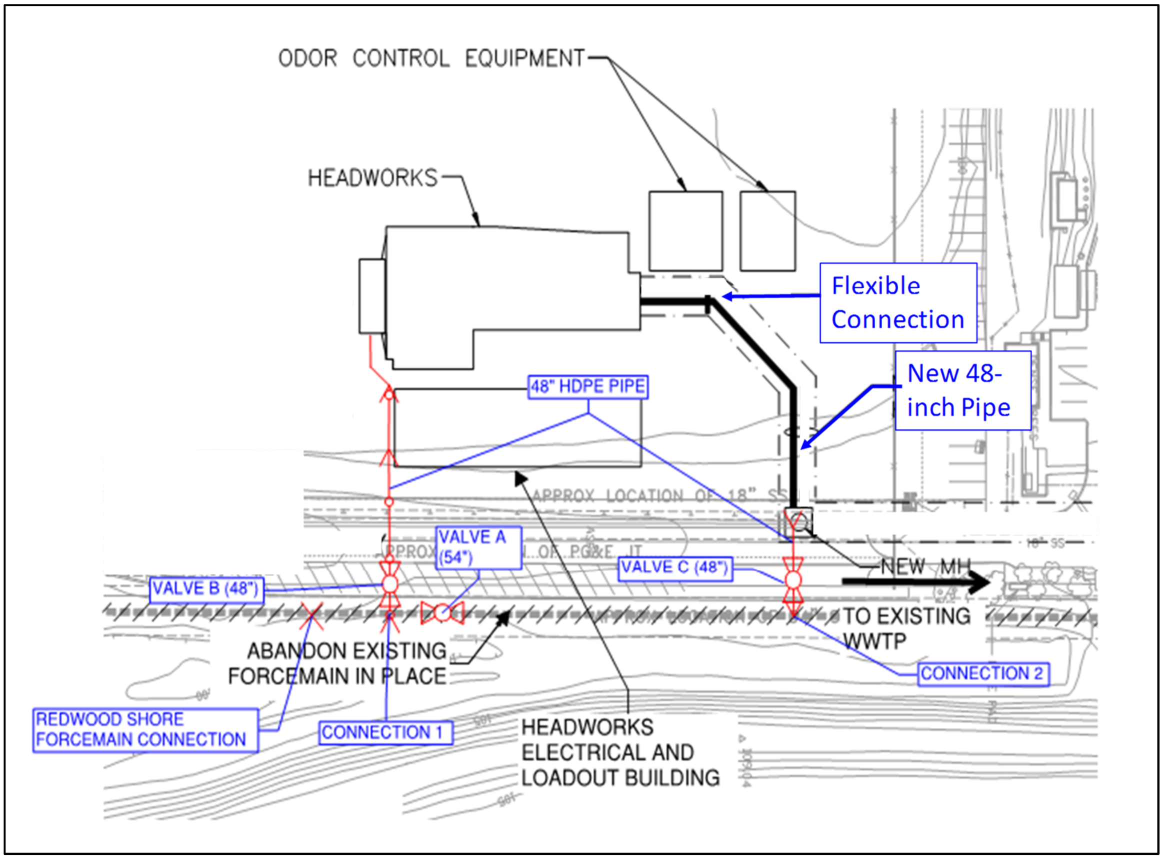

Figure 6-2
Conceptual Layout of Early Startup of Headworks and FoP Odor Control Facilities

Figure 6-2 includes the following facilities:

- The proposed Headworks Facility and FoP Odor Control Facilities.
- A portion of one of the ICP between the Headworks Facility and a manhole located near the existing entrance gate to the plant.
- New piping to connect the 18-inch Redwood Shores forcemain to the existing 54-inch forcemain.
- A new 48-inch HDPE pipe to convey raw sewage from the existing 54-inch forcemain at Connection Point 1 to the influent channel of the Headworks Facility.
- A new 48-inch HDPE pipe to convey screened and de-gritted sewage from the manhole at the end of the ICP back into the existing 54-inch forcemain.

- Connection Point 1 – This connection point includes a new 54-inch by 54-inch by 48-inch tee, a 54-inch valve on the existing 54-inch forcemain (Valve A), and a new 48-inch valve on the new 48-inch pipe (Valve B). The new valves and tee may need to be pile-supported.
- Connection Point 2 – This connection point includes a new 54-inch by 54-inch by 48-inch tee, and a new 48-inch valve on the new 48-inch pipe (Valve C). The new valve and tee may need to be pile-supported.

Under the configuration shown in Figure 6-2, the Headworks Facility would operate as follows:

- During dry weather conditions, raw sewage from the existing 54-inch forcemain will be diverted to the new Headworks Facility for preliminary treatment. Effluent from the Headworks will be sent back into the 54-inch forcemain using a portion of the ICP, where it will be conveyed to the Influent Mix Box. This will be accomplished by closing Valves A and opening Valves B and C.
- During wet weather conditions, raw sewage will not be diverted to the Headworks Facility. Since the Headworks Facility is at a higher elevation than the Influent Mix Box, sending wet weather flows to the Headworks Facility during interim operation would increase the pressure in the existing 54-inch force main most likely beyond its pressure rating. Therefore, wet weather flows will be conveyed through the existing 54-inch forcemain directly to the Influent Mix Box, bypassing the Headworks Facility. Under this scenario, operation of the influent conveyance and preliminary treatment facilities will match the existing operations. This will be accomplished by opening Valves A and closing Valves B and C.

The Headworks Facility Early Startup approach was evaluated in the Headworks Early Startup TM (Appendix N), prepared under TO 2015-04. The findings of this TM were as follows:

- The Headworks and FoP Odor Control Facilities can be constructed and started up potentially over a year and a half prior to construction and startup of the RLS and ICPs.
- Some additional facilities (valves, pipe connections, etc.) are required to implement the Headworks Early Startup approach.
- The Headworks Early Startup approach results in a lower construction cost for the Headworks and FoP Odor Control Facilities because they would be constructed over a year and a half earlier than under alternate approaches and the costs have this amount of time less to increase due to inflation.
- The Headworks Early Startup approach results in O&M cost savings because it allows SVCW to realize the benefits of improved screenings and grit removal much earlier than if construction of the Headworks Facility were delayed until after the Gravity Pipeline, RLS, and ICP are constructed.
- The cost of the additional facilities required to implement the Headworks Early Startup approach is more than offset by the cost savings associated with the approach. The net savings associated with the approach is approximately $1.0M.

Based on the findings of the Headworks Early Startup TM, SVCW is considering the Headworks Early Startup approach if the Design-Bid-Build delivery method were selected as the preferred method for executing the CIP Projects. Under this approach, the sequence of construction will be as follows:

- The soils in the proposed staging area and the area around the RLS, Headworks Facility, FoP Odor Control Facility, and western end of the ICPs will be stabilized and fill will be brought into these areas under the Civil Site Improvements Project.
- The piles needed around the RLS shaft, the Headworks Facility, the FoP Odor Control Facility will be driven.
- Excavation for the structures that will extend below existing grade will be performed.
- Concrete foundations and walls for major structure will be installed, then equipment pads will be poured.
- Equipment and piping will be installed along with electrical, instrumentation, and control cables.
- Programming, calibration, and testing will be performed well in advance of other systems such as the RLS therefore relieving SVCW from the extreme complexity of multi critical systems start up and acceptance.
- Startup will occur once all above steps have been completed.

6.3 Schedule

The following production schedule may be seen in Table 6-1. These dates are based on Version 26 of the Program Schedule, dated December, 2016. Note that this schedule assumes the sequence outlined in Section 6.1.2.

Table 6-1 FoP and Headworks Schedule*

Task	Start Date	End Date
Drain and Dry FoP Pond (Start after SEP 1 and end by JAN 31)	Oct 24, 2016	Dec 27, 2016
Disc FoP Pond to assist drying	Jul 3,2017	Aug 2, 2017
FoP Civil Site Improvements Phase 1 Soil Stabilization (Dry Weather work MAY 15 - OCT 15)	Aug 3,2017	Nov 29, 2017
FoP Civil Site Improvements Phase 2 Paving, Grading, Site Preparation (Dry Weather work MAY 15 - OCT 15)	Nov 1, 2017	Feb 2, 2018
FoP Civil Site Improvements Phase 3 Storm Drain Installation	Apr 15, 2021	Oct 22, 2021
Headworks Bid and Award	Oct 11, 2018	Feb 18, 2019
Headworks Shop Drawings	Feb 19, 2019	Aug 23, 2019
Headworks Piles	Feb 19, 2019	Jun 21, 2019
Headworks Construction	Jun 24, 2019	Jan 12, 2021
Headworks Startup and Commissioning, assumes temporary pipeline to the 54" Force Main	Jan 13, 2021	Apr 14, 2021
FoP Civil Site Improvements Phase 3 Storm Drain Installation	Apr 15, 2021	Oct 22, 2021

Table 6-1 FoP and Headworks Schedule*

Task	Start Date	End Date
FoP Civil Site Improvements - Phase 4 Final Pavement, Landscape, Wall	May 12, 2022	Sep 16, 2022
FoP Final Demo and Final Cleanup	Sep 19, 2022	Feb 7, 2023

*Schedule Under Current Design/Bid/Build Agreement

6.4 Construction Energy

Energy is consumed in construction in the form of heavy equipment, generators and lighting. Construction equipment including excavators, and pile drivers, as well as trucks hauling materials to the site burn diesel fuel. Transportation to the jobsite generally requires automobiles powered by gasoline, as do onsite generators. Greenhouse Gas (GHG) emissions associated with the construction of the Headworks facilities are summarized in Table 6-2 below.

Table 6-2 Project Component GHG

Project Component	GHG (Metric Tons)
Headworks Facility	147
Flow Diversion Facility	133
RLS Shaft	753
Total	**1,033**

Section 7

Operation & Maintenance

7.1 Control Descriptions

The sections below describe how the major process equipment will be controlled.

7.1.1 Screen Facility

As discussed in Section 3.6.2, the Screening Facility will consist of four screens. One or two screens will be online during dry weather operations and all four screens will be online during wet weather operations. The screening facility will be changed from two screen operation to four screen operation manually on a seasonal basis.

When in two screen operation, both screens will normally be in operation. If a screen needs to be taken off-line for maintenance, one of the wet weather screens will need to be brought on-line. During four screen operation, three screens would normally be in operation. The fourth screen would be brought into operation, if one of the other screens needs to be taken off-line for maintenance.

The rakes that remove the material accumulated on the face of the screens will have the ability to operate at either low speed or high speed. The rakes will normally operate at low speed, but will increase to high speed when the differential level across the face of the screens increases above an operator adjustable set-point.

7.1.2 Grit Separators

Grit separators will be brought on and offline manually on a seasonal basis. During the dry weather season, one or two grit separators would normally be in operation. During the wet weather season, all three grit separators will be in operation.

As discussed in Sections 3.6.6 and 3.6.7, there will be one grit pump and grit washer dedicated to each grit separator. The grit pump and washers will be in continuous operation whenever their respective grit separators are in operation.

7.1.3 Screenings and Grit Bins

Screenings and grit bins will be emptied manually. When a bin is filled, it will be hauled away on a truck to a disposal facility where it will be emptied. An empty bin will be installed in the place of the bin that was removed. As discussed in Section 3.0, the grit bins will need to be changed out once every two days and the screenings bins will need to be changed out once every 5 days.

7.2 Annual Operation and Maintenance (O&M)

The annual requirements for O&M staff labor, power, chemical usage, and debris hauling associated with the Headworks Facility are described in detail below.

7.2.1 Labor

Table 7-1 includes the annual operation and maintenance activities associated with the Headworks Facility as well as the labor associated with each activity and the frequency of each activity. The total number of labor hours was divided by 2,080 hours to determine the number of Full-Time Equivalents (FTE) of labor required. The cost associated with the labor was then calculated based on a cost of $150,000/FTE, per the Life Cycle Cost Guidance TM (Appendix O).

Table 7-1 Itemized Labor Costs

Activity	Staff	Frequency		Total Annual
	Hours	No.	Basis	Staff Hours
Sampling				
Collection and Equip Maintenance	0.5	1	per day	182.5
Screens				
Inspection/Rounds	0.25	1	per day	91.25
Area Housekeeping	1	1	per day	365
PM	0.5	1	per week /screen	104
Annual Inspection	8	2	per year /screen	64
Motorized gates				
Inspection	0.5	2	per year /gate	16
Channel Cleaning	2	1	per week	104
Grit Handling				
Inspection/Rounds	0.25	1	per day	91.25
Area housekeeping	0.5	1	per day	182.5
Pump Maintenance	0.5	1	per day	182.5
Coanda Cones - repair/adjust	0.5	1	per month	6
Screenings Washer Compactors				
Inspection/Rounds	0.25	1	per day	91.25
PM	0.5	2	per week	52
Major repair	4	1	per month	48
Dumpster loading				
Dumpster moving	5	3	per week	78
Dumpster area house keeping	0.25	1	per day	91.25
Dumpster repair	8	2	per year	16
Odor Control				
Oversight	0.25	1	per day	91.25
Maintenance	1	1	per week	52
Calibration	1	1	per month	12
Acid Wash	4	2	per year	8
Other Mechanical Systems				
Inspection/maintenance	1	1	per week	52
Electrical Gear Maintenance				
Inspection/maintenance	1	1	per week	52
Instrument Controls				
Calibration, Programming, etc.	1	1	per week	52
Maintenance Management				
Work Orders, Procurement, etc.	1	1	per week	52
			Total Staff Hours	2,136.75
			FTEs	1.0
			Total Labor Cost	$ 154,093

7.2.2 Power

The power costs associated with the Headworks Facility Project are itemized in Table 7-2 below. Power costs for the project are determined by multiplying the estimated annual power usage of each type of equipment by the electrical cost. For the Headworks Facility Project, the electric cost is $0.129 per kilowatt-hour used, per the Life Cycle Cost Guidance TM (Appendix O).

Table 7-2 Power Costs for the SVCW Headworks Facility

Equipment	Power Demand (Hp)	Total No. of Units	Average No. Operating	Total Power Use (kWh/yr.)	Annual Power Cost
Process					
Screens	5	4	1	42695	$ 5,507.65
Washer Compactors	12.5	3	1	106737	$ 13,769
Grit Pumps	7.5	4	2	128085	$ 16,523
Grit Classifier	2	4	2	34156	$ 4,406
Grit Conveyor	5	2	1	42695	$ 5,508
Gates					
Slide Gates	2	16	0	0	$ -
HVAC					
Supply Fan	10	2	2	170780	$ 22,031
Supply Fan	5	4	4	170780	$ 22,031
Supply Fan	3	1	1	25617	$ 3,305
Supply Fan	2	2	2	34156	$ 4,406
Exhaust Fan	5	3	3	128085	$ 16,523
Exhaust Fan	3	2	2	51234	$ 6,609
Exhaust Fan	2	1	1	17078	$ 2,203
Odor Control					
Odor Control Fan	40	2	1	341560	$ 44,061
Recirculation Pump	17.5	2	1	149432	$ 19,277
Misc.					
Door	0.5	6	0	0	$ -
Sump Pump	20	2	1	170780	$ 22,031
Valves	1	2	0	0	$ -
Screenings Bridge Crane	20	1	0	0	$ -
PTF to Diversion Structure	2	1	0	0	$ -
Pressure Washer	20	1	0	0	$ -
				Total	$ 188,912

7.2.3 Chemicals

Chemical costs associated with the Headworks Facility Project are itemized in Table 7-3 below. As shown, the Headworks Facility will require 25 percent Sodium Hydroxide (NaOH) and 12.5 percent Sodium Hypochlorite (NaOCl) for odor control.

Table 7-3 Chemical Costs for the SVCW Headworks Facility

Chemical Name	Average Daily Demand (gpd)	Total Annual Demand (gal)	Cost per Gallon	Total Cost
25% NaOH	400	146,000	$0.85	$ 124,000
12.5% NaOCl	450	164,250	$1.20	$ 197,000
			Total	$ 321,000

7.2.4 Debris Hauling

Debris hauling costs are the fees associated with hauling and disposal of screenings and grit. These costs are listed in Table 7-4. The annual generation of grit and screenings shown in Table 7-4 is based on the screenings loads presented in Section 3.6.4. Hauling Costs were based on an average of hauling costs for wastewater treatment facilities in the area. Hauling costs were assumed to remain constant over the 50-year life cycle period, not including escalation. However, these costs could change in the future, due to landfill availability and regulations.

Table 7-4 Debris Hauling Costs for SVCW Headworks Facility

Source	Annual Generation (tons/yr.)	Haul Cost ($/wet ton)	Total Cost
Grit	80.3	100	$ 8,000
Screenings	511	100	$ 51,000
		Total	$ 59,000

7.3 Periodic Equipment Rehabilitation & Replacement

The rehabilitation and replacement activities associated with the Headworks Facility are itemized in Table 7-5, below. The frequency and cost associated with each activity are also shown. Rehabilitation and replacement activities and costs were determined on an equipment-by-equipment basis, based on typical equipment lifespan and costs.

Table 7-5 Rehabilitation and Replacement Costs for SVCW Headworks Facility

Equipment	No. of Units	Type of Rehabilitation	No.	Basis	Cost of Rehab
Screens	4	Major Overhaul	1	every 8 years /screen	$ 160,000.00
Motorized Gate	16	Repair	2	every 5 years /gate	$ 55,385
Grit Pump	4	Pump overhaul	2	every year /pump	$ 4,615
Grit Pump	4	Replace Impeller	1	every 10 years	$ 30,000
Grit Basin	4	Repair	1	every 5 years /basin	$ 4,615
Sump Pump	2	Replacement	1	every 10 years /pump	$ 400,000
Grit Washer	4	Replacement	1	every 20 years /unit	$ 640,000
Washer Compacter	3	Replacement	1	every 20 years /unit	$ 180,000
Chemical Scrubber	2	Replacement	1	every 20 years	$ 600,000
Chemical Scrubber	2	Replace Media	1	every 5 years	$ 24,000
Chemical Scrubber	3	Replace Sensor	1	every 3 years	$ 2,400

Table 7-5 Rehabilitation and Replacement Costs for SVCW Headworks Facility (continued)

Equipment	No. of Units	Type of Rehabilitation	No.	Basis	Cost of Rehab
Chemical Scrubber	1	Acid Wash	2	per year	$ 4,500
Chemical Scrubber	2	Replace Fan Belt	1	every 5 years	$ 3,000
Chemical Scrubber	4	Rehab Recirc. Pump	1	every 5 years	$ 60,000
Chemical Metering Pump	2	Replacement	1	every 5 years	$ 3,500

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Section 8

Life Cycle Costs

8.1 Overview

This section presents the 50-Year LCC associated with the Headworks Facility that will be installed as part of the SVCW CIP. The LCCs are for a 50-year period from 2016 to 2066. The LCCs were prepared in accordance with SVCW's Life Cycle Cost Analysis Guidelines TM, dated July 13, 2016, (Appendix O). This work is being completed as part of the SVCW Headworks Facility Project. LCCs include the following cost components:

- Capital Costs
- Annual O&M Costs, including
  - Labor
  - Power
  - Chemicals
  - Debris Hauling
- Periodic Equipment Rehabilitation and Replacement Costs

The cost for each of the components listed above were developed for each year over a 50-year period between 2016 and 2066 in present day dollars, as described in Section 8.2 through 8.8 below. The Net Present Value of the cash flow over that 50-year period was then calculated for all the cost components as described in Section 7.3.

8.2 Capital Cost

8.2.1 Construction Costs

An Opinion of Probable Construction Cost (OPCC) of the Headworks Facility Project is summarized in Table 8-1. A detailed breakdown of costs is included in Appendix P. The OPCC was prepared using the computerized estimating system Sage Timberline Estimating System (TES). The system operates using a customized database that includes costs for over 130,000 items, which are continuously updated. Current prevailing wage rates were used in the estimate to calculate labor based on the intended project construction bid period. Construction equipment pricing was based on Primedia Blue Book Equipment Rates adjusted for the bid period. Material pricing was based on the TES database in addition to bid and budget pricing obtained by CDM Smith and adjusted to market conditions. Major equipment prices were based on vendor quotes escalated to midpoint of construction. The OPCC included the following markups on the direct costs:

- Sales Tax (Material): 9 percent
- Field Direct Cots: 10 percent of direct costs + sales tax
- Field Overhead & Profit: 5 percent of direct costs + sales tax + field direct costs
- Home Office Overhead & Profit: 10 percent of direct costs + sales tax + field direct costs
- General Contractor Bond: 2 percent of direct costs + above markups
- Builder's Risk Insurance: 1 percent of direct costs + above markups
- General Liability Insurance: 1.5 percent of direct costs + above markups

The level of accuracy of the OPCC is consistent with the Association for the Advancement of Cost Engineering (AACE) best practice for a Class IV estimate which defines project definition between 1-15 percent. The expected level of accuracy of a Class IV OPCC ranges from -30 percent for the lower range of cost and +50 percent for the high range.

Table 8-1 Opinion of Probable Cost of Construction Summary

Area	Opinion of Probable Cost of Construction ($M)
Site Work	1.5
Diversion Box 1	0.7
Screening Facility	5.4
Screening Building	0.9
Grit Removal Facility (Vortex Tray Separators & Grit Pumps)	8.6
Diversion Box 2	1.5
Screenings/Grit Handling Facility	7.2
Odor Control	2.3
Electrical/Mechanical Building (without RLS VFDs)	2.8
Plant Drain Pump Station	0.5
Total	**31.4**

Notes:

1. Costs include the following markups:
   Sales Tax: 9 percent
   Field Indirect Costs: 10 percent
   Field Overhead & Profit: 5 percent
   Home Office Overhead & Profit: 10 percent
   General Contractor Bonds: 2 percent
   Builder's Risk Insurance: 1 percent
   General Liability Insurance: 1.5 percent
2. SVCW will apply 20 percent to this OPCC for a construction contingency, but the 20 percent markup is not included in the costs shown in this table
3. SVCW will apply 2-5 percent to this OPCC for change order during construction, but the 2-5 percent markup is not included in the costs shown in this table.
4. SVCW will escalate costs to the midpoint of construction, but the escalation is not shown in this table

8.2.2 Total Project Capital Costs

The capital cost, in 2016 dollars, is calculated based on the project's construction cost, project contingency, soft costs, and market fluctuations, per Equation 1, below. The result from Equation 1 is then escalated to the mid-point of construction.

Equation 1 – Capital Costs

$$Capital\ Cost = Construction\ Cost * (1 + Project\ Contingency + \sum Soft\ Cost + Market\ Fluctuations)$$

The calculation of the capital cost is summarized in Table 8-2 below. As shown, the capital cost was determined to be between \$57.5M and \$64.6M, depending on market fluctuations.

Table 8-2 SVCW Headworks Facility Capital Cost

	Rate
Raw Construction Cost (2016 Dollars)[1]	$31,400,000
Project Contingency[2]	25%
Soft Costs[2]	
CM, ESDC, Testing, Inspection	18%
Contract Change Orders (CCO)	5 %
Planning	5%
Design	10%
Project Management	5%
Market Fluctuations	
Low	-5%
Base	0%
High	15%
Escalation[2]	4%
Mid-Point of Construction[3]	2019
Capital Cost (2019 Dollars)	
Low Market Fluctuation	$57,500,000
Base Market Fluctuation	$59,300,000
High Market Fluctuation	$64,600,000

[1] Based on the construction costs presented in Section 8.2.1

[2] Based on guidance in the Life Cycle Cost Analysis Guidelines TM, dated July 2016.

[3] Based on CIP Program Schedule Version #21, dated July 2016

8.3 Annual Operation & Maintenance Costs

The annual requirements for O&M staff labor, power, chemicals, and debris hauling are detailed in Section 7.2. A summary of the annual costs for each of these items is included in Table 8-3.

Table 8-3 SVCW Headworks Facility Capital Cost

Item	Annual Cost
O&M Staff Labor	$154,000
Power	$189,000
Chemicals	$321,000
Debris Hauling	$59,000
Total	$723,000

8.4 Periodic Equipment Rehabilitation and Replacement Costs

The costs for periodic equipment rehabilitation and replacement are presented in Section 7.3.

8.5 Net Present Value (NPV) Calculations

NPV of the cost components discussed in Sections 8.2, 8.3, and 8.4 was calculated in three steps. First, the annual O&M costs and periodic rehabilitation and replacement costs for each year from 2016 to 2066 were tabulated based on the information presented in Section 8.3 and 8.4, in terms of 2016 dollars. The tabulated costs are shown in Table 8-4 below.

Next, the costs for each year were escalated to the year in which the cost would be incurred using Equation 2. The escalated costs for each year are shown in Table 8-5 below.

Equation 2 – Costs Before Year of Beneficial Use

$$FV = PV * (1 + i)^{(Y_n - Y_{2016})}$$

Where:

FV= Future Value
PV = Present Value
i = Escalation (4 percent)
Y_n = Year of Cost Occurrence
Y_{2016} = Present Year (2016)

The NPV of the escalated costs were then determined by discounting the costs to the Year of Beneficial Use, using Equation 3. The NPV of the O&M costs for each year are shown in Table 8-6 below. For this LCC analysis, the Year of Beneficial Use was assumed to be 2022. Discounting was performed, per Equation 3, on all future costs occurring after the Year of Beneficial Use. All costs incurred before the Year of Beneficial Use are considered "sunk costs" and are calculated using Equation 2 and then added to the sum of costs calculated with Equation 3 to determine the 50-year LCC at the Year of Beneficial Use.

Equation 3 – Discounting Function

$$Z_i = FV_i * (1 + r)^{-(Y_n - Y_b)}$$

Where:

Z_i= Future Cost at Year of Beneficial Use
FV_i = Future Value, as calculated by Equation 1
r = Discount Rate (7 percent for rehab and replacement, 3 percent for all else)
Y_n = Year of Cost Occurrence
Y_b = Year of Beneficial Use

Table 8-3 O&M Costs for SVCW Headworks Facility for Years 2016 – 2066 (2016 dollars).

Year	Labor	Power	Chemicals	Debris Hauling	Rehab & Replace
2016	$0	$0	$0	$0	$0
2017	$0	$0	$0	$0	$0
2018	$0	$0	$0	$0	$0
2019	$0	$0	$0	$0	$0
2020	$154,093	$94,456	$160,600	$29,565	$4,558
2021	$154,093	$188,912	$321,200	$59,130	$9,115
2022	$154,093	$188,912	$321,200	$59,130	$9,115
2023	$154,093	$188,912	$321,200	$59,130	$11,515
2024	$154,093	$188,912	$321,200	$59,130	$9,115
2025	$154,093	$188,912	$321,200	$59,130	$159,615
2026	$154,093	$188,912	$321,200	$59,130	$11,515
2027	$154,093	$188,912	$321,200	$59,130	$9,115
2028	$154,093	$188,912	$321,200	$59,130	$169,115
2029	$154,093	$188,912	$321,200	$59,130	$11,515
2030	$154,093	$188,912	$321,200	$59,130	$589,615
2031	$154,093	$188,912	$321,200	$59,130	$9,115
2032	$154,093	$188,912	$321,200	$59,130	$11,515
2033	$154,093	$188,912	$321,200	$59,130	$9,115
2034	$154,093	$188,912	$321,200	$59,130	$9,115
2035	$154,093	$188,912	$321,200	$59,130	$162,015
2036	$154,093	$188,912	$321,200	$59,130	$169,115
2037	$154,093	$188,912	$321,200	$59,130	$9,115
2038	$154,093	$188,912	$321,200	$59,130	$11,515
2039	$154,093	$188,912	$321,200	$59,130	$9,115
2040	$154,093	$188,912	$321,200	$59,130	$2,009,615
2041	$154,093	$188,912	$321,200	$59,130	$11,515
2042	$154,093	$188,912	$321,200	$59,130	$9,115
2043	$154,093	$188,912	$321,200	$59,130	$9,115
2044	$154,093	$188,912	$321,200	$59,130	$171,515
2045	$154,093	$188,912	$321,200	$59,130	$159,615
2046	$154,093	$188,912	$321,200	$59,130	$9,115
2047	$154,093	$188,912	$321,200	$59,130	$11,515
2048	$154,093	$188,912	$321,200	$59,130	$9,115
2049	$154,093	$188,912	$321,200	$59,130	$9,115
2050	$154,093	$188,912	$321,200	$59,130	$592,015
2051	$154,093	$188,912	$321,200	$59,130	$9,115
2052	$154,093	$188,912	$321,200	$59,130	$169,115
2053	$154,093	$188,912	$321,200	$59,130	$11,515
2054	$154,093	$188,912	$321,200	$59,130	$9,115
2055	$154,093	$188,912	$321,200	$59,130	$159,615
2056	$154,093	$188,912	$321,200	$59,130	$11,515
2057	$154,093	$188,912	$321,200	$59,130	$9,115
2058	$154,093	$188,912	$321,200	$59,130	$9,115
2059	$154,093	$188,912	$321,200	$59,130	$11,515
2060	$154,093	$188,912	$321,200	$59,130	$2,169,615
2061	$154,093	$188,912	$321,200	$59,130	$9,115
2062	$154,093	$188,912	$321,200	$59,130	$11,515
2063	$154,093	$188,912	$321,200	$59,130	$9,115
2064	$154,093	$188,912	$321,200	$59,130	$9,115
2065	$154,093	$188,912	$321,200	$59,130	$162,015
2066	$154,093	$188,912	$321,200	$59,130	$9,115
Total	$7,242,350	$8,784,430	$14,935,800	$2,749,545	$7,174,365

Table 8-4 O&M Costs for SVCW Headworks Facility for Years 2016 – 2066 (Future Values).

Year	Labor	Power	Chemicals	Debris Hauling	Rehab & Replace
2016	$0	$0	$0	$0	$0
2017	$0	$0	$0	$0	$0
2018	$0	$0	$0	$0	$0
2019	$0	$0	$0	$0	$0
2020	$180,266	$110,500	$187,879	$34,587	$5,332
2021	$187,477	$229,841	$390,789	$71,941	$11,090
2022	$194,976	$239,035	$406,420	$74,818	$11,534
2023	$202,775	$248,596	$422,677	$77,811	$15,153
2024	$210,886	$258,540	$439,584	$80,923	$12,475
2025	$219,322	$268,881	$457,168	$84,160	$227,182
2026	$228,095	$279,637	$475,454	$87,527	$17,046
2027	$237,218	$290,822	$494,473	$91,028	$14,033
2028	$246,707	$302,455	$514,252	$94,669	$270,759
2029	$256,575	$314,553	$534,822	$98,456	$19,174
2030	$266,838	$327,135	$556,214	$102,394	$1,021,023
2031	$277,512	$340,221	$578,463	$106,490	$16,416
2032	$288,612	$353,830	$601,602	$110,749	$21,568
2033	$300,157	$367,983	$625,666	$115,179	$17,756
2034	$312,163	$382,702	$650,692	$119,787	$18,466
2035	$324,650	$398,010	$676,720	$124,578	$341,342
2036	$337,636	$413,931	$703,789	$129,561	$370,553
2037	$351,141	$430,488	$731,940	$134,744	$20,772
2038	$365,187	$447,707	$761,218	$140,133	$27,291
2039	$379,794	$465,616	$791,667	$145,739	$22,467
2040	$394,986	$484,240	$823,333	$151,568	$5,151,255
2041	$410,786	$503,610	$856,267	$157,631	$30,698
2042	$427,217	$523,754	$890,517	$163,936	$25,272
2043	$444,306	$544,704	$926,138	$170,494	$26,283
2044	$462,078	$566,492	$963,184	$177,313	$514,324
2045	$480,561	$589,152	$1,001,711	$184,406	$497,785
2046	$499,783	$612,718	$1,041,779	$191,782	$29,565
2047	$519,775	$637,227	$1,083,450	$199,453	$38,843
2048	$540,566	$662,716	$1,126,788	$207,432	$31,977
2049	$562,188	$689,225	$1,171,860	$215,729	$33,256
2050	$584,676	$716,794	$1,218,734	$224,358	$2,246,294
2051	$608,063	$745,465	$1,267,484	$233,332	$35,970
2052	$632,385	$775,284	$1,318,183	$242,666	$694,038
2053	$657,681	$806,295	$1,370,910	$252,372	$49,149
2054	$683,988	$838,547	$1,425,747	$262,467	$40,461
2055	$711,348	$872,089	$1,482,777	$272,966	$736,843
2056	$739,802	$906,973	$1,542,088	$283,884	$55,286
2057	$769,394	$943,252	$1,603,771	$295,240	$45,514
2058	$800,169	$980,982	$1,667,922	$307,049	$47,334
2059	$832,176	$1,020,221	$1,734,639	$319,331	$62,189
2060	$865,463	$1,061,030	$1,804,025	$332,105	$12,185,678
2061	$900,082	$1,103,471	$1,876,186	$345,389	$53,245
2062	$936,085	$1,147,610	$1,951,233	$359,204	$69,954
2063	$973,528	$1,193,514	$2,029,282	$373,572	$57,589
2064	$1,012,469	$1,241,255	$2,110,454	$388,515	$59,893
2065	$1,052,968	$1,290,905	$2,194,872	$404,056	$1,107,108
2066	$1,095,087	$1,342,541	$2,282,667	$420,218	$64,780
Total	$23,965,598	$29,270,548	$49,767,490	$9,161,743	$26,472,014

Table 8-5 O&M Costs for SVCW Headworks Facility for Years 2016 – 2066 (Net Present Value).

Year	Labor	Power	Chemicals	Debris Hauling	Rehab & Replace
2016	$0	$0	$0	$0	$0
2017	$0	$0	$0	$0	$0
2018	$0	$0	$0	$0	$0
2019	$0	$0	$0	$0	$0
2020	$180,266	$110,500	$187,879	$34,587	$5,332
2021	$187,477	$229,841	$390,789	$71,941	$11,090
2022	$194,976	$239,035	$406,420	$74,818	$11,534
2023	$196,869	$241,355	$410,366	$75,545	$14,162
2024	$198,781	$243,699	$414,350	$76,278	$10,896
2025	$200,710	$246,065	$418,373	$77,019	$185,449
2026	$202,659	$248,454	$422,435	$77,766	$13,004
2027	$204,627	$250,866	$426,536	$78,521	$10,005
2028	$206,613	$253,301	$430,678	$79,284	$180,418
2029	$208,619	$255,761	$434,859	$80,054	$11,941
2030	$210,645	$258,244	$439,081	$80,831	$594,245
2031	$212,690	$260,751	$443,344	$81,616	$8,929
2032	$214,755	$263,282	$447,648	$82,408	$10,964
2033	$216,840	$265,839	$451,994	$83,208	$8,436
2034	$218,945	$268,419	$456,382	$84,016	$8,199
2035	$221,071	$271,026	$460,813	$84,832	$141,645
2036	$223,217	$273,657	$465,287	$85,655	$143,707
2037	$225,384	$276,314	$469,805	$86,487	$7,529
2038	$227,572	$278,996	$474,366	$87,326	$9,244
2039	$229,782	$281,705	$478,971	$88,174	$7,112
2040	$232,013	$284,440	$483,622	$89,030	$1,524,071
2041	$234,265	$287,202	$488,317	$89,895	$8,488
2042	$236,540	$289,990	$493,058	$90,767	$6,531
2043	$238,836	$292,805	$497,845	$91,649	$6,348
2044	$241,155	$295,648	$502,678	$92,538	$116,090
2045	$243,496	$298,519	$507,559	$93,437	$105,006
2046	$245,860	$301,417	$512,486	$94,344	$5,829
2047	$248,247	$304,343	$517,462	$95,260	$7,157
2048	$250,657	$307,298	$522,486	$96,185	$5,506
2049	$253,091	$310,281	$527,559	$97,119	$5,352
2050	$255,548	$313,294	$532,680	$98,062	$337,848
2051	$258,029	$316,336	$537,852	$99,014	$5,056
2052	$260,534	$319,407	$543,074	$99,975	$91,174
2053	$263,064	$322,508	$548,347	$100,946	$6,034
2054	$265,618	$325,639	$553,670	$101,926	$4,643
2055	$268,197	$328,800	$559,046	$102,915	$79,015
2056	$270,801	$331,993	$564,473	$103,914	$5,541
2057	$273,430	$335,216	$569,954	$104,923	$4,263
2058	$276,084	$338,470	$575,487	$105,942	$4,143
2059	$278,765	$341,757	$581,074	$106,971	$5,088
2060	$281,471	$345,075	$586,716	$108,009	$931,679
2061	$284,204	$348,425	$592,412	$109,058	$3,805
2062	$286,963	$351,808	$598,164	$110,117	$4,672
2063	$289,749	$355,223	$603,971	$111,186	$3,594
2064	$292,562	$358,672	$609,835	$112,265	$3,493
2065	$295,403	$362,154	$615,756	$113,355	$60,351
2066	$298,271	$365,670	$621,734	$114,456	$3,300
Total	$11,305,353	$13,749,497	$23,377,695	$4,303,621	$4,737,916

8.6 Life Cycle Cost (LCC) Summary

The 50-year LCC associated with the SVCW Headwork Facility, calculated as described above, is summarized in Table 8-6. A pie chart showing the breakdown of life cycle costs is included in Figure 8-1. As shown, the total 50-year LCC is determined to be between $115M and $122M, depending on market fluctuations.

Table 8-6 50-Year Life Cycle Cost for SVCW Headworks Facility

Item	Net Present Value
Capital Cost (2019 Dollars)[1]	**$58 – 65 M**
NPV of O&M Costs, Total (2022 Dollars)	**$58 M**
Labor	$11 M
Power	$14 M
Chemicals	$23 M
Debris Hauling	$4 M
Rehabilitation & Replacement	$5 M
50-year LCC (2022 dollars)[1]	**$115 – $122 M**

[1] Range based on market fluctuations from -5 to 15 percent.

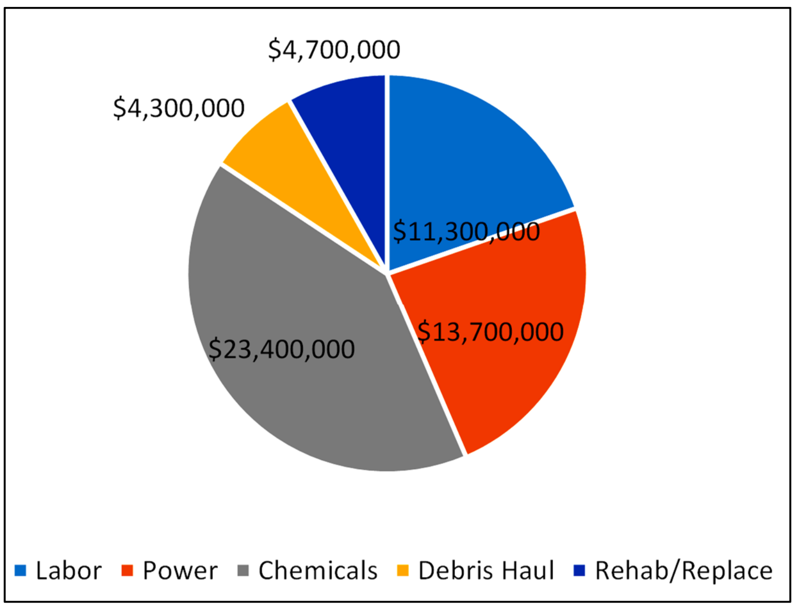

Figure 8-1
50-Year Life Cycle

Section 9

Permitting and Environmental Impacts

9.1 Required Permits

The construction activities of the Headworks Facility Project are located within an existing 10-acre ornamental pond. On June 13, 2016, the Regional Water Quality Control Board (RWQCB) made the determination that construction of the FoP Projects in the CIP, including the construction of the Headworks Facility, will be permitted by waste discharge requirements (WDRs) under the SVCW's existing National Pollutant Discharge Elimination System (NPDES) permit. Further, because all construction activities will occur within SVCW's existing WWTP property boundary, an air permit to construct and a local construction permit may be the only anticipated to be the only possibly required permits for the Project.

9.2 Property Acquisition

The Headworks Facility Project is anticipated to be constructed within the existing WWTP site boundaries. Therefore, no property acquisition is anticipated to be required for the project.

9.3 Stakeholders

In addition to the employees and visitors of the WWTP, some additional stakeholders for the Project include those residents and employees who live or work adjacent to the existing WWTP site. Rate payers within the service areas of the SVCW member agencies are also stakeholders.

9.4 Environmental Impacts

This section of the report details the environmental impacts of the Headworks Facility Project during both the construction of the Project and the operation of the Project after it has been constructed.

9.4.1 Visual Environmental Impacts

The Project will have minor visual environmental impacts on the existing FoP area, both during the construction and operation phases of the project. The primary viewers of the Project area are employees and visitors of the WWTP, recreationalists who use the existing trails in the Project vicinity and the Shore Dogs Park, and the tenants and users at The Pointe Office complex.

Construction Impacts

The new Headworks Facility will be constructed in the FoP area, which is characterized as expansive, given the flat topography and limited number of structures on the site. In addition to the open views, the site is frequented by a variety of birds that also contribute to the aesthetic experience of the area. Currently, there is no lighting in the FoP area which will need to be added with the new Headworks Facility.

The FoP projects, including the new Headworks Facility Project, will be constructed in the 10-acre ornamental pond located within the WWTP property boundary. The ornamental pond will be maintained in dry conditions prior to the construction of the proposed Project. The ornamental ponds were created by SVCW as a means of dust control, not as a visual amenity. However, when the ponds are full, they provide a visual resource only for the immediately surrounding area and is not considered a part of the public viewshed. With the construction of this project and others in the FoP area, the loss of the pond represents the loss of a visual resource for the area.

Operational Impacts

Once constructed, all structures constructed for the Headworks Facility Project will extend approximately 10 feet below grade, and 38 feet above grade. However, the height of the constructed structures will not exceed the height of the existing fixed film reactors at the WWTP. Therefore, although the visual quality of the project site would change with the construction of the Project, the facility will only be visible from certain vantage points and will be screened to integrate the facility with the existing landscape. Figure 9.1 shows an artist rendering view of the proposed WWTP facilities from the southerly direction.

Figure 9-1
Artist Rendering of Completed WWTP Facilities

9.4.2 Air Quality Impacts

Construction Impacts

Construction and associated activities will result in temporary increases in air pollution emissions from construction equipment exhaust, earth disturbance, truck traffic, and construction-related vehicle trips to and from the site. According to the current program implementation schedule, the Project will be constructed between the years 2018 and 2020. A summary of the annual emissions from construction-related activities for the project, inclusive of the Influent Connector Pipeline Project which will connect the new facilities constructed in this project to the existing WWTP, is presented in Table 9-1 below.

Table 9-1 Annual (tons) Emissions from Construction of the Headworks Facility and the Influent Connector Pipeline

Year	ROG	NOx	CO	SO_2	PM_{10}	$PM_{2.5}$
2018	0.24	2.60	1.90	3.56E-03	0.11	0.10
2019	0.12	1.26	0.84	1.59E-03	0.06	0.06
2020	5.72E-03	0.06	0.04	8.00E-05	2.77E-03	2.56E-03

Furthermore, there will be short term emissions of construction related greenhouse gas emissions during the period of construction mentioned above (2018-2020). A summary of the annual GHG emissions from construction-related activities for the project, inclusive of the Influent Connector Pipeline Project which will connect the new facilities constructed in this project to the existing WWTP, is presented in Table 9-2 below. The Bay Area Air Quality Management District currently has no recommended significance threshold of GHG emissions resulting from construction projects. However, SVCW plans on implementing some of the practices listed below to reduce construction GHG emissions to less than significant levels:

- Using alternative-fueled (e.g., biodiesel, electric) construction vehicles/equipment of at least 15 percent of the fleet, as feasible;
- Using local building materials (within 100 miles) of at least 10 percent; and
- Recycling at least 50 percent of construction waste or demolition materials.

Table 9-2 Annual (tons) Greenhouse Gas Emissions from Construction of the Headworks Facility and the Influent Connector Pipeline

Year	GHG
2018	317
2019	140
2020	7

Operational Impacts

The Project will have minor air quality impacts due to construction activities. However, air quality impacts will be negligible during operation of the new Headworks Facility since it will generate very few new vehicle trips. Therefore, these few trips would result in negligible emission increases.

In the Draft EIR, standby generators on the roof of the building next to the Headworks Facility were included in the Headworks Facility Project. However, during the Project planning phases, SVCW may make a decision to de-scope the standby generators from the Headworks Facility Project. Therefore, the air quality and GHG emissions impacts during operation for these generators is not included in this report.

9.4.3 Impacts to Biological Resources

All new structures anticipated to be included in the Headworks Facility Project will be constructed within the existing southern ornamental pond. Because this ornamental pond has been periodically filled with recycled water from SVCW's Recycled Water Facility since its operation in the year 2000, the pond has served as a resting and nesting habitat for many species of birds. However, because the ponds have been operated with periodic dry periods, this project is not anticipated to have a large impact on the bird populations and are therefore not classified as a sensitive biological community.

Construction Impacts

Construction activities may result in disturbances to the existing Salt Marsh Harvest Mouse, California Ridgway's Rail, and nesting bird populations. However, no temporary or permanent loss of habitat will occur due to Project construction as the existing ornamental pond area is not considered suitable habitat for these populations. This along with various mitigation measures, which include the following, will reduce the potential impacts to these species to a less than significant level:

- Prior to ground disturbances adjacent to potential habitats or nesting areas, exclusion barriers and/or fencing will be installed to exclude individuals of these species from areas of active construction
- Food-related trash items such as wrappers, cans, bottles, and food scraps will be disposed of in solid, closed containers (trash cans) and removed at the end of each work day from the investigation site to eliminate an attraction of predators of listed species
- Initiation of construction activities during the avian nesting season (February 1 through August 31) will be avoided to the extent feasible
- If construction initiation during the nesting season cannot be avoided, pre-construction nesting bird surveys will be conducted within 14 days of initial ground disturbance

Operational Impacts

During operation of the Headworks Facility, there are no anticipated impacts to biological resources within the Project area.

Appendix A

Program Supplied General Background Section and Reason for Project

SVCW
Wastewater Conveyance System and Treatment Reliability Improvement Project
Project Planning Reports

Program Supplied

General Background Section and Reason for the Project

February 15, 2017

Note to design teams: SVCW is providing the following text to the design teams for use in their project planning reports. The progressive design build procurement, the WIFIA funding application, and public outreach efforts may also find this information useful. The intended audience is assumed to be unfamiliar with SVCW facilities and its history, such as staff at the SWRCB and progressive design build contractors. Firms may edit the text to fit the flow, voice, structure, and style of their reports.

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1. BACKGROUND

1.1. SVCW is a Wastewater Utility in San Mateo County

Silicon Valley Clean Water (SVCW) is a Joint Powers Authority (JPA) that owns and operates a regional wastewater treatment plant at the eastern end of Redwood Shores, within Redwood City, and related wastewater pumping and transmission facilities. SVCW treats the majority of the wastewater generated from the mid-peninsula of San Mateo County south of the San Mateo Bridge. The JPA members include the cities of Belmont, Redwood City, and San Carlos, and the West Bay Sanitary District (which provides sanitary sewer collection services to the cities of Menlo Park, Portola Valley, and portions of Atherton, Woodside, East Palo Alto, and unincorporated areas of San Mateo County).

The individual members of the JPA own and operate the sanitary sewer collection systems within their respective jurisdictions. West Bay Sanitary District (WBSD) also owns the existing flow equalization facility (FEF) that is leased to SVCW and used to store wastewater during wet weather conditions. SVCW owns and operates the wastewater treatment plant (WWTP) and the sanitary sewer force main and pump stations that convey the wastewater from the member agency connections to the treatment plant.

1.2. Existing Conveyance System

SVCW's existing conveyance system assets include four pump stations, one for each of the four member agencies, a wet weather booster station located in the San Carlos Pump Station, an influent lift station located at the WWTP, and an approximately ninemile-long force main. SVCW leases from the WBSD a flow equalization facility, which is an integral part of SVCW's existing conveyance system.

1.3. History of SVCW and the Conveyance System

To understand the need for the Wastewater Conveyance System and Treatment Reliability Improvement Project (the Project) it is useful to know the history of SVCW, the assumptions used during the original design of the conveyance system, why the various components were built, and why at different times. This description of the history of SVCW will illustrate that the conveyance system is being operated in a manner different than its original design intent and, now, beyond its useful life.

Until the mid-1960's the mid-peninsula cities had their own wastewater treatment plants. Redwood City Sanitary District owned and operated the Redwood City Sewage Treatment Facility. Belmont and San Carlos owned and operated the Belmont/San Carlos Joint Sewage Treatment Facility. The developer of Redwood Shores (Mobil Land) owned the Redwood Shores Treatment Plant and it was operated by Redwood City Sanitary District. The Redwood City and Belmont/San Carlos plants separately discharged effluent to San Francisco Bay. The Redwood Shores Plant consisted of oxidation ponds and had no discharge as all the wastewater was evaporated. The level of treatment provided by these three plants and the locations of their outfalls could not meet the new stricter wastewater treatment and disposal regulations being imposed and developed at the state (Porter-Cologne Act, 1969) and federal (Clean Water Act, 1972) levels.

The Regional Water Quality Control Board (Regional Board) ordered a 10-to-1 dilution requirement for San Francisco Bay discharges. With encouragement from the Regional Board, in June 1969, the three cities formed the *Strategic Consolidation Sewerage Plan Joint Powers Authority* (SCSP JPA) for the purpose of addressing the new water quality regulations on a regional basis. To meet the 10-to-1 dilution requirement as soon as possible, the SCSP JPA would build connecting pipelines and a deep-water outfall for discharging the effluent from the existing three small treatment plants in advance of constructing the regional treatment plant. The site of the regional treatment plant needed to be decided so design of the new outfall could begin. After considering several sites, the SCSP JPA selected the Redwood Shores Plant site at the mouth of Steinberger Slough for the regional plant.

The pipeline consisted of six miles of reinforced concrete pipe that connected the treatment plants to the deep-water outfall located at the mouth of Steinberger Slough[1]. This new conveyance system was designed as a low pressure force main. In 1969 designs were completed for the pipeline as well as for the Redwood City Pumping Plant

[1] It should be noted that reinforced concrete pipe was the pipe of choice when the pipeline was designed in the early 1970's. High density polyethylene (HDPE) pipe was not available in large diameters at that time. The highly corrosive nature of the Redwood Shores saline soils made steel a poor candidate for this alignment.

and the San Carlos Pumping Plant. These pumping plants were built adjacent to the respective individual treatment plants. The pump stations, pipeline, and deep water outfall were put into service in 1971. The outfall, pipeline, and the Redwood City Pumping Plant (renamed Redwood City Pump Station) are still in use today.

Concurrent with the SCSP JPA improvement plans, Belmont's capital plans anticipated needing a new pump station and a pipeline that would connect it to the Belmont/San Carlos Joint Plant until the regional plant was operational. By the time the regional plant was operational and the Belmont/San Carlos Joint Plant closed, Belmont would also need a direct connection to the new SCSP force main. Design for a new pump station and direct connection forcemain on the west side of U.S. Highway 101 finished in 1973. The force main consisted of two segments. The first was from the new Belmont pump station to the point of the future connection to the 54-inch force main. This section was 1200 feet of 24-inch wrapped and cement lined steel pipe. The second segment was downstream of the future connection point and terminated at the San Carlos/Belmont Joint Plant. In this segment the pipe size was reduced to 20-inches and the material changed to asbestos cement pipe. This change in size and material was likely due to the City wanting to reduce costs for this segment that would be used for less than 10 years.

In the mid-1970's, in response to Regional Board direction, the service area for the regional plant originally envisioned by the SCSP JPA expanded to include the West Bay Sanitary District service area. In November 1975 the members of the SCSP JPA and West Bay Sanitary District (previous named Menlo Park Sanitary District) founded South Bay System Authority (SBSA, renamed in 2014 to Silicon Valley Clean Water) JPA as the successor to the Strategic Consolidation Sewerage Plan JPA.

This addition necessitated expanding the conveyance system to connect WBSD. Design of a 2.7-mile-long 33-inch diameter reinforced concrete pipe force main between the Redwood City Pump Station and the future Menlo Park Pump Station site was completed in 1976. The pipe was put into service when the regional plant became operational in 1982. The addition of WBSD to the system required that a booster pump station be added to the force main system, as the additional WBSD flows were not anticipated in the original forcemain headloss and pressure calculations.

The five segments of the existing force main, with year built, are described in Table 1.

Table 1
Existing Force Main Location, Size and Length

Segment	Location	Pipe Inside Diameter (ID) (in)	Year Built and Material	Age of Pipeline (years)	Length [(1)]	
					Lineal Feet	Miles
1	Between Menlo Park Pump Station and Redwood City Pump Station	33	1977 RCP	40	14,450	2.74
2	Between Redwood City Pump Station and San Carlos Pump Station	48	1971 RCP	46	12,950	2.45
3	Between San Carlos Pump Station and Belmont "T"	54	1971 RCP	46	3,550	0.67
4	Between Belmont Pump Station and Belmont "T"	24	1974 WSCL/C [(2)]	43	1,150	0.22
5	Between Belmont "T" and SBSA wastewater treatment plant	54	1971 RCP	46	15,500	2.94
Total Force Main					**47,600**	**9.0**

Based on: Table 6.1 of the SVCW Conveyance System Master Plan. Winzler & Kelly. 2011.
1. Lengths are rounded to the nearest 50 feet and tenth of a mile.
2. WSCL/C = Wrapped and cement-lined steel. Construction date estimated based on design drawings being completed in Feb. 1973.

In anticipation of higher flows and the higher water surface elevation of the regional WWTP, SBSA modified existing pump stations or built new one(s). The (1971) Redwood City and the (1974) Belmont Pump Stations were enlarged. A new San Carlos Pump station replaced the 1971 San Carlos Pump Station. The Menlo Park Pump Station was a new pump station that was subsequently modified in 1990 as part of WBSD's flow equalization project. Table 2 provides a summary of dates related to the pump stations.

Table 2
Age of Existing Pump Stations

Pump Station	Existing PS Operational	Enlarged, New or Modified	Years in Service
Menlo Park	1982	1990	35
Redwood City	1971	1982	46
San Carlos		1982 (new)	35
Belmont	1974[a]	1982	43

[a] 1974 is based on the date of the force main design drawings.

Design of SBSA's regional WWTP was completed in December 1977 and the new plant became operational in 1982. When the regional WWTP plant was put into service, the four smaller plants were decommissioned and the new and upgraded pump stations began to pump wastewater to the regional plant.

2. Reasons the Project is Needed

The SVCW Wastewater Conveyance System and Treatment Plant Reliability Improvement Project is necessary to eliminate ongoing reliability concerns and accommodate changes in wastewater flowrates. Replacement of the conveyance system is SVCW's highest priority due to its age and continual state of failure. The existing SVCW conveyance system components are beyond their useful life. The American Society of Civil Engineers published a report entitled "Failure to Act" with the purpose "to provide an objective analysis of the economic implications for the United States of its continued underinvestment in infrastructure." Table 3 lists the useful life for force mains and pump stations used in the ASCE report.

Table 3
Useful Lives of Wastewater
Pump Stations and Force Mains

Component	Useful Life (years)
Force Mains	25
Pumping Stations – Concrete Structures	50
Pumping Stations – Mechanical and Electrical	15

Source: Table 5 of *Failure to Act, the economic impact of current investment trends in water and wastewater treatment infrastructure*. American Society of Civil Engineers. 2011.

2.1. Force Mains

SVCW's 46-year-old concrete force main is in poor condition and needs to be replaced. The pipeline suffers from several problems caused by the soils in which it is installed and the sewage characteristics. Problems have compounded, resulting in a history of numerous leaks. These leaks range from minor to the occasional catastrophic failure. Leaks require repairs along streets and in backyards and sometimes within biologically sensitive environments.

One section of the original force main that had the most leaks was replaced in 2015 with a fused-jointed high density polyethylene (HDPE) pipe. This was a 1.7-mile long portion of the 48-inch diameter force main from the Redwood City Pump Station to the north end of Inner Bair Island. The Project will replace the remaining original force main that begins where the 48-inch replacement project ended (the north end of Inner Bair Island) and terminates at the WWTP.

Much of the existing force main is buried in young bay mud soils that are poorly suited to the existing pipeline material and joint system. Young bay mud has two main problems; it is expansive and corrosive. Expansive soils are weak, unstable, have high shrink-swell potential, and settle over time. The pipeline consists of 12-foot-long reinforced concrete pipe sections that are connected to each other with single non-restrained "O-ring" joints. The young bay mud soil does not provide sufficient support for the reinforced concrete pipe and its joints. This results in pipe movement and separation at the joints and is the cause of the majority of the leak events.

The bay mud soil is highly corrosive to buried steel and concrete that comes into direct contact with the soil. The pipe is also subjected to microbiologically influenced corrosion (MIC) from sewer gases inside the pipe. Internal and external corrosion of the concrete and reinforcing steel leads to more significant leaks. When surges in flow occur (such as during a power outage) the resulting pressure and vacuum surge conditions have broken the weakened pipeline resulting in major sewage spills. These types of leaks tend to be catastrophic with the potential of uncontrollable discharge of untreated wastewater to the environment.

The frequency of pipeline leaks is expected to increase as the pipe ages, given the current poor condition of the pipelines, continued movement of weak soils, and acceleration of the internal and external corrosion.

In addition to the problems related to the soil, the existing pipeline was designed as a low-pressure force main pipeline and not for typical force main pressures. When WBSD was added to the conveyance system and as wet weather flows have risen, flows in the force main have grown higher than the original design anticipated. When the WBSD flows were added, a booster pump station, and later a flow equalization facility, were added to the system.

With Herculean efforts, SVCW maintains pressures and surges in the conveyance system to within the force main's pressure limits, though this approach comes with significant risk. SVCW must carefully manage the flow in the pipeline to minimize leaks by opening and closing valves, turning on and off pumps (including the booster and influent lift pumps), diverting flow to storage, and backing up sewage in member agency collection systems. During wet weather events, wastewater flows from the WBSD collection system are diverted to the WBSD flow equalization facilities. When flows subside, the WBSD wastewater is pumped from the flow equalization facilities through the Menlo Park Pump Station and to the treatment plant. Sometimes these pressure management efforts require using all available pumps and valves leaving limited or no backup equipment.

The reasons provided for replacing the pipelines are corroborated by industry accepted guidelines of useful life. The 46-years is well beyond a typical force main's lifespan of 25 years.

2.2. Pump Stations

All five pump stations are in varying states of condition, ranging from poor to very poor. Despite system-wide repairs and regular maintenance, the pump stations are in need of replacement to provide safe and reliable operation and to accommodate the future projected flows through the system. Each pump station is at least 35 to 46 years old, well beyond the 15-year useful life for the mechanical and electrical components, and approaching the life of the concrete structure. In most instances the condition of the equipment has degraded to the extent that the systems require extensive maintenance to ensure functionality and reliability. To keep the pump stations operational, SVCW is spending millions of dollars to replace various pump station components, such as control systems, pumps, and valves. These components will not be used after the Project is completed.

The solution to the current conveyance system problems SVCW is facing is to replace the original pipeline with a new pipeline that is designed for local soils conditions and system flows, and to replace or rehabilitate the pump stations. The conveyance pipeline and the pumping system improvements are interconnected and need to be planned, designed, and constructed in tandem.

2.3. Headworks

The Project also includes construction of a headworks to house screening and grit removal facilities. This process will be the first step in treatment. It removes rags, sand, grit, and debris that damage pumps and other process equipment.

The original SVCW wastewater treatment facility was built with no headworks. The plant's current partial screening and grit removal processes continue to allow excessive downstream grit and unscreened material that cause premature wear on equipment and result in high maintenance and repair costs. Large debris and inorganic solids such as rags that are not removed by the existing screening equipment are removed manually. Manual removal of rags is labor intensive and places plant personnel in challenging work environments. SVCW recently installed new digester mix pumps, rotary screen presses, and gravity belt thickeners. This new equipment is very susceptible to damage caused by rags and debris. Without the headworks, this new equipment will experience the same premature wear as the older equipment.

SVCW's decision to install screening and grit removal facilities was made for purposes of protecting its employees, addressing the continued high costs for labor and equipment damage, and increase the reliability of the overall treatment process. Effective screening of incoming wastewater will save both operation and maintenance costs and improve SVCW's operational capabilities.

3. Proposed Conveyance System Project Overview

The Project proposes a combination of rehabilitating, repurposing, and decommissioning existing SVCW conveyance system assets, and the construction of replacement assets. Brief summaries of the major components included in the Project are provided in the following paragraphs.

3.1. Pipelines

A 15-foot outside diameter tunnel will be built using a tunnel boring machine to connect the recently constructed 48-inch replacement force main (located at the northern end of Inner Bair Island) to the WWTP. The distance between top of the tunnel and the ground surface will range from 20 to 52 feet. Inside this tunnel will be a new 11-foot inside diameter gravity pipeline. This new gravity pipeline will replace the remaining portion of the 48-inch and the entire existing 54-inch force main pipelines. The Belmont Pump Station would be connected to the new gravity pipeline by rehabilitating the existing 24-

inch pipeline and a portion of the 54-inch pipeline. The 33-inch force main pipeline that connects the Menlo Park Pump Station to the Redwood City Pump Station would remain as it exists.

3.2. Pump Stations

The Menlo Park Pump Station and the Belmont Pump Station will be rehabilitated and remain as part of the proposed project. A new pump station will be built on the existing Redwood City Pump Station site and the existing pump station building will be repurposed to house auxiliary equipment that supports the new Redwood City Pump Station. The San Carlos Pump Station will no longer be needed and will be decommissioned. Portions of the San Carlos Pump Station building and yard will be repurposed to house odor control and ancillary equipment needed by other elements of the proposed Project. At the downstream end of the gravity pipeline, a new deep pump station (called the receiving lift station) will be built to pump the wastewater from about 60 feet below grade to the new headworks.

3.3. Headworks

A headworks facility will be constructed downstream of the receiving lift station to provide coarse screening and grit removal from the raw wastewater. This is a new treatment process being added to the WWTP treatment train. Two new large-diameter pipes will be built to connect the headworks to the existing primary treatment process. Odor control facilities for the receiving lift station and headworks will be installed adjacent to the headworks facility.

- END -

Appendix B

Preliminary Geotechnical Investigation

DCM Consulting, Inc.

P.O. Box 225, Lafayette, CA 94549, Telephone: 925.322.9590 www.dcmconsults.com

Draft Technical Memorandum

To:	Bill Schilling CDM Smith	Date:	January 17, 2017
From:	Dave Mathy DCM Consulting, Inc.	File:	No. 222
Subject:	Silicon Valley Clean Water (SVCW) Headworks Facility at Front of Plant Preliminary Foundation Design Parameters SVCW Waste Water Treatment Plant Redwood City, California		

1.0 INTRODUCTION

The purpose of this technical memorandum is to provide preliminary geotechnical engineering recommendations for structure foundations in support of CDM Smith's conceptual design of new headworks facility structures at the SVCW waste water treatment plant in Redwood City, California. The SVCW waste water treatment plant is located at the northeastern end of the Redwood Shores Peninsula on the western margin of San Francisco Bay. The treatment plant site is on reclaimed tidal marshland with the first construction of dikes for land reclamation on the Redwood Shores Peninsula in the early 1900s. In the 1950s, significant levees and fills were placed on the Redwood Shores Peninsula for land development. The most recent fills at the project site were placed during development of the SVCW waste water treatment plant in the late 1970s to early 1980s. The soils underlying the waste water treatment plant consist of very thick deposits of Young Bay Mud (YBM) underlain by Old Bay Clay (OBC). Bedrock is hundreds of feet deep at the waste water treatment plant site (approximately 600 feet deep as referenced in U.S.G.S. Open File Report 90-496, 1990). The YBM is characterized by extremely low unit weight, extremely high moisture content, low shear strength and high compressibility. The YBM is considered to be normally consolidated and is still consolidating (settling) at the treatment plant under the weight of areal fills placed in the late 1970s (i.e. underconsolidated with respect to the late 1970s fill placement). As a result of the thick deposit of soft and weak YBM, the waste water treatment plant structures are supported by deep driven pile foundations deriving capacity by skin friction within the underlying OBC.

The new headworks facility site is located at the front of the treatment plant in an area presently designated as an ornamental pond (Front of Plant area). The current ground surface elevation within the Front of Plant area varies from Elevation 99 to Elevation 100. The Front of Plant area was not filled upon with engineered areal fill during original plant construction in 1978/1979, however, this area was reportedly used as a construction staging area and as a result thin (non-engineered) fills of highly variable composition and consistency with near surface buried construction debris can be encountered. When the ornamental pond is drained, occasional construction debris can be seen on the ground surface. Since completion of the original treatment plant in 1978/1979, the Front of Plant area has been flooded with a few feet of standing water and used as on ornamental pond. As a result, the Young Bay Mud within the Front of Plant has been nearly continuously submerged below surface waters. The headworks facility, which will be located immediately, east of a future Receiving Lift Station (RLS) also within the Front of Plant area, will include the following:

- headworks building, footprint area approximately 7,900 square feet;
- electrical and loadout building, footprint area approximately 5,200 square feet; and
- odor control equipment buildings, footprint areas of approximately 1,500 and 1,200 square feet.

The Front of Plant area, including the RLS and Headworks Facility, will be raised in elevation with about 4 feet of areal fill to a finished grade elevation of approximately Elevation 103 to 104. The at-grade portions of the Headworks Facility will be at Elevation 103 to 104, however the grit chamber portion of the headworks building will extend down to Elevation 94 (approximately 9 to 10 feet below finished grade).

The preliminary pile foundation design criteria presented herein is based on:

- CPT probes completed within the Front of Plant area to map the bottom of YBM;
- recent deep geotechnical borings completed for the RLS project by GTC Consultants;
- physical laboratory testing of soil samples taken from recent test borings for the RLS project;
- construction precedent of pile driving in 2015 for the plant's Influent Screening Facility;
- construction precedent of pile driving in 2010 for the plant's Administration Building Stairwell and Elevator Shaft;
- foundation design precedent for the City of Redwood City's Recycled Water Treatment Facility in 2004; and
- foundation design precedent for the original waste water treatment plant in 1977-1979.

2.0 FINDINGS

2.1. Cone Penetration Tests and Geotechnical Borings

In order to establish the thickness of YBM across the Front of Plant area, a total of 22 Cone Penetration Test (CPT) probes were completed in 2015. Appendix A includes a map of the Front of Plant area with 24 CPT locations (CPT Nos. 21 and 22 were not completed) along with depth to the bottom of Young Bay Mud (YBM) at each CPT location and bottom of YBM elevation contours. CPT's completed within the Front of Plant area were pushed with a small track mounted all terrain rig with limited depth capability. As a result the CPT's completed in the Front of Plant area extend completely through the YBM and met refusal in the top of the OBC with 10' to 25' of penetration into the OBC. The purpose of the Front of Plant CPT's was simply to map the bottom of the YBM/top of the OBC contact (see Appendix A).

In addition to the Front of Plant CPT probes, GTC Consultants completed 6 deep geotechnical borings (well into the OBC) for the RLS project immediately west of the Headworks Facility site in 2015. Appendix B includes the GTC boring location map and boring logs. At the time of GTC Consultants' drilling of test boring B-101, DCM Consultants obtained undisturbed soil samples for laboratory testing specific to the Headwork Facility Project. Undisturbed Shelby tube soil samples were retrieved from GTC Consultants at the time of drilling and delivered to Cooper Testing Laboratories on the same day. Appendix C contains laboratory test results completed specifically for the Headworks Facility Project. CPT-1 is approximately 50 feet north of GTC Consultants' B-101. CPT-1 indicates that the bottom of the YBM is approximately 45 feet deep (approximately El. 55). Geotechnical boring B-101 by GTC Consultants logs zero blow count (i.e. N=0) very soft YBM from ground surface to 40 feet deep. At 45 feet deep (El. 54.5) B-101 logs a blow count of N=24 which is a stiff clay and represents the bottom of YBM/top of the OBC. The remaining borings by GTC Consultants similarly log the bottom of YBM at El. 54 to 57. Therefore, there is good correlation in logging the bottom of YBM between the Front of Plant CPTs and geotechnical borings completed by GTC Consultants for the RLS. The geotechnical borings completed by GTC Consultants for the RLS describe the soils below the YBM as Upper Layered Sediments and Old Bay Deposits. For purposes of this Technical Memorandum all soils below the YBM are described as Old Bay Clay (OBC).

2.2. Engineering Properties of Soils

YOUNG BAY MUD (YBM)

- Thickness: 45 to 55 feet under the Headworks Building and Electrical and Loadout Building and 55 to 75 feet under the Odor Control Equipment Buildings (see Appendix A)
- Composition: Fat Clay (CH) and Elastic Silt (MH)
- Consistency: Very soft, Standard Penetration Test Blow Count, N = 0 to 2
- Moisture Content: 73% to 105% (note that moisture contents > 100% indicate that there is more water than soil solids in a given unit volume of YBM)
- Average Dry Unit Weight: 50 pcf
- Average Total Unit Weight: 92 pcf
- Average Buoyant (effective) Unit Weight: 30 pcf
- Overconsolidation Ratio: 1
- Compression Index, Cc: 1.2 to 1.3
- Ko: 0.65
- Poisson's Ratio: 0.50

- Undrained Shear Strength (Su): 80 psf to 330 psf
- Su/p′: 0.20 to 0.30
- Increase in Su with depth: 9 psf/ft
- Young’s Modulus: approx. 30,000 psf

OLD BAY CLAY (OBC)

- Thickness: > 80’
- Composition: Lean Clay (CL) to Fat Clay (CH) with significant non-cohesive Poorly Graded Sand (SP-SM) interlayered with minor Poorly Graded Gravel (GP), non-cohesive sands and gravels occur from about El. 35 to El. 5, ranging from 25’ to 30’ thick
- Consistency: Stiff to very stiff clays (N = 8 to 25) and medium dense to dense sands and gravels (N = 15 to 50)
- Average Moisture Content: 45% in clays, 21% in sands
- Average Dry Unit Weight: 72 pcf in clays, 105 pcf in sands
- Average Total Unit Weight: 104 pcf in clays, 127 pcf in sands
- Average Buoyant (effective) Unit Weight: 42 pcf in clays, 65 pcf in sands
- Overconsolidation Ratio: approx. 4
- Compression Index, Cc: 0.25
- Ko: approx. 1.0
- Poisson’s Ratio: 0.50
- Undrained Shear Strength: Average 1,400 psf in clays
- Su/p’ Ratio: 0.30 to 0.60
- Increase in Su with depth: approx. 30 psf/ft
- Young’s Modulus: approx. 500,000 psf

2.3. Construction Precedent

All of the original waste water treatment structures at SVCW are supported by driven, pre-cast, pre-stressed concrete piles. The concrete piles were driven through the YBM and into the underlying OBC.

Pile capacity is generated by the depth of embedment in the OBC. For the original plant construction (circa 1978/1979), typical design pile capacity was 50 tons per pile for 12-inch-square piles with pile lengths of 100 to 105 feet.

Remodeling for the new Administration Building in 2010 included the addition of a stairwell and elevator shaft to the building entry. The stairwell and elevator shaft addition is supported by a total of 11, 14-inch-square pre cast, pre-stressed concrete piles that are 106 to 116 feet long. Net pile design capacity was approximately 80 tons per pile. (Net pile capacity is gross capacity minus negative skin friction in the YBM.) During construction, obstructions were encountered in the upper fill soils that required coring and removal (through a concrete slab) to allow for pipe installation. An APE D30-22 diesel hammer with a maximum rated energy of approximately 69,000 ft.-lbs. was used to drive all piles. The pile driving contractor was Stroer and Graff, Inc. of Antioch, California. The final pile driving blow count for the last foot of driving ranged from 9 to 29 blows per foot with an average of 15 blows per foot at fuel stop setting, FS=4.

Construction of the new Influent Screening Facility in 2015 included driving a total of 16, 14-inch-square, pre-cast, pre-stressed concrete piles that are 109 feet long. Net pile design pile capacity was approximately 100 tons per pile. During construction obstructions were encountered in the upper fill and existing sedimentation tank structure backfill that required excavation for removal. Obstructions consisted of boulder sized chunks of concrete debris. A Delmag D-30 diesel hammer with a maximum rated energy of approximately 69,000 ft.-lbs. was used to drive all piles. The pile driving contractor was Stroer and Graff, Inc. of Antioch, California. The final pile driving blow count for the last foot of driving ranged from 8 to 18 blows per foot with an average of 12 blows per foot at fuel stop setting FS=3. Pile driving for the Influent Screening Structure also included PDA and CAPWAP instrumentation by Abe Construction Services, Inc. of Livermore, California. The Abe Construction Services report for the Influent Screening Facility pile driving is included for reference as Appendix D. From the PDA results, the average gross pile capacity is 100 tons. Net pile capacity after deducting for negative skin friction in 75 feet of YBM is 100 – 16 = 84 tons. Restriking on one sample pile, three days after installation indicated a 30-ton setup gain (approximately +30% gain) occurred after driving. Pile capacity gains such as this are expected for friction piles in OBC.

3.0 PRELIMINARY FOUNDATION RECOMMENDATIONS

3.1. Front of Plant Areal Settlement

Present ground surface elevations in the Front of Plant area are approximately El. 99 to El. 100. Planned finished grade in the Front of Plant area is approximately El. 103 to 104. Therefore, approximately 4 feet of areal fill will be placed over the entire Front of Plant area including the Headworks Facility area. Adding 4 feet of areal fill over the YBM will cause long-term consolidation settlement. Long-term consolidation settlements will be uneven reflecting the variable thickness of the YBM under the Headworks Facilities. As shown in Appendix A the thickness of YBM under the Headworks Facilities area varies from about 45’ to 75’. Assuming the new fill will have a total unit weight of 135 pcf, the total areal surcharge load on the YBM will be on the order of 540 psf. This is a significant load on the underlying YBM and will lead to long-term consolidation settlements of approximately 2’ to 2.8’ as a function of

YBM depths of 45’ to 75’, respectively. In the first 25 years consolidation settlements should be in the range of 1’ to 1.4’. At the end of 50 years, consolidation settlements should be in the range of 1.3’ to 1.7’. Long-term consolidation settlement will have the following impacts on Front of Plant structures and site improvements:

- Reduction in finished ground surface elevations;
- Changes in surface drainage slopes and drainage structure elevations;
- Negative skin friction on pile foundations in YBM (as the YBM consolidates and settles, soil adhesion on the pile surface pulls the pile downward). [This also applies to the deep RLS structure.]
- Differential settlement between pile supported structures (or deep structures such as the RLS) and non-pile-supported pipelines, pavements and drainage facilities; and
- Differential settlement between the Front of Plant area and existing plant area where the majority of consolidation settlement has already occurred in the existing plant area.

As a result of filling the Front of Plant Area to approximately El. 104, all pile foundations must be designed to include negative skin friction from the consolidating YBM.

3.2. Pile Foundations

Pile foundations for the new Headworks Facility structures should consist of 14-inch square, pre-cast, pre-stressed concrete piles that reach a minimum of 80 feet below present ground surface (i.e. below El. 100) and derive support by skin friction in the OBC. Starting at depths of 45’ to 75’ below present ground surface (i.e. below El. 100), the allowable “positive” pile skin friction in the OBC may be taken as 750 psf. The allowable “positive” pile skin friction can be increased by one-third for short-term, transient wind and seismic loads. As previously described in Section 3.1, the YBM from present ground surface to 45’ to 75’ below present ground surface will be consolidating under new areal fill loading and will therefore produce a “negative” skin friction on the piles. The “negative” skin friction in the Young Bay Mud should be taken as -100 psf. For an allowable 50 ton capacity on an individual 14-inch square pile, the total required pile length below El. 100 is a function of the YBM thickness and negative skin friction deduction from gross pile capacity in the OBC. For a YBM thickness of 45’, a 14-inch square pile with a pile surface area of 4.67sf/ft, and a desired 50 ton capacity, the pile length below El. 100 is calculated as follows:

- 100,000 lbs = (4.67 sf/ft * 750 psf * L) – (45’ * 4.67sf/ft *100 psf)

  L = 35’ of required embedment in OBC

  Total pile length below El. 100 = 45’ + 35’ = 80’

Similar calculation for a YBM thickness of 55’ results in a pile length below El. 100 of 91’. For a YBM thickness of 65’, total pile length below El. 100 is 102’ and for a YBM thickness of 75’, total pile length below El. 100 is 115'. For practical purposes, including transportation, and for installation safety, pile lengths in excess of 109' (109' long piles were used for the Influent Screening structure) should be avoided. Therefore, where the YBM thickness is on the order of 75', preliminary design pile capacities of less than 50 tons per pile should be considered.

For piles in tension, the YBM should be ignored and the allowable uplift capacity should come solely from the OBC at 750 psf pile skin friction.

Total settlement of any individual pile should be less than one-half inch. Differential settlement between any two piles should be less than one-quarter inch. Center to center pile spacing should be at least 3 times pile width.

The lateral capacity of the 14-inch-square piles was evaluated by L-Pile (a lateral load vs. lateral pile deflection program) for the Administration Building Stairwell and Elevator Shaft project in 2010 and is included for reference as Appendix E. While site specific conditions will be different, the Administration Building Stairwell and Elevator Shaft conditions are reasonably close to the Front of Plant. The P-Y curves in Appendix E were run for a lateral load of 5 kips, 10 kips and 15 kips. As demonstrated by Kie-Con in 2015 (for the Influent Screening Facility project), a lateral load of 15 kips is too much for a Kie-Con designed 14-inch square pile (see Appendix F, for reference). Therefore, an allowable lateral load of 10 kips per pile should be used for preliminary design. At 10 kips applied lateral load the top of pile deflection for "fixed head" conditions is under 0.50". Lateral loading on the Headworks Facilities structures may be resisted by the sum of individual pile allowable lateral load capacity with modifications for areas of close pile spacing and group effects. Friction across the base of the structures should not be included in lateral load resistance as the Young Bay Mud will be consolidating creating a slight gap between the bottom of the pile supported structure and underlying subgrade.

Pile driving at the new Headworks Facility structures must be carefully planned. The Young Bay Mud will be within 3 to 4 feet of the finished ground surface (as measured from finished grade, El. 104). In the past, heavy construction equipment within the SVCW waste water treatment plant has punched through pavement and thin fills becoming stuck in the soft Young Bay Mud. Crane mats should be used to transport and support heavy equipment such as the pile driving crane and outriggers. In addition, there are fragile, shallow pipelines and utilities (e.g. plant electrical service in Radio Road) in and around the existing waste water treatment plant that must be protected from construction equipment live loading. Limitations on construction equipment travel paths at the waste water treatment plant, including Radio Road, and positioning of heavy construction equipment such as the pile driving crane must be coordinated with SVCW engineering staff.

The pile driving hammer should be consistent with the pile design, construction precedent and the subsurface conditions described herein and should have a minimum energy rating on the order of 50,000 foot pounds. Piles may be driven from the finished ground surface at El. 104 to deeper elevations (e.g. El. 94 for the grit chamber) by the use of a follower to reach top of pile elevation.

As previously discussed, the Front of Plant area was reportedly used for construction staging during the original waste water treatment plant construction. Construction debris is likely present in the top several feet of the Front of Plant area. In order to get through the new areal Front of Plant fill and likely remnant construction debris from 1978/1979, pre-drilling should be required to a minimum depth of about 15’ to 20’. The pre-drilled auger-hole diameter should be a maximum of 70% of the pile width. The purpose of pre-drilling is to ensure removal of fill and construction debris prior to pile driving to protect the piles and minimize vibrations on nearby structures/pipelines during pile driving.

4.0 LIMITATIONS

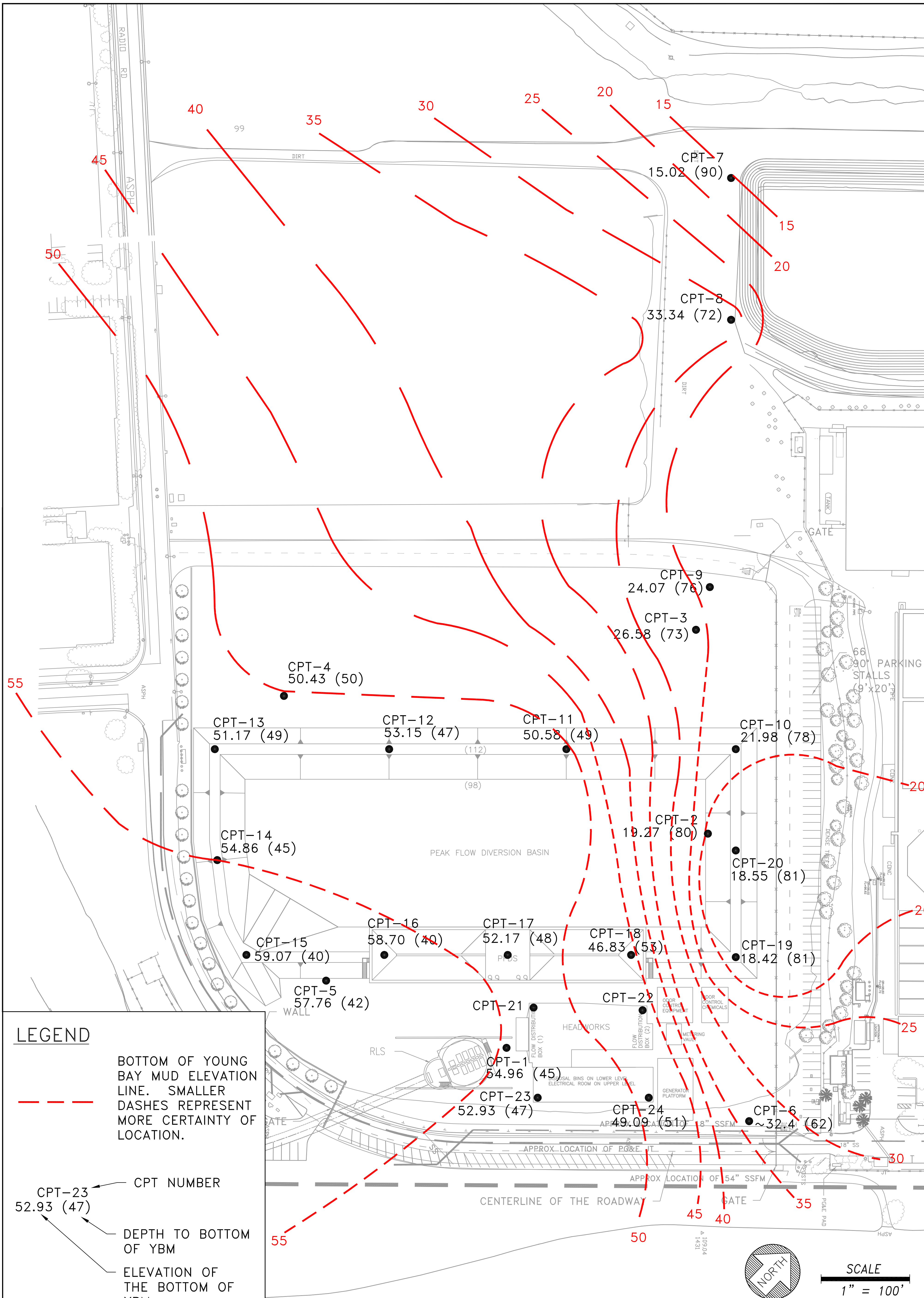
This Technical Memorandum has been prepared for the exclusive use of CDM Smith and SVCW in support of CDM Smith’s conceptual design of the Headworks Facility project as described herein. This Technical Memorandum may not be used for any other purpose or for any other project. The preliminary geotechnical design parameters for pile foundations as described herein are to be followed up with a design level geotechnical investigation, analysis and report with specific recommendations for final pile lengths as a function of variable underlying YBM thickness including an indicator pile program, final lateral pile load capacity with site specific P-Y curves, seismic design parameters, mitigation measures for differential settlement between the pile supported structures and non-pile supported site improvements including pipelines, etc. Within the limitations of scope, schedule and budget, DCM Consulting, Inc.’s services have been provided in accordance with generally accepted practices in the field of geotechnical engineering in the San Francisco Bay Area at the time the services were completed. The conclusions and opinions presented in this Technical Memorandum are based on the author’s professional knowledge, judgment and experience. No warranty or other conditions express or implied should be understood.

David C. Mathy
C.E. 28082
G.E. 569

Attachments

- Appendix A – Front of Plant CPTs and YBM Contours
- Appendix B – Geotechnical Borings for the RLS
- Appendix C – Laboratory Testing Completed for the Headworks Facility
- Appendix D – Abe Construction Services PDA Report for the Influent Screening Facility
- Appendix E – P-Y Curves Completed for the Administration Building Stairwell and Elevator
- Appendix F – Limitation on 14-inch-square Pre-cast, Pre-stressed Pile Lateral Capacity from Kie-Con

APPENDIX A



FREYER & LAURETA, INC.
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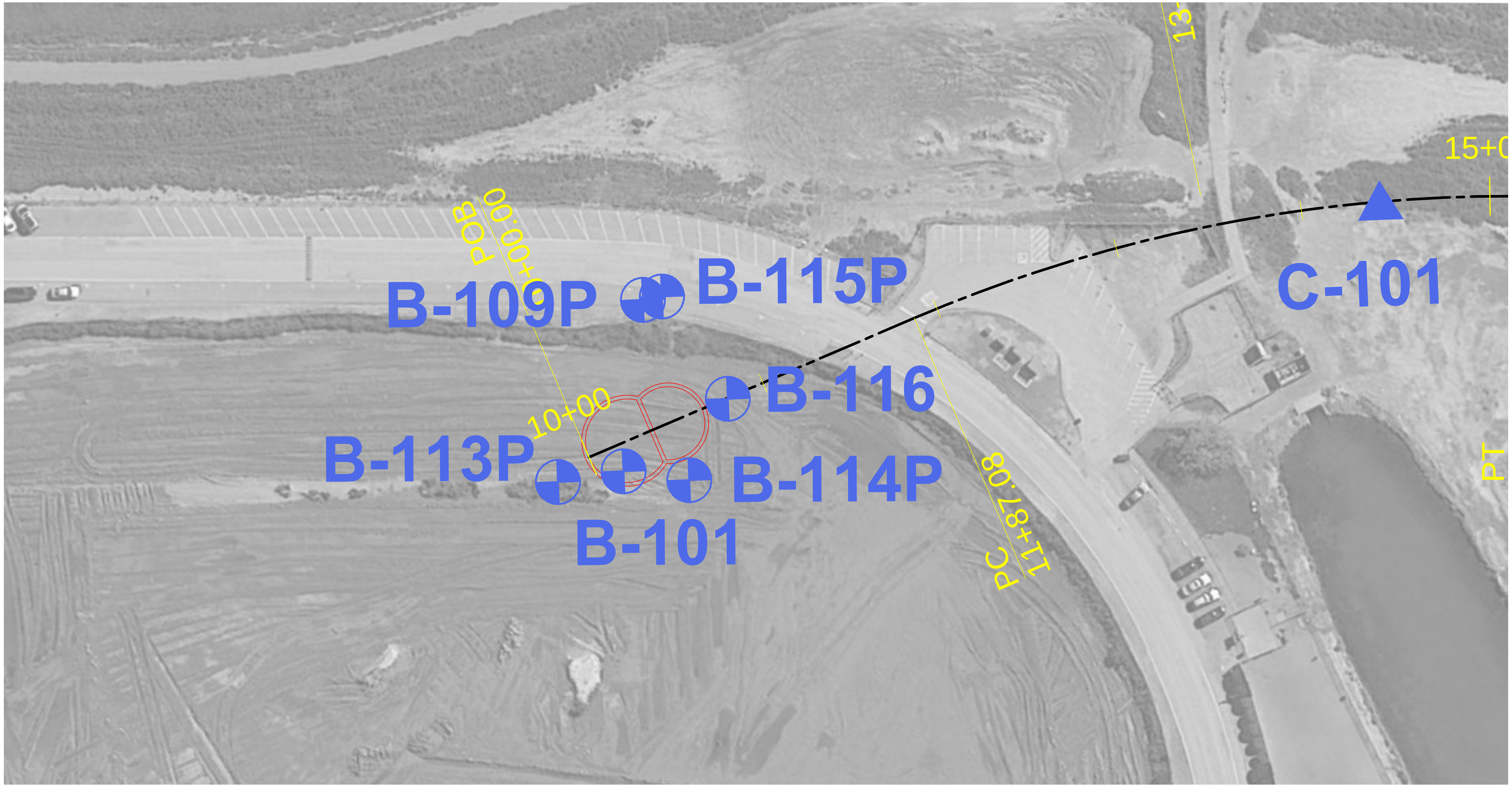
DRAFT - WORK IN PROGRESS
BOTTOM OF YBM CONTOURS
FRONT OF PLANT IMPROVEMENT
SILICON VALLEY CLEAN WATER

VERSION AS OF 12/04/2015

APPENDIX B



PLAN
SCALE: 1" = 30'

LEGEND

B-101 — Phase 1 Geotechnical Borings

C-103 — Phase 1 Cone Penetrometer Tests

Centerline of Proposed Tunnel Alignment

Tunnel Shafts

GEOTECHNICAL CONSULTANTS, INC.
500 Sansome Street, Suite 402
San Francisco, CA 94111

PHASE 1 GEOTECHNICAL EXPLORATION LOCATION MAP	PLATE
SILICON VALLEY CLEAN WATER TUNNEL, ALTERNATIVE 4BE REDWOOD CITY CALIFORNIA	1
DECEMBER 2015	SF14014A

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-121.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-101
DRILLING DATE: September 23-24, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
					"ARTIFICIAL FILL (af)" CLAYEY SILT with GRAVEL (ML), dark olive brown, wet, soft, with mixed gravel, some fine to medium grained sand, with scattered cobbles. (POND SEDIMENTS)						
					"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), very dark greenish gray, moist, very soft, no odor, no organics.						
94.5	5	0									
89.5	10					46	98				C
		WOR									
						47	94	90	36	181 (UCS)	
84.5	15	0									OC
79.5	20	WOR									
					Abundant shells.						
74.5	25					48	92				C
		WOR									
					Minor shell fragments.	51	82	71	35	386 (TXUU)	
69.5	30	0	0.13		Soft.						
64.5	35	0	0.14								OC
59.5	40					51	85				C
		WOR 75 psi				56	73	65	28	330 (UCS)	
54.5	45	24			Greenish gray, stiff, minor silt.						
					"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), light olive brown, moist, stiff, minor silt, medium plasticity.						
49.5	50	21		1.15		97	28	43	21	1283 (UCS)	CORR

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-121.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-101
DRILLING DATE: September 23-24, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			28			"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont. At 55 feet: stiff to very stiff.						
39.5	60		200psi 250psi 385psi						30	19		GS (-#200=87%)
			30			SANDY SILT to SILTY SAND (ML/SM), olive brown, wet, stiff silt to dense sand, minor clay fines.						
34.5	65		22			POORLY GRADED SAND with SILT (SP-SM), olive brown, wet, medium dense, fine grained sand.						
29.5	70		48			CLAYEY SAND (SC), brown, wet. LEAN CLAY (CL), olive brown, wet, hard, minor fine grained sand.	104	21				CORR, GS (-#200=94%)
24.5	75		30			POORLY GRADED SAND with SILT (SP-SM), dark olive gray, wet, dense, medium to coarse grained sand, with trace very fine gravel.						GS (-#200=10%)
19.5	80		30			POORLY GRACED SAND with SILT and GRAVEL (SP-SM), dark olive gray, wet, dense, mixed fine to coarse gravel, subrounded to angular, spherical to elongated, medium to coarse sand.						GS (-#200=12%)
14.5	85		50			POORLY GRADED SAND (SP), coarse grained. POORLY GRADED GRAVEL (GP), fine subrounded to rounded, up to 1/2 inch. POORLY GRADED SAND with SILT (SP-SM), dark olive gray, wet, dense, mixed fine to coarse gravel, subrounded to angular, medium to coarse sand.						
9.5	90		46				117	17				GS (-#200=11%)
4.5	95		33			"OLD BAY DEPOSITS (Qobd)" FAT CLAY (CH), greenish gray, moist, very stiff.						
-0.5	100		25			SILTY CLAY (CH), greenish gray, moist, stiff, moderate to high plasticity.	73	50	79	28	1595 (UCS)	
-5.5	105											

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-121.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-101
DRILLING DATE: September 23-24, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
		■	29		2.2 1.8		"OLD BAY DEPOSITS (Qobd)" cont. SILTY CLAY (CH) cont. At 110 feet: stiff to very stiff.	64	61	94	29	1376 (UCS)	
-15.5	115												
-20.5	120	■	7		1.05		Medium stiff to stiff, with scattered shell fragments.	65	60			1000 (UCS)	

NOTES:
1) Bottom of boring at 121.5 feet.
2) Groundwater measured at approximately 1.3 feet on 9/24/15.
3) Boring backfilled with cement grout on 9/24/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 86.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-109P
DRILLING DATE: September 24-25, 2015
ELEVATION: 102.7 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								3.5 inches asphalt; 6 inches of aggregate base.						
								"ARTIFICIAL FILL (af)" POORLY GRADED SAND (SP), grayish brown, damp, fine grained.						
97.7	5		1					Very loose, wet.						
			2					"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), very dark greenish gray, moist, no organics, no odor.						
92.7	10													
			0 psi		0.09	0.07		Very soft.	48 45	92 100	102	41	161 (TxUU)	C
87.7	15													
82.7	20		0 psi 50 psi			0.22		Soft.	52 54	83 78	88	35	412 (TxUU)	C
77.7	25													
72.7	30		WOR			0.19		Very soft.						
67.7	35													
62.7	40		WOR			0.17			53	77	75	32		
57.7	45													
								SILTY CLAY (CH), greenish gray, moist, stiff, moderate to high plasticity.						
52.7	50		18			1.75 1.3								
								"UPPER LAYERED SEDIMENTS (Quls)" SILTY CLAY (CL), light olive brown, moist, stiff, low plasticity.						

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 86.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-109P
DRILLING DATE: September 24-25, 2015
ELEVATION: 102.7 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								"UPPER LAYERED SEDIMENTS (Quls)" cont. SILTY CLAY (CL) cont.						
								SANDY CLAY (CL), olive brown, moist, stiff.						
42.7	60		36					POORLY GRADED SAND with SILT (SP-SM), olive brown, wet, medium dense, fine grained sand.	105	22				CORR
37.7	65		17					SILT with CLAY and SAND (ML), olive green, moist, stiff, non-plastic silt.						
								SILTY SAND (SM), olive brown, moist, dense, fine grained sand.						
32.7	70		38											GS (-#200=17%)
27.7	75		22					Olive gray, wet, medium dense, fine grained.						GS (-#200=22%)
22.7	80		27					Increased amount of medium grained sand.						GS (-#200=12%)
17.7	85		45					Olive gray, wet, dense, medium to coarse grained, trace to minor fine rounded gravel.						
								SANDY GRAVEL (GP), olive brown, wet, dense, fine gravel, subrounded to subangular, matrix of medium to coarse grained sand with clayey silt fines.						

NOTES:
1) Bottom of boring at 86.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring completed as Piezometer B-109P on 9/25/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 85 ft, 6-inch diameter Rotary Wash, 85 to 121.5 feet 4-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-113P
DRILLING DATE: October 14-15, 2015
ELEVATION: 99.9 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								"ARTIFICIAL FILL (af)" CLAY (CL), dark gray, damp, soft.						
94.9	5		0		0.16	0.25		"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, wet, very soft.						
89.9	10		50 psi		0.09	0.15			46	100	101	41	155 (TxUU)	
84.9	15		0		0.15	0.3		Soft.						
79.9	20													
74.9	25		0		0.19	0.4								
69.9	30		50 psi		0.45			Medium stiff, trace shells.	51 50	85 88	88	36	344 (TxUU)	C
64.9	35													
59.9	40													
54.9	45		16			1.8		"UPPER LAYERED SEDIMENTS (Quls)" FAT CLAY (CH), grayish brown, moist, stiff, minor orange mottling.						
49.9	50		18			1.2		Dark olive brown with grayish brown mottling, trace concretions up to 1/2 inch.	92	31	60	25	1606 (UCS)	CORR

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 85 ft, 6-inch diameter Rotary Wash, 85 to 121.5 feet 4-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-113P
DRILLING DATE: October 14-15, 2015
ELEVATION: 99.9 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
		21		2.6	"UPPER LAYERED SEDIMENTS (Quls)" cont. FAT CLAY (CH) cont. At 55 feet: Very stiff, increasing orange mottling.						
39.9	60	7		1.2	SILTY CLAY (CL), grayish brown with minor orange mottling, moist, stiff.						
34.9	65	28		1.0	Grades to Clayey Sand.	106	22				GS (-#200=39%)
					POORLY GRADED SAND (SP), dark brown to dark gray, wet, medium dense, fine to medium grained.						
29.9	70	16									
24.9	75	24			WELL GRADED SAND with CLAY (SW-SC), gray to brown, wet, medium dense, gravel up to 1/4 inch diameter, fine to coarse sand.						GS (-#200=10%)
19.9	80	26			Decreasing gravel, dense.						
14.9	85	26			"OLD BAY DEPOSITS (Qobd)" LEAN CLAYEY GRAVEL with SAND to GRAVELLY FAT CLAY (GC/CH), dark olive brown, moist, stiff to very stiff.						
9.9	90	36			Dark gray.			45	23		
4.9	95										
-0.1	100	15		2.0	Very dark gray with trace orange mottling, moist, stiff.	69	54			1244 (UCS)	
-5.1	105										

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 85 ft, 6-inch diameter Rotary Wash, 85 to 121.5 feet 4-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-113P
DRILLING DATE: October 14-15, 2015
ELEVATION: 99.9 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			12			1.2		"OLD BAY DEPOSITS (Qobd)" LEAN CLAYEY GRAVEL with SAND to GRAVELLY FAT CLAY (GC/CH) cont.	63	61	79	32	984 (UCS)	
-15.1	115													
-20.1	120		16			1.75		Dark greenish gray, trace shells.						

NOTES:
1) Bottom of boring at 121.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring completed as Piezometer B-113P on 10/15/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 121.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-114P
DRILLING DATE: October 20-21, 2015
ELEVATION: 99.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
					"ARTIFICIAL FILL (af)" LEAN CLAY (CL), dark gray, moist, soft, minor orange mottling, trace plant debris. (POND SEDIMENTS)						
94.6	5	0	0.15		"YOUNG BAY MUD (Qybm)" FAT CLAY to ELASTIC SILT (CH/MH), dark gray, wet, soft.						
89.6	10	50psi	0.15			44 46	105 96	83	39	285 (TxUU)	C
84.6	15	0		0.5							
79.6	20	0		0.4	Abundant shells.						
74.6	25	0		0.4							
69.6	30	0	0.24	0.6	Abundant shell fragments.	48	92	83	35		CORR
64.6	35	0		0.5							
59.6	40	4	0.52	1.25	Moist, stiff.						
					"UPPER LAYERED SEDIMENTS (Quls)" FAT CLAY (CH), grayish brown to dark olive brown, moist, very stiff, trace black and orange mottling.						
54.6	45	23		2.0		100	26	55	24	1999 (UCS)	
49.6	50	15		1.9	Gray to orange mottling, stiff.						

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 121.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-114P
DRILLING DATE: October 20-21, 2015
ELEVATION: 99.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
		25	2.7	"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont. At 55 feet: Brownish gray with dark gray and orange mottling, very stiff.						
39.6	60	32		CLAYEY SAND (SC), medium brown, wet, medium dense, fine grained sand, minor silt.						
34.6	65	26								GS (-#200=29%)
29.6	70	15								GS (-#200=24%)
24.6	75	34		Fine to medium grained sand.	101	17				DS, CORR
		26								GS (-#200=13%)
19.6	80	23		WELL GRADED SAND and CLAY (SW-SC), brown to gray, wet, medium dense, gravel clasts 3/4 inches in diameter, fine to coarse grained sand.						GS (-#200=9%)
14.6	85	33		Dense, increasing fine gravel.						GS (-#200=9%)
9.6	90	16		"OLD BAY DEPOSITS (Qobd)" FAT CLAY (CH), dark greenish brown, moist, very stiff, trace gravel.						
4.6	95	29	2.4		100	26	67	23	2130 (UCS)	
-0.4	100	16	2.4	No gravel.						
-5.4	105	18	3.5	Dark greenish gray.						

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 121.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-114P
DRILLING DATE: October 20-21, 2015
ELEVATION: 99.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			13			1.5		"OLD BAY DEPOSITS (Qobd)" cont. LEAN CLAY (CL) cont. At 110 feet: Stiff.	63	61			827 (UCS)	
-15.4	115													
-20.4	120		11			1.5		Dark gray.						

NOTES:
1) Bottom of boring at 121.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring completed as Piezometer B-114P on 10/21/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 98 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: K. Khatri, J. Thurber
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-115P
DRILLING DATE: November 2-3, 2015
ELEVATION: 102.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								2 inches Asphalt Concrete.						
								"ARTIFICIAL FILL (af)" CLAYEY SAND (SC), brown, moist.						
								GRAVELLY CLAY (CL), dark gray, damp, very stiff, angular 1/4 -1 inch diameter gravel clasts, filter fabric fragment.						
97.5	5							Medium brown, moist, 3 inch diameter hard gravel clasts.						
								LEAN CLAY with GRAVEL (CL), gray brown, moist to wet, stiff.						
								"YOUNG BAY MUD (Qybm)"						
92.5	10							FAT CLAY (CH), dark gray, wet, soft.						
87.5	15													
82.5	20													
77.5	25													
72.5	30													
67.5	35													
								Trace shell fragments.						
62.5	40													
								Shell fragments.						
57.5	45							"UPPER LAYERED SEDIMENTS (Quls)" FAT CLAY (CH), dark olive brown to grayish brown, wet, trace shell fragments.						
52.5	50													

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 98 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: K. Khatri, J. Thurber
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-115P
DRILLING DATE: November 2-3, 2015
ELEVATION: 102.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
		40	2.5	"UPPER LAYERED SEDIMENTS (Quls)" cont. FAT CLAY (CH) cont. At 55 feet: dark brown with gray mottling, moist, hard.	88 90	34 32	69	29	2221 (UCS)	
42.5	60	29	1.4	SILTY SAND (SM), dark brown, moist, medium dense, fine grained sand.						CORR
37.5	65	8		SILTY CLAY (CL), brown, wet, soft.						
				SILTY SAND (SM), dark brown, wet, loose, very fine grained sand.						
32.5	70	41		Very dark brown, dense, trace medium grained sand.						
27.5	75	27		POORLY GRADED SAND with SILT (SP-SM) to SILTY SAND (SM), dark brown to dark gray, wet, medium dense, fine to medium grained sand.						GS (-#200=8%)
22.5	80	30		Dark gray, dense, trace coarse grained sand, trace gravel up to 1 inch in diameter.						CORR
17.5	85	27		Increasing grain size, coarse grained sand to fine gravel.						GS (-#200=14%)
12.5	90	29		LEAN CLAY (CL), dark greenish gray, wet, very stiff.						
7.5	95	47	2.7	Dark grayish brown, moist, hard.						

NOTES:
1) Bottom of boring at 98 feet.
2) Groundwater not observed due to drilling method.
3) Boring reamed to 10 inches in diameter and completed as 5-inch diameter well (Piezometer B-115P) on 11/3/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road at Tunnel/RLS Shaft interface, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to xxxx ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: D. Agnew, M. Simpson
CHECKED BY: J. Seibold

DRILL HOLE NO.: B-116
DRILLING DATE: October 27-28, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
							"ARTIFICIAL FILL (af)" SILTY CLAY/CLAYEY SILT (CL/ML), dark gray, moist. (POND SEDIMENTS)						
							"YOUNG BAY MUD (Qybm)" ELASTIC SILT to FAT CLAY (MH/CH), dark olive gray to very dark gray, moist to wet, very soft.						
94.5	5			0.24	0.275								
89.5	10		0				Wet. Minor organics.	47	96	102	44		CORR
84.5	15		0	0.20 0.40			Minor shells.	49	88			297 (TxUU)	
79.5	20		0	0.19			Decreasing elasticity.						
							FAT CLAY (CH), dark gray, wet, very soft. Abundant shells.						
74.5	25		0	0.26			Minor organics.		95				OC
69.5	30		50psi					51 54	86 78	89	37	385 (TxUU)	C
64.5	35		0	0.26			Abundant shells.						
59.5	40		0 12	0.26 0.27									
							"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), mottled olive gray, dark gray, and light olive gray, moist, stiff to very stiff, trace fine grained sand, trace concretions and carbonate cement.						
54.5	45		20 10		1.8 2.7		Yellowish brown.	104	23	46	20	1125 (UCS)	
49.5	50		18 12		1.9 2.1		Minor orange mottling.						CORR

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road at Tunnel/RLS Shaft interface, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to xxxx ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: D. Agnew, M. Simpson
CHECKED BY: J. Seibold

DRILL HOLE NO.: B-116
DRILLING DATE: October 27-28, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			31				"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont. At 56 feet: Very stiff, trace black mottling.	94	30			2225 (UCS)	
			14										
39.5	60		32		2.4								
			33				SILTY SAND (SM), medium brown, wet, dense, fine grained sand.						
34.5	65		18				SANDY SILT/SILTY SAND (ML/SM), brown, wet, medium dense, fine grained sand.	103	25				FC (-#200=64%)
			41				Very dense.						
29.5	70		35				POORLY GRADED SAND with SILT (SP-SM), dark brown to dark gray, wet, medium dense, fine to coarse grained sand.	100	23				CORR, DS, GS (-#200=10%)
			21				Increasing grain size. Trace gravel clasts to 1/2 inch in diameter.						
24.5	75		19				SILTY SAND (SM), brown to gray, wet, medium dense, fine to coarse grained sand, fine gravel, trace gravel clasts up to 1 1/3 inch diameter.						GS (-#200=12%)
19.5	80		30				WELL GRADED SAND with SILT (SW-SM), brown to gray, wet, dense, trace gravel up to 1 inch diameter.						GS (-#200=10%)
							Trace to minor clay.						
14.5	85		30				Mixture of sand, gravel, and clay.						
							FAT CLAY (CH), dark brownish gray, moist, hard.						
9.5	90		30		3.75		Brownish gray and grayish olive brown mottling, very stiff.	95	30	63	29	2412 (UCS)	
4.5	95		38		2.75		Dark gray with brownish gray mottling, hard.						
-0.5	100		18		2.5		Dark bluish gray, very stiff.	71	52			1280 (UCS)	
-5.5	105												

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 2/3/16

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road at Tunnel/RLS Shaft interface, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to xxxx ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: D. Agnew, M. Simpson
CHECKED BY: J. Seibold

DRILL HOLE NO.: B-116
DRILLING DATE: October 27-28, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
		■	18		3.5		"UPPER LAYERED SEDIMENTS (Quls)" cont. FAT CLAY (CH) cont.	65	59	89	36	1263 (UCS)	
-15.5	115												
-20.5	120	■	18		2.2		Very dark gray.						

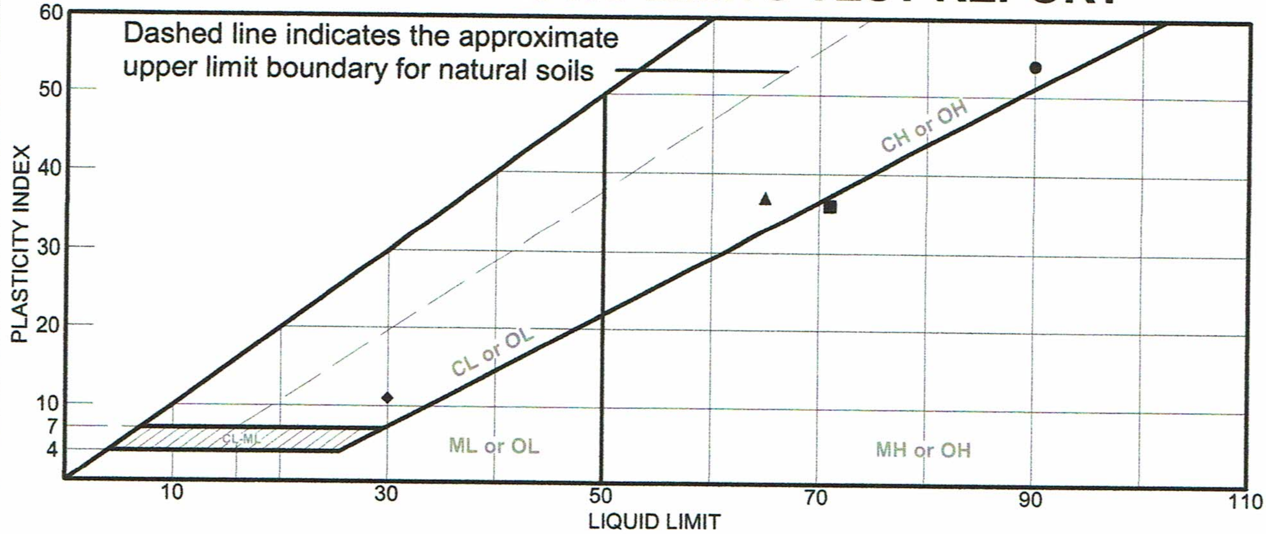
NOTES:
1) Bottom of boring at 121.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring backfilled with cement grout on 10/28/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

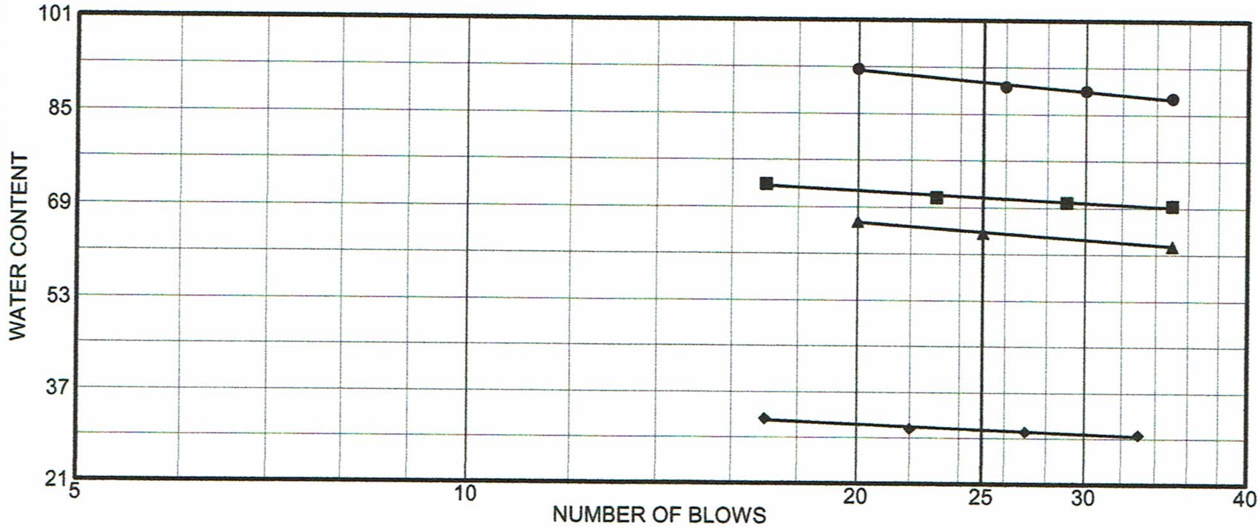
LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

APPENDIX C

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Greenish Gray Fat CLAY (Bay Mud)	90	36	54			
■	Greenish Gray Elastic SILT (Bay Mud)	71	35	36			
▲	Greenish Gray Fat CLAY (Bay Mud)	65	28	37			
◆	Olive Brown Lean CLAY	30	19	11	99.9	86.6	CL

Project No. 836-002 **Client:** DCM Consulting, Inc.

Project: SVCW Headworks

● **Source:** B-101 **Elev./Depth:** 10-13'

■ **Source:** B-101 **Elev./Depth:** 25-28'

▲ **Source:** B-101 **Elev./Depth:** 40-43'

◆ **Source:** B-101 **Elev./Depth:** 60-63'

Remarks:

●

■

▲

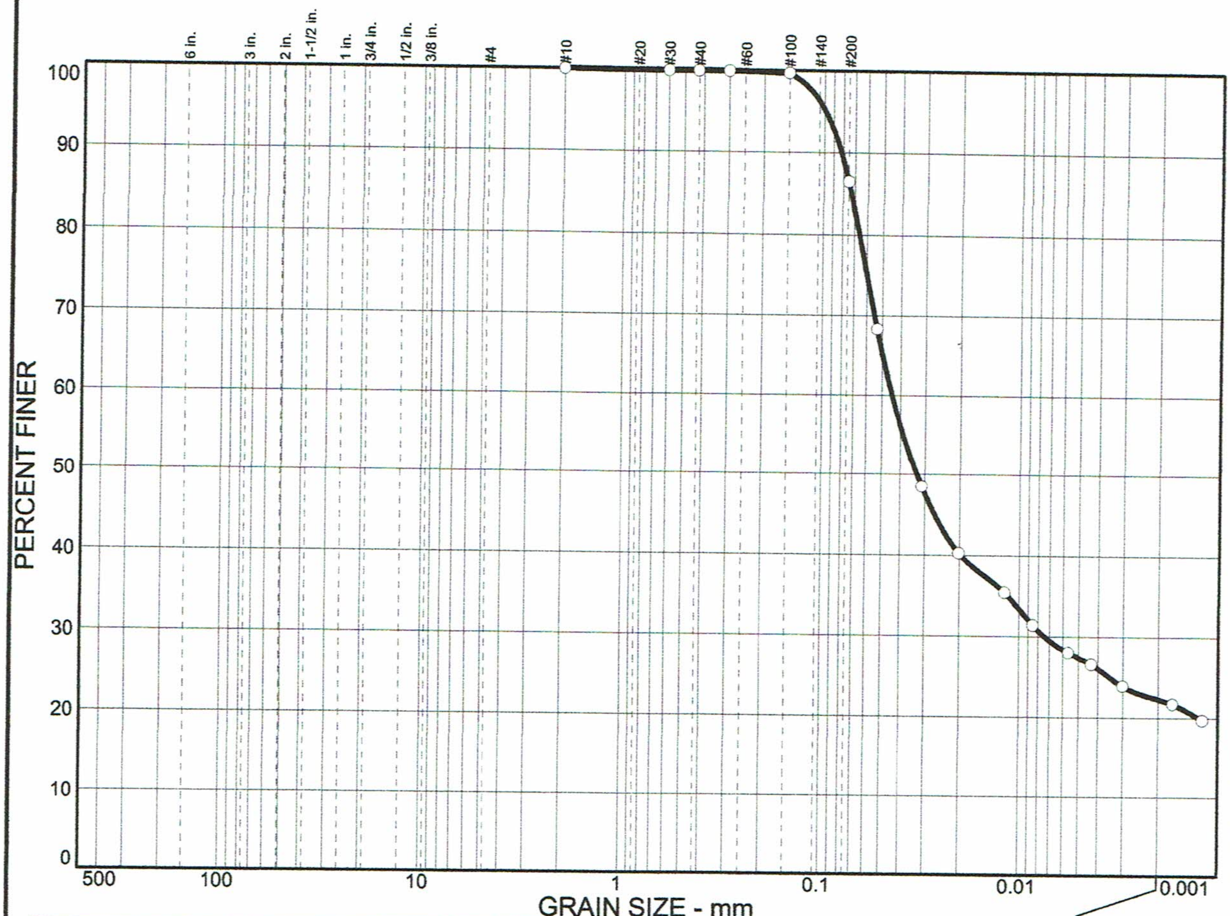
◆

LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	13.4	64.3	22.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#30	99.9		
#40	99.9		
#50	99.9		
#100	99.7		
#200	86.6		
#270	68.3		
0.0311 mm.	48.5		
0.0202 mm.	40.3		
0.0119 mm.	35.4		
0.0085 mm.	31.4		
0.0056 mm.	28.0		
0.0043 mm.	26.6		
0.0030 mm.	23.9		
0.0017 mm.	21.7		
0.0012 mm.	19.7		

* (no specification provided)

Soil Description

Olive Brown Lean CLAY

Atterberg Limits

PL= 19 LL= 30 PI= 11

Coefficients

D_{85}= 0.0724 D_{60}= 0.0442 D_{50}= 0.0329
D_{30}= 0.0074 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO=

Remarks

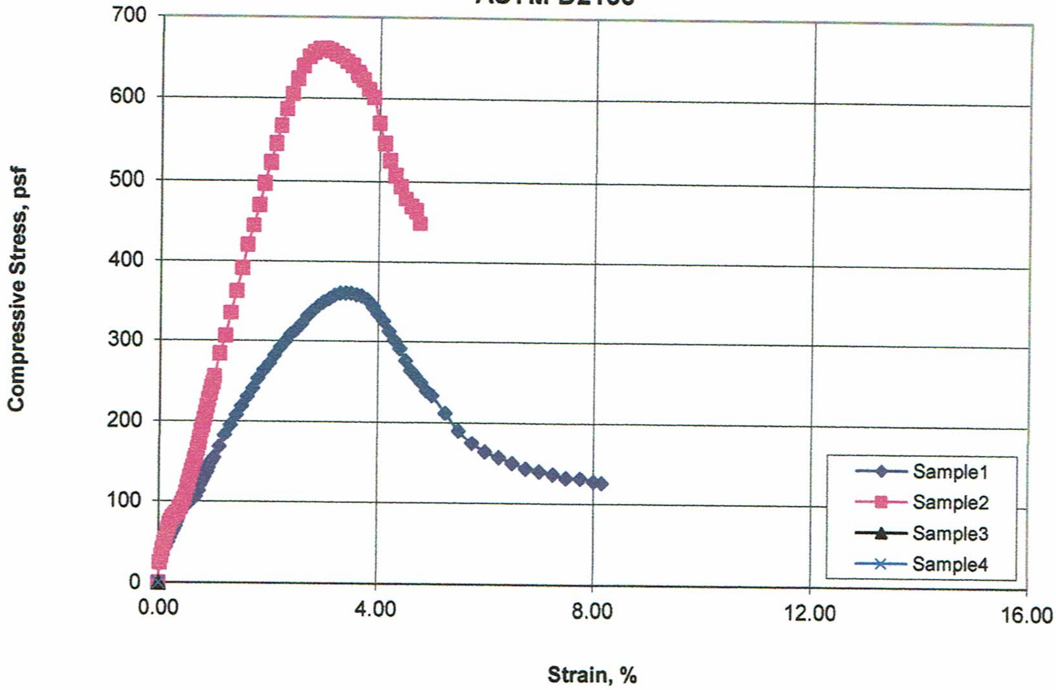
Sample No.:
Location:
Source of Sample: B-101
Date: 10/16/15
Elev./Depth: 60-63'

COOPER TESTING LABORATORY

Client: DCM Consulting, Inc.
Project: SVCW Headworks
Project No: 836-002
Figure

Unconfined Compressive Strength

ASTM D2166



Sample No.:	1	2	3	4	
Unconfined Compressive Strength, psf	361	661			
Unconfined Compressive Strength, psi	2.5	4.6			
Undrained Shear Strength, psf	181	330			
Failure Strain, %	3.4	3.0			
Strain Rate, % per minute	1.0	1.0			
Strain Rate, inches/minute	0.06	0.06			
Moisture Content, %	94.1	72.7			
Dry Density, pcf	46.5	56.1			
Saturation, %	96.8	97.8			
Void Ratio	2.625	2.006			
Specimen Diameter, inches	2.875	2.875			
Specimen Height, inches	6.10	6.08			
Height to Diameter Ratio	2.1	2.1			
Assumed Specific Gravity	2.70	2.70			

	Sample Location			
	Boring	Sample	Depth, ft.	Soil Description
1	B-101		10-13(Tip-4.5")	Greenish Gray Fat CLAY (Bay Mud)
2	B-101		40-43(Tip-5")	Greenish Gray Fat CLAY (Bay Mud)
3				
4				

Job No.: 836-002

Client: DCM Consulting, Inc.

Project: SVCW Headworks

Date: 10/13/2015 By: MD/RU

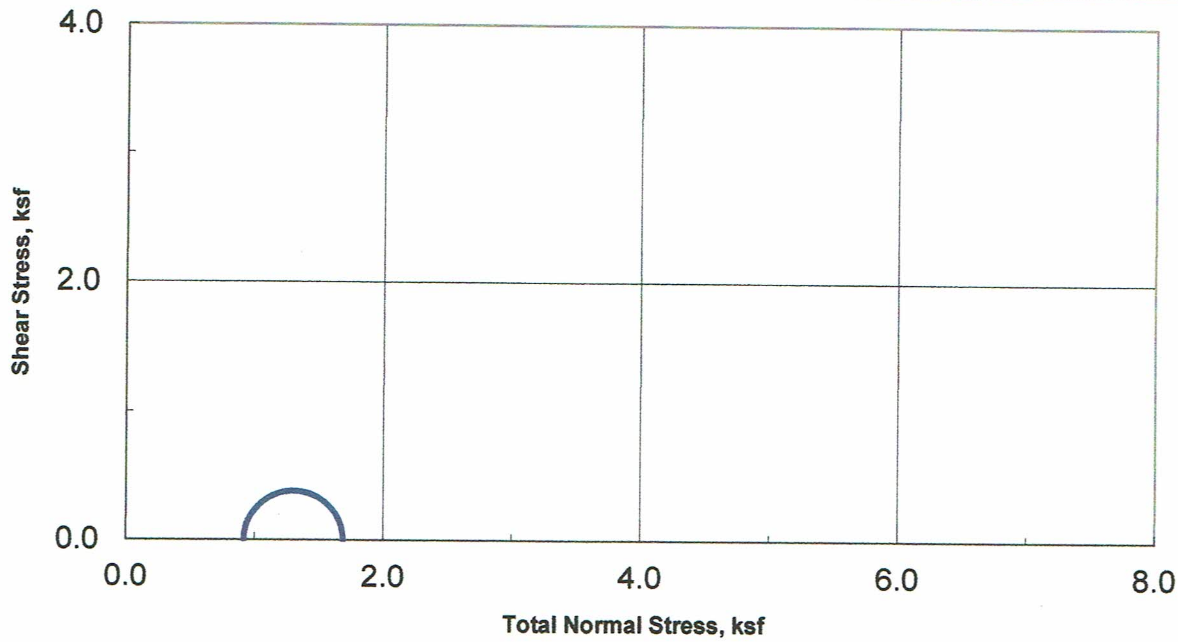
Type of Sample: Undisturbed

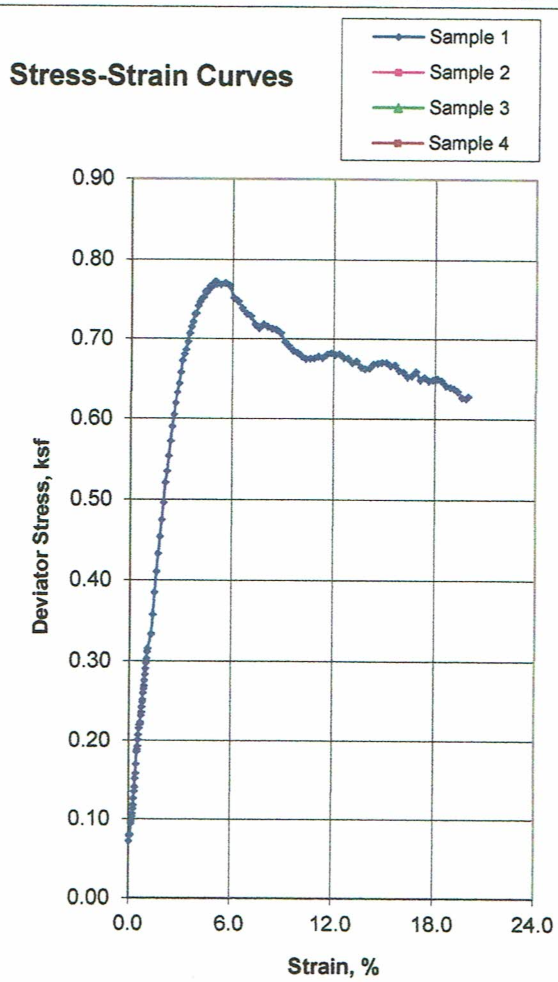
Remarks:

COOPER TESTING LABORATORY

Cooper Testing Labs, Inc.
937 Commercial Street
Palo Alto, CA 94303

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data

	1	2	3	4
Moisture %	82.2			
Dry Den,pcf	51.2			
Void Ratio	2.291			
Saturation %	96.9			
Height in	6.09			
Diameter in	2.88			
Cell psi	6.4			
Strain %	4.95			
Deviator, ksf	0.772			
Rate %/min	1.04			
in/min	0.064			

Job No.:	836-002			
Client:	DCM Consulting, Inc.			
Project:	SVCW Headworks			
Boring:	B-101			
Sample:				
Depth ft:	25-28(Tip-6.5")			

Visual Soil Description

Sample #	
1	Greenish Gray Elastic SILT (Bay Mud)
2	
3	
4	

Remarks:

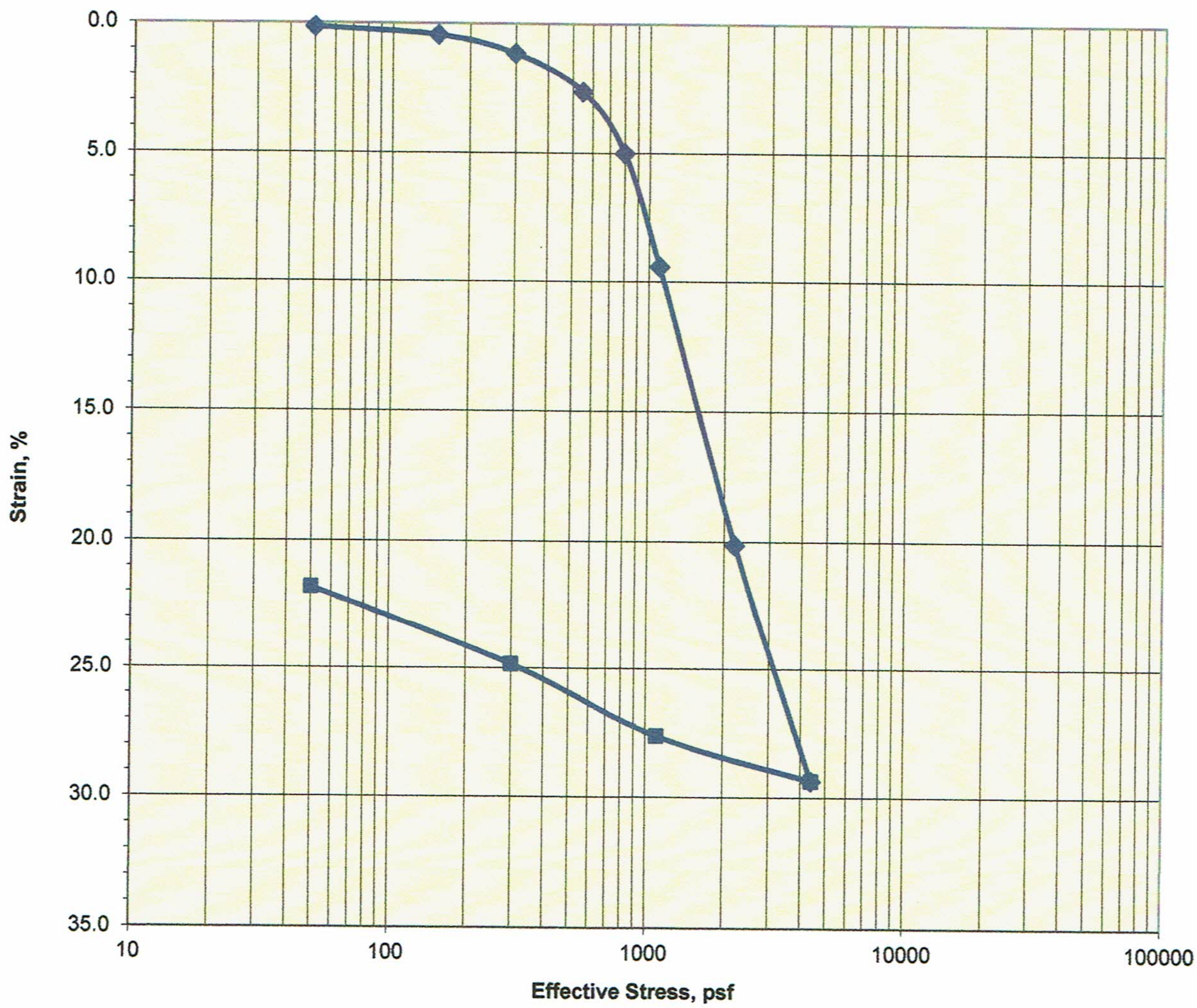
Note: Strengths are picked at the peak deviator stress or 15% strain which ever occurs first per ASTM D2850.

COOPER TESTING LABORATORY

Consolidation Test
ASTM D2435

Job No.:	836-002	**Boring:**	B-101	**Run By:**	MD
Client:	DCM Consulting, Inc.	**Sample:**		**Reduced:**	PJ
Project:	SVCW Headworks	**Depth, ft.:**	10-13(Tip-4")	**Checked:**	PJ/DC
Soil Type:	Greenish Gray Fat CLAY (Bay Mud)			**Date:**	10/16/2015

Strain-Log-P Curve

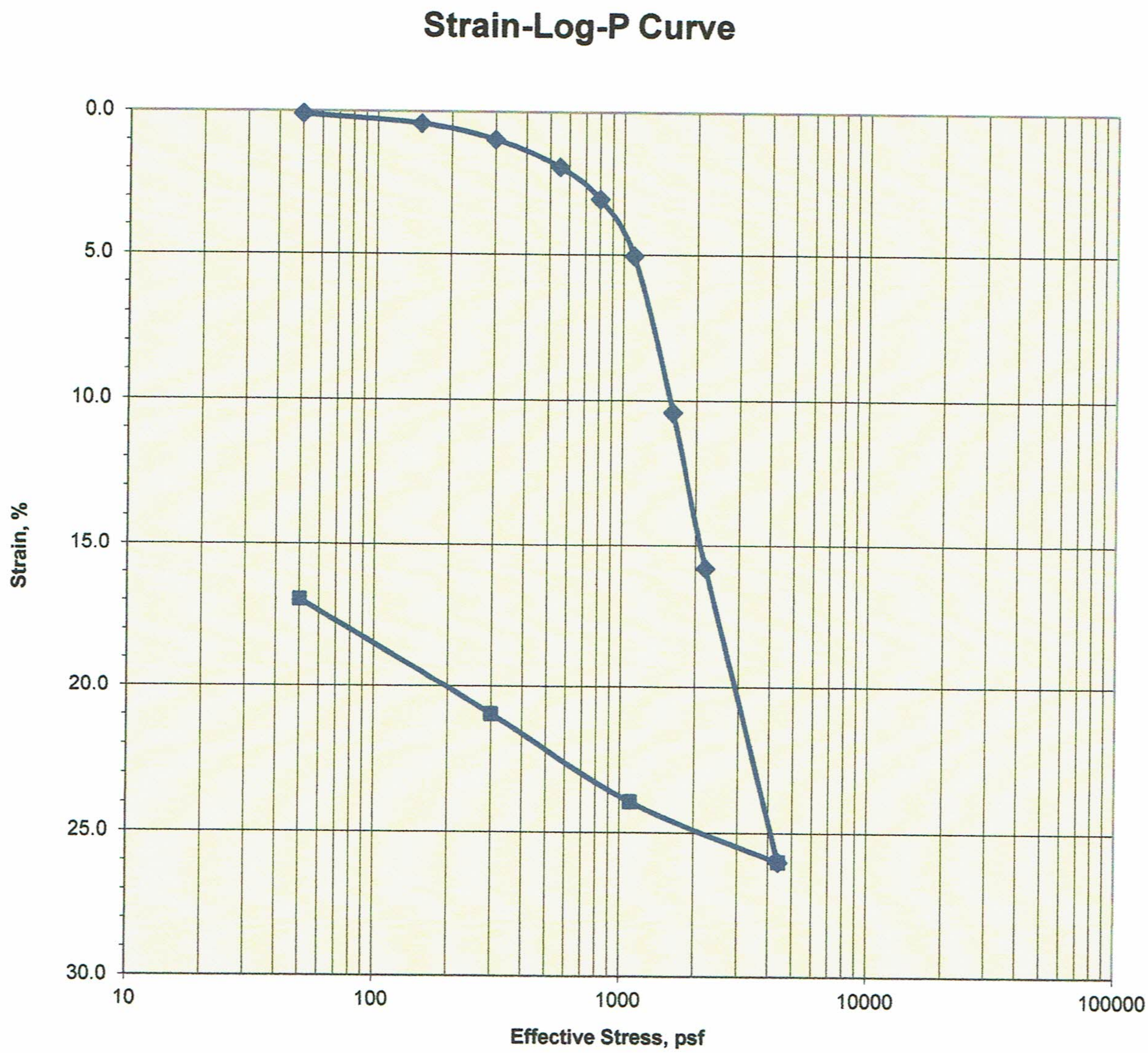


Assumed Gs 2.7	Initial	Final
Moisture %:	97.6	68.5
Dry Density, pcf:	45.8	59.1
Void Ratio:	2.680	1.850
% Saturation:	98.4	100.0

Remarks:

Consolidation Test
ASTM D2435

Job No.:	836-002	**Boring:**	B-101	**Run By:**	MD
Client:	DCM Consulting, Inc.	**Sample:**		**Reduced:**	PJ
Project:	SVCW Headworks	**Depth, ft.:**	25-28(Tip-6")	**Checked:**	PJ/DC
Soil Type:	Greenish Gray Elastic SILT (Bay Mud)			**Date:**	10/20/2015



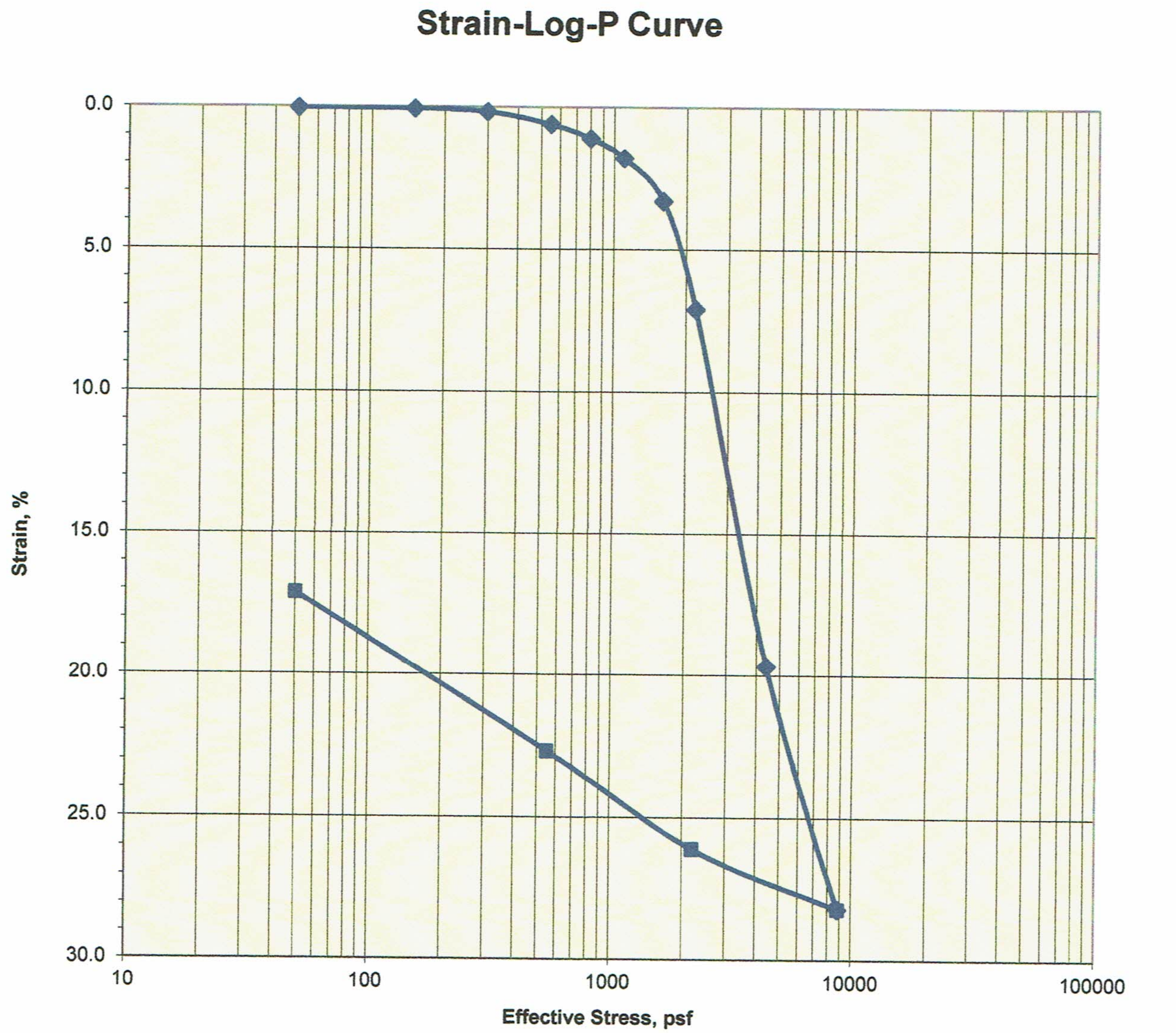
Assumed Gs 2.65	Initial	Final
Moisture %:	92.2	69.8
Dry Density, pcf:	47.8	58.0
Void Ratio:	2.462	1.851
% Saturation:	99.3	100.0

Remarks:

Consolidation Test
ASTM D2435

COOPER TESTING LABORATORY

Job No.:	836-002	**Boring:**	B-101	**Run By:**	MD
Client:	DCM Consulting, Inc.	**Sample:**		**Reduced:**	PJ
Project:	SVCW Headworks	**Depth, ft.:**	40-43(Tip-4")	**Checked:**	PJ/DC
Soil Type:	Greenish Gray Fat CLAY (Bay Mud)			**Date:**	10/20/2015



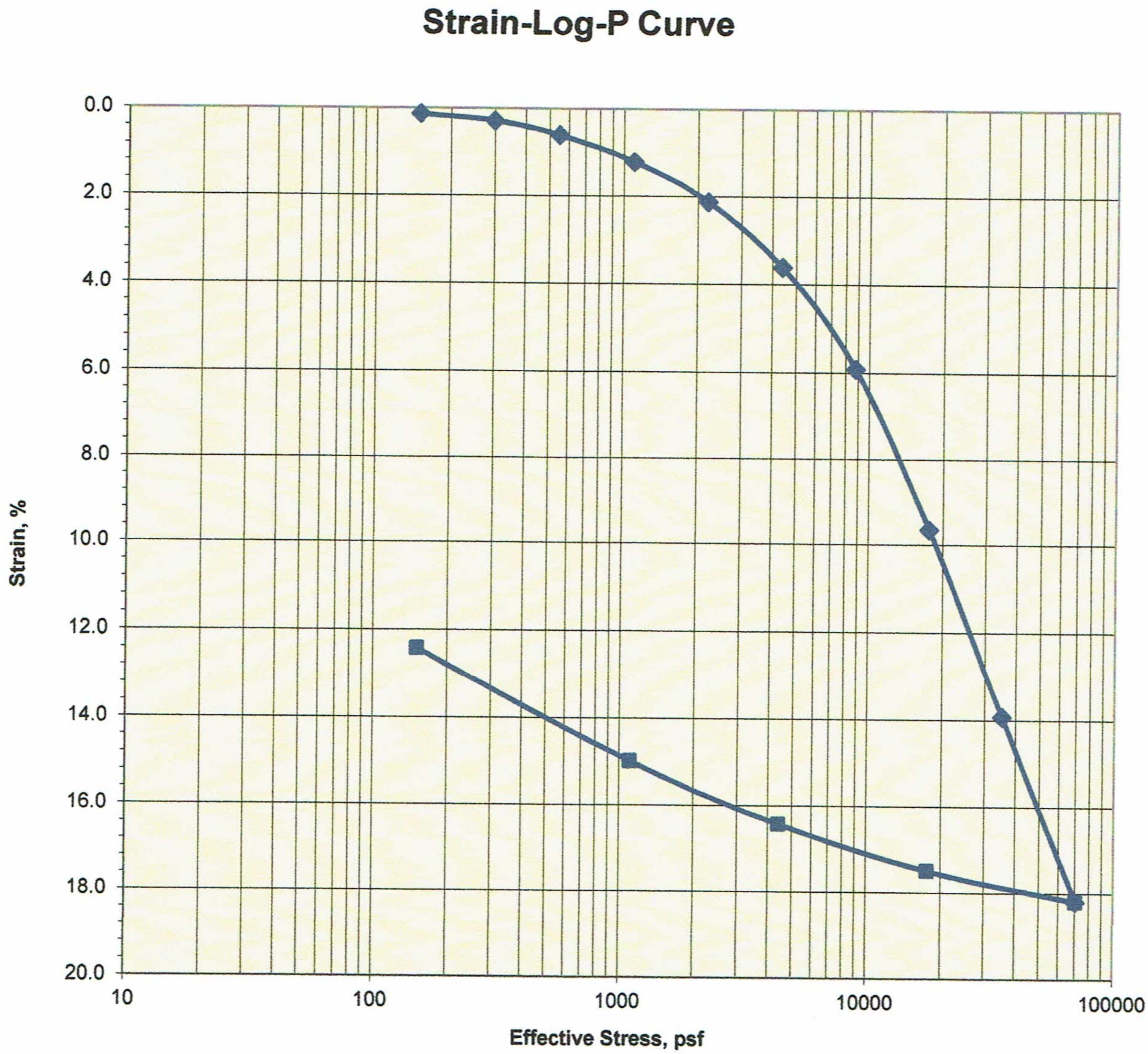
Assumed Gs 2.7	Initial	Final
Moisture %:	85.2	63.8
Dry Density, pcf:	50.9	61.9
Void Ratio:	2.314	1.724
% Saturation:	99.4	100.0

Remarks:

Consolidation Test
ASTM D2435

COOPER TESTING LABORATORY

Job No.:	836-002	**Boring:**	B-101	**Run By:**	MD
Client:	DCM Consulting, Inc.	**Sample:**		**Reduced:**	PJ
Project:	SVCW Headworks	**Depth, ft.:**	60-63(Tip-8")	**Checked:**	PJ/DC
Soil Type:	Olive Brown Lean CLAY			**Date:**	10/23/2015



Assumed Gs 2.75	Initial	Final
Moisture %:	25.0	20.2
Dry Density, pcf:	96.8	110.3
Void Ratio:	0.773	0.556
% Saturation:	89.1	100.0

Remarks:

APPENDIX D

Abe Construction Services, Inc.

5111 Doolan Rd, Livermore, CA 94551
PHONE: 925-944-6363 FAX: 925-476-1588
EMAIL: SA@ACSpile.com

Dynamic Pile Test Report

Company:	Stroer & Graff		June 4, 2015
Attn:	Dan McWilliams	**From:**	Steve Abe
Re:	Silicon Valley Clean Water Plant Redwood City, CA		Job No. 15037

This report presents dynamic pile monitoring results for the project referenced above obtained during initial driving for sixteen piles on June 1 and June 2, and during one restrike for Pile 14 on June 4, 2015. The primary test objectives were to evaluate soil resistance at the time of testing, pile driving stresses, and hammer performance. The dynamic testing was performed using a Model PAX Pile Driving Analyzer (PDA) according to the ASTM D4945 test standard. Subsequent CAPWAP analysis was performed for selected restrike test data to further evaluate pile capacity and soil resistance distributions.

Pile Details

The piles consist of 109 ft long 14" square PCPS concrete piles with an ultimate concrete strength of 6000 PSI and effective concrete prestress of 999 PSI with maximum allowable compression and tension driving stress limits of 4.10 KSI and 1.23 KSI.

Hammer / Driving System Details

The piles were driven with an APE D30-32 diesel hammer which has a maximum rated energy of 74.42 kip-ft.

Subsurface Soil Conditions

The general soil profile was not provided at the time of testing, however the piles driven in 30ft oversized predrilled holes.

DYNAMIC TEST RESULTS

The following PDA calculated Case Method results are printed versus blow number and pile penetration depth in Appendix A as well as CAPWAP analysis results which are included in Appendix B.

- RMX- the Case Method ultimate static capacity estimate using a Case Damping factor of 0.7
- EMX- maximum energy transferred to the pile.
- CSX- the maximum axial compression stress at the sensor location, computed using the average of two strain transducer measurements.
- TSX- the maximum axial tension stress at the sensor location, computed using the average of two strain transducer measurements.

The PDA results and CAPWAP Analysis results are summarized in the following table for selected pile penetration depths.

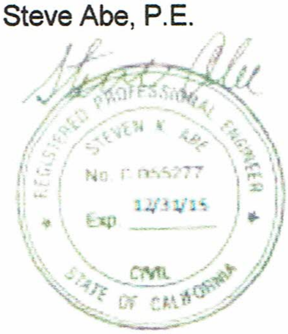
					PDA Results				
Pile No.	Type	Date	Depth BG	Blow Count	RMX (kips)	CSX (KSI)	TSX (KSI)	STK (ft)	EMX (kip-ft)
Pile 1	EOD	6/1	105.8	10	160	3.25	1.57	6.9	22.4
Pile 2	EOD	6/2	106.0	11	221	3.76	1.40	7.5	26.9
Pile 3	EOD	6/2	106.0	11	220	3.31	1.34	7.3	23.9
Pile 4	EOD	6/2	105.5	12	232	3.34	1.52	7.3	23.8
Pile 5	EOD	6/1	105.0	19	174	3.17	1.44	6.9	21.7
Pile 6	EOD	6/2	105.5	10	160	3.27	1.43	7.1	22.3
Pile 7	EOD	6/2	106.1	8	204	3.35	1.55	7.3	23.0
Pile 8	EOD	6/2	105.5	12	218	3.28	1.38	7.2	22.7
Pile 9	EOD	6/1	106.4	7	99	2.93	1.40	6.6	19.9
Pile 10	EOD	6/1	106.0	9	205	3.23	1.44	7.4	23.1
Pile 11	EOD	6/1	105.5	12	266	3.52	1.44	7.4	25.4
Pile 12	EOD	6/2	105.3	13	224	3.19	1.34	7.3	22.1
Pile 13	EOD	6/1	105.5	8	137	3.33	1.46	7.1	23.9
Pile 14	EOD	6/1	103.0	15	240	3.31	1.19	7.3	23.6
Pile 14R	BOR	6/4	104.0	40	304	4.37	0.83	7.9	26.4
Pile 15	EOD	6/1	106.5	16	258	3.27	1.23	7.2	23.0
Pile 16	EOD	6/1	106.1	9	212	3.08	1.24	7.1	22.2

The restrike CAPWAP capacity for Pile 14 was approximately 302 kips consisting of 187 kips shaft resistance and 115 kips toe resistance. Comparison of the EOD and BOR RMX capacity estimates for Pile 14 indicate that about 60 kips set-up gain occurred after driving. The RMX capacity estimates at EOD for the other piles ranged from 160 kips to 266 kips. The measured tensile driving stresses did exceed the allowable driving stress limits during initial driving, however no pile damage was observed in the PDA records for any piles.

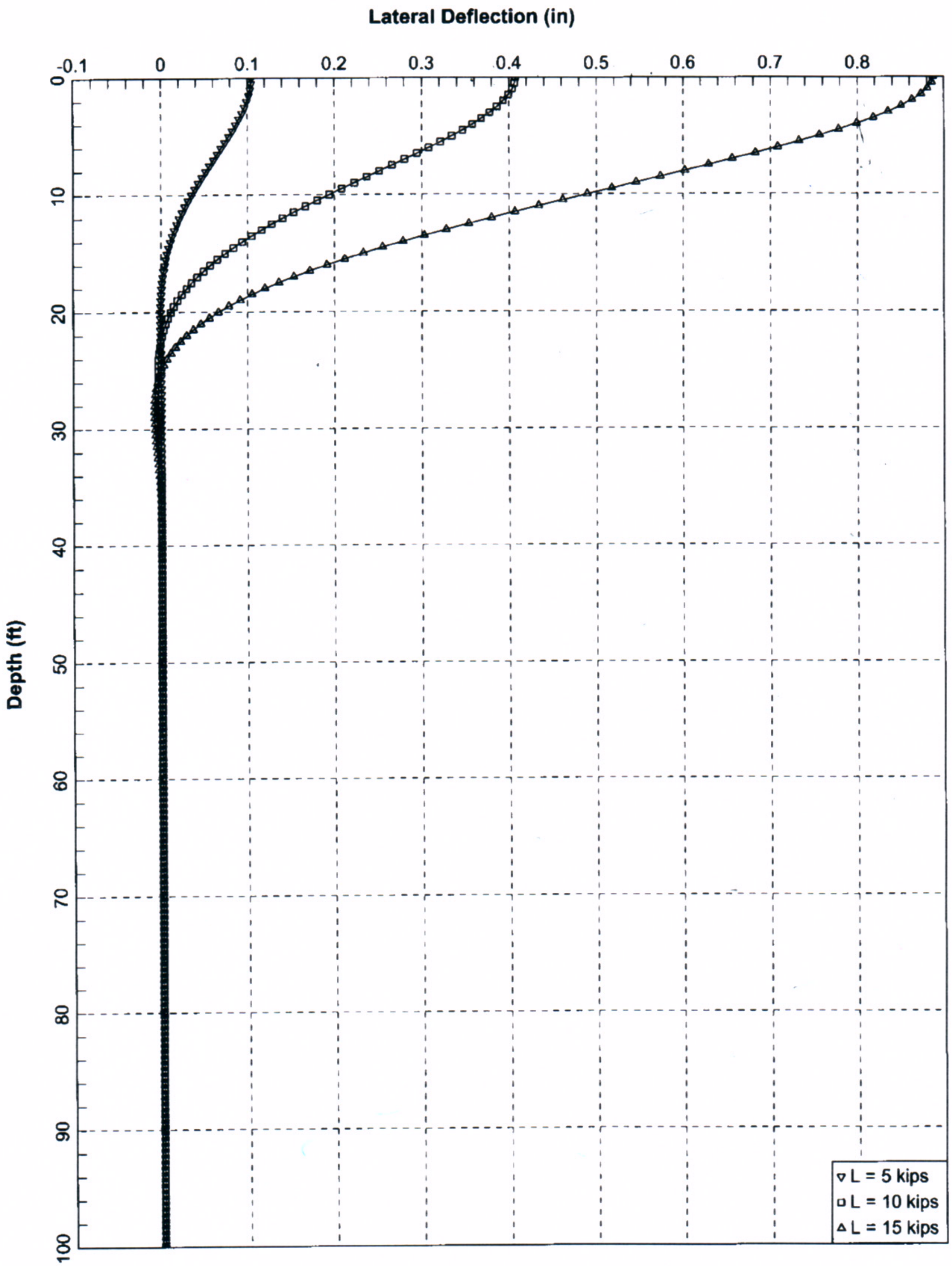
Please review the attached "LIMITATIONS AND CONSIDERATIONS REGARDING DYNAMIC TEST RESULTS". I appreciate the opportunity to assist you with this project. Please contact me if you have any questions regarding these results, or if we may be of further service.

Sincerely,

ACS, Inc.
Steve Abe, P.E.

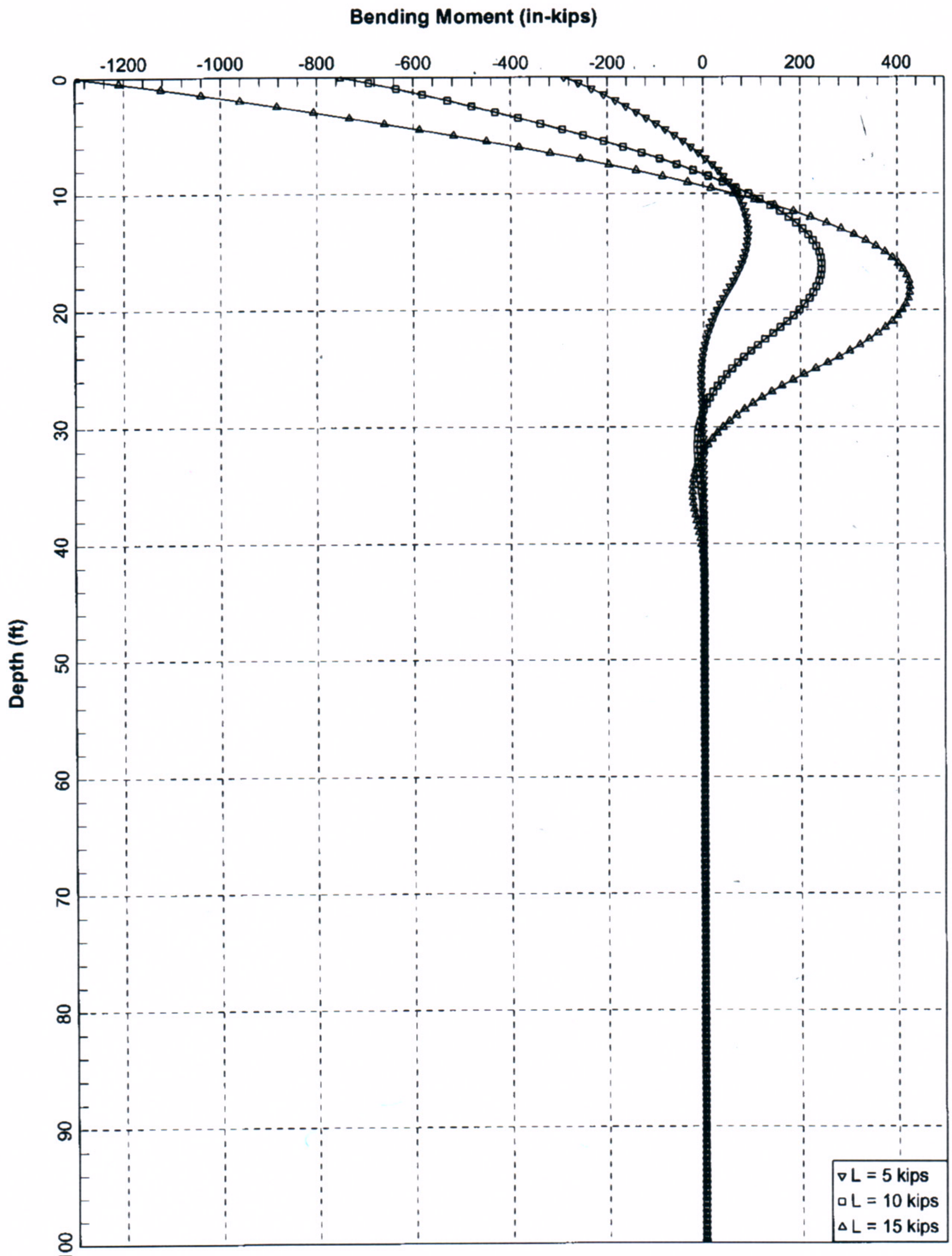


APPENDIX E



Lateral Deflection - 14-inch PCCP - Fixed Head Condition

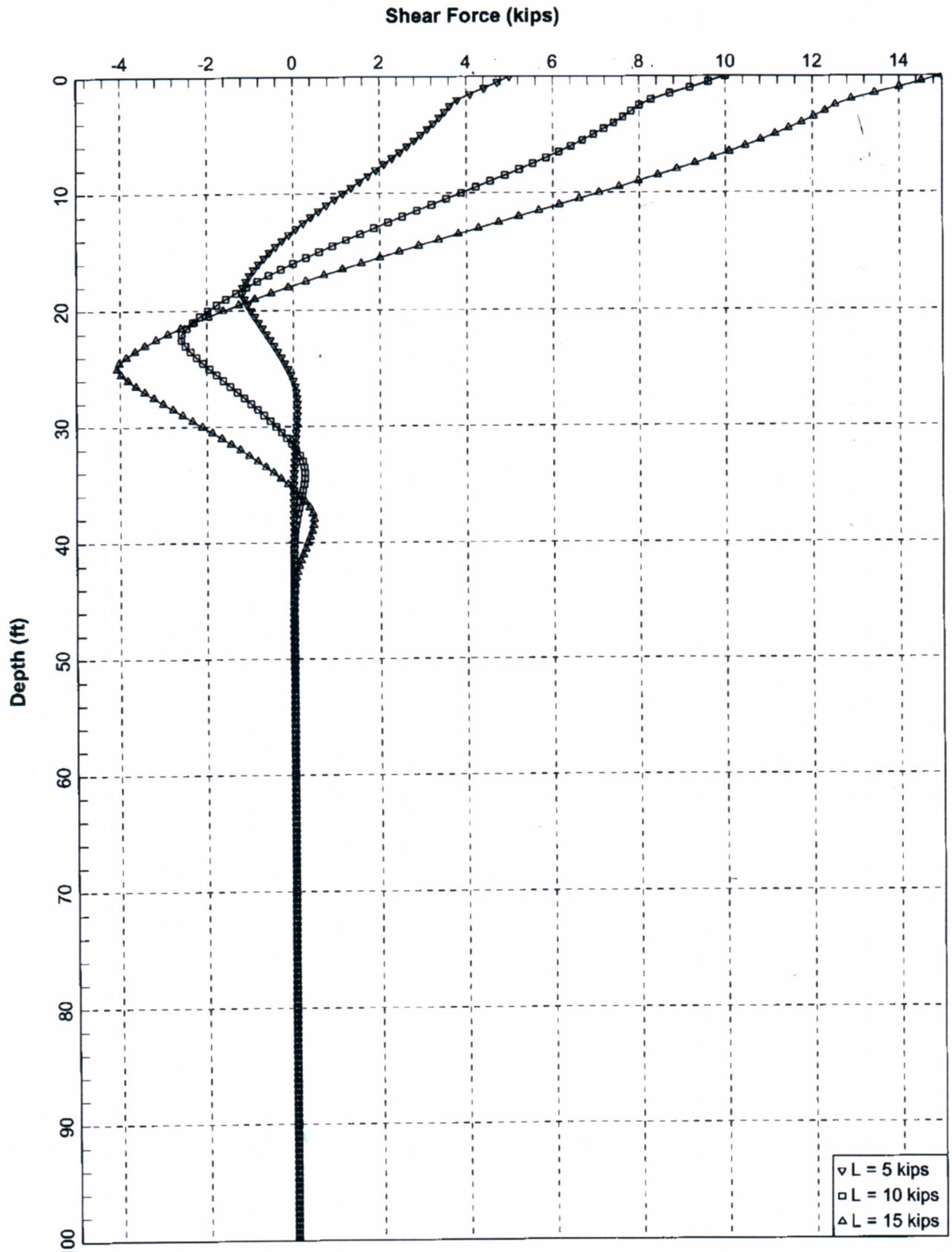
SBSA Administration and Control Building Project
New Stairway/Elevator Structure



Bending Moment - 14-inch PCCP - Fixed Head Condition

SBSA Administration and Control Building Project

New Stairway/Elevator Structure



Shear Force - 14-inch PCCP - Fixed Head Condition

SBSA Administration and Control Building Project
New Stairway/Elevator Structure

APPENDIX F

KIE-CON Inc.

3551 WILBUR AVENUE, ANTIOCH, CA 94509

REQUEST FOR INFORMATION

RFI #: RFI-409-2015-1

To:	**Project Manager**	Copy to:			
Company					
Email:		From:	Danny Wong	Total Pg:	2
Fax #:		Tel:	925.754.9494 x 7107	Fax:	925.754.0624
Phone #:		Email:	dwong@kiecon.com	Date:	2/20/2015
Project:	**Influent Screen Phase 1, San Mateo, CA**			**KC ref**	**409-2015**
Reference	**REQUEST FOR INIFORMATION; PRESTRESSED PILES**				

LADIES / GENTLEMEN:

We are in the process of preparing the shop drawing. And we need the EOR to look into the lateral load on the pile.

The contract drawing calls for 15 kips working load, yielding 1100 k-in fixed moment. Using the standard 1.4 factor, the factored moment becomes 128.3 k-ft. This is way beyond a 14" square pile capacity. Please request for the EOR to reduce the lateral load and soil engineer regenerate the new appropriate Lpile moment profile. If reduction not possible, then the EOR need to add more piles.

Attached is the interaction diagram of a 14" sq pile with 6 #9 rebars extended into the pile cap. The project factored loads are also shown. 6 #9 is probably the maximum number of rebars we like to put in without congestion.

☐ **Please Review** ☑ **Please Review & Reply** ☐ ____________

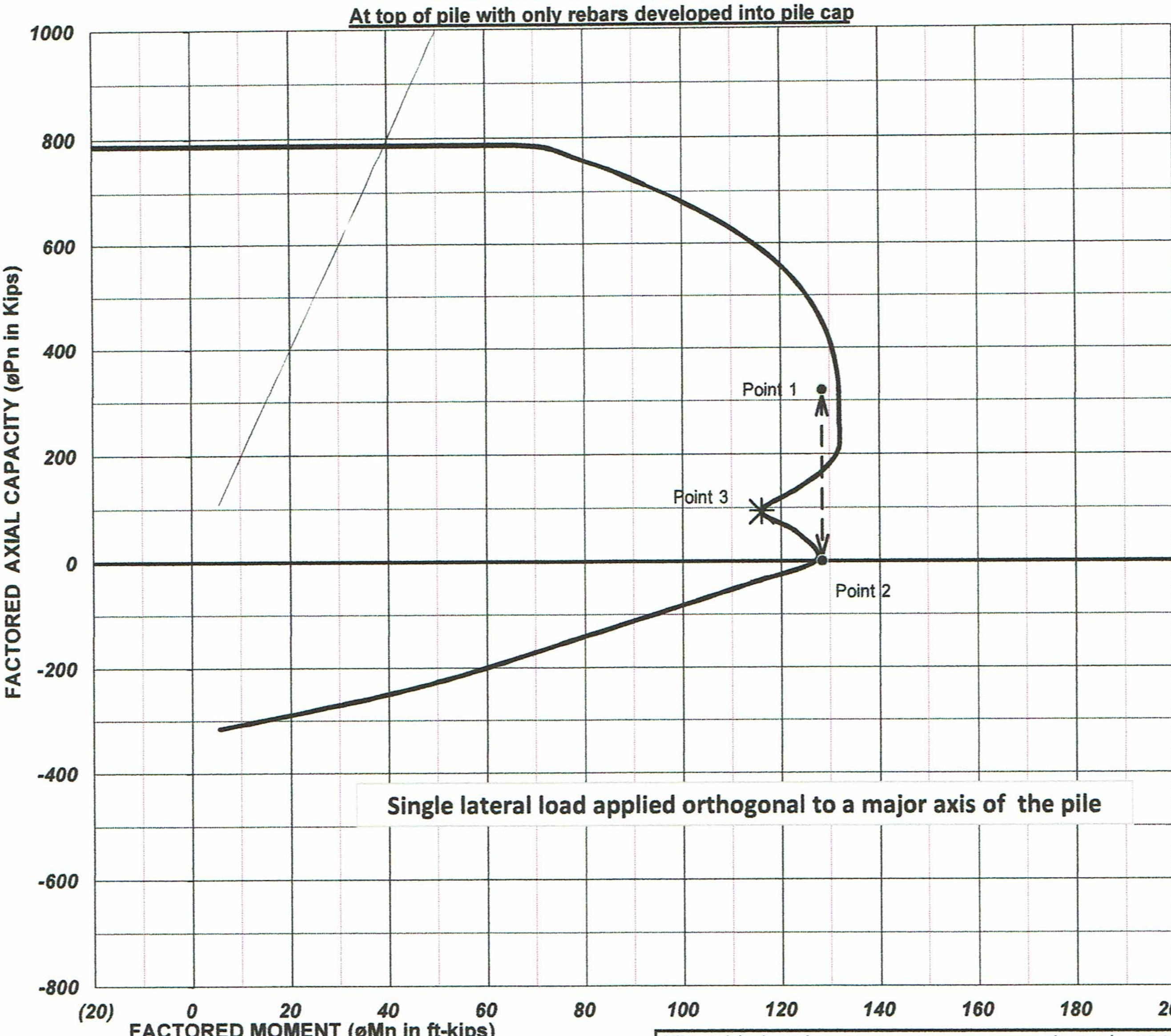
Reply:

Name / Signature: ______________________ **Date:** ______________

PILE INTERACTION DIAGRAM

Influent Screen - Non-Tension Piles

At top of pile with only rebars developed into pile cap



This is at the top of pile with rebars extended into pile cap.
14" Square Pile f'c = 6,000 psi Min. Cover = 2.0 "
No Strand Developed Into Pilecap
Effective Prestress (fpc) = 0 psi
6-#9 Rebar (GR60) Inside Spiral Wire
No Rebar (GR60) In Outside Corners

Allowable Loads

D = 133 kips	L = 67 kips	Lateral = 15.0 kips
		E / 1.4 = 67 kips
Drag = 0 kips	T = 0 kips	Moment = 92 k-ft

Factored Loads

1.2[D +DD] + 1.0E + fi*L =	320 kips	<---Point 1
1.4 x allowable moment =	128 k-ft	**NG: exceed Capacity**
Ten max = 1.4Ten =	0 kips	<---Point 2
1.4 x allowable moment =	128 k-ft	**NG: exceed Capacity**
Controlling MomentCapacity :	116 k-ft	<--Point 3; Curve Controlling

PILE DESIGNER
dwong@kiecon.com (Danny Wong)

CONTRACTOR:
TBD

NO	BY	DATE	REVISION
△			
△			

KIE-CON Inc.

3551 WILBUR AVENUE
ANTIOCH, CALIFORNIA
925/754-9494 FX 925/754-0624

JOB: **Influent Screen**

LOCATION: **San Mateo, CA**

BY: **WBW** DATE: **07/01/14** EST **E14-140** SHT:

Appendix C

Grit Sampling Summary Technical Memorandum

Memorandum

To: *Bill Bryan, SVCW*

From: *Jan Davel, CDM Smith*

Prepared By: *Bill Schilling, CDM Smith*

Date: *December 30, 2016*

Subject: *Headworks Facility Project - Grit Sampling Summary*

1.0 Introduction

This Technical Memorandum (TM) summarizes the grit sampling that was performed as part of the Silicon Valley Clean Water (SVCW) Headworks Facility Project (Project).

2.0 Project Background and Purpose

SVCW is implementing a Capital Improvement Program (CIP) to improve the reliability of their conveyance system and wastewater treatment plant (WWTP). The CIP includes rehabilitation and repurposing of several collection system pump stations and installation of the following facilities:

- Gravity Pipeline to replace the existing 54-inch force main that conveys wastewater to the treatment plant.
- Receiving Lift Station (RLS) located on the treatment plant site at the end of the new Gravity Pipeline.
- Headworks Facility to remove screenings and grit from influent wastewater.
- Influent Connector Pipe to convey flow from the Headworks Facility to the primary clarifiers.
- Odor control facilities to treat foul air venting from the Gravity Pipeline, RLS and Headworks Facility, referred to as the Front of Plant (FoP) Odor Control Facilities.
- Odor control facility to treat foul air venting from one of the Gravity Pipeline drop shafts, referred to as the San Carlos Odor Control Facility.

An Environmental Impact Report Project Description (EIR Project Description) is currently being prepared for the CIP. The Headworks Project is being performed to support the development of the EIR Project Description by developing the conceptual layout of the Headworks Facility and the FoP Odor Control Facility. Another goal of the Project is to develop a conceptual level cost estimate for the Headworks and FoP Odor Control Facilities.

The grit sampling discussed in this TM is being used to develop and verify the conceptual layout of the Headworks Facility being developed for the EIR Project Description.

3.0 Grit Sample Collection and Analysis

Grit sampling was performed by both SVCW personnel and by Black Dog Analytical, LLC. during the period between April, 2014 and February, 2016. The samples were collected at various locations within the plant, using various methods, and under various influent conditions. A summary of the sampling events is provided below. For each event, the sampling date and location are noted along with information regarding the sampling method and the influent conditions during the time of sampling. Detailed discussion on the results of the grit sampling is provided in Section 4.0.

3.1 Grit Sampling Performed by SVCW

SVCW conducted the following grit sampling events:

- March 4, 2014 – Primary sludge samples were collected from the suction piping on the primary sludge pumps. Four liters (L) of sample were collected from each of the four primary clarifiers that were in service. From these samples a composite sample was prepared and analyzed as described below. The sampling was performed during dry weather conditions.

- April 23, 2014 – Primary sludge samples of an unknown volume were collected from the floor of one of the primary clarifiers, which had been drained for maintenance purposes. Samples were collected from various areas of the primary clarifier floor and a composite sample was prepared. The sample were analyzed for particle size distribution as described below.

- December 11, 2014 – Primary sludge samples were collected from the discharge side of the primary sludge pumps during wet weather conditions. The volume of sample collected and the number of primary clarifiers that sample was collected from is unknown. From these samples a composite sample was prepared and analyzed as described below.

- October 5, 2015 – Samples were collected from the 60-inch influent pipe which delivers raw sewage into the Influent Mix Box. The samples were collected from the 3 o'clock position on the pipe. Several gallons of water were collected every hour from this location for a period of 24 hours. From these samples a composite sample was prepared and analyzed as described below. This sampling was performed during dry weather conditions.

The dates, locations, and influent flow conditions for the sampling events conducted by SVCW are summarized in Table 1.

The samples collected during the sampling events conducted by SVCW were analyzed for Total Suspended Solids (TSS) concentration, Volatile Suspended Solids (VSS) concentration, and particle size distribution. The samples were dried, then placed in an oven at 550 degrees for a period of 30 minutes. The samples were then passed through a series of sieves ranging in size from 74 micrometers (um) to 12.7 millimeters (mm). The amount of sample retained on each sieve was then weighed and the particle size distribution was determined.

Table 1. Sampling Events Performed by SVCW

Sampling Date	Sampling Location	Influent Conditions During Sampling
March 4, 2014	Primary Sludge Pump Suction	Dry Weather
April 23, 2014	Primary Clarifier Floor	Dry Weather
December 11, 2014	Primary Sludge Pump Discharge	Wet Weather
October 5, 2015	Influent Pipe	Dry Weather

It should be noted that there was one additional grit sample collected and analyzed by SVCW, which is not discussed in this TM. On March 24, 2014 SVCW collected 16-L of sample from the Gravity Thickener Feed Box located downstream of the existing hydrocyclones, which are used to remove grit from the primary sludge. The sample was collected during dry weather and analyzed as discussed above. This grit sample is not discussed in this TM because this TM is focused on the grit characteristics in the raw influent and this sample was not a raw influent sample.

3.2 Grit Sampling Performed by Black Dog Analytical, LLC.

The Black Dog Analytical, LLC grit sampling events are summarized below. The dates, locations, times, and influent flow conditions for the sampling events conducted by Black Dog Analytical, LLC are summarized in Table 2.

- February 3, 2016 – Samples were collected from the Influent Mix Box using a slotted pipe, pump, and grit settler as described below and in Appendix A. Samples were collected for a period of 6 hours from 8:40 am to 2:40 pm during dry weather conditions.

- March 5, 2016 – Samples were collected from the Influent Mix Box using a slotted pipe, pump, and grit settler as described below and in Appendix A. Samples were collected for a period of 5.25 hours from 8:15 am to 1:30 pm during dry weather conditions.

- March 11, 2016 – Samples were collected from the Influent Mix Box using a slotted pipe, pump, and grit settler as described below and in Appendix A. Samples were collected for a period of 7 hours from 12:45 pm to 7:45 pm during the middle of a wet weather event.

The sample collection and analysis methods used by Black Dog Analytical, LLC are described in detail in the Grit Characterization Study Technical Memorandum included in Appendix A. In general, the samples were collected from the locations described above by drawing wastewater through a slotted pipe and pumping it to a grit settler which operates at an overflow rate of 3 gallons per minute per square foot (3 gpm/ft^2). A flow splitting device is used between the sample pump and grit settler to maintain the target overflow rate. A schematic of the sample collection system used by Black Dog Analytical, LLC is shown in Figure 1.

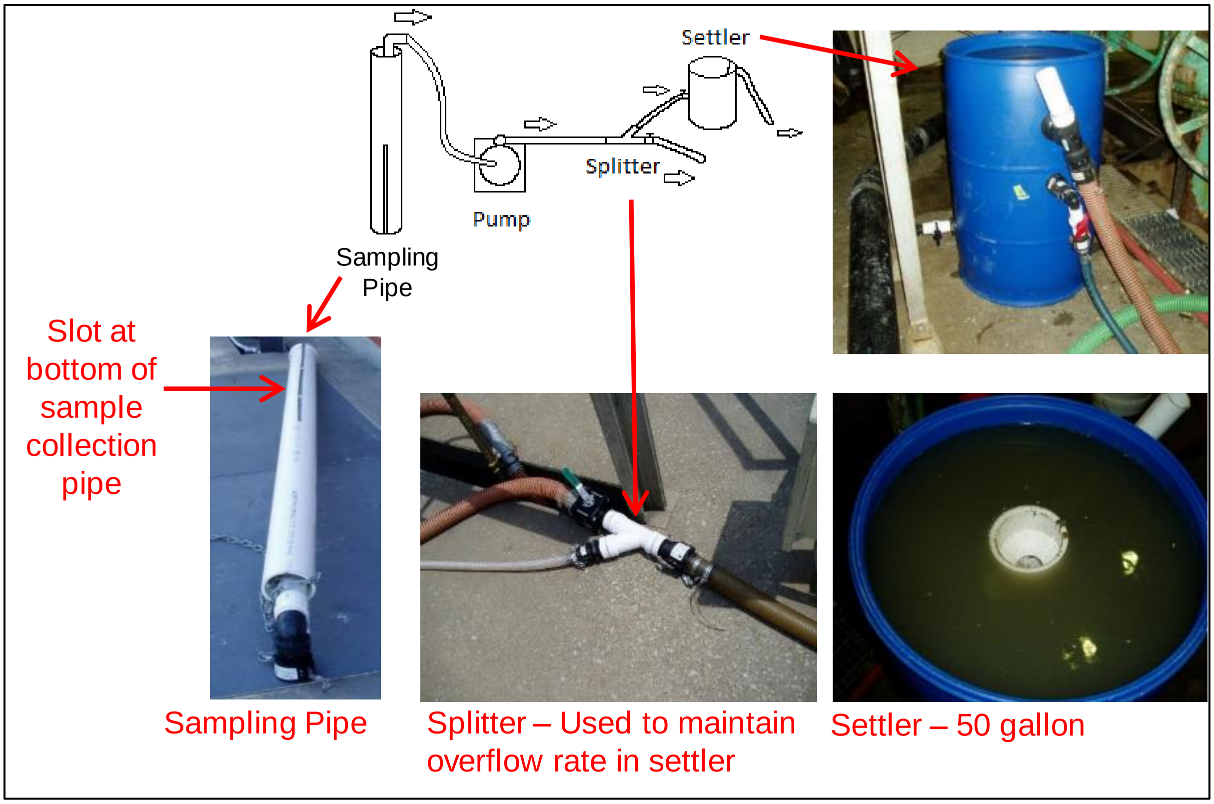


Figure 1
Black Dog Analytical, LLC Grit Sample Collection System

The grit retained in the settler shown in Figure 1 is dewatered and then passed through a series of sieves ranging in size from 53 um to 6.3 mm. The sample retained on each sieve is weighed. This information is used to determine the physical size distribution and the total mass of grit in the sample. The grit retained on each sieve is then subjected to a settling velocity test. The results of the settling velocity tests are used to determine the distribution of settling velocities in the grit sample.

Table 2. Sampling Events Performed by Black Dog Analytical, LLC.

Sampling Date	Sampling Location	Influent Conditions During Sampling	Start Time	End Time	Sampling Duration (hours)	Avg. Influent Flow During Sampling (mgd)
February 3, 2016	Influent Mix Box	Dry Weather	8:40am	2:40pm	6	16.5
March 5, 2016	Influent Mix Box	Dry Weather	8:15am	1:30pm	5.25	20.5
March 11, 2016	Influent Mix Box	Wet Weather	12:45pm	7:45pm	7	35.5

4.0 Grit Sampling Results

A summary of the results from each of the grit sampling events is presented below. The results from the grit sampling performed by SVCW is described in greater detail in the presentation slides included in Appendix B. The results from the grit sampling performed by Black Dog Analytical, LLC is described in greater detail in Appendix A.

4.1 Grit Sampling Performed by SVCW

The results of the grit sampling performed by SVCW are summarized in Table 3 and Figures 2–5 below. Table 3 summarizes the mass of grit collected in each sample. Figures 2–5 show the distribution of physical particle sizes in each sample.

Table 3. Sampling Events Performed by SVCW

Sampling Date	Total Mass of Grit Collected (grams)
March 4, 2014	12.38
April 23, 2014	5,918
December 11, 2014	104.5
October 5, 2015	15.05

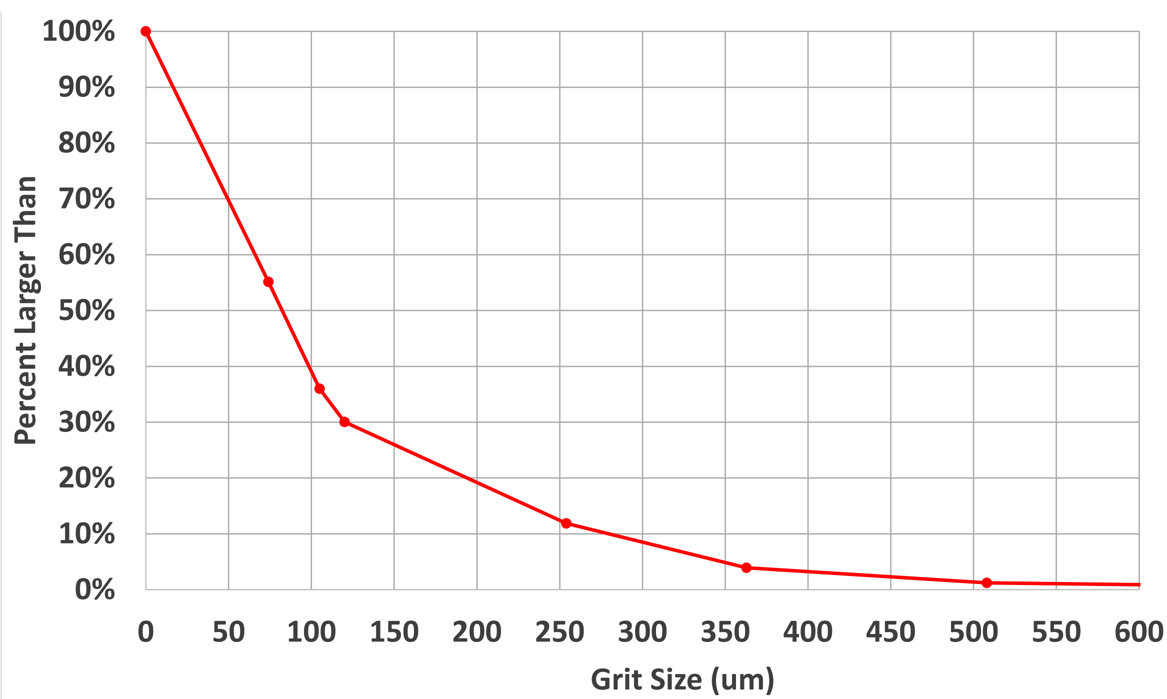


Figure 2
3/4/14 Sample: Physical Size Distribution of Grit in Primary Sludge Pump Suction

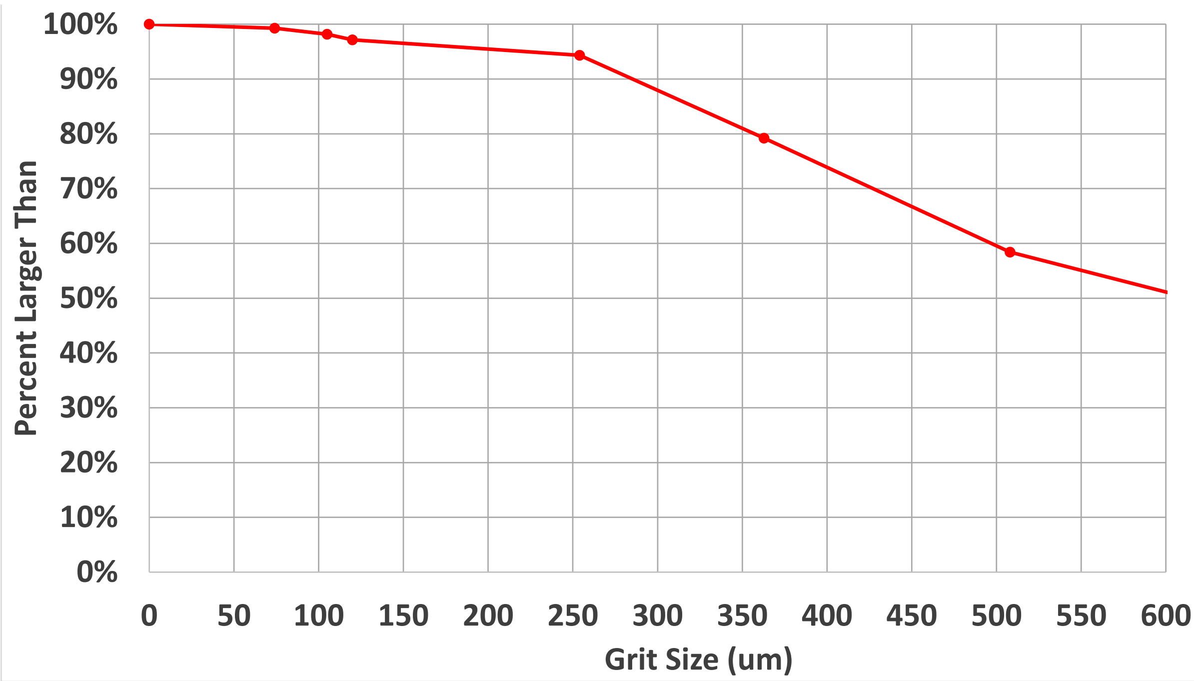


Figure 3
4/23/14 Sample: Physical Size Distribution of Grit in Sludge on Primary Clarifier Floor

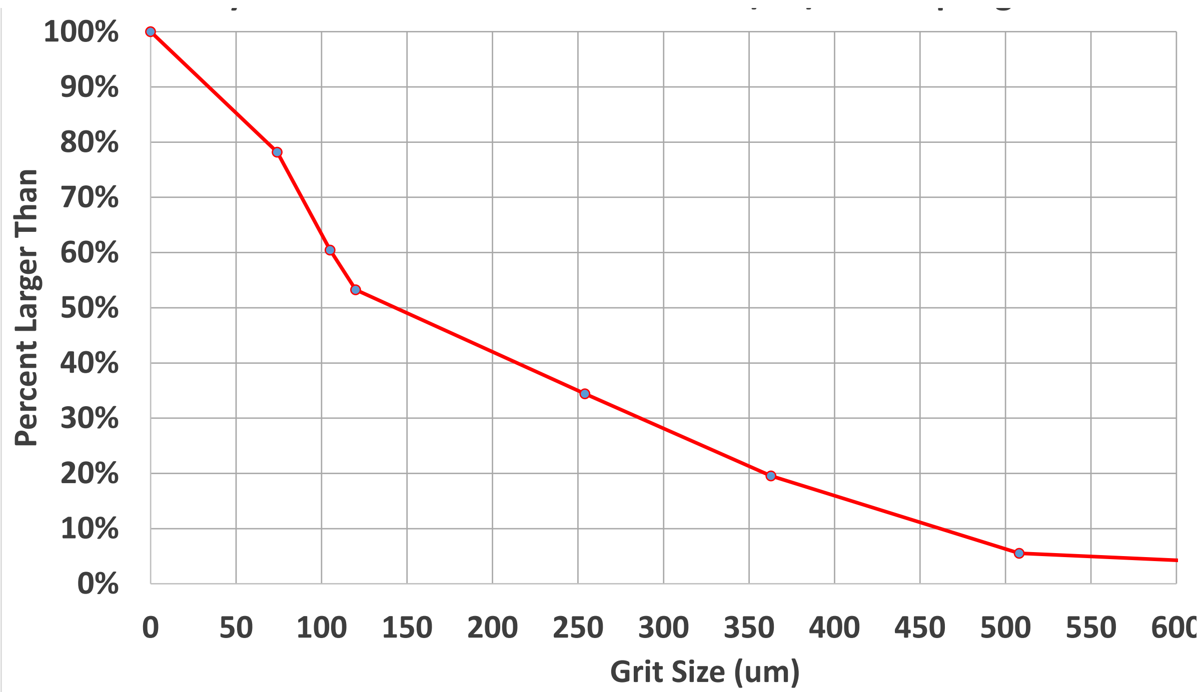


Figure 4
12/11/14 Sample: Physical Size Distribution of Grit in Primary Sludge Pump Discharge

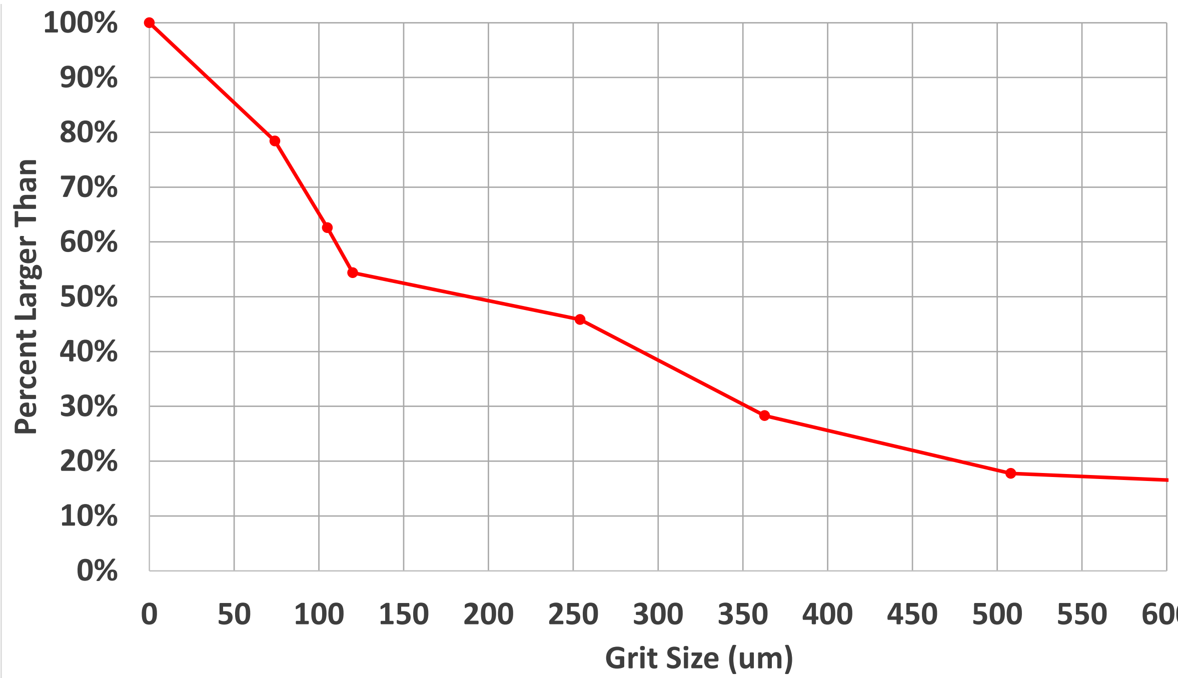


Figure 5
10/5/15 Sample: Physical Size Distribution of Grit in Influent Pipe

4.2 Grit Sampling Performed by Black Dog Analytical, LLC.

The results of the grit sampling performed by Black Dog Analytical, LLC are summarized in Table 4 and Figures 6–8, below. Table 4 summarizes the concentration of grit in each sample. Figures 6–8 show the distribution of both physical particle sizes and Sand Equivalent Sizes (SES) in each sample.

Table 4. Concentrations of Grit in Influent Wastewater

Sampling Date	Grit Concentration (lbs/MG)
February 3, 2016	4.61
March 5, 2016	11.2
March 11, 2016	38.0

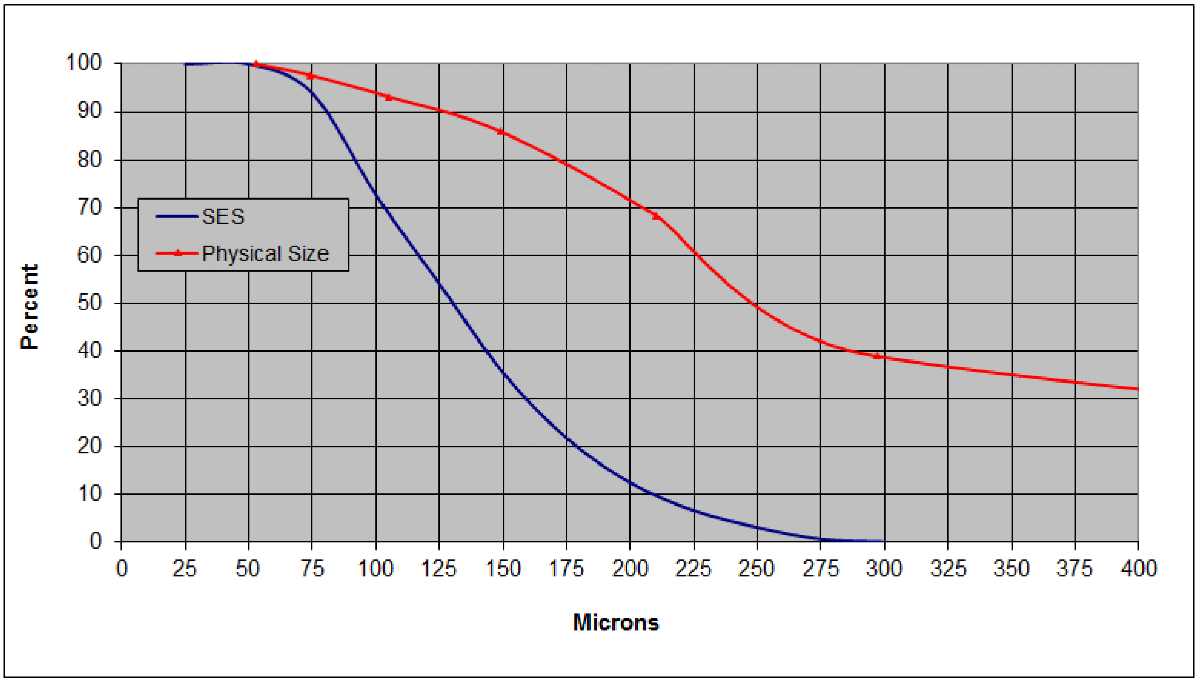


Figure 6
February 3, 2016 Sample: Influent Grit Physical Size and Sand Equivalent Size

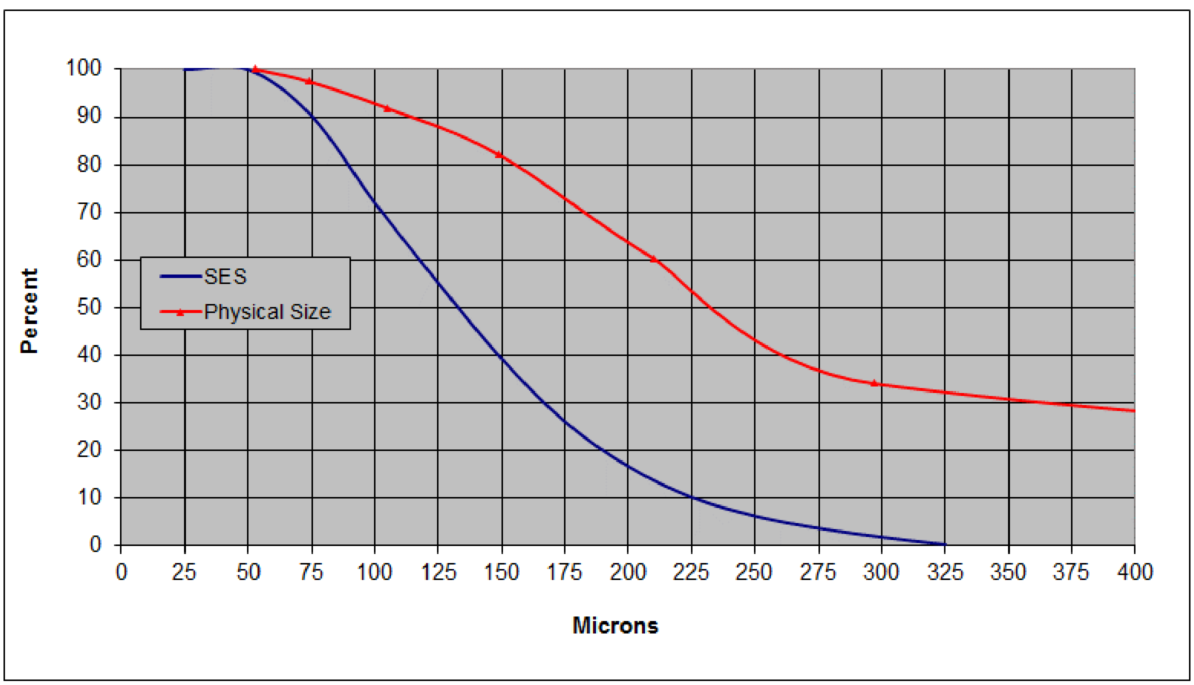


Figure 7
March 5, 2016 Sample: Influent Grit Physical Size and Sand Equivalent Size

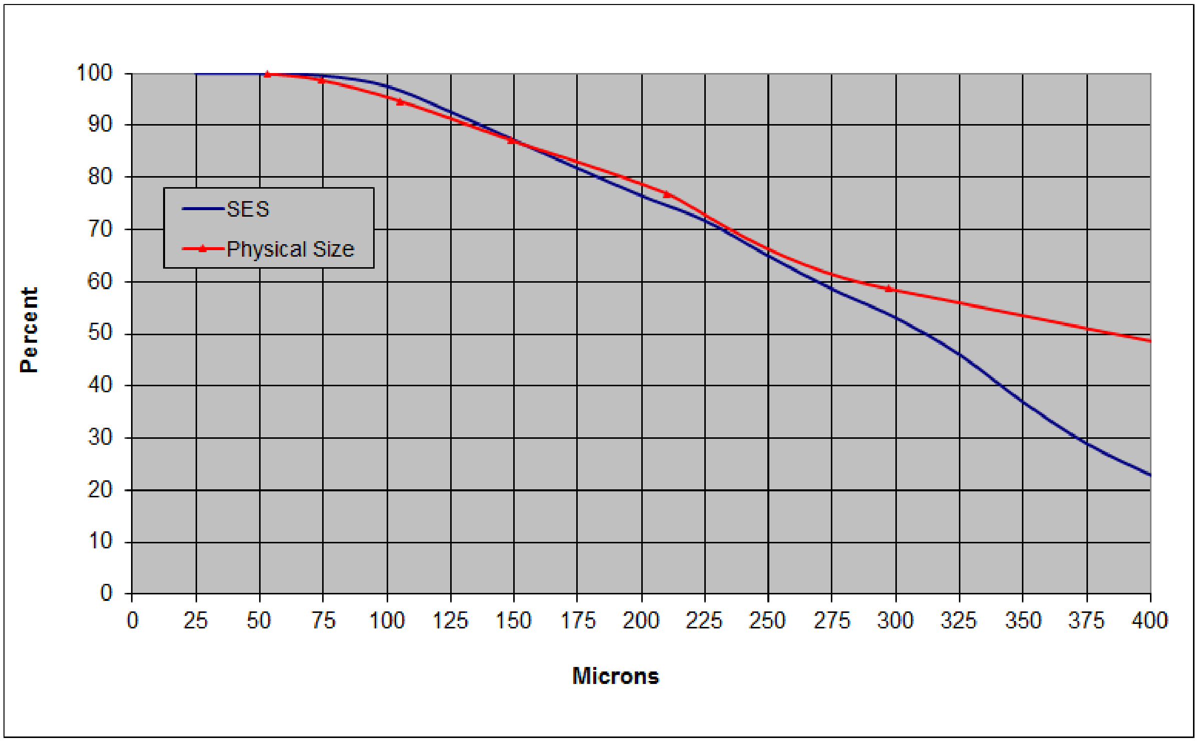


Figure 8
March 11, 2016 Sample: Influent Grit Physical Size and Sand Equivalent Size

5.0 Discussion

Evaluation of the data presented in this TM along with recommendations on how the data should be used to develop design criteria for the Headworks Facility will be provided in the *Headworks Facility Project – Grit Facility Design Criteria Update* TM, dated August 03, 2016. The following are notes regarding the sampling events discussed above that should be considered in evaluating the data.

- The grit sample collected on April 23, 2014 from the floor of one of the primary clarifiers had a much higher fraction of large grit particles versus the other grit samples collected by SVCW. This could be the result of large grit particles settling in the primary clarifiers and not being transported into the sludge pump hoppers. This is further supported by the fact that the grit sample collected by SVCW from the influent pipe had a higher fraction of large grit versus the sample collected downstream of the primary clarifiers, during similar influent flow conditions (i.e. dry weather flow conditions) on March 4, 2015.

- The sample collected on December 11, 2014 from the primary sludge pump discharge pipe had a higher fraction of large grit particles versus the sample collected on March 4, 2014 from the suction side of the primary sludge pump. This could be a result of the fact that the

December 11, 2014 samples was collected during wet weather. The wet weather conditions result in higher flows through the primary clarifiers, allowing larger grit particles to be scoured from the floor of the clarifier.

- The sample collected from the influent pipe on October 5, 2015 was collected from the 3 o'clock position in the pipe. Collecting the sample from this position could have resulted in missing some of the grit near the bottom of the pipe. This would increase the fraction of fine grit in the sample.

- The samples collected by SVCW were sieved after removing volatile materials by burning them in a muffle furnace at 550 degrees Fahrenheit for a period of 30 minutes. This process removes the organic material covering the grit particles and allows for determination of the VSS content of the grit and the physical size of the clean grit particles.

- The samples collected by Black Dog Analytical were analyzed without removing the organic material coating the outside of the grit. The grit entering the Headworks Facility will have organic material coating the outside of it. Therefore, evaluating the characteristics of the grit with the organic material on it, is a better indicator of how it will behave in the Headworks Facility.

- The samples by Black Dog Analytical were passed through a series of sieves before the settling velocity of the grit particles were measured. As the grit passes through the sieve, a small portion of the organic material coating the grit could be removed by the sieve. This could have a minor impact of the settling velocity measurement.

Appendix A

Grit Characterization Study TM by Black Dog Analytical, LLC

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Black Dog Analytical, LLC

Grit Characterization Study

Silicon Valley Clean Water - Redwood, CA

Prepared for:

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Prepared by:

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April 2016

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

DEFINITIONS AND ABBREVIATIONS

Acronym	Definition
gpm	Gallon(s) per minute
Grit	A settleable inorganic kernel with attached organics larger than 50 microns and characterized by physical size and settling velocity
Grit Concentration	The amount of grit present in the waste stream based on the fixed solids measurements
Grit Fixed Solids (FS)	Also expressed as "**fixed solids**" - the inorganic portion of sample remaining after organics are removed by ashing in a muffle furnace at 550^{o}C
lbs/MG	Pounds per million gallons
MG	Million gallons
MGD	Million gallons per day
NR1	The Reynolds number for the trial SES
NR2	The Revised Reynolds number
SAA	Surface Active Agents - – material affixed to the grit particle, such as organics, fats, oils, and greases that may affect the settling velocity of municipal grit
Sample	All material accumulated in the bottom of the grit settler which includes settleable organics
Sand Equivalent Size (SES)	The sand particle size, measured in microns, having the same settling velocity as the selected grit particle
Sed h, cm	The height of water in the Imhoff cone through which the sediment passed to reach the surface of accumulated material during SES determination
Sed Time, sec	The time required for sediment to reach the recorded volume during SES determination
Sed. Vol., cc	Sedimentation Volume (cc or ml) – The amount of material that settles in the Imhoff Cone during SES determinations
SES, dl, u	Trial Sand Equivalent Size, in microns
VIS	Vertically Integrated Sampler
Vol Frac, %	The cumulative sedimentation percentage occurring during SES determination
WWTP	Wastewater Treatment Plant

1.0 INTRODUCTION AND OBJECTIVES

The Silicon Valley Clean Water wastewater treatment plant serves Belmont, Redwood City, San Carlos and the West Bay Sanitary District of San Mateo, CA. The agency is assessing the quantities and characteristics of grit entering the WWTP.

In conventional grit removal system design, grit has commonly been treated as clean sand with a specific gravity of 2.65. Metcalf and Eddy's Wastewater Engineering: Treatment and Reuse (standard textbook) says "Grit consists of sand, gravel, cinders, or other heavy materials that have specific gravities or settling velocities considerably greater than those of organic particles". These inorganic solids are often associated with Surface Active Agents (SAA) that include fats, oils, greases, and other organic materials can lower their effective specific gravity to 1.3 (Tchobanoglous 2003). The shape and composition of grit and inert solids also greatly affects settling velocities. Material with similar effective specific gravities may have very different settling velocities due to the shape of the particle.

When determining quantities of grit during this study, grit will be defined as settleable inorganic material larger than 50 microns. Settling velocities, attached organics and SAA have been considered during the on-site laboratory analyses. The settling velocity is expressed as the Sand Equivalent Size (SES), which is the sand particle size having the same settling velocity as the more buoyant grit particle. Materials less than 50 microns in size have been considered silt or clay and thus excluded from the data.

<u>Objectives</u>

The purpose of this study was to determine:

1. the amounts and characteristics of grit entering the WWTP
2. Train facility staff to collect samples during high flow conditions

2.0 METHODS AND MATERIALS

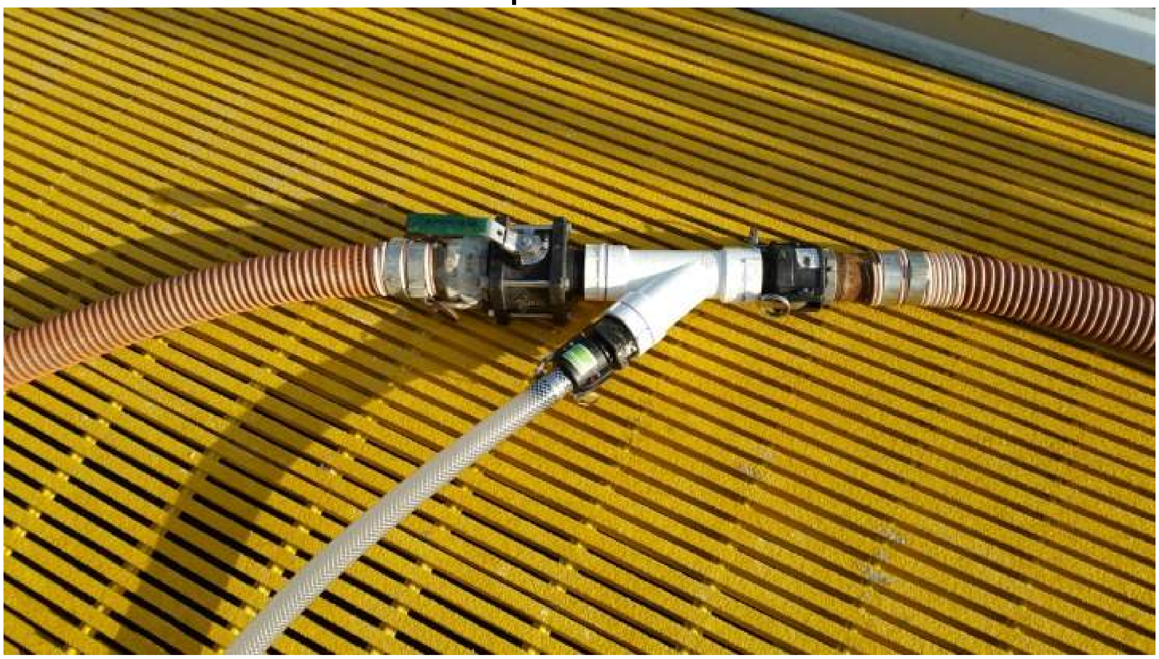
2.1 Obtaining Representative Grit Fixed Solids (FS) Sample

Sampling was timed to include the daily peak flow ramp-up. Influent samples were collected by securing a slotted sampler in the mouth of the pipe exiting the influent junction box prior to screening (Figure 2.1). Because the pipe was submerged, the slot was positioned to collect sample from only the height of the pipe. The sampler was plumbed to a two-inch gas powered trash pump and sample was drawn continuously by the pump throughout the study period. Flow exiting the trash pump was returned to the channel through an opening by the screens.

Figure 2.1
Influent Sampling Site

A portion of the sample collected by the trash pump was diverted to a grit settler. A PVC wye was used to split the flow (Figure 2.2), and a valve following the wye was used to increase flow to the settler if necessary. A one-inch hose supplied the grit settler, while a single two-inch hose returned the majority of flow back to the waste stream.

Figure 2.2
PVC Splitter and Valve



Grit settlers (Figure 2.3) are constructed from 55-gallon plastic drums with an influent port and a discharge weir. Flow enters the tank and is diverted to the side with a 90^o elbow to reduce the velocity and turbulence. Grit settles to the bottom of the tank, and wastewater exits through the discharge fitting at the top of the tank and is returned to the waste stream. 50-micron grit with a Specific Gravity of 2.65 settles at a rate of 5.02 in/min. *((g(sg$_p$ – 1)d^2_p/18v)*196.850* = inches/minute). In order to settle this grit, the overflow rate must be less than 3 gpm/ft^2 of surface area. The settler has a diameter of 24-inches, or a surface area of 3.14 ft^2 ($A = \pi r^2$). At 10 gpm, the overflow rate (Q/A) is 3.18 gpm/ft^2, approximating the design requirements for the settler (*10gpm/3.14ft^2 = 3.18 gpm/ft^2*). The actual settler feed rate is adjusted to between 7.5 and 8.0 gpm to insure settling of fine grit, and this is checked by timing the overflow rate of the settler with a 5-gallon bucket and stopwatch. Feed rates are checked periodically and adjusted when necessary.

Figure 2.3
Grit Settler

2.2 Determination of Grit Particle Distribution

A maximum 200-gram portion of the sample collected by the Grit Settler is immediately classified through a series of sieves. Wet sieving for size fractions and the SES settling tests are conducted on fresh grit from the sewer waste stream samples as the Surface Active Agents (SAA) attached to the grit kernel may substantially reduce its effective specific gravity and consequently it's settling velocity. If the total sample size exceeds 200-grams, the sample is split and the fraction is recorded on the field bench sheet. Sieve sizes used are listed below in Table 2.1.

Table 2.1
Sieve Size Equivalents

		Opening	
U.S. Sieve Size	Tyler Equivalent	Microns	Inches
1/4	3.25 mesh	6300	0.2500
1/8	6.5 mesh	3180	0.1250
#12	10 mesh	1680	0.0661
#20	20 mesh	841	0.0331
#50	48 mesh	297	0.0117
#70	65 mesh	210	0.0083
#100	100 mesh	149	0.0059
#140	150 mesh	106	0.0041
#200	200 mesh	74	0.0029
#270	270 mesh	53	0.0021
Pan			

2.3 Determination of Sand Equivalent Size (SES) Distribution

Settling tests were conducted immediately on solids passing the U.S. #20 sieve and sequentially retained on the #50, #70, #100, #150, #200, and #270 sieves. Large organics often interfere with the settling of grit on screens larger than #50. A portion of the retained material is placed into a modified Imhoff cone and filled with water (see Figure 2.4). The column is inverted, and as the grit settles in the cone corresponding time and volume measurements are recorded. The objective of these measurements is to determine the size of a sand sphere having the same settling velocity as the collected grit fraction.

Figure 2.4
Modified Imhoff Cone for SES Measurements

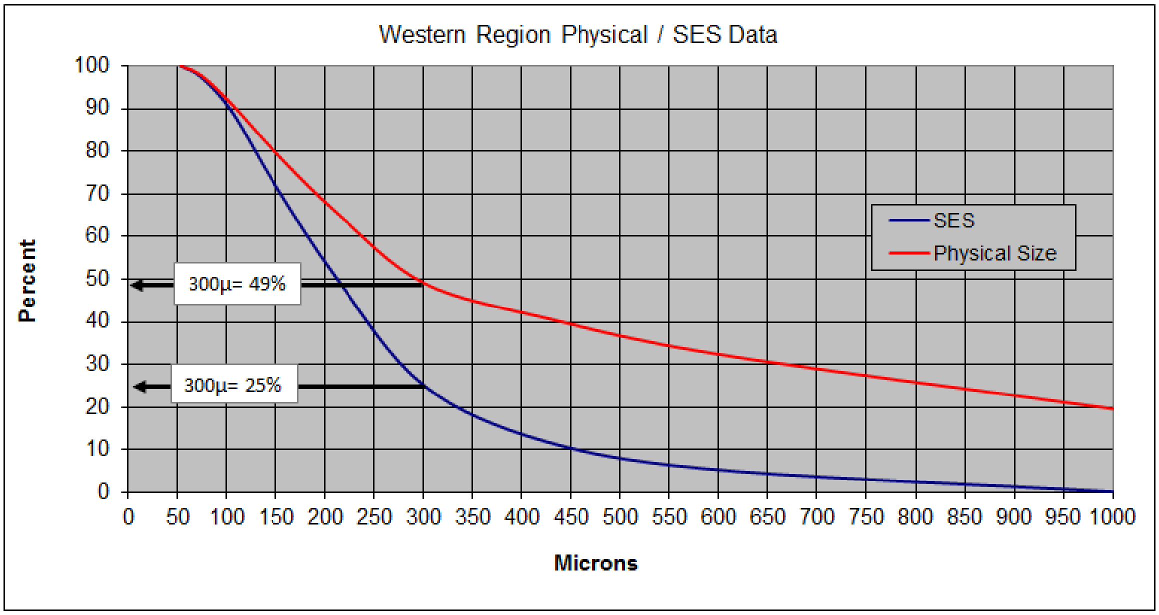
2.4 Sand Equivalent Size Description

The settling velocity of a grit particle depends on several factors that may include surface active agents affixed to the grit particle, the composition, and the shape of the grit particle. Particles with slow settling velocities are said to be "light" and may have low specific gravity or be angular in shape. Conversely, fast settling particles are said to be "heavy" and may have high specific gravities and a rounder shape. Clean, round silica sand is known to have a Specific Gravity of 2.65. However, because grit is seldom clean or round, and may not be made of silica, settling velocities are often much slower. Like Specific Gravity, Sand Equivalent Size is a way of describing the settling characteristics of municipal grit. By definition, Sand Equivalent Size (SES) is "the clean sand particle size, measured in microns, having the same settling velocity of the collected grit particle". For example, a 300-micron **silica sand** particle with a specific gravity of 2.65 will settle at a known velocity.

A 300-micron **grit particle** composed of a different material (i.e., limestone), or a silica sand particle (2.65 SG) with a shape that is not round, will settle slower, perhaps with a settling velocity similar to that of a 150-micron sand particle. Therefore, we say that the 300-micron grit particle has a **Sand Equivalent Size** of 150-microns. Additionally, sieve analyses are a "two-dimensional" test, and ignore the thickness of the grit particle. Therefore, a visually "coarse" distribution may in fact behave like a much finer one.

By comparing the physical size and the SES of the grit, the effects of shape and composition can be demonstrated. The following is an example of a "companion plot" that charts physical size and SES of municipal grit.

Figure 2.5
Physical Size versus Sand Equivalent Size:
Cumulative Distributions



The preceding chart compares cumulative distributions. For example, from Figure 2.5, 49% of the charted grit has a physical size of 300-microns and larger, while only 25% of the grit has a Sand Equivalent Size of 300-microns and larger. This difference is a result of the composition and shape previously discussed, and this grit is "light". As particles become smaller, they attain a more rounded shape, resulting from larger, flat particles breaking up into smaller pieces. Grit chamber design must consider the settling velocity of the grit, as specific gravity and physical size distributions alone fail to provide enough information on grit behavior.

2.5 Solids Analysis

The weight measurements of the grit particles retained on each of the ten sieves were determined according to methods SM2540B and SM2540E as outlined in Standard Methods for the Examination of Water and Wastewater, 1998 APHA, AWWA, WEF, 20th edition. Fixed solids fractions were arranged into fractional and cumulative distributions.

From this data a cumulative curve factoring physical size and weight of fixed solids is generated. All solids data are listed in Appendix A-2 “Solids Analysis Benchsheet.”

Data from the settling tests are entered into a spreadsheet for each size fraction that converts the settling velocities and volumes into Sand Equivalent Size. The SES value generated is plotted against the corresponding volume fraction to generate a series of SES charts. Each chart is divided into 25-micron SES intervals and the percentages of grit falling within each interval are entered into a spreadsheet for analysis. From this data, a cumulative curve factoring SES and weight of fixed solids per size fraction is generated. By comparing the “SES” curve with the “Physical Size” curve, we can determine the amount of grit that can bypass a grit removal system designed around a known sand particle size.

The SES charts are also used to compare the average SES within a sieve fraction with the average physical size of clean, round silica sand for that same sieve fraction. To calculate the concentration of grit present in the sewer during normal flow conditions, the volume of wastewater sampled each day is compared to the measured volume of wastewater passing through the sewer during the sampling periods. The total amount of grit collected during each sampling period is applied to the total volume of wastewater to determine the lbs/MG of grit present in the collection system.

3.0 DISCUSSION OF RESULTS

Sampling occurred on February 3, 2016 under normal flow conditions prior to screening. High flow events were captured on March 5 and 11. Sampling conditions are listed below in Table 3.1 and flow trend charts in Figure 3.1, 3.2 and 3.3.

Table 3.1
SVCW WWTP Grit Evaluation Sampling Period

Date	Start Time	End Time	Hours	Avg Flow During Study (MGD)	Settler Feed Rate (gpm)
February 3, 2016	8:40	14:40	6.0	16.5	7.97
March 5, 2016	8:15	13:30	5.25	20.5	6.60
March 11, 2016	12:45	19:45	7.0	35.5	7.87

Figure 3.1
Influent Flow Data: 3 Feb 2016

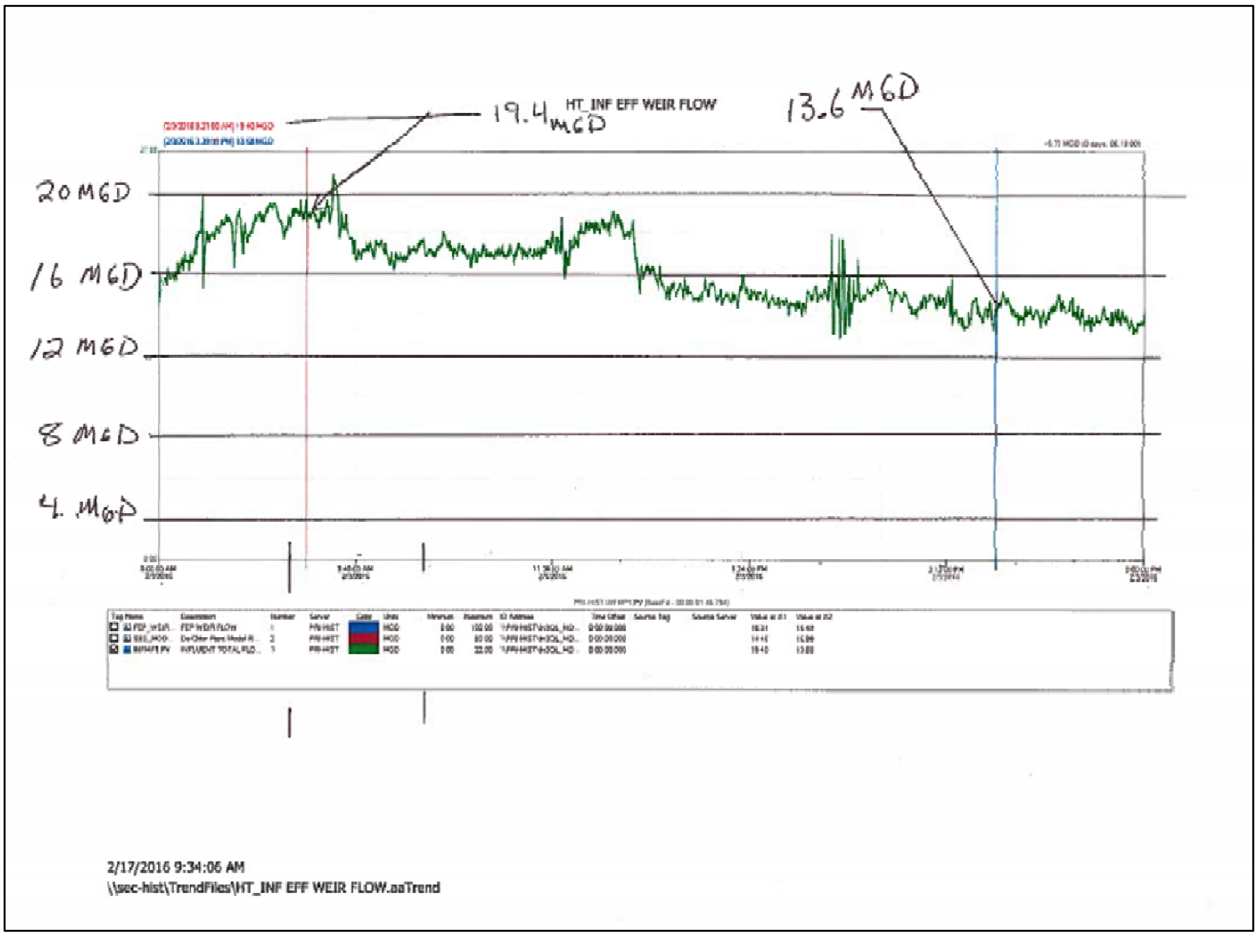


Figure 3.2
Influent Flow Data: 5 Mar 2016

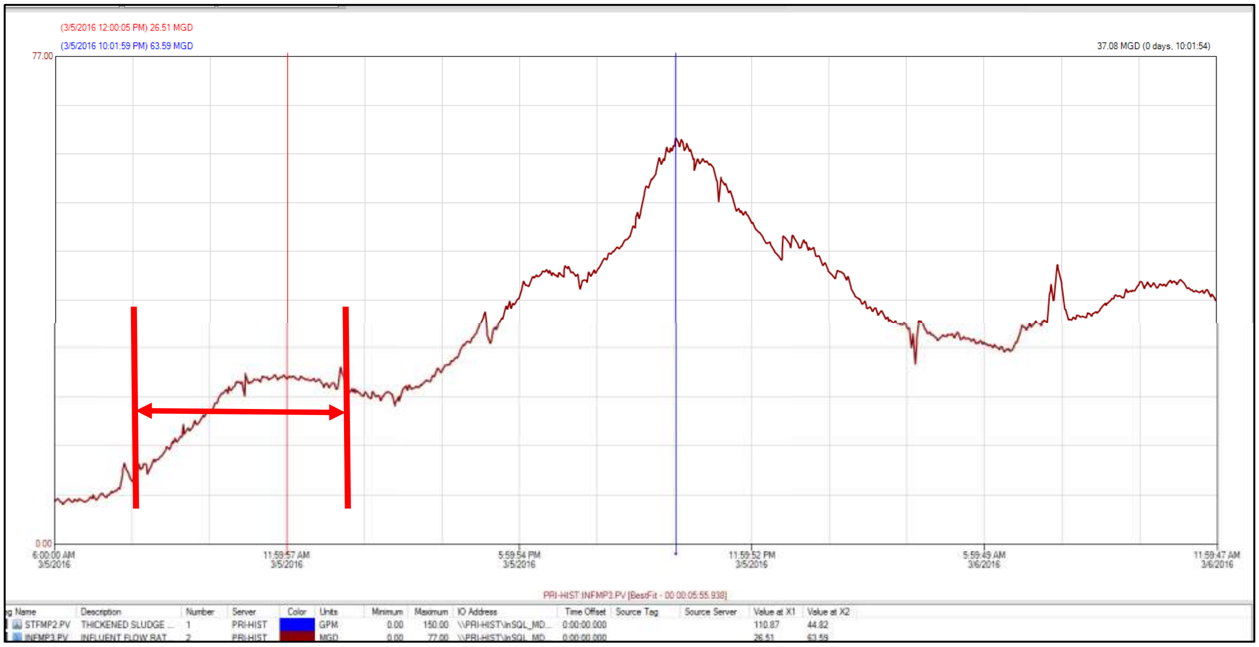
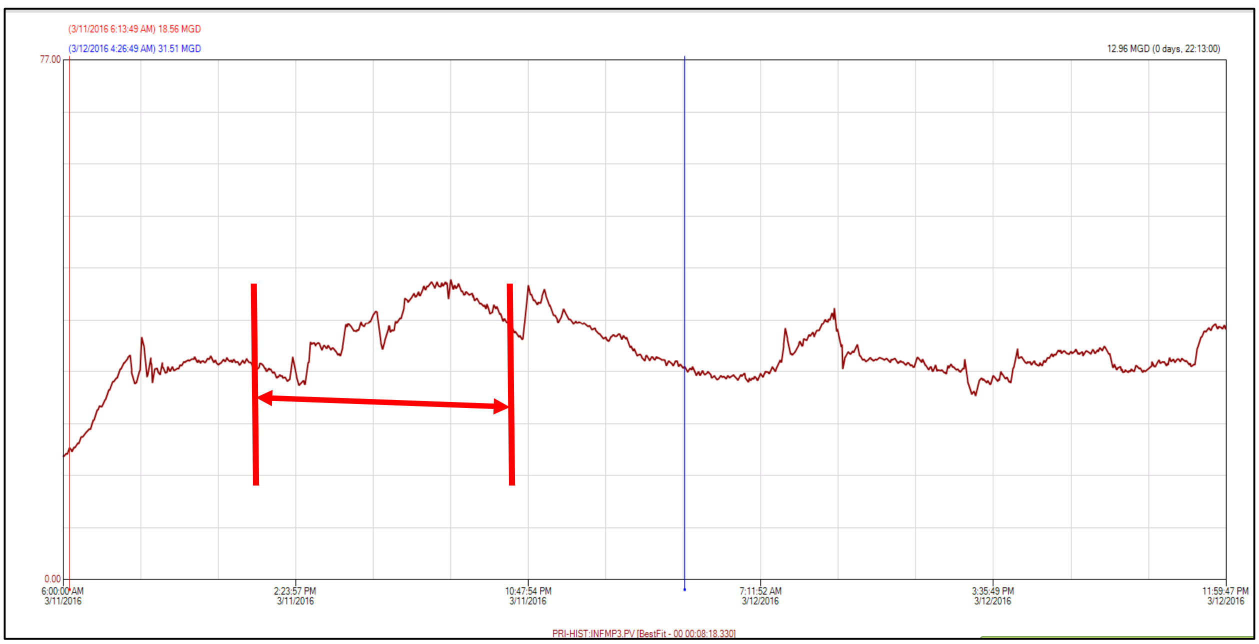


Figure 3.3
Influent Flow Data: 11 Mar 2016



3.1 Distributional Data

Figure 3.4 and 3.5 plot the daily fractional and cumulative distributions of grit collected from the pre-screen influent sampling site, and Figure 3.6 plots the fractional concentrations of grit entering the facility. From Figures 3.4 and 3.5, on February 3 and March 5 distributions were similar, with between 34.0 and 36.9% of collected grit larger than 297-microns and between 61.1% and 66.0 smaller. March 11 produced a coarser distribution with 58.7% of collected grit larger than 297-microns and 41.3% smaller. Concentrations of grit entering the facility were extremely low, resulting in 4.61 lbs/MG on February 3 and 11.16 lbs/MG on March 5. Concentrations were higher on March 11, totaling 38.0 lbs/MG. The national average for influent grit is 55 lbs/MG. The starting time on February 3 was selected to target the typical morning peak flow ramp up. However, facility staff indicated that flows were much higher than expected, suggesting the ramp up was missed and the daily first flush of grit occurred prior to sampling. From Figure 3.1, flows were nearing the daily max shortly after sampling was initiated, nearing 21 MGD.

Figure 3.4
Fractional Distribution of Influent Grit at the SVCW WWTP

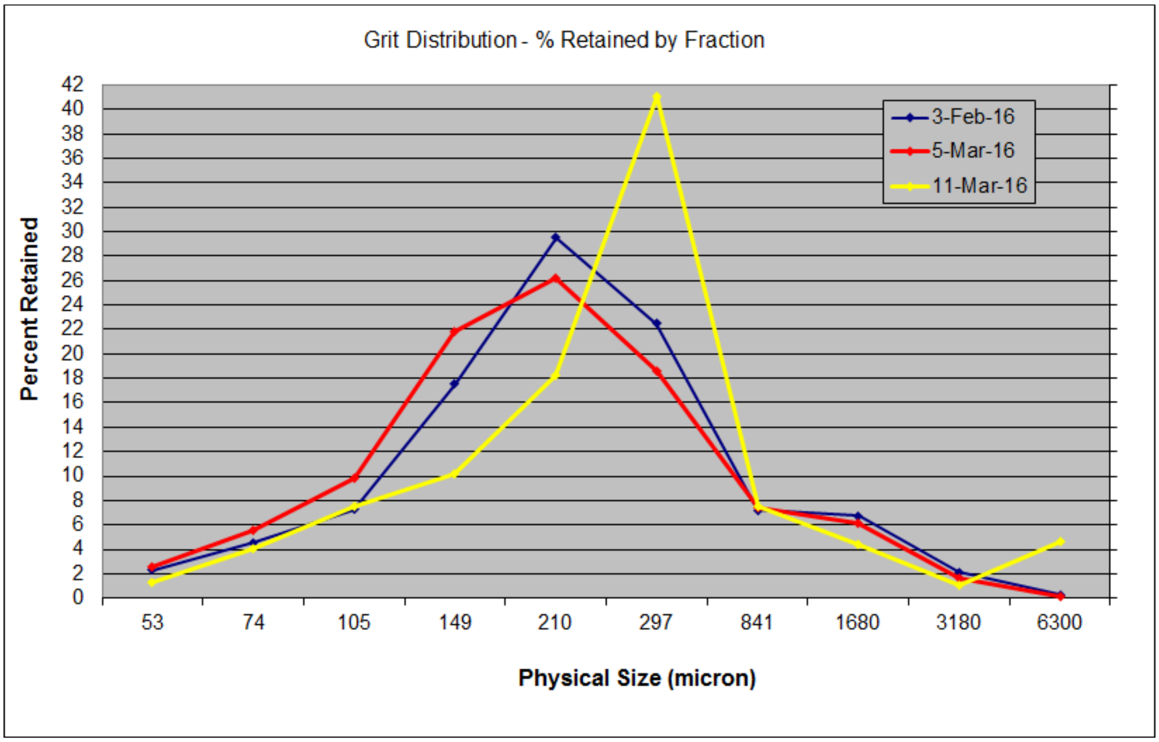


Figure 3.5
Cumulative Distribution of Grit at the SVCW WWTP

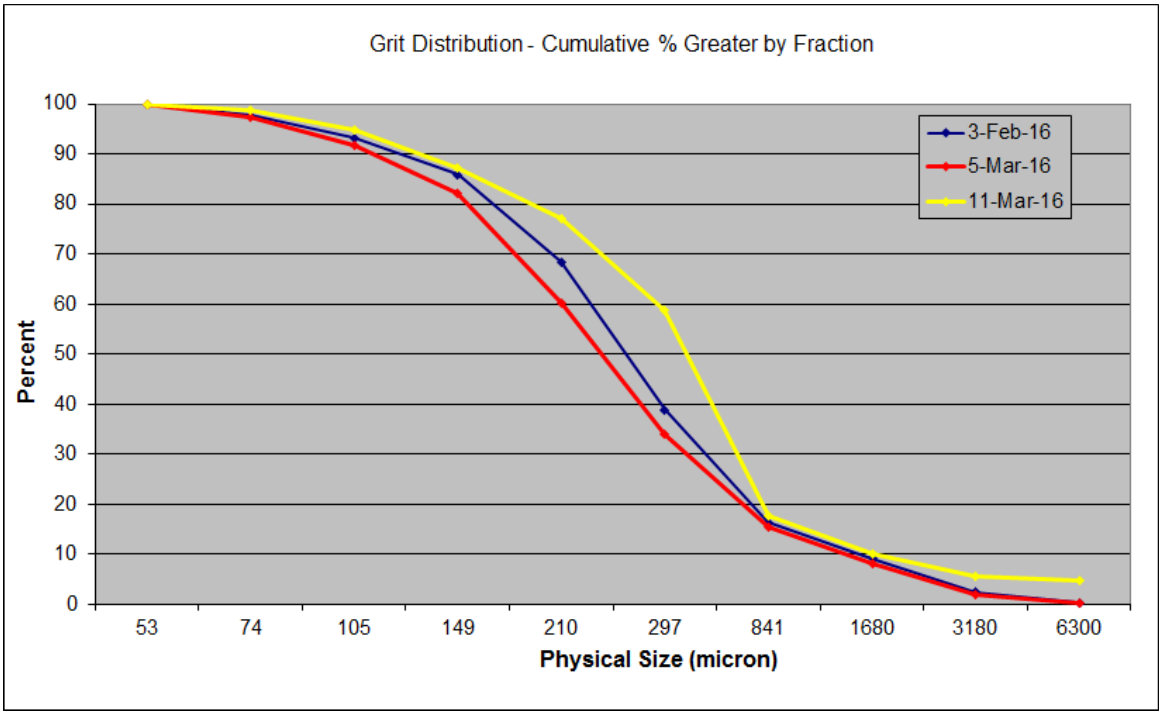
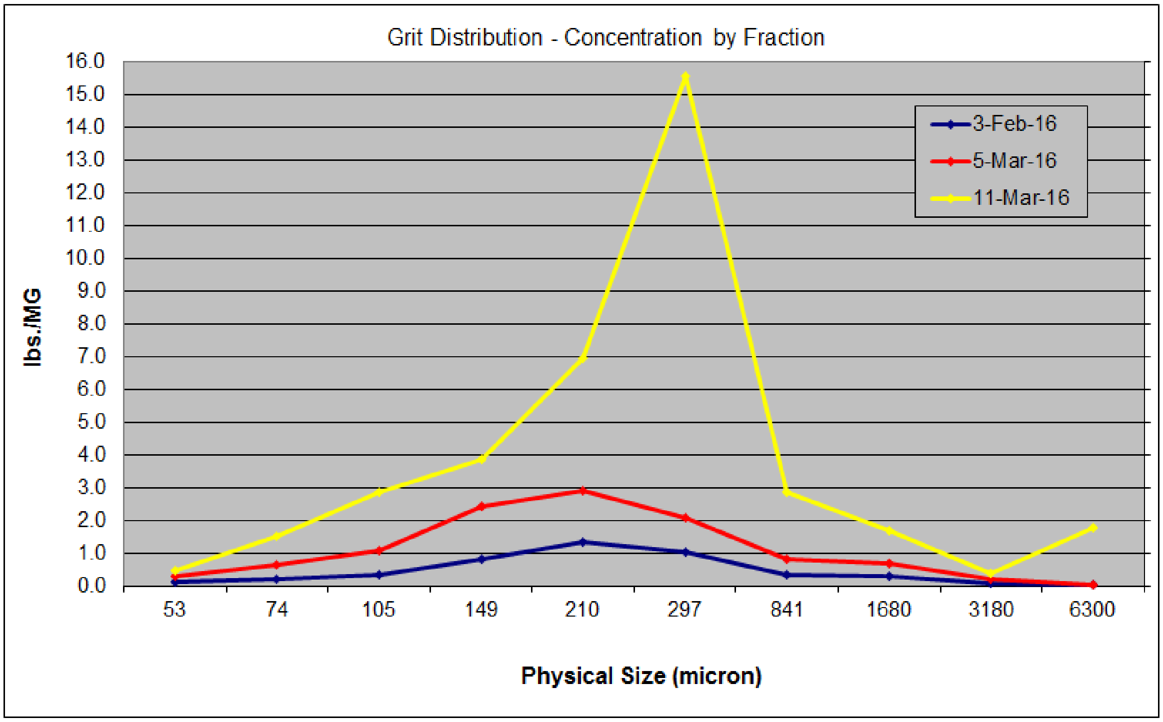


Figure 3.6
Fractional Concentrations of Grit at the SVCW WWTP



3.2 Settling Velocity Data

Sand Equivalent Size (SES) vs. Physical Size companion plots can be used to determine grit removal system design parameters. Table 3.2 lists theoretical removal efficiencies for a system designed to remove grit based on the SES data collected from the influent sampling site. Predicted efficiencies listed in Table 3.2 are shown graphically in Figures 3.7, 3.8 and 3.9.

Table 3.2
Predicted Removal Efficiencies (%) of a System Designed to Remove Grit of a Specific SES at the SVCW WWTP

Sample Date	300-micron SES Design	150-micron SES Design	100-micron SES Design	75-micron SES Design
February 3, 2016	0.1	35.4	72.6	93.9
March 5, 2016	1.8	39.3	72.0	90.3
March 11, 2016	53.1	87.2	97.6	99.6

Figures 3.7, 3.8 and 3.9 compare the physical and Sand Equivalent Size (SES) distributions of the influent samples. Figure 3.10 compares the physical size distributions with a clean sand distribution. Values found in Figure 3.10 are determined from the median SES of material on each sieve, and fractional data is not applied as is the previous companion charts.

Figure 3.7
Comparison of the SVCW WWTP Influent Grit Physical Size and Sand Equivalent Size: February 3, 2016

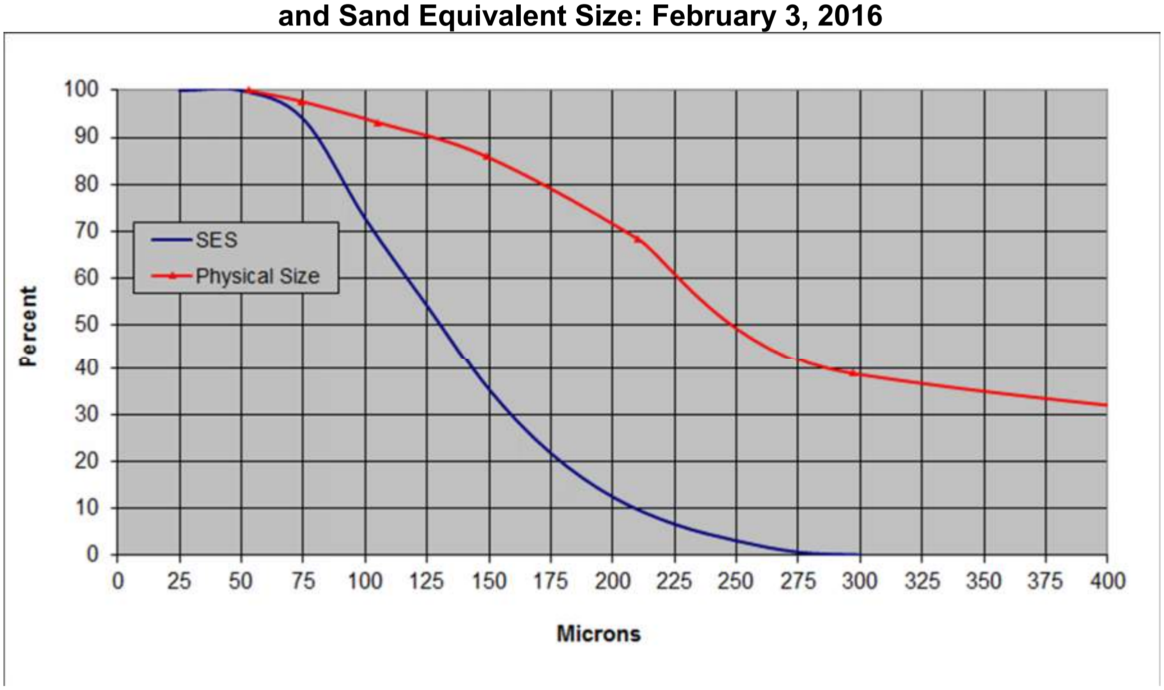


Figure 3.8
Comparison of the SVCW WWTP Influent Grit Physical Size and Sand Equivalent Size: March 5, 2016

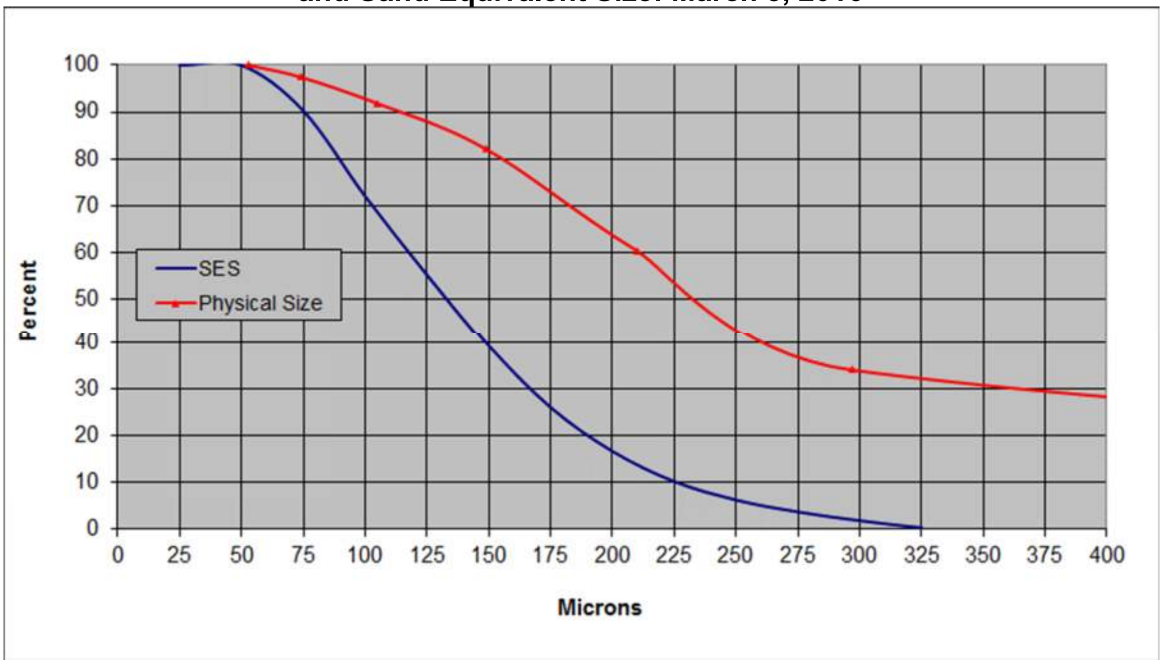


Figure 3.9
Comparison of the SVCW WWTP Influent Grit Physical Size and Sand Equivalent Size: March 11, 2016

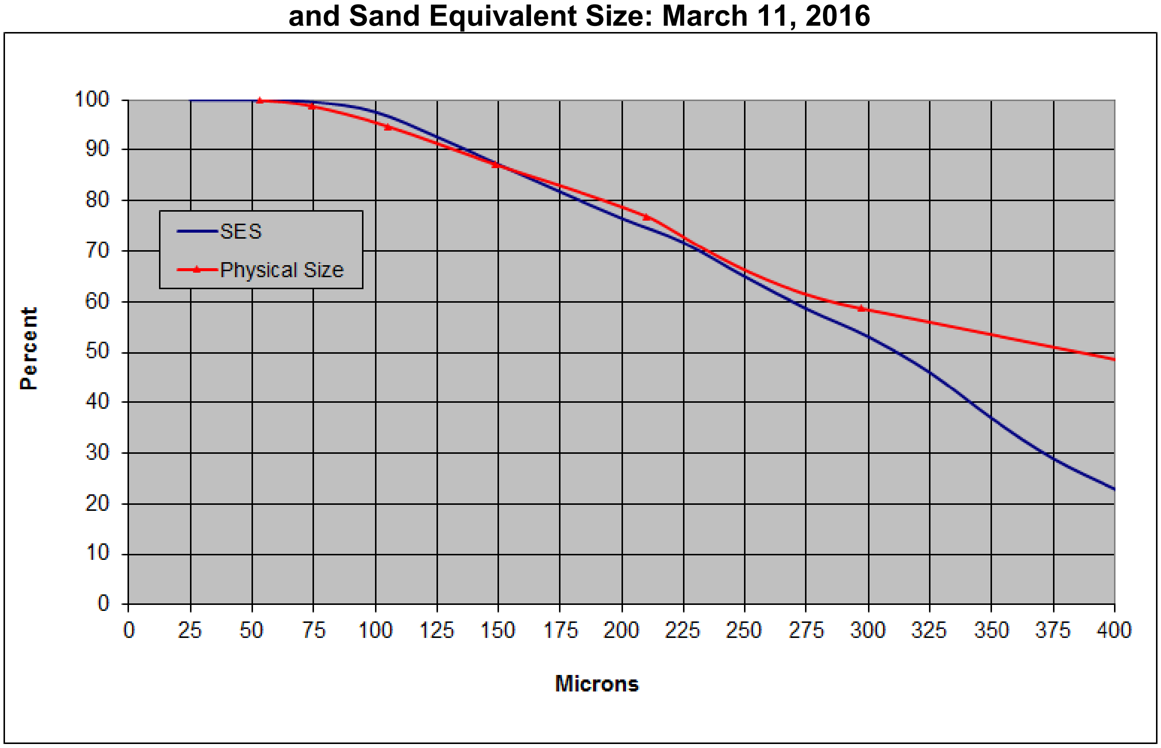
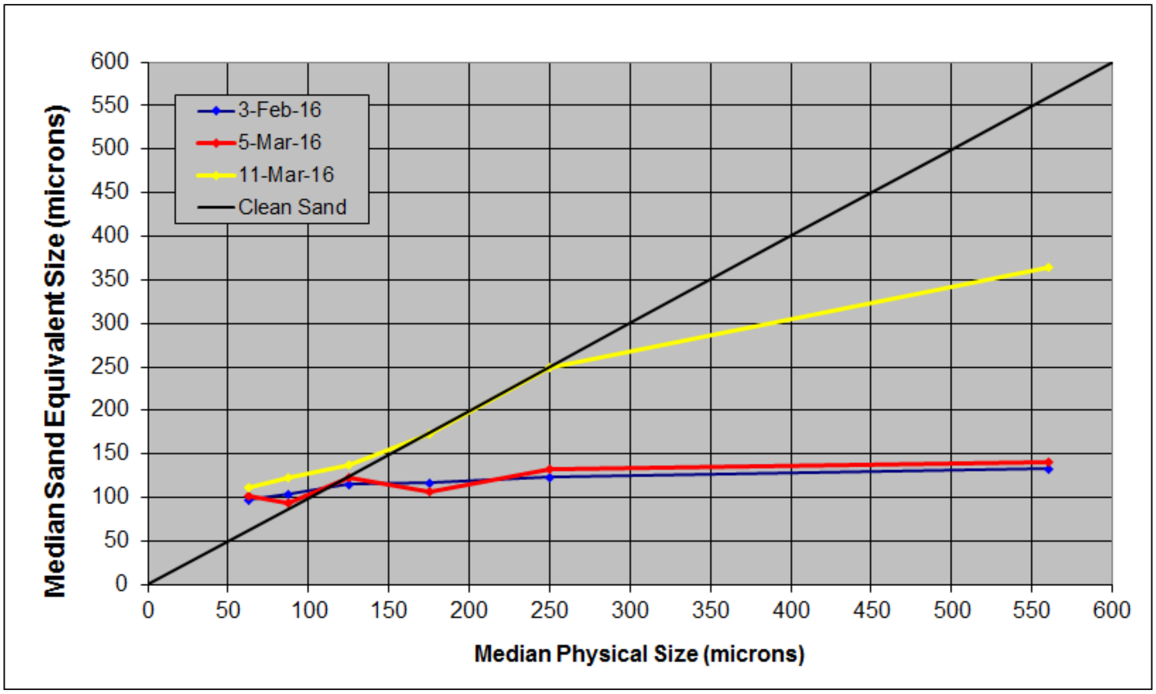


Figure 3.10
Median Size Distribution of Influent Grit at the SVCW WWTP vs. a Clean Sand Distribution



Grit entering the facility on February 3 and March 5 was light, having SES values significantly lower than their respective physical sizes. This is typical for baseline grit that remains suspended in the water column and is always present. It is likely that heavier grit accumulates in the collection system and only enters the facility when flow conditions are high enough for transport of this material. This is supported by the March 11 sampling event, producing grit with SES values approaching the clean sand line.

4.0 CONCLUSIONS

1. At the SVCW WWTP, on February 3 and March 5 distributions were similar, with between 34.0 and 36.9% of collected grit larger than 297-microns and between 61.1% and 66.0 smaller. March 11 produced a coarser distribution with 58.7% of collected grit larger than 297-microns and 41.3% smaller (Figures 3.4 and 3.5).
2. Concentrations of grit entering the facility were extremely low, resulting in 4.61 lbs/MG on February 3 and 11.16 lbs/MG on March 5. Concentrations were higher on March 11, totaling 38.0 lbs/MG (Figure 3.6).
3. Under normal flow conditions, a grit removal system design based on the settling characteristics determined for this location will remove 35.4% of 150-micron grit. Efficiency improves 72.6% for a 100-micron system, and 93.9% for a 75-micron system. The March 5 high flow trial produced similar results at 39.3%, 72.0% and 90.3% estimated efficiencies. Predicted removal efficiencies determined for the March 11 high flow trial were significantly higher at 87.2%, 97.6% and 99.6% respectively. This is a result of a coarser distribution and faster settling velocities of material entering the facility. (Table 3.2).

5.0 BIBLIOGRAPHY

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Tchobanoglous, G., Burton, F.L. and Stensel, H.D., “Wastewater Engineering: Treatment and Reuse”, 4^{th} Edition, 2003. TATA McGraw-Hill

APPENDIX A
RAW DATA

A-1 Concentration Calculation Spreadsheet

SVCW WRF - Pre-screen Influent

Sample Site	Start Time	End Time	Sampling Time (hrs.)	Settler Feed Rate (gpm)	Plant Flow (MGD)	Amount of Flow During Sampling Period (MG)	Gallons Sampled	Total Grit FS Collected (grams)
February 3, 2016	8:40	14:40	6.00	7.97	16.500	4.125	2,870	6.00
March 5, 2016	8:15	13:30	5.25	6.60	20.500	4.484	2,080	10.53
March 11, 2015	12:45	19:45	7.00	7.87	35.500	10.354	3,306	56.94

Sample Site	Sample Dilution/mls of sample	Total Sample Volume (gal)	Sample Dilution/volume analyzed (mls)	Weight of Sample Put in Wet Sieve (gm)	Total FS Weight (gm)	Total Grit FS Collected (pounds)	Total Grit FS Entering Channel During Sampling (pounds)	Concentration (lbs/MG)
February 3, 2016	1	0.0003	1		6.00	0.01	19.0	4.612
March 5, 2016	1	0.0003	1		10.53	0.02	50.1	11.162
March 11, 2015	1	0.0003	1		56.94	0.13	393.2	37.980

A-2 Solids Analysis Bench Sheets

Fixed Solids - SVCF WRF

		Fixed Solids Sample Weight (grams)		
		Sample Site	Pre-screen Influent	
Micron	US Sieve	3-Feb-16	5-Mar-16	11-Mar-16
6300	1/4	0.018	0.019	2.624
3180	1/8	0.127	0.176	0.587
1680	#12	0.402	0.641	2.520
841	#20	0.432	0.777	4.263
297	#50	1.345	1.938	23.313
210	#70	1.764	2.737	10.375
149	#100	1.049	2.271	5.799
105	#140	0.435	1.020	4.293
74	#200	0.271	0.586	2.283
53	#270	0.137	0.267	0.724
<53	pan	0.024	0.097	0.155
Total FS Weight		6.00	10.53	56.94

		Fixed Solids Sample Percent Retained		
		Sample Site	Pre-screen Influent	
Micron	US Sieve	3-Feb-16	5-Mar-16	11-Mar-16
6300	1/4	0.30	0.18	4.62
3180	1/8	2.12	1.69	1.03
1680	#12	6.72	6.14	4.44
841	#20	7.22	7.45	7.51
297	#50	22.49	18.58	41.06
210	#70	29.50	26.24	18.27
149	#100	17.54	21.77	10.21
105	#140	7.27	9.78	7.56
74	#200	4.53	5.62	4.02
53	#270	2.29	2.56	1.28
<53	pan	0.40	0.93	0.27
Total (%) minus pan		100.00	100.00	100.00

		Fixed Solids Sample Cumulative %>		
		Sample Site	Pre-screen Influent	
Micron	US Sieve	3-Feb-16	5-Mar-16	11-Mar-16
53	#270	100	100	100
74	#200	97.71	97.44	98.72
105	#140	93.18	91.82	94.70
149	#100	85.90	82.05	87.14
210	#70	68.36	60.28	76.93
297	#50	38.86	34.04	58.66
841	#20	16.37	15.46	17.60
1680	#12	9.15	8.01	10.09
3180	1/8	2.42	1.87	5.66
6300	1/4	0.30	0.18	4.62

>297u	38.86	34.04	58.66
<297u	61.14	65.96	41.34

A-3 Grit Concentration Calculation Bench Sheet

Influent

Micron	US Sieve	3-Feb-16 %	3-Feb-16 lbs/MG	5-Mar-16 %	5-Mar-16 lbs/MG	11-Mar-16 %	11-Mar-16 lbs/MG
6300	0.25	0.301	0.014	0.182	0.020	4.621	1.755
3180	0.125	2.124	0.098	1.687	0.188	1.034	0.393
1680	#12	6.722	0.310	6.145	0.686	4.438	1.686
841	#20	7.224	0.333	7.448	0.831	7.508	2.851
297	#50	22.492	1.037	18.577	2.074	41.050	15.594
210	#70	29.498	1.361	26.237	2.929	18.272	6.940
149	#100	17.542	0.809	21.770	2.430	10.213	3.879
105	#140	7.274	0.335	9.778	1.091	7.561	2.872
74	#200	4.532	0.209	5.617	0.627	4.021	1.527
53	#270	2.291	0.106	2.559	0.286	1.275	0.484
<53	pan	0.401	0.019	0.930	0.104	0.273	0.104
	Total (lbs)	4.61	4.61	11.16	11.16	37.98	37.98

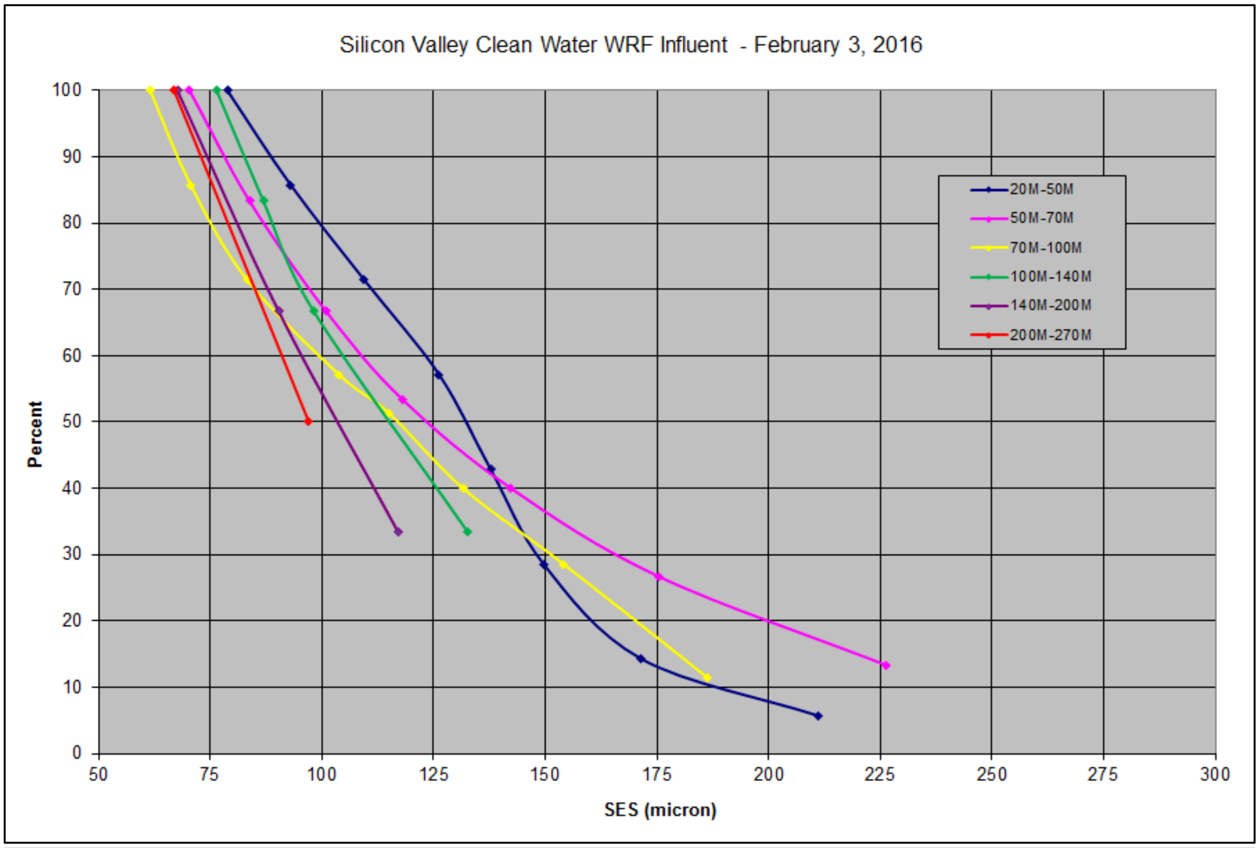
A-4 SES Data Analysis

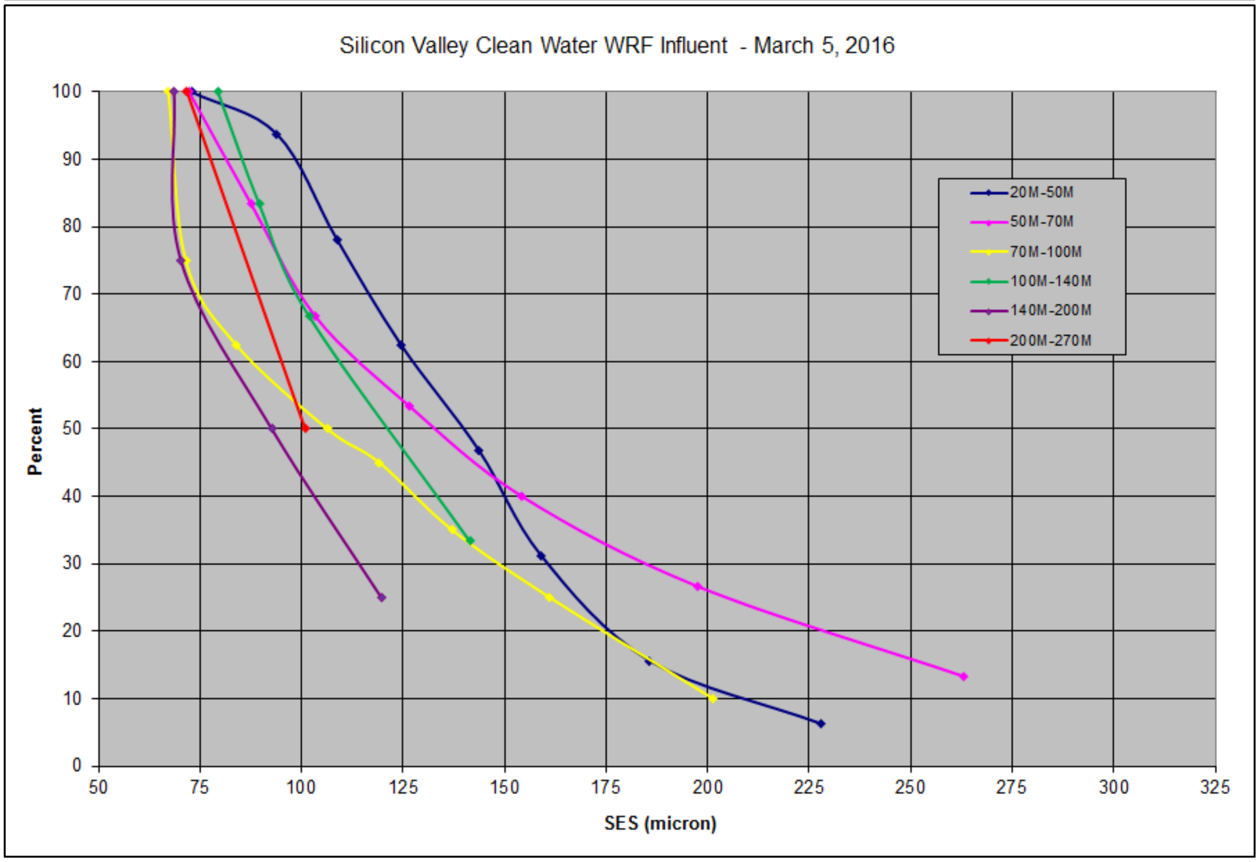
		Silicon Valley Clean Water WRF Influent - February 3, 2016									
sed vol, cc	fractional volume, %	sed time, sec	sed h, cm	sed vel, cm/s	SES, d1 µ	NR1	NR2	SES, d2 µ		SES, µ	vol frac, %≥
20M - 50M, 300µ - 820µ											
0.2	6	18.59	53.4	2.87E+00	211.1	6.1	6.1	211.1		211.1	6
0.5	14	25.47	52.4	2.06E+00	171.5	3.5	3.5	171.5		171.5	14
1.0	29	31.42	51.4	1.64E+00	149.7	2.4	2.4	149.7		149.7	29
1.5	43	35.73	50.7	1.42E+00	137.8	2.0	2.0	137.8		137.8	43
2.0	57	41.19	50.2	1.22E+00	126.3	1.5	1.5	126.3		126.3	57
2.5	71	52.63	49.7	9.45E-01	109.5	1.0	1.0	109.5		109.5	71
3.0	86	70.23	49.3	7.02E-01	93.1	0.7	0.7	93.1		93.1	86
3.5	100	94.97	48.9	5.15E-01	78.9	0.4	0.4	78.9		78.9	100
50M - 70M, 200µ - 300µ											
0.20	13	16.69	53.4	3.20E+00	226.4	7.2	7.2	226.4		226.4	13
0.4	27	24.64	52.7	2.14E+00	175.5	3.8	3.8	175.5		175.5	27
0.6	40	34.74	52.2	1.50E+00	142.4	2.1	2.1	142.4		142.4	40
0.8	53	47.82	51.8	1.08E+00	118.2	1.3	1.3	118.2		118.2	53
1.0	67	63.06	51.4	8.16E-01	101.0	0.8	0.8	101.0		101.0	67
1.3	83	88.37	51.1	5.78E-01	83.8	0.5	0.5	83.8		83.8	83
1.5	100	121.92	50.7	4.16E-01	70.4	0.3	0.3	70.4		70.4	100
70M - 100M, 150µ - 200µ											
0.20	11	22.65	53.4	2.36E+00	186.4	4.4	4.4	186.4		186.4	11
0.5	29	30.46	52.4	1.72E+00	154.1	2.7	2.7	154.1		154.1	29
0.7	40	39.64	52.0	1.31E+00	131.7	1.7	1.7	131.7		131.7	40
0.9	51	50.08	51.6	1.03E+00	114.9	1.2	1.2	114.9		114.9	51
1.0	57	59.92	51.4	8.58E-01	103.9	0.9	0.9	103.9		103.9	57
1.3	71	89.45	51.1	5.71E-01	83.3	0.5	0.5	83.3		83.3	71
1.5	86	121.06	50.7	4.19E-01	70.7	0.3	0.3	70.7		70.7	86
1.8	100	156.57	50.4	3.22E-01	61.6	0.2	0.2	61.6		61.6	100
100M - 140M, 100µ - 150µ											
0.20	33	40.16	53.4	1.33E+00	132.8	1.8	1.8	132.8		132.8	33
0.4	67	68.03	52.7	7.75E-01	98.2	0.8	0.8	98.2		98.2	67
0.5	83	84.82	52.4	6.18E-01	86.9	0.5	0.5	86.9		86.9	83
0.6	100	107.39	52.2	4.86E-01	76.4	0.4	0.4	76.4		76.4	100
140M - 200M, 75µ - 100µ											
0.20	33	50.11	53.4	1.07E+00	117.2	1.2	1.2	117.2		117.2	33
0.4	67	79.33	52.7	6.64E-01	90.4	0.6	0.6	90.4		90.4	67
0.6	100	135.22	52.2	3.86E-01	67.7	0.3	0.3	67.7		67.7	100
200M - 270M, 50µ - 75µ											
0.10	50	71.22	54.0	7.58E-01	97.1	0.7	0.7	97.1		97.1	50
0.20	100	141.36	53.4	3.78E-01	67.0	0.3	0.3	67.0		67.0	100

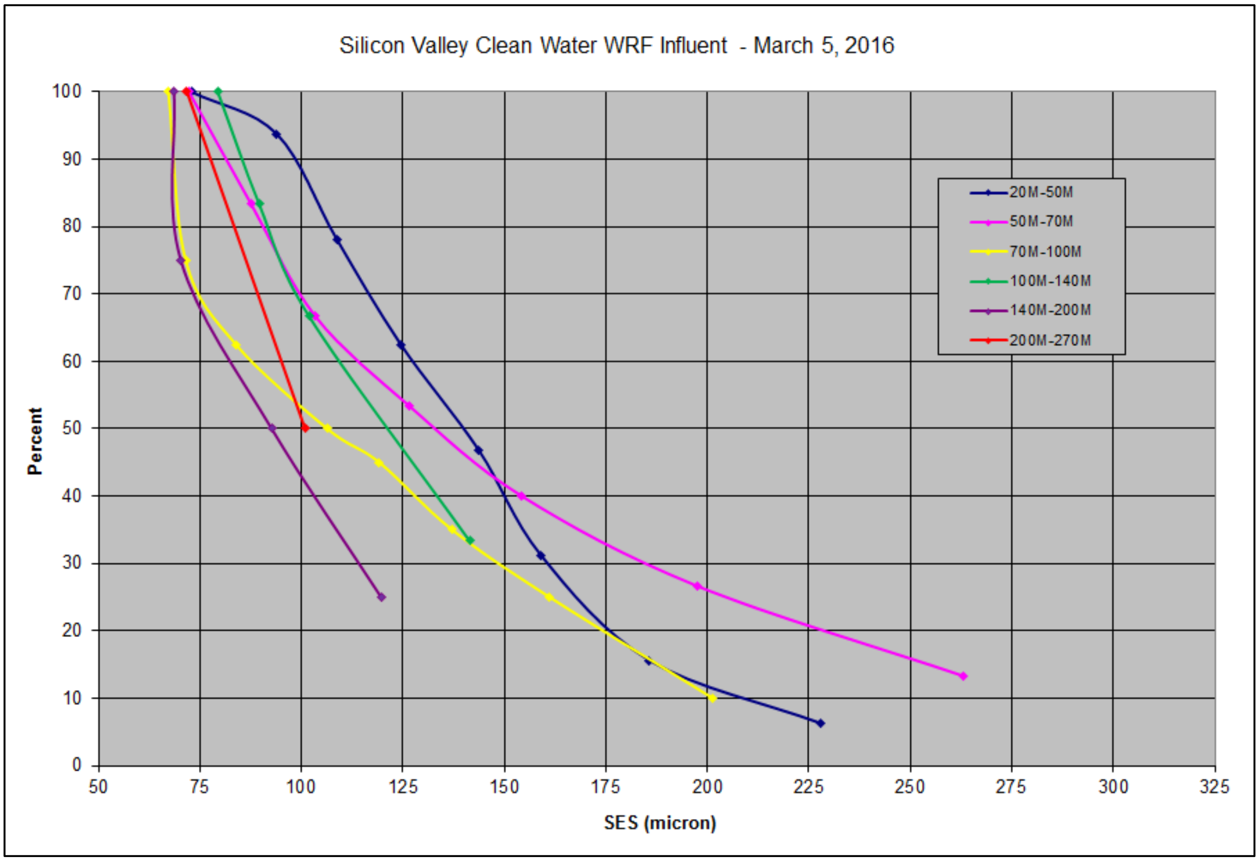
		Silicon Valley Clean Water WRF Influent - March 5, 2016								
sed vol, cc	fractional volume, %	sed time, sec	sed h, cm	sed vel, cm/s	SES, d1 µ	NR1	NR2	SES, d2 µ	SES, µ	vol frac, %≥
<u>20M - 50M, 300µ - 820µ</u>										
0.2	6	16.50	53.4	3.24E+00	228.1	7.4	7.4	228.1	228.1	6
0.5	16	22.36	52.4	2.34E+00	185.7	4.4	4.4	185.7	185.7	16
1.0	31	28.36	51.4	1.81E+00	159.0	2.9	2.9	159.0	159.0	31
1.5	47	33.25	50.7	1.53E+00	143.7	2.2	2.2	143.7	143.7	47
2.0	63	42.23	50.2	1.19E+00	124.5	1.5	1.5	124.5	124.5	63
2.5	78	53.32	49.7	9.32E-01	108.7	1.0	1.0	108.7	108.7	78
3.0	94	69.02	49.3	7.14E-01	94.0	0.7	0.7	94.0	94.0	94
3.2	100	110.36	49.2	4.45E-01	73.0	0.3	0.3	73.0	73.0	100
<u>50M - 70M, 200µ - 300µ</u>										
0.20	13	13.36	53.4	4.00E+00	262.9	10.5	10.5	262.9	262.9	13
0.4	27	20.36	52.7	2.59E+00	197.5	5.1	5.1	197.5	197.5	27
0.6	40	30.26	52.2	1.72E+00	154.3	2.7	2.7	154.3	154.3	40
0.8	53	42.25	51.8	1.23E+00	126.7	1.6	1.6	126.7	126.7	53
1.0	67	60.36	51.4	8.52E-01	103.5	0.9	0.9	103.5	103.5	67
1.3	83	81.36	51.1	6.28E-01	87.6	0.6	0.6	87.6	87.6	83
1.5	100	115.87	50.7	4.38E-01	72.3	0.3	0.3	72.3	72.3	100
<u>70M - 100M, 150µ - 200µ</u>										
0.20	10	20.02	53.4	2.67E+00	201.3	5.4	5.4	201.3	201.3	10
0.5	25	28.25	52.4	1.86E+00	161.2	3.0	3.0	161.2	161.2	25
0.7	35	36.91	52.0	1.41E+00	137.1	1.9	1.9	137.1	137.1	35
0.9	45	46.90	51.6	1.10E+00	119.2	1.3	1.3	119.2	119.2	45
1.0	50	57.36	51.4	8.97E-01	106.4	1.0	1.0	106.4	106.4	50
1.3	63	88.25	51.1	5.79E-01	83.9	0.5	0.5	83.9	83.9	63
1.5	75	118.46	50.7	4.28E-01	71.5	0.3	0.3	71.5	71.5	75
2.0	100	131.80	50.2	3.81E-01	67.2	0.3	0.3	67.2	67.2	100
<u>100M - 140M, 100µ - 150µ</u>										
0.20	33	35.96	53.4	1.49E+00	141.5	2.1	2.1	141.5	141.5	33
0.4	67	63.58	52.7	8.29E-01	101.9	0.8	0.8	101.9	101.9	67
0.5	83	80.15	52.4	6.54E-01	89.6	0.6	0.6	89.6	89.6	83
0.6	100	100.02	52.2	5.22E-01	79.4	0.4	0.4	79.4	79.4	100
<u>140M - 200M, 75µ - 100µ</u>										
0.20	25	48.26	53.4	1.11E+00	119.6	1.3	1.3	119.6	119.6	25
0.4	50	75.69	52.7	6.96E-01	92.7	0.6	0.6	92.7	92.7	50
0.6	75	125.84	52.2	4.15E-01	70.3	0.3	0.3	70.3	70.3	75
0.8	100	130.64	51.8	3.96E-01	68.6	0.3	0.3	68.6	68.6	100
<u>200M - 270M, 50µ - 75µ</u>										
0.10	50	66.39	54.0	8.14E-01	100.9	0.8	0.8	100.9	100.9	50
0.20	100	123.69	53.4	4.32E-01	71.8	0.3	0.3	71.8	71.8	100

		Silicon Valley Clean Water WRF Influent - March 11, 2016								
sed vol, cc	fractional volume, %	sed time, sec	sed h, cm	sed vel, cm/s	SES, d1 µ	NR1	NR2	SES, d2 µ	SES, µ	vol frac, %≥
20M - 50M, 300µ - 820µ										
0.5	12	6.25	52.4	8.39E+00	466.9	39.2	39.2	466.9	466.9	12
1.0	24	6.83	51.4	7.53E+00	425.5	32.0	32.0	425.5	425.5	24
1.5	35	7.41	50.7	6.85E+00	393.1	26.9	26.9	393.1	393.1	35
2.0	47	8.01	50.2	6.27E+00	366.1	22.9	22.9	366.1	366.1	47
2.5	59	8.60	49.7	5.78E+00	343.8	19.9	19.9	343.8	343.8	59
3.0	71	9.31	49.3	5.30E+00	321.7	17.0	17.0	321.7	321.7	71
3.5	82	10.98	48.9	4.46E+00	283.7	12.6	12.6	283.7	283.7	82
4.0	94	16.47	48.6	2.95E+00	214.7	6.3	6.3	214.7	214.7	94
4.3	100	42.38	48.5	1.14E+00	121.8	1.4	1.4	121.8	121.8	100
50M - 70M, 200µ - 300µ										
0.50	17	10.20	52.4	5.14E+00	314.6	16.2	16.2	314.6	314.6	17
1.0	33	11.74	51.4	4.38E+00	280.2	12.3	12.3	280.2	280.2	33
1.5	50	13.76	50.7	3.69E+00	248.7	9.2	9.2	248.7	248.7	50
2.0	67	16.50	50.2	3.04E+00	218.9	6.7	6.7	218.9	218.9	67
2.5	83	19.79	49.7	2.51E+00	193.8	4.9	4.9	193.8	193.8	83
3.0	100	28.98	49.3	1.70E+00	153.1	2.6	2.6	153.1	153.1	100
70M - 100M, 150µ - 200µ										
0.50	19	17.79	52.4	2.95E+00	214.5	6.3	6.3	214.5	214.5	19
1.0	38	22.01	51.4	2.34E+00	185.3	4.3	4.3	185.3	185.3	38
1.5	58	26.43	50.7	1.92E+00	164.5	3.2	3.2	164.5	164.5	58
2.0	77	33.72	50.2	1.49E+00	141.6	2.1	2.1	141.6	141.6	77
2.5	96	58.35	49.7	8.52E-01	103.5	0.9	0.9	103.5	103.5	96
2.6	100	90.68	49.6	5.47E-01	81.4	0.4	0.4	81.4	81.4	100
100M - 140M, 100µ - 150µ										
0.20	9	16.72	53.4	3.20E+00	226.1	7.2	7.2	226.1	226.1	9
0.5	22	24.60	52.4	2.13E+00	175.1	3.7	3.7	175.1	175.1	22
1.0	43	33.23	51.4	1.55E+00	144.8	2.2	2.2	144.8	144.8	43
1.5	65	42.90	50.7	1.18E+00	124.2	1.5	1.5	124.2	124.2	65
2.0	87	56.02	50.2	8.96E-01	106.4	1.0	1.0	106.4	106.4	87
2.3	100	92.50	49.9	5.39E-01	80.8	0.4	0.4	80.8	80.8	100
140M - 200M, 75µ - 100µ										
0.50	14	30.05	52.4	1.74E+00	155.4	2.7	2.7	155.4	155.4	14
1.0	29	35.62	51.4	1.44E+00	139.1	2.0	2.0	139.1	139.1	29
1.5	43	41.49	50.7	1.22E+00	126.5	1.5	1.5	126.5	126.5	43
2.0	57	46.96	50.2	1.07E+00	117.3	1.3	1.3	117.3	117.3	57
2.5	71	62.68	49.7	7.93E-01	99.5	0.8	0.8	99.5	99.5	71
3.0	86	92.81	49.3	5.31E-01	80.2	0.4	0.4	80.2	80.2	86
3.5	100	145.92	48.9	3.35E-01	62.9	0.2	0.2	62.9	62.9	100
200M - 270M, 50µ - 75µ										
0.10	40	52.06	54.0	1.04E+00	115.4	1.2	1.2	115.4	115.4	40
0.20	80	70.11	53.4	7.62E-01	97.3	0.7	0.7	97.3	97.3	80
0.3	100	123.65	53.2	4.30E-01	71.7	0.3	0.3	71.7	71.7	100

A-5 SES Charts






Silicon Valley Clean Water WRF Influent - March 5, 2016
Percent
SES (micron)
20M-50M
50M-70M
70M-100M
100M-140M
140M-200M
200M-270M
0
10
20
30
40
50
60
70
80
90
100
50
75
100
125
150
175
200
225
250
275
300
325

A-6 SES Chart Analysis

Silicon Valley Clean Water WRF Influent - February 3, 2016

Sieve Size >	1/4	1/8	#12	#20	#50	#70	#100	#140	#200	#270	% Total in SES Range			
fxd solids fraction	0.30	2.12	6.72	7.22	22.49	29.50	17.54	7.27	4.53	2.29				
											SES (micron)	% Percent Retained	Cumulative % Retained	% >
SES Interval											25			100
25-50											50	0.00	0.00	100.00
50-75						6.0	20.0		11.0	14.0	75	6.10	6.10	93.90
75-100					21.0	27.0	20.0	35.0	35.0	41.0	100	21.27	27.37	72.63
100-125				21.0	21.0	19.0	16.0	24.0	30.0	39.0	125	18.65	46.02	53.98
125-150			21.0	21.0	30.0	12.0	13.0	25.0	24.0	6.0	150	18.54	64.56	35.44
150-175		21.0	21.0	30.0	15.0	9.0	14.0	16.0			175	13.67	78.23	21.77
175-200	21.0	21.0	30.0	15.0	6.0	7.0	13.0				200	9.30	87.53	12.47
200-225	21.0	30.0	15.0	6.0	4.0	7.0	4.0				225	5.81	93.34	6.66
225-250	30.0	15.0	6.0	4.0	3.0	6.0					250	3.55	96.89	3.11
250-275	15.0	6.0	4.0	3.0		6.0					275	2.43	99.32	0.68
275-300	6.0	4.0	3.0			1.0					300	0.60	99.92	0.08
>300	7.0	3.0									>300	0.08	100.00	0.00
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		100.00		

Silicon Valley Clean Water WRF Influent - March 5, 2016

Sieve Size >	1/4	1/8	#12	#20	#50	#70	#100	#140	#200	#270	% Total in SES Range			
fxd solids fraction	0.18	1.69	6.14	7.45	18.58	26.24	21.77	9.78	5.62	2.56				
											SES (micron)	% Percent Retained	Cumulative % Retained	% >
SES Interval											25			100
25-50											50	0.00	0.00	100.00
50-75					1.0	3.0	31.0		33.0	6.0	75	9.73	9.73	90.27
75-100				1.0	11.0	27.0	16.0	32.0	24.0	44.0	100	18.29	28.02	71.98
100-125			1.0	11.0	26.0	16.0	11.0	21.0	24.0	44.0	125	16.83	44.85	55.15
125-150		1.0	11.0	26.0	22.0	12.0	13.0	20.0	19.0	6.0	150	15.87	60.72	39.28
150-175	1.0	11.0	26.0	22.0	19.0	9.0	9.0	20.0			175	13.23	73.95	26.05
175-200	11.0	26.0	22.0	19.0	9.0	7.0	9.0	7.0			200	9.38	83.33	16.67
200-225	26.0	22.0	19.0	9.0	5.0	5.0	9.0				225	6.46	89.78	10.22
225-250	22.0	19.0	9.0	5.0	5.0	5.0	2.0				250	3.96	93.74	6.26
250-275	19.0	9.0	5.0	5.0	2.0	5.0					275	2.55	96.29	3.71
275-300	9.0	5.0	5.0	2.0		5.0					300	1.87	98.16	1.84
300-325	5.0	5.0	2.0			5.0					325	1.53	99.69	0.31
>325	7.0	2.0				1.0					>325	0.31	100.00	0.00
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		100.00		

Silicon Valley Clean Water WRF Influent - March 11, 2016

Sieve Size >	1/4	1/8	#12	#20	#50	#70	#100	#140	#200	#270	% Total in SES Range			
fxd solids fraction	4.62	1.03	4.44	7.51	41.06	18.27	10.21	7.56	4.02	1.28				
											SES (micron)	% Percent Retained	Cumulative % Retained	% >
SES Interval											25			100
25-50											50	0.00	0.00	100.00
50-75									10.0	2.0	75	0.43	0.43	99.57
75-100							3.0	9.0	19.0	21.0	100	2.02	2.45	97.55
100-125							11.0	27.0	26.0	56.0	125	4.92	7.37	92.63
125-150					2.0		15.0	24.0	25.0	21.0	150	5.44	12.81	87.19
150-175				2.0	2.0		23.0	17.0	20.0		175	5.41	18.22	81.78
175-200			2.0	2.0	2.0	9.0	19.0	8.0			200	5.25	23.47	76.53
200-225		2.0	2.0	2.0	2.0	11.0	13.0	5.0			225	4.80	28.27	71.73
225-250	2.0	2.0	2.0	2.0	4.0	17.0	13.0	5.0			250	6.81	35.07	64.93
250-275	2.0	2.0	2.0	4.0	5.0	17.0	3.0	5.0			275	6.35	41.42	58.58
275-300	2.0	2.0	4.0	5.0	6.0	13.0					300	5.50	46.92	53.08
300-325	2.0	4.0	5.0	6.0	9.0	14.0					325	7.06	53.98	46.02
325-350	4.0	5.0	6.0	9.0	14.0	12.0					350	9.12	63.10	36.90
350-375	5.0	6.0	9.0	14.0	12.0	7.0					375	7.95	71.05	28.95
375-400	6.0	9.0	14.0	12.0	10.0						400	6.00	77.05	22.95
400-425	9.0	14.0	12.0	10.0	9.0						425	5.54	82.59	17.41
425-450	14.0	12.0	10.0	9.0	8.0						450	5.18	87.76	12.24
450-475	12.0	10.0	9.0	8.0	7.0						475	4.53	92.30	7.70
475-500	10.0	9.0	8.0	7.0	5.0						500	3.49	95.79	4.21
500-525	9.0	8.0	7.0	5.0	3.0						525	2.42	98.20	1.80
>525	23.0	15.0	8.0	3.0							>525	1.80	100.00	0.00
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		100.00		

A-7 Median SES versus Median Physical Size

SVCW WRF Influent					
Median Size (microns)	Size Range (microns)		3-Feb-16	5-Mar-16	11-Mar-16
62.5	50	75	97	101	111
87.5	75	100	104	93	123
125	100	150	115	122	137
175	150	200	117	106	173
250	200	300	123	133	249
560	300	820	133	140	365

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APPENDIX B
CALCULATIONS

Drag Coefficient (C_d)

$24/N_R + 3/\text{sqrt } N_R + 0.34$

Reynolds number (N_R)

(settling velocity of particle)(diameter of particle)/kinematic viscosity

Stoke's Law

Settling velocity (m/s) = $g(sg_p – 1)d^2{}_p/18v$

Where g = acceleration due to gravity (9.81 m/s^2)
sg_p = specific gravity of particle
d_p = diameter of particle
v = kinematic viscosity (m^2/s)

% Total Solids

(grams dry weight/grams wet weight)*100

% Total Volatile Solids

[(grams dry weight - grams ash weight)/ grams dry weight]*100

Appendix B

SVCW Grit Sampling Data

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SVCW

Silicon Valley Clean Water

SVCW

Grit Assay

November 5, 2015

SVCW Grit Assays

March 3, 2014 Average Flow

Micron	Weight Captured On Screen Grams	ADDWF % of Total Weight
508	0.1515	**1.22%**
363	0.3362	**2.72%**
254	0.9829	**7.94%**
120	2.2478	**18.16%**
105	0.7392	**5.97%**
74	2.3686	**19.13%**
< 74	5.5523	**44.85%**

Hand Composite
480 mg/L TSS
92 mg/L FSS
388 mg/L VSS

<74u in size at ~45% of the total grit weight for this ADDWF sample vs. ~22% of the total grit weight for the Storm sample

SVCW
Silicon Valley Clean Water

SVCW Grit Assay

Pre 3/4/2015 & Post 3/24/2015 Samples
(Existing Hydrocyclones & Walking Beam Performance)

Pre Degritting			Post Degritting			
Weight Captured On Screen Grams	ADDWF % of Total Weight		Weight Captured On Screen Grams	ADDWF % of Total Weight		% Change
0.0000	**0.00%**		0.0000	**0.00%**		0.00%
0.0000	**0.00%**		0.0000	**0.00%**		0.00%
0.0000	**0.00%**		0.0000	**0.00%**		0.00%
0.0000	**0.00%**		0.0000	**0.00%**		0.00%
0.0000	**0.00%**		0.0000	**0.00%**		0.00%
0.0000	**0.00%**		0.0000	**0.00%**		0.00%
0.1515	**1.22%**		0.0236	**0.21%**		1.01%
0.3362	**2.72%**		0.3643	**3.29%**		-0.57%
0.9829	**7.94%**		1.6778	**15.14%**		-7.20%
2.2478	**18.16%**		1.1665	**10.53%**		7.63%
0.7392	**5.97%**		1.2434	**11.22%**		-5.25%
2.3686	**19.13%**		2.6583	**23.99%**		-4.85%
5.5523	**44.85%**		3.9475	**35.62%**		9.23%

59.6% of the post grit <105u in size.

SVCW Grit Assay

April 23, 2014 Sample

Collected from the Primary Gallery Floor

(Clarifier Cleanout)

Micron	Weight Captured On Screen Grams	% of Total Weight
12,700	9.04	**0.15%**
6,350	156.81	**2.65%**
3,175	611.21	**10.33%**
2,117	277.16	**4.68%**
1,270	430.41	**7.27%**
847	386.39	**6.53%**
508	1,585.13	**26.78%**
363	1,230.91	**20.80%**
254	896.11	**15.14%**
120	166.76	**2.82%**
105	60.67	**1.03%**
74	66.40	**1.12%**
< 74	41.70	**0.70%**

SVCW
Silicon Valley Clean Water

SVCW Grit Assay

April 23, 2014 Sample

Marked Sample Difference – Why?

1. Larger grit passes hopper?
2. Larger grit removed in batches when it accumulates to the point under water mounds of grit slide or collapse into the hopper?
3. Variations in the pumping rates between the clarifiers impacting the grit removal for some units?
4. PC flights are not consistently striking the floors clean resulting in accumulation of grit and periodically sweeping the grit out?
5. As the main flights sweep the floor into the hopper, the resulting slug load is pumped out of the hopper relatively quick and we are not capturing this slug in our grab samples?
6. Pump run combination results in grit scouring?

SVCW Grit Assays

December 11, 2014 Storm Sample

Micron	Weight Captured On Screen Grams	% of Total Weight
1,270	0.2617	**0.25%**
847	0.6639	**0.64%**
508	4.8505	**4.64%**
363	14.6374	**14.00%**
254	15.5674	**14.89%**
120	19.6813	**18.83%**
105	7.5433	**7.22%**
74	18.5362	**17.74%**
< 74	22.7750	**21.79%**

SVCW Grit Assays

October 5, 2015 Average Flow

Multiple 24HC Sample Aliquots

New Influent Sample Location

Micron	Weight Captured On Screen Grams	ADDWF % of Total Weight
2,117	0.0122	**0.08%**
1,270	0.5670	**3.77%**
847	1.4257	**9.48%**
508	0.6643	**4.42%**
363	1.5882	**10.56%**
254	2.6415	**17.56%**
120	1.2846	**8.54%**
105	1.2312	**8.18%**
74	2.3820	**15.83%**
< 74	3.2486	**21.59%**

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Appendix D

Headworks Technology Workshop Presentation

Headworks Technology Workshop

WWTP Headworks and Screening Facility (CIP # 9160)

SVCW
Silicon Valley Clean Water

CDM Smith

August 5, 2015

Presentation Agenda

1. **Potential FOP Site Layout**
2. **Screenings (15 min)**
    1. Screens – Types & opening
    2. Screenings processing
3. **Grit (20 min)**
    1. Removal
    2. Washing
    3. SFPUC Demonstration
4. **Equipment Layouts (10 min)**
5. **Questions and discussion (15 min)**

CDM Smith

POTENTIAL FOP SITE LAYOUT

SVCW

POTENTIAL FRONT OF PLANT IMPROVEMENTS

CDM Smith

SCREENS – SCREEN TYPES & OPENING

Screening – Technologies Available

- Single Rake Bar Screens (Climber)
- Multi-rake Bar Screens (Catenary)
- Continuous Element Screens (Perf Plate)
- Center-flow Band Screens
- Stair Screens
- Inclined Cylindrical Screens
- Grinder/Auger Screens

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Single Rake Bar Screen (Climber)

- **Advantages**
  - Up to 210 ft3/hr.
  - No movable parts in flow
  - Many US installations
  - Two speed motor
- **Disadvantages**
  - Rake engagement problematic
  - Long rake travel time
  - Screen height
  - High equipment cost
  - Low solids capture
  - Difficult to odor control

CDM Smith

Multi-rake Bar Screen

- **Advantages**
  - Low headloss
  - Low screen height
  - Good conveyor
  - Many US installations
  - Extremely reliable; good competition
  - Easy to odor control
- **Disadvantages**
  - Moderate screenings capture ratio (SCR)
  - Submerged lower bearing/sprocket
  - Heavy chain and rakes

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Continuous Element Bar Screens

- **Advantages**
  - Advantages of multi-rake without the chain and rake
  - Less prone to material catching between bars
  - Higher SCR than multi-rakes
  - Higher carrying capacity than multi-rakes
  - Wash water for cleaning instead of brushes compatible with sluices
- **Disadvantages**
  - Large wash water requirement (24 gpm for 48" screen)
  - Potential for carryover if wash water fails
  - Limited installation base in large plants (PS 64 in San Diego closest)
  - High maintenance

Continuous Element Screens (Perforated Plate)

- **Advantages**
  - High SCR
  - Better at lifting large debris
  - No submerged lower bearing
- **Disadvantages**
  - Headloss higher than bar screen
  - Problems with cleaning brush/spray
  - Must be laid back to prevent "log rolling"
  - Plate damage & replacement
  - Open slots between steps and bottom

Center Flow Band Screens

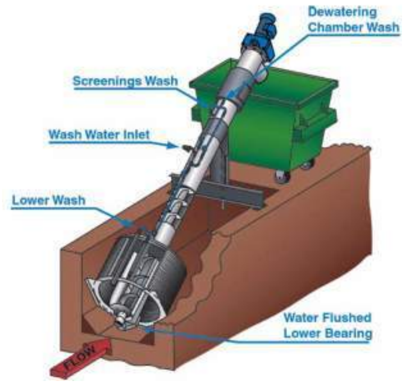
- **Advantages**
  - Twice the screening area per sq. ft.
  - Low headloss
  - No downstream carryover
  - High SCR
- **Disadvantages**
  - High Cost
  - Few large US installations on wastewater

Stair Screens

- **Advantages**
  - Provides some dewatering
  - No downstream carryover
  - No cleaning brushes or spray
  - Low profile
  - Drive system above water
  - High SCR
- **Disadvantages**
  - Accumulation below first step
  - Clogging of fingers
  - Wear on finger spacers

Inclined Cylindrical Screens

- **Advantages**
  - Operates intermittently
  - Low capital cost
  - Can pivot unit out of channel
  - No separate washer compactor
- **Disadvantages**
  - Large footprint
  - High headloss
  - Requires wide channel
  - Small plants



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Screen Technology Comparison

Criteria	Single Rake Bar Screen	Multi-rake Bar Screen	Continuous Element Bar	Continuous Element Perf	Center Flow Band Screen	Stair Screen	Inclined Cylindrical Screen
Available in 1/4" and 3/8"?	Yes	Yes	Yes	Yes	Yes	Yes	No
Available with Adequate Capacity?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Installations of Similar Size	No	Yes	Yes	Yes	Yes	?	No
Adequate Removal	No	Yes	Yes	Yes	Yes	No	No
Proven Experience in US	Yes	Yes	Yes	Yes	No	Yes	No
Meets Overall Objectives?	***No***	***Yes***	***Yes***	***Yes***	***No***	***No***	***No***

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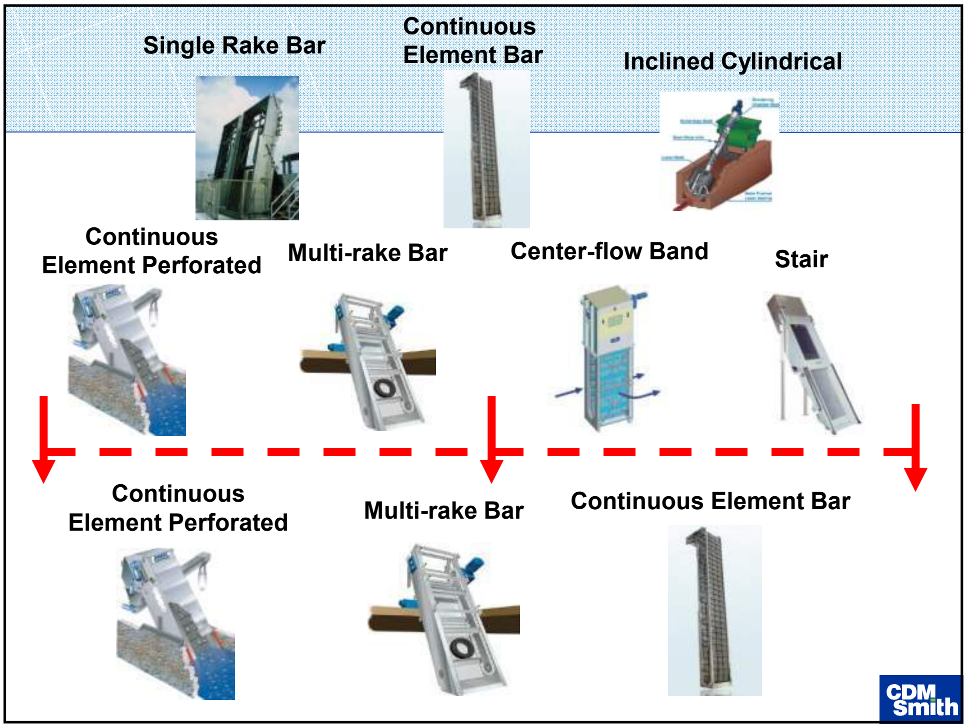
Single Rake Bar
Continuous Element Bar
Inclined Cylindrical
Continuous Element Perforated
Multi-rake Bar
Center-flow Band
Stair
Continuous Element Perforated
Multi-rake Bar
Continuous Element Bar
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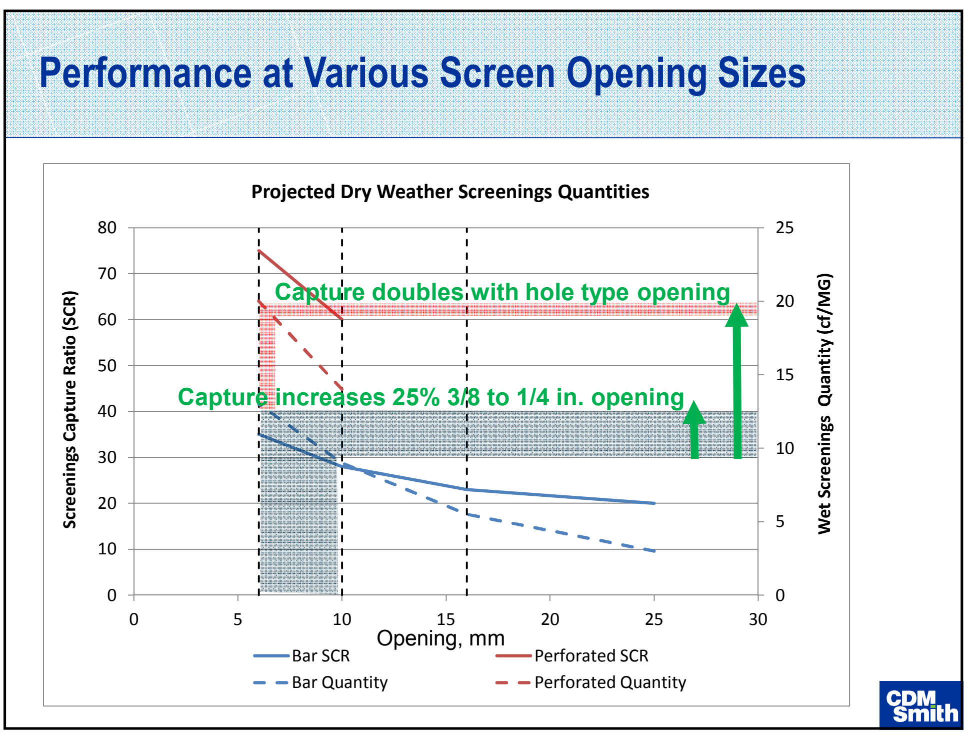

Performance at Various Screen Opening Sizes
Projected Dry Weather Screenings Quantities
Capture doubles with hole type opening
Capture increases 25% 3/8 to 1/4 in. opening
Screenings Capture Ratio (SCR)
Wet Screenings Quantity (cf/MG)
Opening, mm
Bar SCR
Perforated SCR
Bar Quantity
Perforated Quantity
CDM Smith

Continuous Element vs. Multi-rake

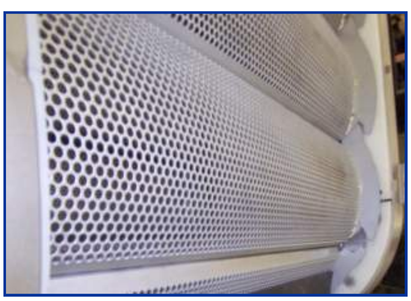
Technology	Screenings to be washed, cf/hr
Multi-rake 3/8 inch	6
Multi- rake ¼ inch	8
Continuous Element	13

Based on 15 mgd

- Data from West Point indicates 3/8 to 1/4 in almost twice the capture
- Multi-rakes can be spec'd to be convertible

Continuous Element (Perf Plate) vs. Multi-Rake

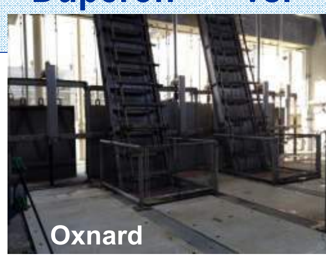
- **Big difference in "carrying capacity"**
  - One has a tray and the other doesn't
  - Perf plate must slope back continuous element to increase capacity
  - Some perf plates have "fingers"



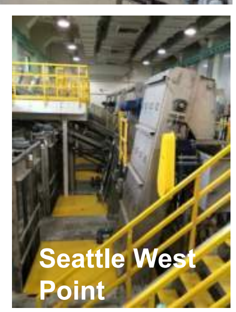
Screen Costs

- Multi-rake and Perf Plate have similar costs
- $200,000 to $250,000 per unit or about 10 % of the construction cost

Duperon vs. Traditional Multi-rakes



- Cheaper
- No bottom sprocket
- “Innovating”
- Very few 6mm
- Prone to grit blinding



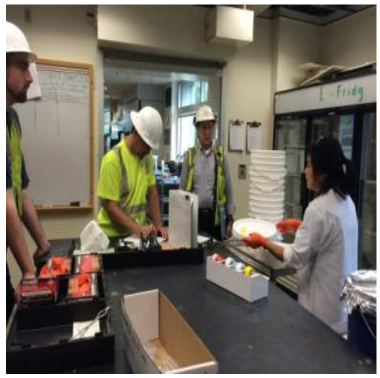
SCREENS – SCREENINGS PROCESSING

Screenings Handling

- **Start with the end in mind**
  - Dryness and Organics Removal
    - Now
    - 10 years from now when it disposal isn't local
  - **Flow through** **or** **Batch**

Washer Compactor Testing

Capacity per Unit	
Mode	cu ft/hr
Batch	42
Through put	420



Performance testing now accepted by credible suppliers

Meeting performance requirements (Batch Mode)

Item	Minimum (%)	
	Specified	Test Results
Volume Reduction	60	73
Weight Reduction	50	84
TSS	40	41
COD Reduction	90	91

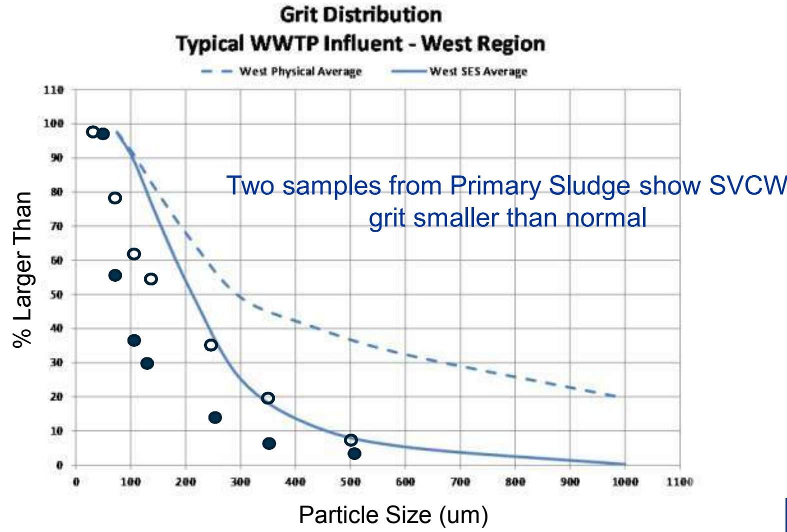
Screenings Handling

- **Screenings Handling *(Cont.)***
  - Disposal Requirements Future changes if any
  - Estimated quantities = 25 cy per week at 15 mgd and ¼ inch screen
  - Container type and size
  - Side stream routing (Fine screens remove grit)
  - Grind or not to grind

CDM Smith

GRIT - REMOVAL

Grit Removal – Typical Grit Size Distribution



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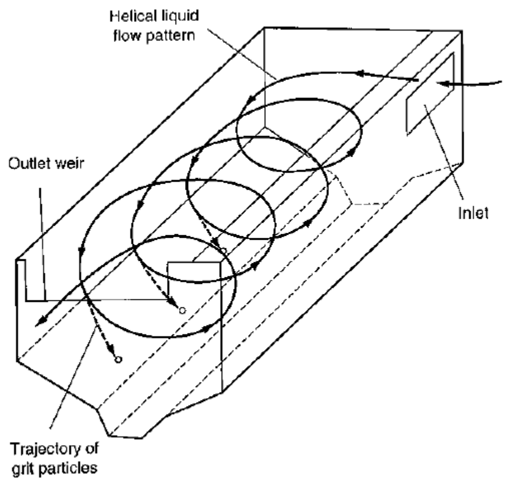
Grit Removal – Available Technologies

- **Channel**
- **Aerated Grit**
- **Vortex Grit**
- **Conical Tray Vortex (Headcell)**

CDM Smith

Aerated Grit – Introduction



Aerated Grit - Performance

Parameter	Value
Performance	- Can be designed to meet any performance criteria.
Advantages	- Good performance - Low Headloss (~6“) - Upstream screening not necessary
Disadvantages	- High maintenance - High power costs - Large footprint - Short Circuiting - High odor generation

Aerated Grit – Design Criteria

Parameter	Value
No. of Channels	3 duty
Depth	16 ft
Width	13 ft
Length	102 ft
Floor Slope	30 degrees
Total Volume	157,000 gal
Overflow Rate	26,700 gpd/ft2
Detention Time	6 min
Blower	15 hp, 315 cfm @ 7 psi

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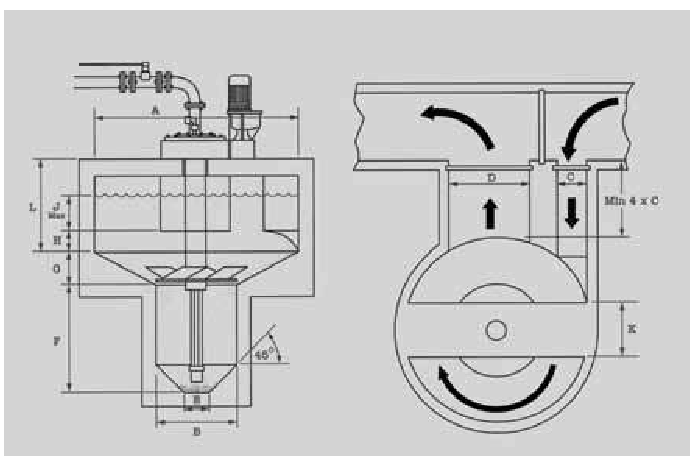
Vortex Grit – Introduction



Source: Ovivo

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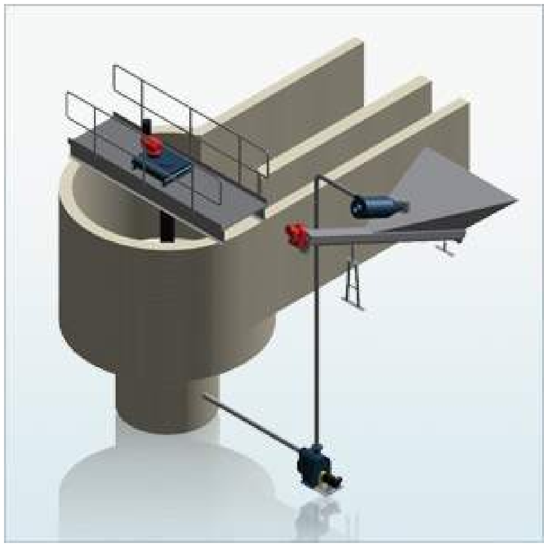
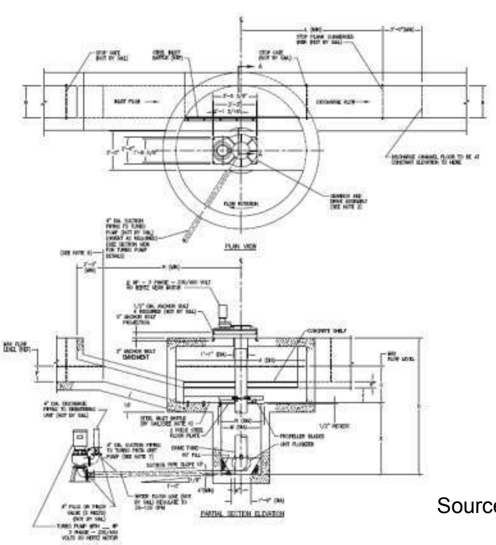
Vortex Grit – 270 Degree Layout



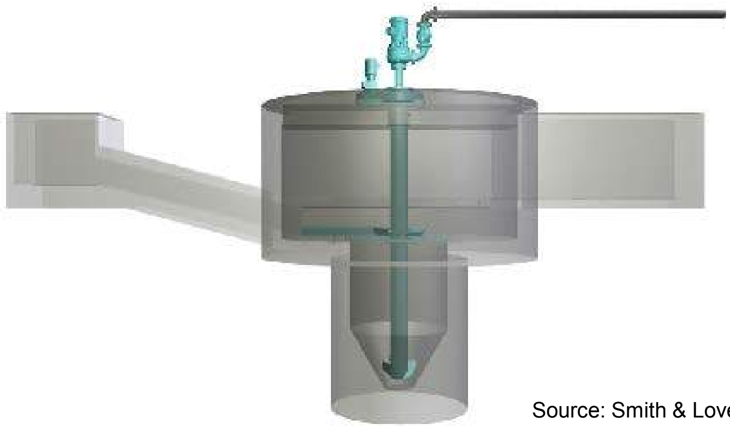
Source:
Hydrodyne

Vortex Grit – 360 Degree Layout



Source: Smith & Loveless

Vortex Grit – 360 Degree Layout



Source: Smith & Loveless

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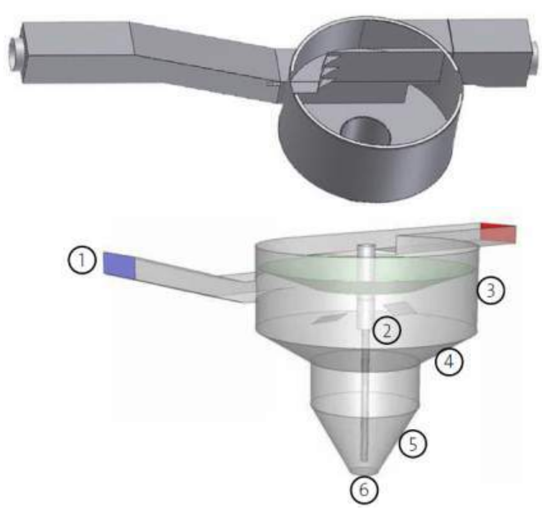
Vortex Grit – 360 Degree Units w/ Baffles



Source:
(Top) Smith & Loveless
(Bottom) Meunier

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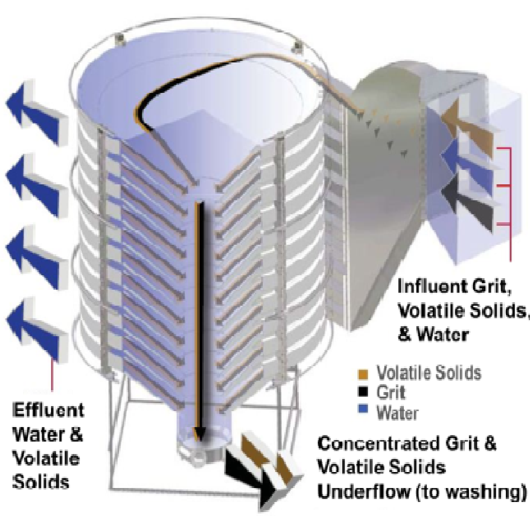
Vortex Grit - Performance

Parameter	Value
Performance	- 65% removal of grit 150 - 200 micron - 38% removal of grit 100 - 150 micron
Advantages	- Low Headloss (< 4") - No fine screening needed - Low maintenance - Many installations
Disadvantages	- Poor performance - Tends to clog at high grit loads - Larger footprint than Headcell - High construction costs

Most SVCW grit smaller than can be removed with Pista

CDM Smith

Conical Tray Vortex (Headcell) - Introduction



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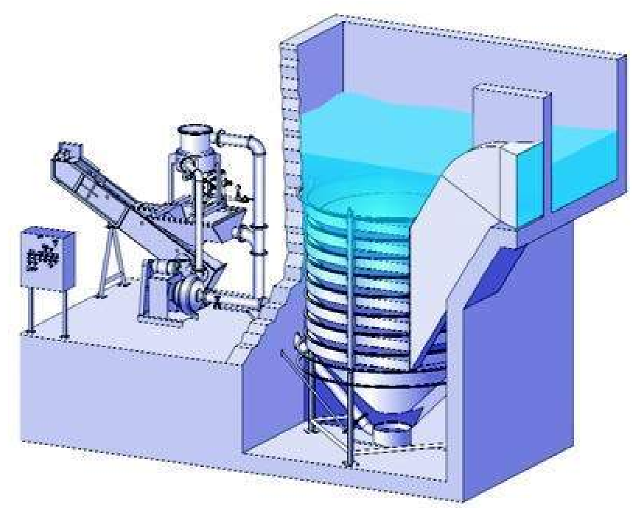
Conical Tray Vortex (Headcell) - Introduction



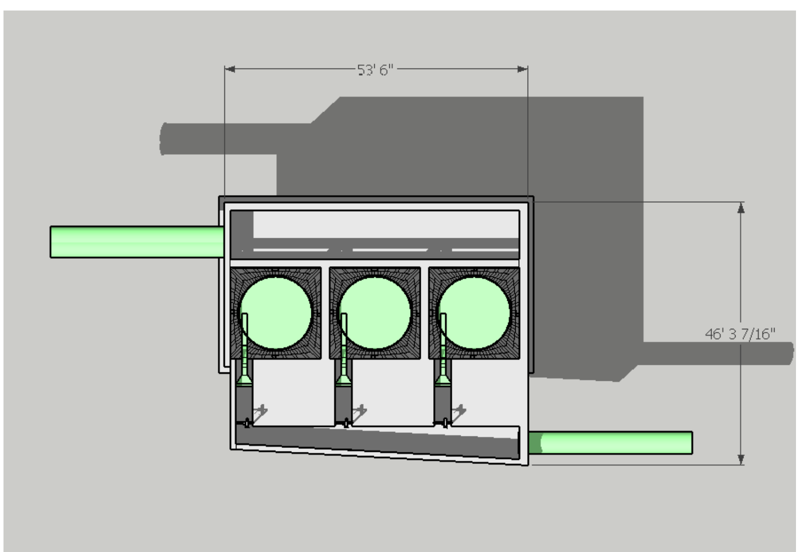
Headcell - Performance

Parameter	Value
Performance	- *95% removal of grit ≥ 75 micron*
Advantages	- Good performance - Small footprint - Low headloss (< 12") - Low maintenance (no moving parts)
Disadvantages	- 1/2" screens recommended upstream - Only one vendor, must sole source - Only 12 installations of similar size

Headcell – Design Criteria

Parameter	Value
No. of Units	3 to 4 duty
Unit Diameter	12 ft.
Trays/Unit	12
Peak Flow/Unit	*30 mgd*
Headloss at Peak Flow	12”

Headcell – Conceptual Layout (3 cell)



Grit Removal – Technology Comparison; 30 mgd

Criteria	Aerated	Vortex	Headcell
Meet Performance Criteria?	**No**	**No**	**Maybe**
Headloss	6"	< 4"	< 12"
Footprint	**5600 ft^2**	**3700 ft^2**	**2100 ft^2**
Screening Required?	Yes	Yes	Yes, $\leq$ 1/2-inch
O&M	High	Low	Low
Installations	Many	Many	140 total 12+ of similar size
Other concern	-	-	Sole Source

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GRIT - WASHING

Grit Pumping

- Flooded Suction Pumps
- Top Mounted, Self Priming Pumps
- Air Lift Pumps
- Vacuum Primed Pumps
- Screw Augers

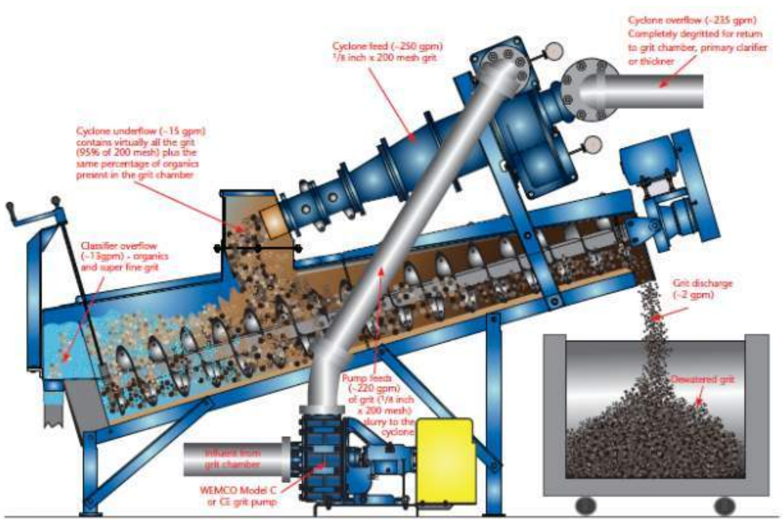
Grit Handling – Available Technologies

- Cyclone/Conventional Washer
- Pista Turbo Washer
- Slurry Cup/Grit Snail
- Cone Washer

Conventional Washer

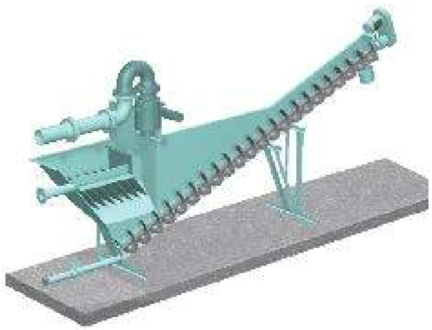
Source: Vulcan

Cyclone & Washer



Source: Wemco

Pista Turbo Washer



Smith & Loveless

Hydro Slurry Cup/Grit Snail

Source: Hydro

Hydro Slurry Cup

Source: Hydro

Hydro Grit Snail

Sourec: Hydro

Cone Washer

Source: Vulcan

Cone Washer

Source: Huber

Grit Handling – Technology Comparison

Parameter	Cyclone/ Conventional Washer	Pista Turbo Washer	Slurry Cup/Grit Snail	Cone Washer*
Removal	95% of ≥ 105 µm	95% of ≥ 105 µm	95% of ≥ 75 µm	95% of ≥ 200 µm
Volatile Solids Content (% by Weight)	≤ 25%	≤ 5%	≤ 15%	≤ 3%
Water Content (% by Weight)	≤ 50%	≤ 10%	≤ 40%	≤ 10%

*Huber just introduced washer capable of capturing < 100 µm (larger footprint)

Grit washing approach will be a balance of clean grit vs. high capture of fine grit

GRIT – SFPUC DEMONSTRATION

Scope of Demonstration

- Side by side comparison of
  - Smith & Loveless Vortex System (360º Pista)
  - Hydro International Conical Tray Vortex (Headcell)
- 6-7 mgd
- Using vendors washing equipment
- Independent testing of Huber Cone Washer

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SITE LAYOUT

SVCW

POTENTIAL FRONT OF PLANT IMPROVEMENTS

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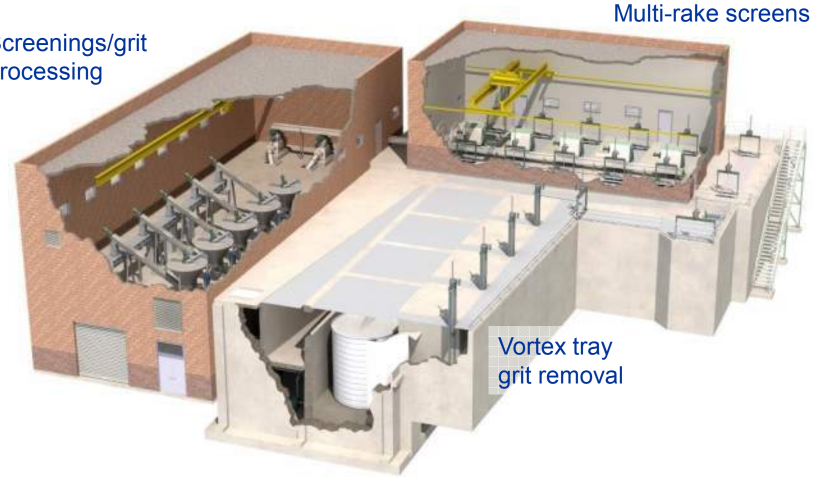
Potential Layouts (Being revised)



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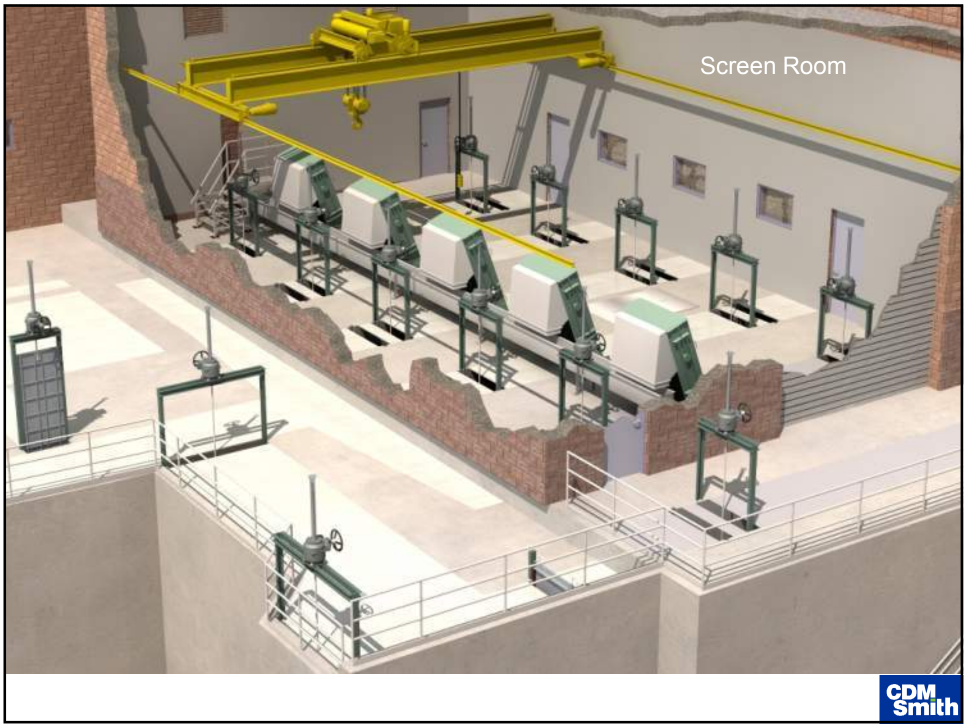
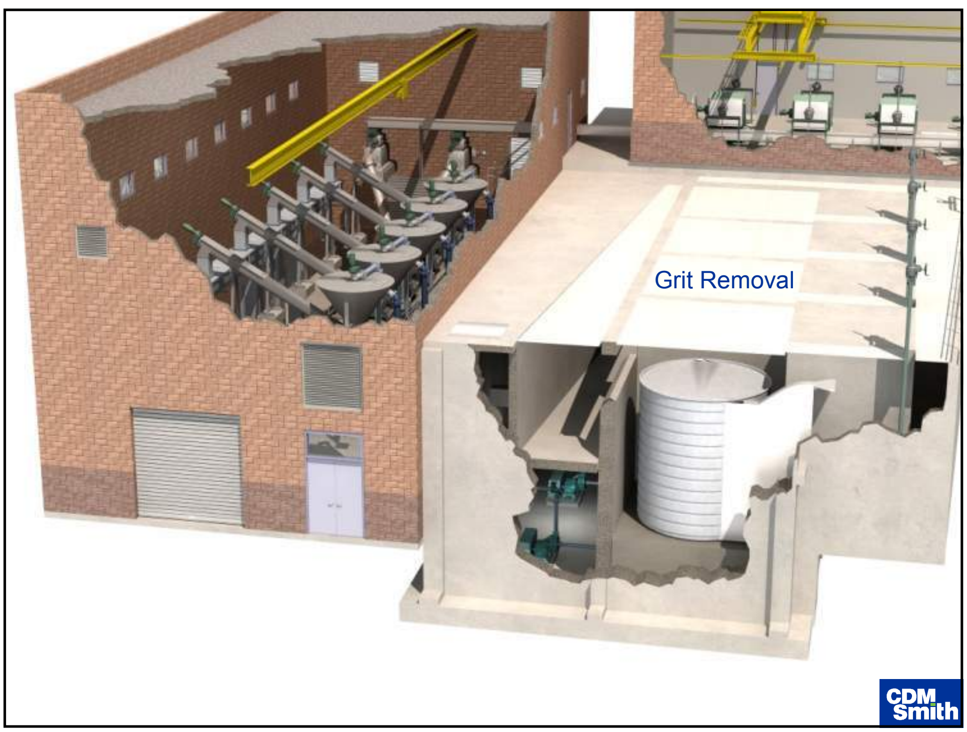

Screen Room
CDM Smith


Grit Removal
CDM Smith

CDM Smith

THANK YOU!

Questions?

Appendix E

Screen Facility Workshop Presentation

Headworks Technology Workshop

WWTP Headworks and Screening Facility (CIP # 9160)

December 1, 2015

Meeting Purpose

- Present draft design criteria that will be used to develop
  - Conceptual layout of headworks facility
  - Conceptual level cost estimate of headworks facility
- Identify data needs to complete conceptual layout/cost estimate

Agenda

- Purpose of Meeting
- Process Flow Diagram
- Design Criteria Development
  - Liquid
    - Headworks Design Flows
    - Screens & Screen Channels
    - Hydraulic Profile
  - Solids
    - Screenings Conveyance
    - Washer/Compactors
    - Screenings Hauling
- Current Screening Facility Startup
- Summary

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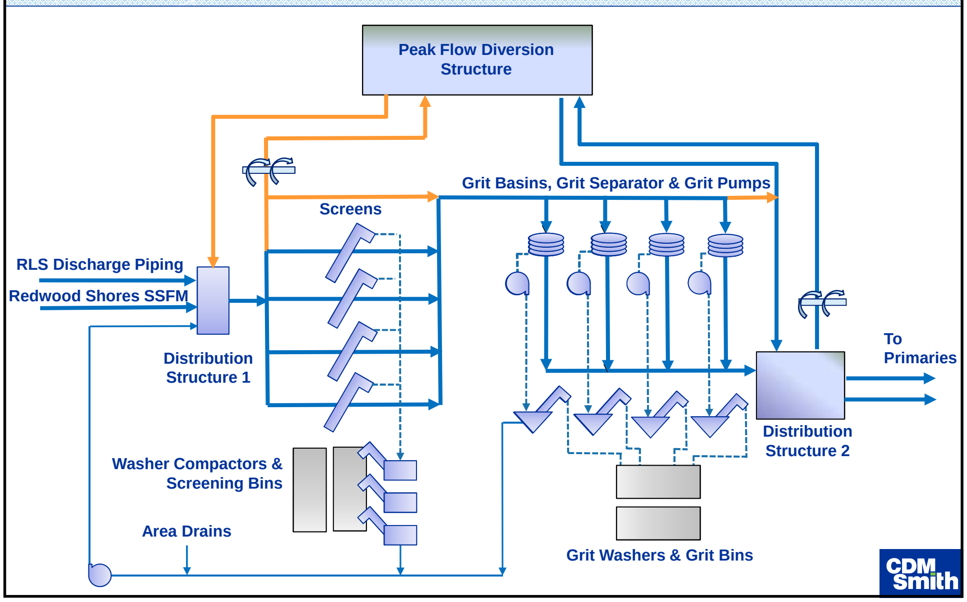
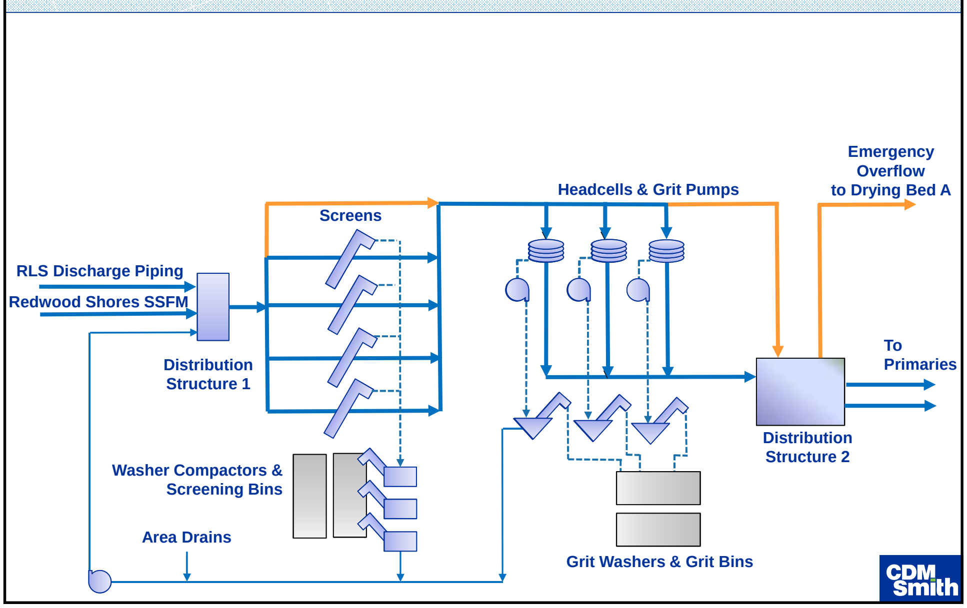
PROCESS FLOW DIAGRAM

Process Flow Diagram – PFDS/PFDB EQ



Process Flow Diagram – Tunnel EQ



DESIGN CRITERIA DEVELOPMENT

HEADWORKS DESIGN FLOWS

Headworks Design Flows

Assumes diurnal flows not always equalized in tunnel

Parameter	Units	Existing	2040 PFDS/ PFDB EQ	2040 Tunnel EQ
Min Dry Weather Flow (MDWF)	mgd	2.5	0	0
Average Dry Weather Flow (ADWF)	mgd	12.8	16	16
Peak Dry Weather Flow (PDWF)	mgd	23	28	28
Peak Wet Weather Flow (PWWF)	mgd	<80	107.9	80

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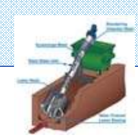
DESIGN CRITERIA DEVELOPMENT

SCREENS & SCREEN CHANNELS

Single Rake Bar

Continuous Element Bar

Inclined Cylindrical



Continuous Element Perforated

Multi-rake Bar

Center-flow Band

Stair

RECOMMENDED FOR FURTHER CONSIDERATION

Continuous Element Perforated

Multi-rake Bar

Continuous Element Bar

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Potential for 2nd Stage Screening

Continuous Element Perforated

Multi-rake Bar

Continuous Element Bar

RECOMMENDED FIRST STAGE SCREENING

Multi-rake Bar with 3/8-inch Openings

Duperon vs. Mahr-Style Bar Screens

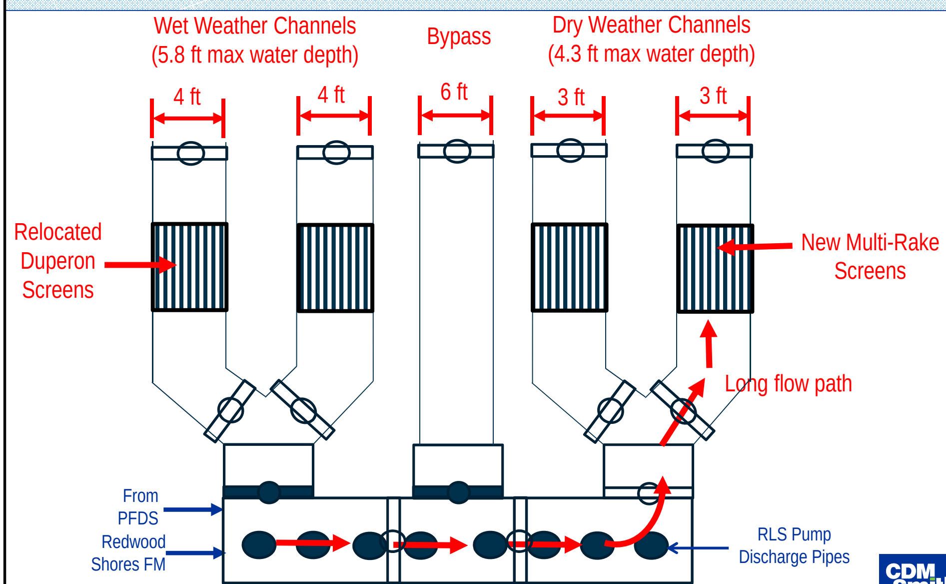
Parameter	Duperon	Mahr-Style
Bottom Sprocket	No	Yes
Rake Teeth	Partial Penetration	Full Penetration
Cost	15% less	15% more

Will assume Mahr-Style for Conceptual Layout/Cost Estimate to be Conservative

Screen Channels – Hydraulic Design Criteria

Parameter	Units	Value
Headloss through screens, max	ft	1
Velocity In Channel	ft/s	1 – 3
Velocity Through Screen Openings	ft/s	2 – 6

Screen Channels – Conceptual Layout



Screen Channels – Velocities

Flow Condition	No. of Channels in Service	Velocity in Channel (ft/s)
Existing Conditions		
MDWF (2.5 mgd)	2	0.4 ← Low
ADWF (12.8 mgd)	2	1.7
PWWF (80 mgd)	4	2.4
2040, PFDS/PFDB EQ		
MDWF (0 mgd)	2	0 ← Low
ADWF (16 mgd)	2	2.1
PWWF (107.9 mgd)	4	2.8
2040, Tunnel EQ		
MDWF (0 mgd)	2	0 ← Low
ADWF (16 mgd)	2	2.1
PWWF (80 mgd)	4	2.4

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Reusing Existing Duperon

- Width = 4 feet
  - Compatible with wet weather channels
- Screen Opening = 3/8 inch
  - Matches design criteria for new screens
- Configured for a slightly deeper channel
  - Screenings discharge chute will be higher & offset from new screens
  - Can still work
- Relocation phasing
  - Need to install new screens & bring them online before relocating Duperons

No fatal flow in reusing existing screen

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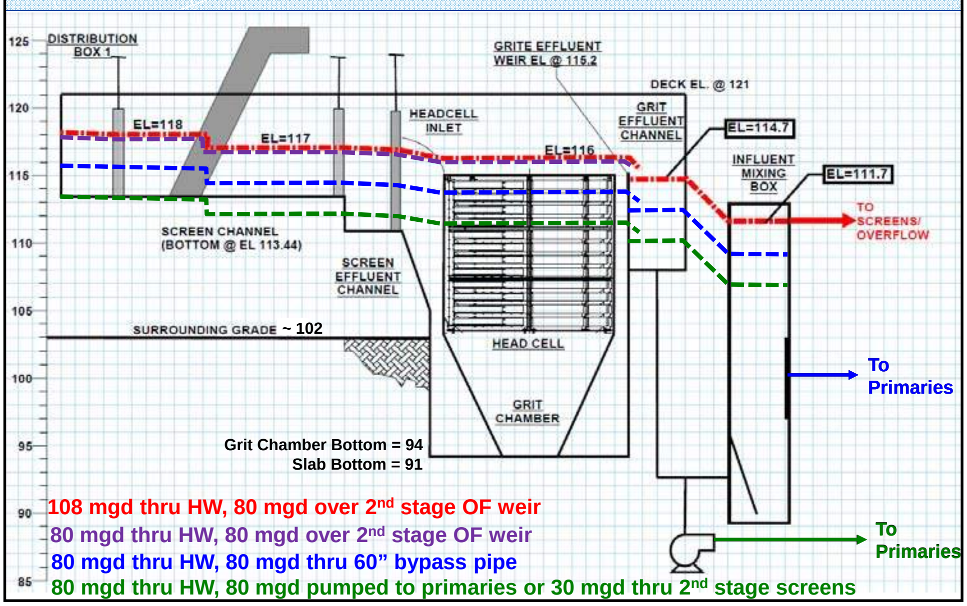
HYDRAULIC PROFILE

Hydraulic Profile



DESIGN CRITERIA DEVELOPMENT

SCREENINGS CONVEYANCE

Screenings Conveyance – Technology Options

- Sluicing
- Screws
- Belts

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Sluicing

- Sloped trough
- Water sprayed into trough
- Water can help in cleaning washing screenings
- Possible layouts
  - 1 sluice per screen
  - 1 sluice for multiple screens
  - 1 sluice split to multiple WCs
- Large loads/objects can overload sluice
- Not compatible with batch mode washer compactors

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Screws – Shafted

- Inclines can cause excessive torque on main bearing and bolt
- Separate screws required for changes in direction (horizontal vs vertical)
- Debris can tangle on shaft
- Abrasive screenings can wear out liner
- Requires center support bearing for long lengths

CDM Smith

Screws – Shaftless

- Should be flat
- Lengths up to 150 feet
- Horizontal or vertical configuration possible
- Abrasive screenings can wear out liner

CDM Smith

Conveyors

Serpentix

Flat Belt

CDM Smith

Screenings Conveyance – Pros & Cons Table

Decision Not Needed to Complete Conceptual Layout/Cost

Method	Pros	Cons
Sluicing	• Prewashes screenings • Few moving parts - Most reliable • Can put in rock trap and magnets • Very long runs possible • Inexpensive	• Uses water
Shafted Screws	• Easy to enclose • Positive movement • Accommodate some rise • No water needed – adds to WC capacity	• Limited to runs less than 30 ft. +/- • earings in trough catch debris
Shaftless Screws	• Easy to enclose • Positive movement • No water needed – adds to WC capacity • Screws segmented to facilitate removal	• Must be nearly flat
Belts	• High capacity • No water needed – adds to WC capacity • Simple to repair • Very long runs possible • Inexpensive	• Messy • Hard to contain debris and odors • Flow splitting messy

DESIGN CRITERIA DEVELOPMENT

WASHER/COMPACTORS

Washer/Compactors – Technology Options

Decision Not Needed to Complete Conceptual Layout/Cost

- Batch Mode
  - Lower Capacity (42 ft^3/hr)
  - Higher COD Reduction
  - Not compatible with sluices
- Flow Through Mode
  - Higher Capacity (420 ft^3/hr)
  - Lower COD Reduction
  - Compatible with sluices

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Grinder

Decision Not Needed to Complete Conceptual Layout/Cost

- Used at facilities with high peak loads (CSO systems)
- Protect washer compactor from metal, rocks, etc.
- Reduces washer compactor wear
- Increases throughput and compacted screenings quality
- “Standard” package offered by JWC and John Meunier
- Requires space in solids profile (could add later)
- Needs backup or standby – very high maintenance

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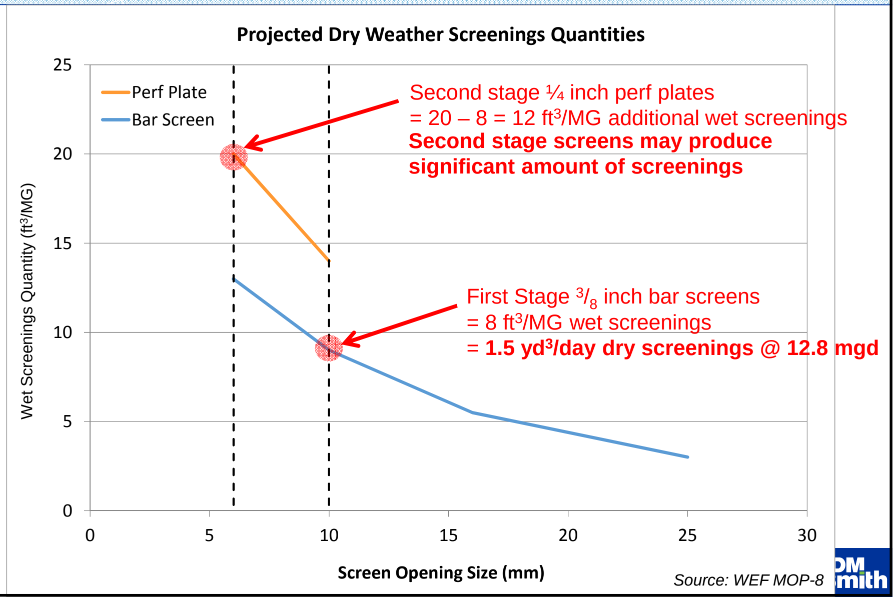
Screenings Quantity vs. Screen Type & Opening Size



Washer/Compactors – Design Criteria

Parameter	Units	Value
Number of Units	-	2 duty, 1 standby
Wet Screenings		
Volume, avg day[1]	yd^3/day	5
Mass, avg day[2]	ton/day	3
Dry Screenings		
Volume Reduction	%	60
Weight Reduction	%	50
COD Reduction	%	N/A
Volume, avg day	yd^3/day	2
Mass, avg day	ton/day	1.4

2 duty needed to operate in batch mode

Not necessary now, but could be in future

[1]Based on 2040 ADWF of 16 mgd x 8 ft^3/MG of wet screenings
[2]Based on a density of 45 lbs/ft^3

DESIGN CRITERIA DEVELOPMENT

SCREENINGS HAULING

Design Criteria – Screenings Hauling

Parameter	Units	Value
Volume, avg day	yd^3/day	2
Mass, avg day	tons/day	1.4
Dumpster Capacity (volume)	yd^3	10
Dumpster Capacity (weight)	tons	8
Time to Fill (volume), Avg	days	5
Time to Fill (weight), Avg	days	6

Assume two 10 yd3 dumpsters (1 duty, 1 standby) for conceptual layout/cost

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CURRENT SCREENING FACILITY STARTUP

Current Screening Facility Startup – Observations

- Grease building up in channel
- Low velocities in channel
- 1 yd^3 compacted screenings per day
- No odors being observed
- Other?

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WRAP-UP

Summary

- Recommended Design Criteria for Conceptual Layout/Costs
  - Two 3-ft wide $^{3}/_{8}$ inch multi-rake screens
  - Two 4-ft wide relocated $^{3}/_{8}$ inch Duperon screens
  - One 6-ft wide bypass channel
  - Sluices, screws, or conveyors for screenings conveyance
  - Three washer compactors (flow-through or batch mode)
  - Two 10 yd^3 dumpsters
  - Mix Box HWL = 111.7 ft

Summary

- Data Needed to Confirm Conceptual Layout/Costs
  – Decision on tunnel equalization
  – Minimum RLS pumping rate
  – Duration of time RLS pumps are off
  – Minimum hour flow rate from Redwood Shores Pump Station
  – Screenings production at current screening facility
  – Input on Influent Mix Box HWL

Meeting Minutes

To: *Bill Bryan, SVCW*

From: *Bill Schilling, CDM Smith*

Date: *January 4, 2016*

Subject: *SVCW Headworks Facility Project - Screening Workshop (Held on December 1, 2015)*

Attendees: *Kim Hackett, Bill Bryan, Monte Hamamoto, Mick Daly, Eric Gable, Nathan Murphy, James Lostica, Cisco Guzman, Rosendo Gallegos, John San Filippo, Bob Huffstutler, Keith McClure (SVCW)*
Jan Davel, Ed Fernbach, Dane Whitmer, Bill Schilling (CDM Smith)

Meeting Objectives

The objectives of this workshop were as follows:

- Present draft design criteria that will be used to develop
  - Conceptual layout of headworks facility
  - Conceptual level cost estimate of headworks facility
- Identify data needs to complete conceptual layout/cost estimate

The discussion that occurred during the workshop is summarized below.

Headworks Flow Schematics

CDM Smith presented two process flow diagrams for the new headworks facility. One process flow diagram included the Peak Flow Diversion Structure (PFDS)/Peak Flow Diversion Basin (PFDB). The second process flow diagram did not include the PFDS/PFDB and was based on the assumption that diurnal and wet weather flows would be equalized in the tunnel. The group discussed the process flow diagrams. The following is a summary of the discussion:

- The flow schematics showed how influent flow from the Receiving Lift Station (RLS) is moved through 4 screens (and 1 bypass channel) and 3 to 4 headcells for degritting prior to being sent to the existing primaries/future 2nd stage screening facility.
- The schematics included solids from screens being processed by 3 washer compactors for placement into one of two bins.

- The grit from the headcells is sent to 3 to 4 grit washers and then disposed of in 1 of 2 bins.
- Overflow from the screenings washer/compactors and grit washers is shown draining to a plant drain pump station. The pump station pumps the flows back to the headworks influent diversion structure. All plant drains in the area of the new headworks were shown to be draining to the plant drain pump station.
  - SVCW staff asked if the drains within the Headworks are floor or trench type drains. CDM Smith said probably floor drains.
  - CDM Smith expects flows from washer compactors, floor drains, grit washers, etc to be ~1 mgd.
  - Keith asked if it is possible to send drains to the RLS. The group decided that this would not be an ideal setup for the following reasons:
    - Having a long drop from drains to RLS wet well water surface could impact odor generation.
    - Don't want to go through shaft wall.
    - Isolation is concern if needing to access RLS wet well and having return flows from HW dropping into well.
    - Could be problematic due to electrical classification issues.
  - SVCW staff asked if they needed separate bins for screenings and grit, or if screenings and grit could be collected in the same bin.
    - Bill Bryan said that grit is really dense, so if the grit was put into the screenings bin it would affect the amount of screenings that could be put in the bin.
    - CDM Smith said that based on the projected amount of screenings/grit that will be produced, multiple bins would be needed anyway.
    - CDM Smith said that it is possible to combine screenings/grit and the idea could be further pursued in preliminary design.

Design Flows

CDM Smith presented design flows for existing conditions, the scenario where flows are equalized in the PFDS/PFDB, and the scenario where flows are stored in the tunnel. CDM Smith explained that even if the PFDS/PFDB is not built and flows are stored in the tunnel, the Headworks facility should be designed to give the plant the flexibility to not do diurnal storage in the tunnel.

Screens and Screen Channels

- CDM Smith discussed the types of screens that were considered for the project and presented the recommended screen type, which is 3/8-inch Multi-Rake Bar screens.

- CDM Smith discussed the general differences between the Duperon and Mahr style screens. CDM Smith recommended assuming Mahr-style screens for the conceptual layout and cost estimate to be conservative. The group briefly discussed the pros and cons of Duperon vs. Mahr style screens.

- CDM Smith asked why Duperon screens were used in the current headworks facility.

  - SVCW said the decision to use Duperon screens was based mostly on cost but that not having a bottom sprocket was an attractive feature.

  - SVCW staff asked if going with a Mahr-style screen that could tilt out of the channel was an option. CDM Smith said, yes, that is an option.

- CDM Smith presented the conceptual layout of the screen channels and the screen channel velocities. SVCW staff had the following comments on the screen channel layout:

  - SVCW staff asked what the depth of the bypass channel was. CDM Smith said that it was the same depth as the wet weather screen channels.

  - SVCW staff asked if a 6-foot wide bypass channel was adequate. CDM Smith said the bypass channel dimension was based on a velocity of 5 ft/s. SVCW staff said there may be significant headloss in the channel at that velocity.

  - Bill Bryan commented that the conceptual layout had a lot of gates and that the number of gates should be minimized to minimize O&M activities.

  - Bill Bryan asked how many channels would be online during peak flows and dry weather flows. CDM Smith explained that two channels would be online during dry weather flows and four channels would be online during wet weather flows.

  - Bill Bryan explained that CDM Smith was asked to look into the viability of re-using the existing Duperon screens, but that the screens didn't necessarily have to be re-used.

Hydraulic Profile

CDM Smith presented a conceptual hydraulic profile for the Headworks Facility. Four scenarios were presented which effect the HGL:

- 108 mgd flows through the new Headworks and over the overflow weir in the 2nd stage screen channels

- 80 mgd flows through the new Headworks and over the overflow weir in the 2nd stage screen channels

- 80 mgd flows through the new headworks and through the 60-inch bypass pipe around the 2nd stage screens

- 80 mgd goes through the new headworks and the influent lift station is used to bypass flow around the 2nd stage screens, limiting the water surface elevation in the grit effluent channel to the elevation associated with 30 mgd flowing through the new screens.

The following comments were made on the hydraulic profile:

- Bill Bryan pointed out to the O&M staff that reducing the height of the headworks facility could result in a significant cost savings associated with construction of the new facility.

- It was discussed that using the 60-inch pipe or ILS to bypass the 2nd stage screens was a more complex control mechanism than relying on the overflow weir in the 2nd stage screen channels, but that those modes of operation would result in a lower headworks.

- CDM Smith said that for the conceptual layout/cost estimate, they were assuming the worst case scenario, which is using the overflow weir in the 2nd stage screen channels.

Screenings Conveyance

CDM Smith presented several technologies for conveying screenings from the screens to the washer/compactors including sluices, shafted screws, shaftless screws, and conveyors. The following comments were made:

- SVCW said they have a desire to have as few moving parts as possible and least maintenance stated. Sluicing seems to be most attractive to them at this time over conveyors and screws.

- CDM Smith said they were assuming sluices for the conceptual layout/cost estimate.

Washer Compactors

CDM Smith discussed technology options and conceptual design criteria for washer/compactors for processing screenings. The following items were discussed during this portion of the workshop:

- CDM Smith discussed flow-through washer compactors and batch mode washer compactors. CDM Smith pointed out that the batch mode washer compactors get the screenings much cleaner, but they have a lower capacity and may not be compatible with sluices.

- CDM Smith said that they production of screenings at the new headworks facility would be about 1 – 1.5 cubic yards per day, similar to what is currently being produced at the existing screening facility.

- CDM Smith said that if 3/8-inch screens are put in at the new facility and ¼-inch screens are put in at the 2nd stage facility, the second stage facility will still produce a significant amount of screenings.

- CDM Smith presented the option for putting grinders upstream of the washer compactors.

- Monte said that grinders did not appear to be needed since we don't have a high leaf load and a few maintenance personnel voiced not wanting them when heard they are high maintenance equipment.
- CDM Smith said they were assuming 2 duty/1 standby washer compactors for the conceptual layout/cost estimate. This setup accommodates the use of batch mode or flow through washer compactors.

Screenings Loading

CDM Smith discussed conceptual design criteria for screenings bins. The following items were discussed during this portion of the workshop:

- CDM Smith said they project that the screenings dumpster will be filled once every 5 days.
- CDM Smith said that for the conceptual layout/cost estimate they will assumed 1 duty/1 standby screenings bin. With this setup, the standby bin can be used while the duty bin is being changed out.

Existing Screening Facility Startup

CDM Smith asked what SVCW was experiencing at the current headworks facility and what they would like to see done differently in this project:

- SVCW staff said there is a mud valve in the middle of the flow stream and the riser is nothing more than a "rag catcher". Incorporate into design that minimizes "rag catcher" behavior.
- SVCW staff suggested having a drain valve at the bottom of the channel that was accessible from the outside of the channel.
  - SVCW expressed some concern that the short section of pipe between the bottom of channel and the valve would get plugged with solids.
  - CDM Smith said that that section of pipe could be flushed out with water or air periodically to keep it from plugging up.
- SVCW staff believes that grease is building up in the screen channels because the way the channels are laid out grease at the top of the water surface stays in the channel and can't be flushed downstream.
- SVCW staff said that the designer should pay close attention to not have dead water spots, e.g., use rounded corners.
- SVCW staff suggested investigating to see if sprayers are needed in the channels.

Sketchup Model Development

CDM Smith showed images of the latest sketchup model. There were no comments on the images shared.

Wrap-up

CDM Smith said that the items they need to confirm the conceptual layout/cost estimate include:

- Decision on tunnel equalization
- Minimum RLS pumping rate
- Duration of time RLS pumps are off
- Minimum hour flow rate from Redwood Shores Pump Station

Action Items

- SVCW: Provide direction on whether or not tunnel will be used for wet weather and/or diurnal flow storage
- SVCW: Confirm minimum RLS pumping rate and duration of minimum pumping rate
- SVCW: Confirm minimum hour pumping rate from Redwood Shores Pump Station

cc: Meeting attendees.

Michael Zafer (CDM Smith)

Appendix F

Grit Facility Workshop Presentation

Headworks Technology Workshop

WWTP Headworks and Screening Facility (CIP # 9160)

SVCW
Silicon Valley Clean Water

CDM Smith

December 17, 2015

Meeting Purpose

- **Present draft design criteria that will be used to develop**
  - Conceptual layout of headworks facility
  - Conceptual level cost estimate of headworks facility
- **Identify data needs to complete conceptual layout/cost estimate**

CDM Smith

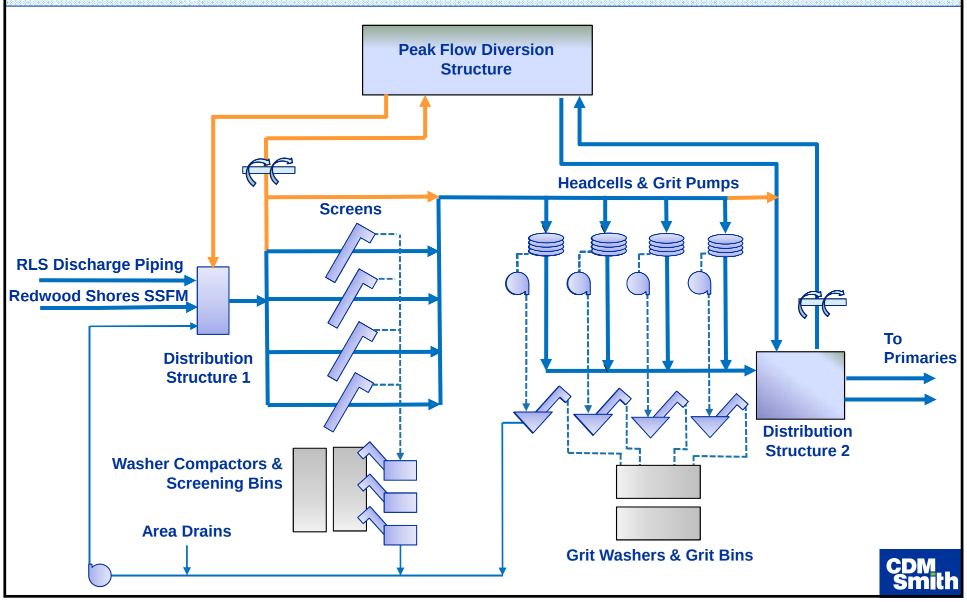
Agenda

- **Purpose of Meeting**
- **Process Flow Diagram**
- **Design Criteria Development**
  - Influent Flows/Grit Loads
  - Grit Separators
  - Grit Washers/Classifiers
  - Grit Loading
- **Procurement Issues**
- **Grit Characterization**
- **Albuquerque Site Visit**
- **Summary/Wrap-Up**

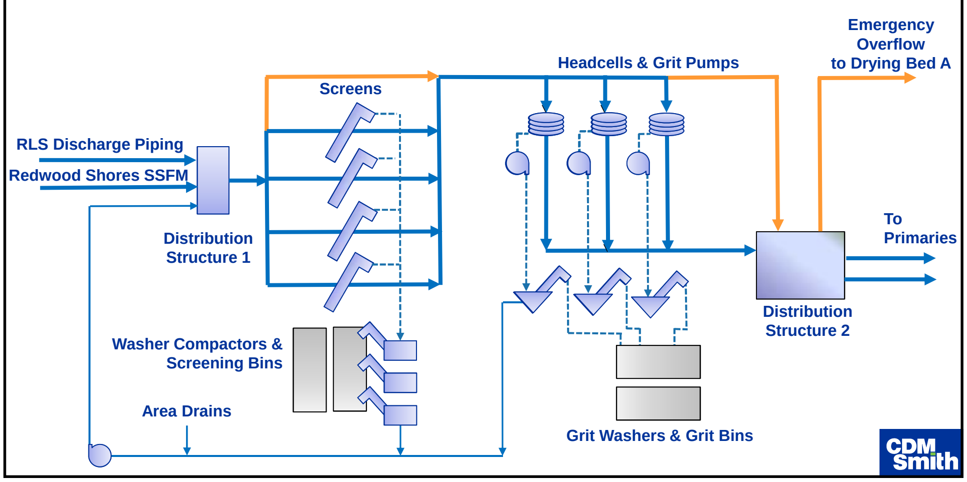
CDM Smith

PROCESS FLOW DIAGRAM

Process Flow Diagram – PFDS/PFDB EQ



Process Flow Diagram – Tunnel EQ



DESIGN CRITERIA DEVELOPMENT

Influent Flows and Loads

Headworks Design Flows

Assumes diurnal flows not always equalized in tunnel ↓

Parameter	Units	Existing	2040 PFDS/ PFDB EQ	2040 Tunnel EQ
Min Dry Weather Flow (MDWF)	mgd	2.5	0	0
Average Dry Weather Flow (ADWF)	mgd	12.8	16	16
Peak Dry Weather Flow (PDWF)	mgd	23	28	28
Peak Wet Weather Flow (PWWF)	mgd	<80	107.9	80

CDM Smith

Influent Grit Characteristics

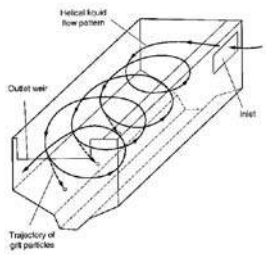
Parameter	Units	Value
Grit Concentration, average	ft3/MG	3
Grit Specific Gravity	-	
Raw Grit	-	1.4 – 1.8
Washed Grit	-	2.0 – 2.65
Raw Grit Load, average		
Volume	yd3/d	2
Mass	tons/d	3
Washed Grit Load, average		
Volume	yd3/d	2
Mass	tons/d	4

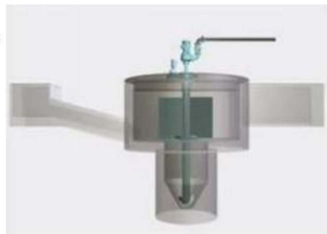
DESIGN CRITERIA DEVELOPMENT

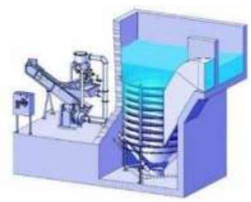
Grit Separation

Grit Separation – Technology Options

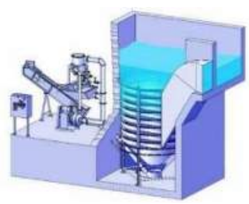
All Options







Recommended For Further Consideration



CDM Smith

Grit Separation – Technology Options

Criteria	Aerated	Vortex	Headcell
Headloss	< 12"	< 12"	< 12"
Footprint	Largest	Middle	Smallest
Screening Required?	Yes	Yes	Yes
O&M	Medium	Low	Low
Installations	Many	Many	140 total 12+ of similar size
Other concern	Odor Control Required	Long Approach Channels	Sole Source

Conceptual layout/cost estimate will be based on Headcell grit separators

CDM Smith

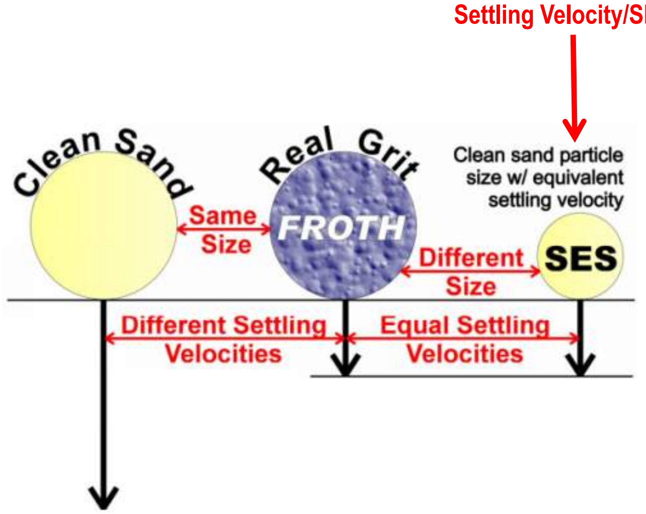
Headcell Sizing Procedure

- **Characterize influent grit**
  - There will be a distribution of settling rates/sand equivalent size (SES)
- **Select cut point (slowest settling particle that will be captured)**
  - Evaluate various cut points based on:
    - Percent of total grit captured
    - Number of Headcells required
  - Final cut point selection based on:
    - Maximizing grit removal
    - Minimizing capital cost of constructing grit basins
- **Size Headcells based on selected cut point**

CDM Smith

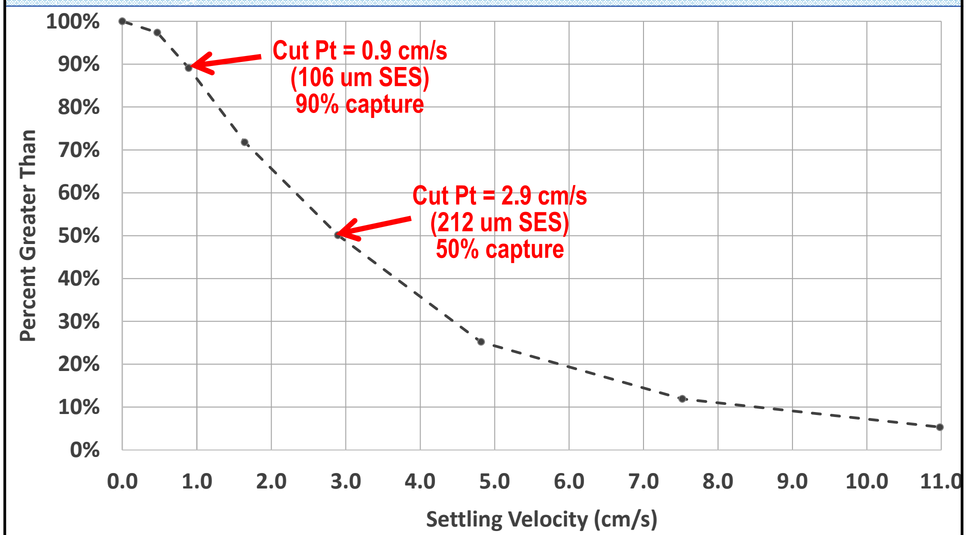
Grit Characterization – Physical Size, Settling Rate, Sand Equivalent Size

Headcell Sizing based on Settling Velocity/SES



CDM Smith

Cut Point Selection – Typical Domestic Wastewater



CDM Smith

Headcell Performance

Based on 12' dia/12 tray Headcell

Settling Velocity Cut Point	SES	Max Flow to Headcell
0.5 cm/s	75 um	15 mgd
0.9 cm/s	106 um	23 mgd
1.6 cm/s	150 um	36 mgd
2.9 cm/s	212 um	46 mgd

CDM Smith

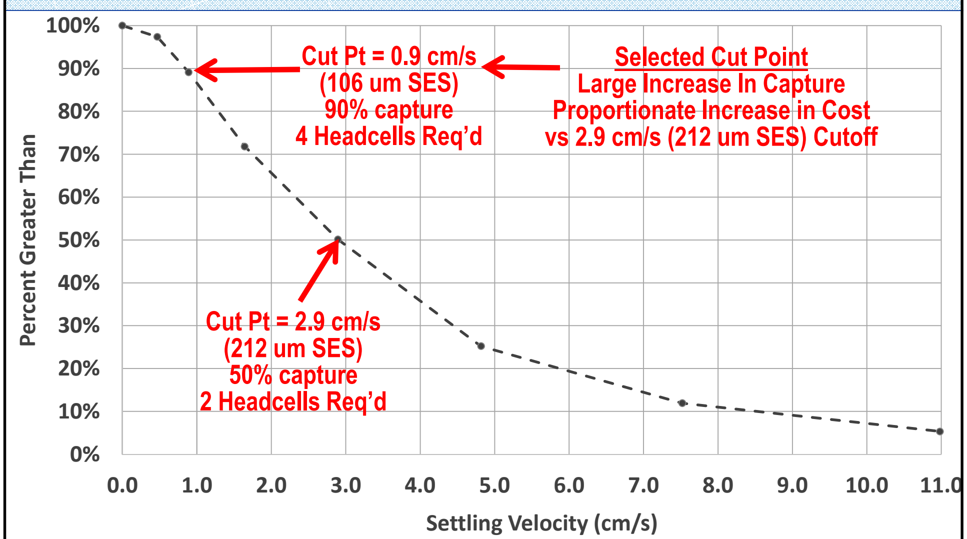
No. of Headcells Required at Various Flows & Cut Points

Settling Velocity Cut Point	SES	Max Flow to Hedcell	No. of Headcells Required		
			ADWF = 16 mgd	PWWF = 80 mgd	PWWF = 108 mgd
0.5 cm/s	75 um	15 mgd	1	6	8
0.9 cm/s	106 um	23 mgd	1	4	5
1.6 cm/s	150 um	36 mgd	1	3	3
2.9 cm/s	212 um	46 mgd	1	2	3

Wet Weather Flow Determines Total Number of Units

CDM Smith

Cut Point Selection @ 80 mgd



CDM Smith

Other Information Supporting Recommended Cut Point

- **0.9 cm/s (106 μm SES) cut point common of recent US projects**
- **0.9 cm/s (106 μm SES) cut point is conservative:**
  - Europe: 2.9 cm/s (212 μm SES) cut point typical
  - US Historical: 65% of 1.6 cm/s (150 μm SES)
- **Grit washing technology can't retain < 0.9 cm/s (106 μm clean sand)**
  - HIL Slurry/Teacup-Grit Snail claims capture down to 0.5 cm/s, 75μm
  - Complicated technology, not recommended
  - Cut point of washing technology doesn't have to be as low as grit separator
- **Grit < 0.9 cm/s (106 μm SES) doesn't affect downstream processes?**
  - Accumulation in downstream processes depends on degree of mixing
  - Equipment abrasion depends on particle shape (e.g. angular vs. smooth)
  - Recommend comparing physical size of wet & dry sieve particles

CDM Smith

Grit Separation – Conceptual Design Criteria

Parameter	Units	Value
Type	-	Headcells
Cut Point, at ADWF	-	0.9 cm/s (106 um SES)
Cut Point, at PWWF	-	0.9 cm/s (106 um SES)
Number	-	4
Tray diameter	ft	12
Number of Trays	-	12
No. of Grit Pumps	-	1 per basin
Grit Pump Flowrate	gpm	400

Design Criteria Will be Updated After Additional Grit Characterization is Performed

CDM Smith

DESIGN CRITERIA DEVELOPMENT

GRIT WASHING

Grit Washers – Technology Options

No decision needed to complete conceptual layout/cost estimate

Parameter	Cyclone/ Conventional Washer	Cone Washer	Slurry Cup/ Grit Snail
Removal	95% of ≥ 105 µm	95% of ≥ 100 µm	95% of ≥ 75 µm
Volatile Solids Content (% by Weight)	≤ 25%	≤ 3%	≤ 15%
Water Content (% by Weight)	≤ 50%	≤ 10%	≤ 40%

Very Clean & Dry Grit

Captures Fine Grit

CDM Smith

Grit Washers – Design Criteria

Parameter	Units	Value
Type	-	Cone Washer
Number	-	1 per grit basin
Flow	gpm	400
Grit	lbs/hr	900
Removal	-	95% of all grit > 100 micron
Effluent Water Content, max	%	40
Effluent VS, max	%	15

Cone washer will be assumed for conceptual layout/cost estimate

CDM Smith

DESIGN CRITERIA DEVELOPMENT

GRIT LOADING

Conceptual Design Criteria – Grit Bins

Parameter	Units	Value
Number	-	1 duty, 1 standby
Capacity		
Volume	yd^3	10
Weight	tons	8
Washed Grit Load, average		
Volume	yd^3/d	2
Mass	tons/d	4
Time to Fill Dumpster		
Volume Basis, avg	days	5
Weight Basis, avg	days	2

Assume two 10 yd3 dumpsters (1 duty, 1 standby) for conceptual layout/cost

CDM Smith

PROCUREMENT ISSUES

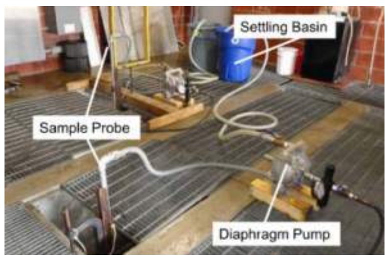
Procurement Issues

- **Sole Sourcing**
  - Get costs from HIL during design for Headcell
  - Have line item on bid form for Headcell cost
- **Performance Testing**
  - Not always required
  - Requires performing grit characterization of:
    - Influent to primary grit removal
    - Effluent from primary grit removal
    - Influent to grit washing/dewatering unit
    - Overflow from grit washing/dewatering unit

GRIT CHARACTERIZATION

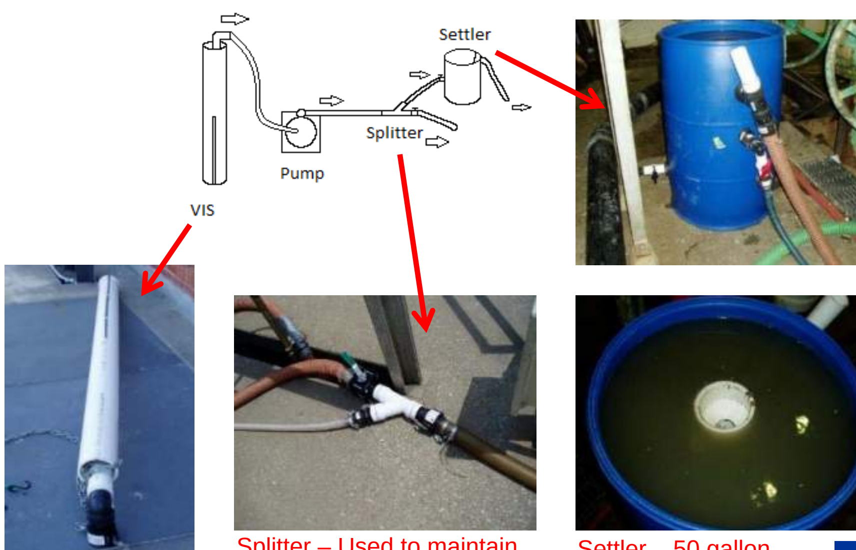
Grit Characterization Needs

- **Additional Grit Characterization Data Recommended Because**
  - Currently do not have any settling velocity data for SVCW influent
  - Currently do not have any wet weather data from the SVCW influent
- **Recommend having Black Dog Analytical perform characterization**



Full depth sampler

Sampling Equipment



Full depth sampler

Splitter – Used to maintain overflow rate in settler

Settler – 50 gallon

Sample Collection

- Collect sample for ~ 6 hour period
- Maintain overflow rate of 3 gpm/ft2 in settler (captures $\leq$ 50 um grit)
- Let sample settle for 20 min
- Decant supernatant
- Rinse sample
- Analyze sample immediately or store at 4 ^{O}C for 12 hours
- Record influent flow during sample collection

Analytical Procedure

- Take portion of homogenized sample
- Sieve wet sample through series of sieves
- Perform settling test on fraction from each sieve
- Dry to determine fixed solids weight for each sieve category
- Generates following data
  - Physical size distribution based on wet sieving
  - Settling Velocity/SES distribution
  - Total grit load per MGD based on dried grit mass

Imhoff Cone Used for Settling tests

Sampling Schedule

- **Goal: Collect one wet weather and one dry weather sample**
- **Initial sampling event**
  - Schedule Black Dog for initial sampling
  - Depending on weather, Black Dog collects dry or wet weather sample
- **Subsequent sampling events**
  - If first sample is wet weather event, could schedule Black Dog for dry weather sampling
  - Otherwise CDM Smith/SVCW could collect additional samples
    - Black Dog trains CDM Smith/SVCW on sampling/analytical methods
    - CDM Smith/SVCW collects additional samples
    - CDM Smith/SVCW performs all analyses or ships to Black Dog
- **Cost = $25,000 - $35,000 per sample + training**

CDM Smith

ALBUQUERQUE SITE VISIT

First Stage Grit Removal

CDM Smith

Screening Facility

Smith

Screening Facility

CDM Smith

Grit Separators

CDM Smith

Grit Pumps

CDM Smith

Grit Washers

CDM Smith

Washer/Compactors

CDM Smith

Grit/Screenings Bin

CDM Smith

Grit/Screenings Bin

CDM Smith

SUMMARY/WRAP UP

Recommended Design Criteria for Conceptual Layout

- Cut Point = 0.9 cm/s, 100 µm cut point
- Four 12 tray/12 foot diameter Headcell Units
- 1 Huber (or equal) cone washer per Headcell
- Two 10 yd^3 dumpsters
- Perform additional grit characterization

CDM Smith

Data Needs for Conceptual Layout

- Additional Grit Characterization Data

CDM Smith

Meeting Minutes

To:	*Bill Bryan, SVCW*
From:	*Bill Schilling, CDM Smith*
Date:	*February 8, 2016*
Subject:	*SVCW Headworks Facility Project – Grit Workshop (Held on December 17, 2015)*
Attendees:	*Kim Hackett, Bill Bryan, Mick Daly, Eric Gable, Cisco Guzman, Rosendo Gallegos, John San Filippo, Kip Edgerly, Jim Lechuva (SVCW)* *Bill Tanner (Covello)* *Jan Davel, Ed Fernbach, Joel Rife, Bill Schilling (CDM Smith)*

Meeting Objectives

The objectives of this workshop were as follows:

- Present draft design criteria that will be used to develop
  - Conceptual layout of headworks facility
  - Conceptual level cost estimate of headworks facility
- Identify data needs to complete conceptual layout/cost estimate

The discussion that occurred during the workshop is summarized below.

Headworks Flow Schematics

CDM Smith presented two process flow diagrams for the new headworks facility. One process flow diagram included the Peak Flow Diversion Structure (PFDS)/Peak Flow Diversion Basin (PFDB). The second process flow diagram did not include the PFDS/PFDB and was based on the assumption that diurnal and wet weather flows would be equalized in the tunnel. The group discussed the process flow diagrams. The following is a summary of the discussion:

- Bill Bryan asked how much plant water would be needed for the headworks facility. Based on the last workshop he understood the plant water demand to be 1 mgd.
- SVCW O&M staff said that the 3 water system doesn't have 1 mgd of available capacity.
- Ed said that the plant water demand would not be 1 mgd. 1 mgd is the approximate amount of overflow coming from the washer/compactors and grit washers.
- Joel said if the 3 water system didn't have enough capacity the plant effluent or possibly primary effluent could be used.

Design Flows

CDM Smith presented design flows for the headworks facility and the design grit concentrations, loads, and specific gravity. There were no comments on this design criteria.

Grit Technology Options

- CDM Smith presented the various technologies considered for grit removal including aerated grit, vortex grit, and conical tray vortex separators (commonly referred to as HeadCell®, the brand name of the conical tray vortex separator manufactured by Hydro International).
- CDM Smith recommended HeadCells® as the preferred grit removal technology on the basis that it has the smallest footprint, performs the best, and has a low O&M cost relative to the other options.
- Bill Bryan asked if Hydro International was the only manufacturer of conical tray vortex separators. Joel said there is one other manufacturer that has made an attempt at manufacturing something similar to the Hydro International HeadCell® unit. Bill Bryan said that SVCW would rather sole source Hydro International versus buying the prototype from another manufacturer.

HeadCell® Sizing/Cutpoint Selection

- Joel discussed the procedure for sizing a HeadCell® unit and selecting a cutpoint. He explained that the cutpoint is selected based on the settling velocity characteristics of the grit entering the plant.
- Joel discussed the concept of sand equivalent size (SES).
- Joel presented settling velocity data for typical municipal wastewater. Based on the typical characteristics, the recommended cutpoint is 100 um and the number of 12-tray, 12-foot diameter HeadCell® units needed at SVCW would be 4.
- Joel presented other information supporting the selection of a 100 um cutpoint including the fact that most European installations are designed for a 200 um cutpoint, that most grit washing equipment can't capture grit smaller than 100 um, and that there is some data that suggests grit smaller than 100 um may not have a significant effect on downstream processes.
- Bill Bryan asked to share any documentation that correlated equipment wear to grit particle size and supported the idea that grit smaller than 100 um did not have a significant effect on equipment.
- Ed said that some particles less than 100 um could damage equipment and that damage to equipment was more related to the shape of the grit. Grit particles that have an angular shape have a greater potential to damage equipment. For example Actiflo sand is 50 – 60 um and is very abrasive.
- Joel said that the grit characteristics would change after the tunnel was installed. SVCW O&M staff asked how the grit would change. Joel explained that the loading patterns of

the grit would change, but the settling velocity characteristics probably would not change. Joel said there may be some impact to the settling velocity data if grease accumulates in the tunnel, as a result of using the tunnel for equalization, and the grit particles become coated in grease.

- Joel presented the recommended design criteria for the conceptual design of the grit facility.

Grit Washers

- Bill presented the technologies considered for grit washing and discussed the pros and cons of each option.

- Bill said that a technology did not need to be picked at this point and that decision could wait until the next phase of design.

- Bill said that CDM Smith recommends the Coanda grit washer because it produces a very clean and dry product and does not have a lot of operational problems. CDM Smith will assumed a Coanda grit washer for the conceptual layout of the grit facility.

- Kim pointed out that the washing technology is limited to 100 um. So, even if the HeadCell® units were designed to capture grit less than 100 um, it would not be captured in the washing system.

- Bill presented the recommended design criteria to be used for the conceptual layout of the grit washers.

Grit Loading

- Bill presented the recommended design criteria to be used for the conceptual layout of the grit bins.

- There were no comments on the bin design criteria.

Procurement Issues

- Bill discussed procurement issues associated with sole sourcing the HeadCells® and doing performance testing

- There were no comments on the presented information.

Grit Characterization

- Joel presented information on the need for grit characterization and how the grit characterization would be performed

- SVCW O&M staff asked if we could use the grit sampling data that was previously collected to design the HeadCells®. Bill Bryan said that CDM Smith has talked with Chuck about the previous sampling and the existing data. CDM Smith explained the previous samples were only analyzed for particle size and not settling velocities. Also, the size analysis was done after the organics were washed off the grit. CDM Smith needs to understand the settling characteristics of the organic coated grit because that is what will go into the HeadCells®. Therefore, additional data was needed.

- SVCW O&M staff asked what the data will be used for and how it will impact the design of the headworks. CDM Smith explained that the data will be used to determine if we need 4 HeadCells® or if less would be sufficient. Eliminating a HeadCell® would result in a significant cost savings.

- SVCW O&M staff said that they get a lot of silt into the collection system.

- Joel asked if there is good mixing in the digesters. O&M staff said that a lot of grit was in the digesters last time they were cleaned.

- Joel pointed out that grit particle with a lot of organics on it can float through the system all the way to the digesters because they have a low settling velocity. However, once this grit gets to the digesters, the organic material will get stripped off, increasing the settling velocity and allowing the particle to settle in the digester.

Albuquerque WWTP Site Visit Review

- First stage grit removal
  - Joel presented slides showing the first stage grit removal at the Albuquerque WWTP.
  - Joel explained that a first stage grit removal system was needed at Albuquerque because of the unique conditions in the collection system.
  - Albuquerque has undertaken significant water conservation efforts recently. As a result of these efforts, the flows in the sewers have dropped. The low flow conditions in the sewers have resulted in increased hydrogen sulfide corrosion in the sewers causing many sewers to collapse. A lot of the debris from the collapsing sewers washes into the plant. The first stage collection was designed to collect this material.
  - The same conditions won't be seen at SVCW, so a first stage grit removal system is not needed.
- Screen Building
  - Joel presented a slide showing the screen building.
  - A building was needed at Albuquerque because of the low temperatures at that site.
  - A building may not be needed at the SVCW facility.
- Screenings sluice
  - Bill Bryan pointed out that the sluice was very long.
  - Bill Bryan asked if we needed two sluices.

  - Ed said that if the system has two sluices, then a diverter is needed to split the screenings between the sluices. The screens need to be laid back at a lower angle so that the diverter can operate properly. This will increase footprint of the facility.

  - SVCW O&M staff said that if work needed to be done on the sluice, then the screenings could just be diverted past the sluice into a temporary dumpster.

  - SVCW O&M staff said they would like a redundant water supply, because that is the only thing they could see failing on the sluice.

- Grit Basins

  - Joel presented slides showing the grit basins at the Albuquerque WWTP.

  - Bill Bryan pointed out that no building is needed over the grit basins.

  - Joel said the grit basins need to be designed so that they can be drained. At Albuquerque the grit pumps could only partially drain the tanks because at a certain point the TDH on the pumps got too high as the level in the grit tanks dropped.

  - Joel said that a better approach would be to have a bypass on the pump suction that drained by gravity to the influent pump station wet well.

  - SVCW O&M staff said that it may be better to use a HeadCell® unit with less trays to limit how deep of an excavation was needed.

  - Joel said that reducing the number of trays may increase the number of HeadCells® needed and that it was also important to limit the number of HeadCells® used so that a good flow split could be achieved into the various grit basins.

  - Ed said that some HeadCell® basin designs have an isolation gate on the effluent side of the basin. He asked if SVCW could see any need to have this feature. SVCW staff agreed that it was not needed

- Grit Washer

  - Joel presented slides showing the Huber Coanda cone grit classifiers at the Albuquerque WWTP.

  - Joel pointed out that because grit is cleaned in the grit washer it doesn't have to be designed to capture the same settling rate particle as the main process because clean grit settles faster than dirty grit.

  - Jan pointed out that there was a diverter at the end of the grit classifier discharge chute that was used to divert the grit into one of two screw conveyors.

  - SVCW O&M staff said they liked the idea of having redundant grit conveyors because of the potential for mechanical failure on those systems.

  - SVCW O&M staff said they liked the fact that the motor was on top of the screw discharge chute on the cone washer. With the motor on top, it can be removed without losing a seal and allowing water to come out.

- Screenings/Grit Bins
  - Joel presented slides showing the screenings/grit bins at the Albuquerque WWTP.
  - Bill Bryan pointed out that the bins are used for both screenings and grit.
  - SVCW O&M staff asked if grit was a biohazardous material and if there were any issues with sending it to the landfill. No one was aware of any issues with sending grit to the landfill.
  - Joel said that a benefit of putting screenings and grit in the same bin is that you won't overload the bin with the very heavy grit.
  - Joel said one disadvantage of this setup is you won't be able to determine how much grit or screenings is being produced. You only know the weight of them combined.
  - SVCW O&M staff said they don't like the way the grit and screenings are discharged into the dumpster. They would like something that spreads the material more evenly across the dumpster.
- Dumpster Conveyor ("Dumpster-veyor")
  - Joel showed slides of the "Dumpster-veyor" at the Albuquerque WWTP.
  - SVCW O&M staff had concerns over how the dumpster would be loaded on and off the skids that rolled along the track.
  - Jan pointed out that the system makes it easier to roll the dumpster back and forth.
  - Bill Bryan said the system reduces the wear on the floor of the building
  - SVCW O&M staff agreed that it is very hard to move dumpsters around using just the wheels that are built onto the dumpster.
  - SVCW O&M staff suggested having a motorized hoist mounted on a wall that could pull the dumpsters in and out of the building without the need for a dumpster-veyor.

Wrap-up

- CDM Smith presented a summary of the main design criteria/assumptions that will be used to develop the conceptual layout of the headworks facility.

Action Items

- SVCW: Confirm whether or not to move forward with performing grit sampling
- CDM Smith: Coordinate grit sampling if determined to be necessary.

cc: Meeting attendees.

Michael Zafer (CDM Smith)

Appendix G

Grit Migrations Technical Memorandum

Technical Memorandum

To: ***Kim Hackett* - Silicon Valley Clean Water**

From: ***Bob Donaldson* - Collaborative Strategies Consulting**

Subject: ***Grit Migration Predictions When Using a Tunnel for Storing Wastewater***

Date: 17 DEC 2015 – V3

Introduction

This Technical Memorandum is being issued at the request of Silicon Valley Clean Water (SVCW) in order to gain a better understanding of how storing wastewater flows in the tunnel will impact the migration of grit present in the liquid stream. While the data presented will give SVCW insight for making determinations concerning grit migration related to diurnal storage, the primary focus of this memorandum is to investigate grit migration issues when the tunnel is used for the more extreme purpose of wet weather grit storage. Furthermore, the wet weather scenarios investigated will be the worse case grit loading scenarios based on conditions experienced in the 1990's. The reason for this more extreme test is with the intent that by examining this data it becomes the best way to make sure that SVCW is building a system that is still reliable even under the most demanding conditions, even if those conditions are considered rare. Tunnel and RLS issues are contemplated.

Assumptions

Grit Characteristics

- This tech memo will focus on the grit characteristics that are encountered during wet weather events that could be classified as either "Fine Silt" or "Very Fine Silt."
- Fine or Very Fine (wet) Silt will have an assumed density of 125 lbs/ft^3.
- The daily grit characteristics produced by average dry weather flows will be considered either Course Sand or Very Course Sand.

Grit Production – Daily Dry Weather

- Daily Dry Weather Grit production is assumed to be 2 to 3 yards of course sand per day.

Grit Production During Significant Storm Events

- The assumed amount of Fine or Very Fine Silt produced during worse case storm events are based solely upon the recollection of the author.
- These assumptions are based on filling a half trailer, one trailer, two trailers or three trailers. As these trailers were changed out based on weight to avoid overloading, at weights above 21.5 tons, it will be assumed that each trailer produced approximately

20 tons of grit. One, two and three trailers of grit are used for the calculation tables, Tables 5 through 10.

- During smaller storm events half trailers were typical. During significant storm events (especially those that were the first very large storm events of the season) during the years starting in 1985 and ending in 2000, one to two trailers would be produced (or 20 to 40 tons) over a 24 to 36 hour period.
- In one particular event there were three trailers, or ~ 60 tons, produced over an 18 to 24 hour period.
- In another separate event, two of the four primary tanks suffered complete failure during a storm event because grit accumulation outpaced the system's ability to remove it.

Grit and Velocity

- For this report it is assumed that suspended grit will settle from the liquid stream at velocities of less than 2 feet per second (fps) and that the grit will not be re-suspended (once settled) until the liquid stream achieves a velocity of 4 (or more) feet per second.
- While 2 fps is an accepted "text book number" where course sand will drop out of the liquid stream, fine silts won't drop out until velocities are under 2 fps. Nonetheless 2 fps will be used in all cases so as to preserve the conservative nature of the predictions made in this report.

Significant Storm Events

- February storms of 1986, 1992 and 1993/January and March of 1995/March of 1996/New Years day of 1997/ January and February of 1998

Findings

The findings will be organized using the following general headings:

- **Dry Weather**
- **Grit Migration during Dry Weather (various related topics)**
- **Wet Weather**
- **Grit Migration**
- **Settling and Resuspension**
- **Table 1 – Interceptor Velocities**
- **Drop Point (Diagram 1)**
- **Table 2 – Length of Grit Loading Zones**
- **Accumulation During Filling (Diagram 2)**
- **Concentration During Draining (Diagram 3)**
- **Tunnel Fouling**
- **Predicting and Managing Concentrated Grit Loads**
- **Managing the System to Obtain Desired Results**
- **Standard Operating Procedure for Emptying the Tunnel after Storm Events**
- **Raw Data Tables 3 and 4**
- **Calculation Tables 5 through 10**
- **Conclusions**
- **Acknowledgments and Disclaimer**

Dry Weather

Grit Migration During Typical Dry Weather Flows

Table 1 shows typical flows experienced by the system during dry weather and wet weather conditions with both free-flow condition and full pipe conditions. **Table 1** also shows that typical dry weather system flows should be enough to move grit down stream from the San Carlos connection to the plant if total system flows are above 20 MGD for some time during the diurnal cycle.

If flows remain above 20 MGD during dry weather for one hour, all grit deposited that day will be removed. It's important to note that it's not necessary that the 20 MGD for one hour be achieved on a daily basis. For example, if 20 MGD were achieved every other day for 30 minutes, the girt would take four days to migrate to the RLS. There is no reason to believe that this process would be a problem, unless the down stream RLS and degritting system could not process four days of stored grit (or about 8 to 10 yards) in case there was a day where the system did hit 20 MGD for one hour with several days worth of grit stored in the tunnel.

This suggestion is not meant to promote one operational mode over another but is noted here to reveal that several days of stored grit migrating down the tunnel is not a problem from a tunnel perspective. The tunnel could contain many weeks worth of dry weather grit and not be adversely impacted in terms of performance. There is more than one way to operate this system to satisfy removal of dry weather grit deposits.

Grit Migration During Typical Dry Weather Flows Upstream of the San Carlos Connection

The **Table 1** scouring flows also apply to the section upstream from the San Carlos connection, indicating flows from Redwood City and West Bay may not be typically adequate to avoid accumulating grit in this section of the tunnel during dry weather conditions. That being said, if very short periodic maintenance flushing events (once a week or every couple weeks) could be implemented to get the grit just past the San Carlos connection (say 3500 ft. / 4 fps [20 MGD]) = 15 minutes, typical system flows down stream from the San Carlos connection should be adequate to remove dry weather grit when system wide flows are over 5 MGD for grit already suspended or over 20 MGD for brief moments to get the grit suspended then over 5 MGD to transport it.

Grit Migration When Using the Tunnel for Diurnal Storage

The data in **Table 1** strongly indicate that a daily draining of the tunnel with a momentary tunnel flow of 20 MGD, when empty, will provide the sufficient flushing to remove any grit deposited during a diurnal storage episode. Assuming Diurnal storage occupying ~ 6000 feet of tunnel length and resuspension at 4 fps = 20 MGD @ 25 minutes will remove all grit.

Table 1

Flow, MGD	Interceptor Velocity, fps			
	11 Foot Diameter		13 Foot Diameter	
	Condition: Free Flow	Condition: Full Pipe	Condition: Free Flow	Condition: Full Pipe
2	1.25		1.00	
5	2.31		1.95	
10	3.18		2.94	
15	3.71		3.50	
20	4.19		3.90	
25	4.65		4.26	
30	5.02	0.46	4.60	0.33
40	5.44	0.62	5.26	0.44
50	5.81	0.77	5.73	0.55
55	6.03	0.85	5.89	0.61
75	6.78	1.15	6.41	0.83
95	7.15	1.46	7.04	1.05
105		1.62		1.16
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Wet Weather

Many of the dry weather flows and ***All*** free-flow conditions experienced during wet weather (say over 30 MGD) ***will always move suspended*** wet-weather-silt-grit from the tunnel. Under ***All*** wet weather flows (including 105 MGD) a full pipe condition ***will always store grit***.

Grit Migration When Using the Tunnel for Wet Weather Storage

The most important aspects concerning grit migration and tunnel storage of wet weather flows are:

A) The rate and process of grit accumulation when the tunnel is in a ***free-flowing*** condition and ***filling to create a full-pipe condition***, and

B) The rate and process of grit being re-suspended in the liquid stream as the ***stored*** volume of accumulated wastewater and grit is drained to the RLS, in a full-pipe condition ***draining to create a free-flow condition***.

The rate of grit deposition, over a particular period of time during the filling phase, will distribute grit along the entire length of the tunnel in those locations that experience a near full pipe and full pipe condition. When the tunnel is drained after a storm event, the collection and concentration of grit will play a key factor in determining how adjusting draining rates during the draining process can mitigate adverse impacts on the the down stream processes, namely the RLS and the degritting systems at the Headworks.

Settling and Resuspending

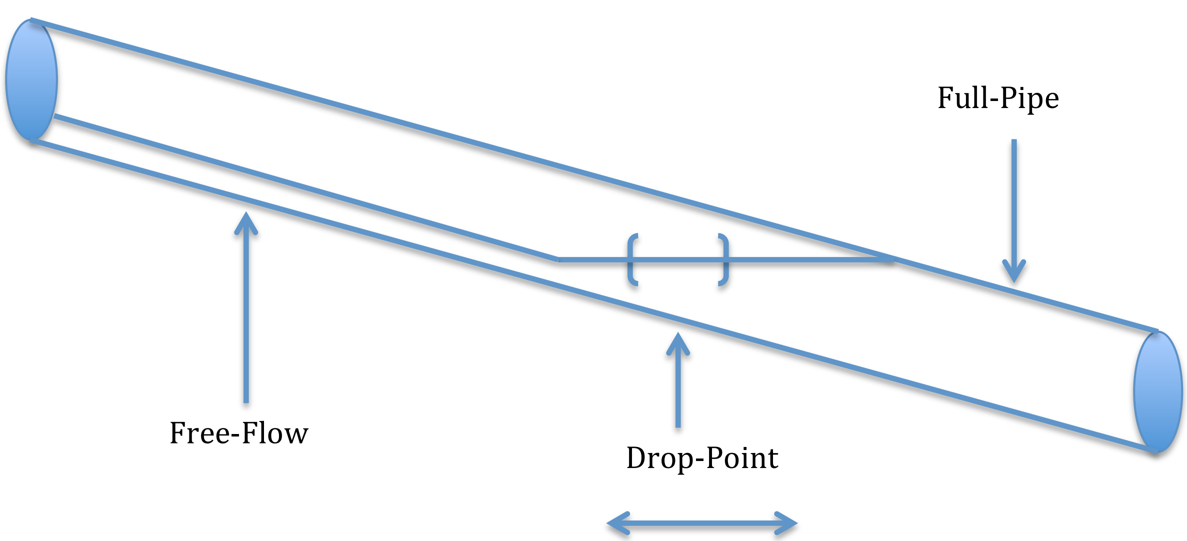
The data in **Table 1** clearly indicates that any free flowing flows in the tunnel from ~ 5 to > 95 MGD ***will result in velocities in excess of two feet per second. In other words, free flow data confirms that grit will never accumulate*** in the tunnel as long as the free-flow flow is above ~5 MGD. **Table 1** also shows that any free-flow conditions above 20 MGD will create resuspension velocities of over four feet per second.

Table 1 data also shows that in every scenario, where the tunnel section is completely full, whether that is an 11 or 13-foot tunnel, at no time does the velocity ever become more than 2 feet per second. ***This data indicates that whenever the tunnel is in a full-pipe condition it always stores grit***.

The current slope of the tunnel is assumed to be 0.0015 meaning that for every 1000 linear feet of tunnel the elevation profile will drop or rise by 1.5 feet. Therefore, at the point of complete inundation at the discharge end of an 11-foot tunnel (inside diameter), the pool created will occupy over 7000 linear feet of tunnel. This very large pool will remain this size for the first 10,500 feet of tunnel filling at which time it will start to be compressed as the pool hits the upstream end of the tunnel at Inner Bair Island causing it to shrink in size until the tunnel is (near) full. Knowing the length of this pool gives some perspective related to the very large portion of "partially filled" pipe that occupies an area of pipe with the free-flow condition on the upstream side of this pool and the full pipe condition on the down stream side of the pool. It is within the partially filled pipe location where the grit falls out of suspension and accumulates.

Knowing that ***free-flow conditions above 5 MGD always MOVES grit*** through the tunnel and that ***full-pipe conditions, regardless of flow, always STORES grit*** in the tunnel, gives us a clear indication that at some point in-between these two conditions, in this very long pool, the wastewater velocity will slow to the extent where the grit will start to settle out of the liquid stream. This report will label this important grit settling location with a unique identifier called the "***Drop-Point***." (**SEE Diagram 1**)

Diagram 1 The Drop-Point is the partially filled pipe location where the velocities drop below 2 fps allowing grit to drop out of the liquid stream. The Drop-Point location moves up or down stream depending on two factors.



The Drop-Point

The distance between the free-flow point and the drop-point defines the front end and the back end of the Grit Load Zone. The free-flow front end is where we know the grit is being resuspended and the Drop-point back end is where we know the grit is settling out because the velocity has dropped below 2 fps.

Its important to track the Drop-Point location, ***because it gives key insights that are necessary to understand in order to successfully predict the behavior of grit migration when using the tunnel for storage purposes***. The Drop-Point changes location based on two factors:

Factor One: as the level of the tunnel changes during a filling or draining mode, the point of slowed velocity (settling velocity) will move the Drop-Point either up or down stream with the changing level in the tunnel.

Factor Two: as the flow into the tunnel from the outlying gravity systems either decreases or increases, the Drop-Point will either move up-stream or down-stream, respectively. As free-flows increase the velocities will increase pushing the drop-point farther down stream allowing it to penetrate more deeply into the partially full tunnel. Conversely as the free-flow rate slows the Drop-Point velocities will move upstream into the shallower portion of the pool. (**SEE Table 2**)

If the flow does not change the Drop-Point will not change based on Factor Two flow changes but will continue to change its location (moving up or down the partially filled tunnel) based solely on the rising or falling level of the tunnel as mentioned in Factor One.

Table 2

"GRIT LOADING ZONE" (Length between free-flow entry point and drop-point)				
	11 Foot Diameter		13 Foot Diameter	
Flow, MGD	Length between free-flow entry point and drop-point (ft)	Depth of partially full pipe (in)	Length between free-flow entry point and drop-point (ft)	Depth of partially full pipe (in)
15	470	2.4	900	2.3
20	840	2.9	1260	2.5
25	1040	3.2	1400	2.7
30	1240	3.5	1790	3.3
40	1590	4.0	2310	4.1
50	2220	5.0	2630	4.6
55	2460	5.4	2760	4.8

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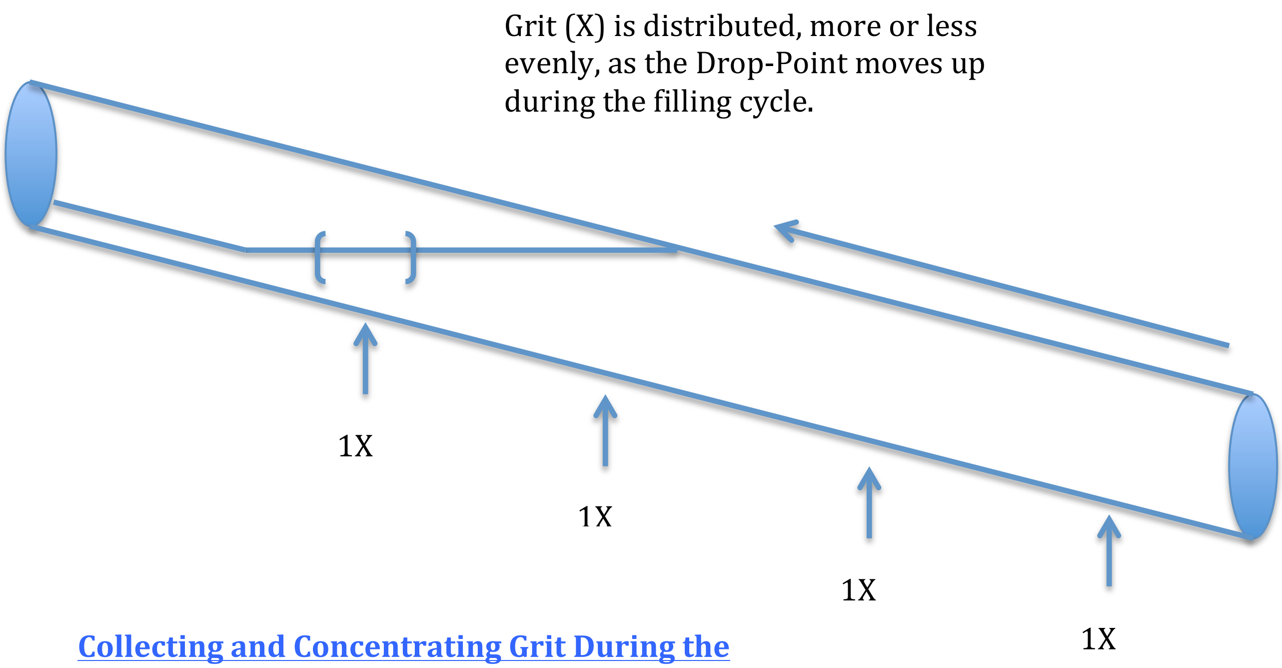
Accumulating Grit During the Filling Phase

As the tunnel is filling from a free-flow condition towards a full-pipe condition, grit will be deposited along the way at the Drop-point, thereby distributing the grit along the entire length of the tunnel invert as the filling process slows flows below 2 fps. The settled grit will not necessarily be evenly distributed along the length of the tunnel because of the hydraulic changes impacting the drop-point location typically encountered during the dynamic flow changes experienced during a storm event (because of the two factors just mentions).

However the distribution will be evenly portioned "enough" that this report will assume that *the grit entering the interceptor will nonetheless settle out, more or less, along the entire length of that portion of tunnel that achieves a near full-pipe condition* (**See Diagram 2**). The reason this assumption can be made is because having the original grit deposits being slightly uneven has little affect on what is to follow: *grit collection and concentration during the draining phase*.

At the moment when the tunnel stops rising at the end of a filling phase, but remains full (e.g. the flow into the tunnel from the contributing systems and the flow out of the tunnel via the RLS are the same and remain the same) the Drop-Point will remain at a stationary location, depositing the incoming grit at that same location until flow conditions change the location of the Drop-Point.

Diagram 2



Collecting and Concentrating Grit During the Draining Phase

As the tunnel switches over from a filling phase to a draining phase the Drop-Point will start to change location moving towards the RLS with the descending water level. As the Free-flow point also descends with the dropping level of the pool, the increased velocity always caused by the free-flow point (remember Table 1) will start to resuspend the grit that was deposited during the filling phase.

As the newly resuspended grit travels down stream past the Drop-Point (because not only is the level dropping but the flow in the tunnel continues flowing down stream) ***this recently resuspended grit will settle again but now on top of a layer of grit that is already present as it was deposited during the initial filling phase***.

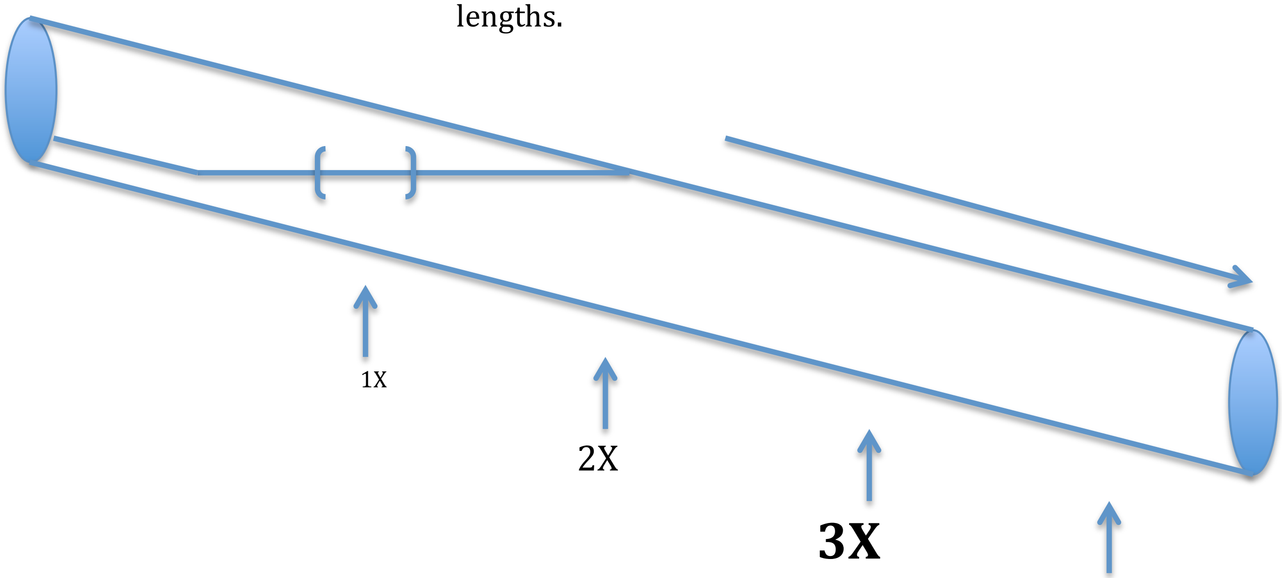
As the draining phase again continues to drop the level and Free-Flow point arrives down stream with the resuspension velocity necessary to resuspend grit, the Free-Flow point will eventually encounter the location of the two layers of grit. As the Free-Flow velocity arrives, the grit that had just previously been resuspended and had settled out, ***and*** now also the original grit layer, are both being resuspended and will both be sent down stream.

Both newly resuspended layers will again be sent down stream, again past the Drop-Point to now resettle on yet a third original layer of grit that was settled during the filling stage. As the draining phase continues the free-flow-resuspension-velocity will now pick up the three layers and deposit them on a forth layer ***and so on and so forth*** (**SEE Diagram 3**).

As this process continues collecting and concentrating the grit, the final draining process of the tunnel will be discharging larger amounts of grit to the RLS in a shorter period of time than would have happened otherwise, as compared to a situation had there been no wet weather storage in the tunnel. Predicting and managing the delivery of the concentrated grit load will be addressed later in this report.

Diagram 3

The descending Free-Flow point re-suspends and the descending Drop-Point then re-settles the ***same grit layers, over and over again,*** during a draining cycle. Grit (X) is now collected, and successively concentrates, as larger amounts of grit span ever-shorter tunnel lengths.



Tunnel Fouling

As the grit concentrates during the draining phase, between the Free-Flow point and the Drop-Point, a question arises that asks:

What are the chances that the grit could pile up in the tunnel to the extent that it would be completely block the tunnel?

The **Table 1** data, along with a closer examination of silt characteristics, seems to indicate that the occurrence of a blocked tunnel is extremely unlikely even under the worst silt-grit conditions because of the amount of grit that is expected and how water velocities change with narrowing orifices.

While a ***full*** tunnel will always store grit a *partially "fouled" full tunnel, will at some point, never store grit*. As the grit starts to concentrate (pile up in the tunnel) and a more narrow tunnel diameter results, the velocity will naturally increase when a successively *smaller bore is available for the same flow* (Bernoulli). And as the fouling creates ever smaller diameters for a given flow, the velocity will continue to increase until it either keeps the grit in suspension that is already in suspension (≥ 2 fps) no longer contributing to the fouling and/or the velocity will increase to the extent that it is scouring the more "narrowed bore" by removing grit via resuspending it at velocities of ≥ 4 fps.

Lastly, "wet fine silt" densities are upwards of 125 lbs/ft^3 (Multiple Sources). Assuming "wet" and assuming 60 tons as a worse case, the resulting volume is about 960 cubic feet of material. If distributed equally in the last 1000 feet of tunnel this would be about one cubic foot of slit per linear foot of tunnel length. Which means it's occupying (blocking) about 1% of the available surface area used for flow assuming an 11-foot diameter tunnel. This is not enough blockage to impact any flow under any condition.

Occupying 100 feet of tunnel the blockage would be 10% of available surface area used for flow, again not nearly enough tunnel blockage to have any affect in flow.

In other example, all 60 tons would need to (simultaneously) occupy only ten feet of linear tunnel space, in a highly concentrated fashion, in order to completely block the tunnel. It becomes very difficult to imagine how this would ever happen knowing the various flows involved and the worse case amounts of grit expected.

Predicting and Managing Delivery of the Concentrated Grit Loads

A few items before we dig into this section.

First, the following information are estimates based on the hydraulic model from Brown & Caldwell combined with assumptions as stated previously at the beginning of this report and again combined with the recollection of past events of silt-grit loading. These are only quasi-empirical guidelines.

Second, the grit zones are probably not as "tight" or as short as noted in the Grit Loading Zone table (**Table 2**). In other words, the grit is probably not as concentrated as what is assumed here. The reason for that is we are using a 2 fps grit drop out velocity assumption. For fine slits the drop out number is lower, downwards to 1 fps (organics are typically assumed to drop out at or less than 1 fps). As such the finer silt is still moving under 2 fps slightly expanding the grit zone and causing the grit zone to be slightly less concentrated that what is indicated. This is good news. And we want to stay with 2 fps so our estimates are conservative.

Three, there are two very important dynamics, occurring simultaneously, that are working with each other to either increase or decrease that actual tons of grit (tons per hour) delivered to the RLS and the degritting system.

A) ***What we want: Stretching out the grit zone so there is less grit per linear foot. In other words, longer grit zones with less concentration.***

Remember the earlier description, using Diagram 3, where the free-flow and drop-point zones sequentially over lap, causing repeated patterns of resuspending and resettling grit over and over again, causing the grit to be ever more concentrated. What we know as a result of this phenomenon ***is the longer the distance this grit zone is the less these over lap cycles occur and lower the concentration exists in the grit loading zone.*** The higher the rate of Free-flow entering the partially full pipe the less recycling and concentrating of grit will occur. Higher flows work in our favor.

B) What we want: Slowing the rate of grit arrival so it is being introduced more slowly over time into the RLS.

The second important parameter is the speed at which this "grit load zone" arrives at the RLS. The faster this grit load zone arrives at the RLS the heavier the grit load will be on the downstream processes. Slowing the experience rate at the RLS by minimizing the delta between the exit flow at the RLS and the flows entering the tunnel from the gravity systems is ***highly effective at reducing grit loading rates on the RLS***. For example, if the flow into the system after a storm is at 40 MGD, its better the pump the RLS at 45 MGD, instead of 65 MGD just before the grit load zone enters the RLS. The delta 5 MGD (45-40=5)has the grit load zone entering at 208,000 gallons an hour whereas the delta 25 MGD (65-40=25) has the grit loads zone entering at 1,042,000 gallons an hour.

In an 11-foot tunnel, 208K gallons an hour is draining the tunnel and bringing in the grit load zone at 322 feet per hour, whereas the 1.042M gallons is draining the tunnel bringing in the grit zone at 1534 feet per hour!

How to Manage the System to Obtain the Desired Conditions

The primary objectives of managing the tunnel once it has been filled from a storm event are:

1- Stretching out the grit zone, so its less concentrated, because its desirable to lessen the grit load on the RLS and we now know this is best done by drawing down the tunnel during influent high flows.

2- Slowing the arrival and duration of the grit zone so the grit is "metered" into the system slowly to reduce the loading rate (tons/hour).

3- The tunnel is drawn down in a reasonable amount of time so as to prepare for another storm event.

As the following data will reveal objective #1 and objective #2 are competing objectives with objective #3.

If the delta between the influent flow to the tunnel and the effluent flow from the RLS is kept very low (objective #1 and #2), lets say 5 MGD, it will take an exceedingly long time to drain and will work against meeting objective #3. (assumed to be too long)

KEY POINT: The best way to resolve this conflict is to better understand the difference in importance between objectives #1 and #2. While both are important, ***the following data tables will reveal that SLOWING the flow into the RLS is the most effective method by which to lower grit loading on the RLS (objective #2) even if the grit zone has suffered from some concentration (objective #1) because we needed higher flows to initially drain the tunnel in order that it be drained in a reasonably short period of time (objective #3).***

Managing the Draining Process is the key to 1) gaining the benefits of using the tunnel for storage 2) draining the tunnel as soon as practical for the next storm event and 3) not overloading the RLS with grit.

Standard Operating Procedure for Emptying the Tunnel after the Storm Event

(This assumes the flow into the plant will be held at 55 MGD as the tunnel is draining. This assumption can change and this SOP will still be effective at meeting the objective if in fact 55 MGD can be replaced with 60 or 65 MGD or higher flows into the plant)

This SOP was developed using the calculation tables 5 and 6 below.

STEP 1 - As the storm event starts to abate and the flows going into the tunnel from the contributing systems start to drop, maintain flow into the plant at 55 MGD (or higher). (NOTE: *This will start the draining process.*)

STEP 2 – As the flow continues to drop from the contributing systems and the plant flow is held at 55 MGD ***the draining process will accelerate***. Maintain 55 MGD. (NOTE: *This step causes a necessary acceleration of the draining process to shorten the draining time even though it will also cause some additional concentration of the grit load zone - we will take care of that at step 3).*

STEP 3 – When the tunnel reaches a point where the last 1500 feet of tunnel (or 2000 feet if you want to be more conservative) remains partially full and continues to drain, ***switch the RLS pumping output to within 5 MGD above the combined flows into the system***. This is called the **RLS Delta 5 pumping mode**. (NOTE: *This will is SLOW the entry of the grit-loading zone and will lengthen the duration of which the RLS experiences the grit-loading zone thereby significantly lowering the loading rate in tons/hour.*)

STEP 4 – Remain in the "**RLS Delta 5 Pumping Mode**" until the contents of the tunnel are completely emptied. (NOTE: *This pumping mode can be programed into a PLC algorithm, the remaining 1500 or 2000 feet of partially filled tunnel can have its own measurement but will also be clearly indicated at the exit point of the tunnel and/or entry point of the RLS wet well.*)

--- End of SOP ---

The above SOP was developed (as noted using the calculation tables 5 and 6 below) to demonstrate that slowing the grit load zone into the RLS, at the very end of the draining process, will meet objectives #2 and #3 which will suffice in avoiding grit overload of the downstream processes, even at the partial expense of objective #1.

A few more notes that are revealed by the data before we dig into the tables:

- While grit loading zone concentration matters, ***slowing the flow*** in response to the concentrated grit zones is ***highly effective at reducing grit-loading rates to the RLS***.

- ***Using a 13 foot diameter*** instead of an 11 foot tunnel doesn't change the total volume of grit but it ***helps significantly to reduce grit loading rates*** of tons per hour by ***two-thirds*** *but will also slow drain times.*

- Remember the intent of this report was to ***prepare SVCW for worse case scenarios***, perhaps 90% of the storms experienced will not give SVCW the type of worse case silt-grit numbers listed in this report.

- The time necessary to empty the tunnel assumes the tunnel is full and that full condition will not happen during most of the storms if 55 MGD is maintained to the plant with the currently predicted flows from the member agencies. In addition, time to empty the tunnel listed in the calculation tables is dependent on the receiving flows dropping as recorded and in some cases they may drop faster-sooner or less-later or any combination.

Raw Data Tables

Tables 3 and 4 are the raw data tables that were used for the calculation tables 5 through 10 that follow.

(Note that the color-coding of the raw data **Table 3** (Influent Flow / Size of Grit Zone) and **Table 4** (Delta / Arriving Rate of Grit) correspond with the colored data fields in the calculation tables 5 thru 10.

Table 3 – Length of Grit Zone (Table 2 Again)

Grit Zone Length				
	11 Foot Diameter		13 Foot Diameter	
Flow, MGD	Length between free-flow point and drop-point (ft)	Depth of partially full pipe (in)	Length between free-flow point and drop-point (ft)	Depth of partially full pipe (in)
15	470	2.4	900	2.3
20	840	2.9	1260	2.5
25	1040	3.2	1400	2.7
30	1240	3.5	1790	3.3
40	1590	4.0	2310	4.1
50	2220	5.0	2630	4.6
55	2460	5.4	2760	4.8

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Table 4 – Rate of Grit Zone Arrival

	RLS is Pumping At 55 MGD				
	13 Foot Tunnel		11 Foot Tunnel		
Delta (to 55)	Flow into the Tunnel (MGD)	Speed at which pond is draining (Feet / Hour)	Flow into the Tunnel (MGD)	Speed at which pond is draining (Feet / Hour)	Delta (to 55)
40	15	1775	15	2351	40
35	20	1574	20	2105	35
30	25	1361	25	1810	30
25	30	1131	30	1534	25
20	35	914	35	1248	20
15	40	688	40	953	15
10	45	475	45	637	10
5	50	227	50	322	5
B&C DEC 2015	>OR: 220 average foot rise/drop per 5 MGD		> OR: 300 average foot rise/drop per 5 MGD		

Calculation Tables

Tables 5 through 10 are calculation tables that illustrate the relationship between the delta of in and out flows, the length of the grit zone and the rate of arrival of the grit zone arrives at the RLS and the degritting system.

Table 5 - 11 foot at 55 MGD (preferred based on drain time)

11 Foot Tunnel / 20 - 40 - 60 Tons - Grit Delivery Rates / RLS Pumping @ 55 MGD							
Delta (MGD)	Flow Into Tunnel (MGD)	Grit (Tons)	Distance Between Free-Flow Point and Drop-Point (Feet) See flow	Rate at Which Free-Flow Location is Arriving at RLS (Feet/Hour) See Delta	Total Duration Between Drop-Point Arrival and Free-Flow Arrival at RLS (Hours)	Approximate Delivery Rate of Grit (Tons / Hour)	Hours Experiencing Grit Loading
30	25	20	1040	1810	0.6	35	0.6
		40	1040	1810	0.6	70	0.6
		60	1040	1810	0.6	104	0.6
25	30	20	1240	1534	0.8	25	0.8
		40	1240	1534	0.8	49	0.8
		60	1240	1534	0.8	74	0.8
15	40	20	1590	953	1.7	12	1.7
		40	1590	953	1.7	24	1.7
		60	1590	953	1.7	36	1.7
5	50	20	2220	322	7.9	3	7.9
		40	2220	322	7.9	5	7.9
		60	2220	322	7.9	8	7.9

Pump Down at Delta 30 Switch to Delta 5 last 1500 feet ~ 15 hour pump down - Full Tunnel - Assumes in flow at 25 MGD							
Pump Down @ Delta 30 Switch to Delta 5 last 1500 feet	Initial tunnel in flow - 25	20	1040	322	3.2	6	3.2
		40	1040	322	3.2	12	3.2
		60	1040	322	3.2	19	3.2

11-foot tunnel - While the grit zone is only 1040 feet long (2220 feet would be better), by introducing the grit load zone over a 3-hour period at the end, the total drain times remain reasonable while not over loading the RLS with grit. 6 tons represents about 3.5 yards of silt material and 19 tons is a little over 11 yards of material per hour a 3-hour period. In order to get a longer and less concentrated grit-loading zone of 2220 feet the drain time would be increased significantly (over 57 hours !!).

Table 6 - 13 foot @ 55 MGD (preferred based on Grit Load)

13 Foot Tunnel / 20 - 40 - 60 Tons - Grit Delivery Rates / RLS Pumping @ 55 MGD							
Delta (MGD)	Flow Into Tunnel (MGD)	Grit (Tons)	Distance Between Free-Flow Point and Drop-Point (Feet) See flow	Rate at Which Free-Flow Location is Arriving at RLS (Feet/Hour) See Delta	Total Duration Between Drop-Point Arrival and Free-Flow Arrival at RLS (Hours)	Approximate Delivery Rate of Grit (Tons / Hour)	Hours Experiencing Grit Loading
30	25	20	1400	1361	1.0	19	1.0
		40	1400	1361	1.0	39	1.0
		60	1400	1361	1.0	58	1.0
25	30	20	1790	1131	1.6	13	1.6
		40	1790	1131	1.6	25	1.6
		60	1790	1131	1.6	38	1.6
15	40	20	2310	688	3.4	6	3.4
		40	2310	688	3.4	12	3.4
		60	2310	688	3.4	18	3.4
5	50	20	2630	227	11.6	2	11.6
		40	2630	227	11.6	3	11.6
		60	2630	227	11.6	5	11.6

Pump Down at Delta 30 Switch to Delta 5 last 1500 feet ~ 21 hour pump down - Full Tunnel – Assumes influent flow at 25							
Pump Down @ Delta 30 Switch to Delta 5 last 1500 feet	Initial tunnel in flow - 25	20	1400	227	6.2	3	6.2
		40	1400	227	6.2	6	6.2
		60	1400	227	6.2	10	6.2

13-foot tunnel - While this grit zone is only 1400 feet long (2630 feet would be better), by introducing the grit load zone over a 3-hour period at the end, the total drain time is about 6 hours longer that the 11-foot tunnel but grit loading is lower with the same delta 5 pumping mode. 3 tons represents about 1.8 yards of silt material and 10 tons is a little over 6 yards of material per hour a 6-hour period. In order to get a longer and less concentrated grit-loading zone of 2630 feet the drain time would be increased significantly (over 82 hours !!).

Table 7 - 11 Foot @ 45 MGD (not preferred)

11 Foot Tunnel / 20 - 40 - 60 Tons - Grit Delivery Rates / RLS Pumping @ 45 MGD							
Delta (MGD)	Flow Into Tunnel (MGD)	Grit (Tons)	Distance Between Free-Flow Point and Drop-Point (Feet) See flow	Rate at Which Free-Flow Location is Arriving at RLS (Feet/Hour) See Delta	Total Duration Between Drop-Point Arrival and Free-Flow Arrival at RLS (Hours)	Approximate Delivery Rate of Grit (Tons / Hour)	Hours Experiencing Grit Loading
30	15	20	470	1810	0.3	77	0.3
		40	470	1810	0.3	154	0.3
		60	470	1810	0.3	231	0.3
25	20	20	840	1534	0.5	37	0.5
		40	840	1534	0.5	73	0.5
		60	840	1534	0.5	110	0.5
15	30	20	1240	953	1.3	15	1.3
		40	1240	953	1.3	31	1.3
		60	1240	953	1.3	46	1.3
5	40	20	1590	322	4.9	4	4.9
		40	1590	322	4.9	8	4.9
		60	1590	322	4.9	12	4.9

Pump Down at Delta 30 Switch to Delta 5 last 1500 feet - 17 hour pump down – Assumes 15 MGD influent – not likely							
Pump Down @ Delta 30 Switch to Delta 5 last 1500 feet	Initial tunnel in flow - 30	20	470	322	1.5	14	1.5
		40	470	322	1.5	27	1.5
		60	470	322	1.5	41	1.5

Table 8 – 13 Foot @ 45 MGD (not preferred)

13 Foot Tunnel / 20 - 40 - 60 Tons - Grit Delivery Rates / RLS Pumping @ 45 MGD							
Delta (MGD)	Flow Into Tunnel (MGD)	Grit (Tons)	Distance Between Free-Flow Point and Drop-Point (Feet) See flow	Rate at Which Free-Flow Location is Arriving at RLS (Feet/Hour) See Delta	Total Duration Between Drop-Point Arrival and Free-Flow Arrival at RLS (Hours)	Approximate Delivery Rate of Grit (Tons / Hour)	Hours Experiencing Grit Loading
30	15	20	900	1361	0.7	30.2	0.7
		40	900	1361	0.7	60.5	0.7
		60	900	1361	0.7	90.7	0.7
25	20	20	1260	1131	1.1	18.0	1.1
		40	1260	1131	1.1	35.9	1.1
		60	1260	1131	1.1	53.9	1.1
15	30	20	1790	688	2.6	7.7	2.6
		40	1790	688	2.6	15.4	2.6
		60	1790	688	2.6	23.1	2.6
5	40	20	2310	227	7.9	3	7.9
		40	2310	227	7.9	5	7.9
		60	2310	227	7.9	8	7.9

Pump Down at Delta 30 Switch to Delta 5 last 1500 feet ~24 hour pump down - Full Tunnel – assumes 15 MGD – not likely							
Pump Down @ Delta 30 Switch to Delta 5 last 1500 feet	Initial tunnel in flow - 15	20	900	227	4.0	5	4.0
		40	900	227	4.0	10	4.0
		60	900	227	4.0	15	4.0

Table 9 – 11 Foot @ 35 MGD (not preferred)

11 Foot Tunnel / 20 - 40 - 60 Tons - Grit Delivery Rates / RLS Pumping @ 35 MGD							
Delta (MGD)	Flow Into Tunnel (MGD)	Grit (Tons)	Distance Between Free-Flow Point and Drop-Point (Feet) See flow	Rate at Which Free-Flow Location is Arriving at RLS (Feet/Hour) See Delta	Total Duration Between Drop-Point Arrival and Free-Flow Arrival at RLS (Hours)	Approximate Delivery Rate of Grit (Tons / Hour)	Hours Experiencing Grit Loading
20	15	20	470	1248	0.4	53	0.4
		40	470	1248	0.4	106	0.4
		60	470	1248	0.4	159	0.4
15	20	20	840	953	0.9	23	0.9
		40	840	953	0.9	45	0.9
		60	840	953	0.9	68	0.9
10	25	20	1040	637	1.6	12	1.6
		40	1040	637	1.6	25	1.6
		60	1040	637	1.6	37	1.6
5	30	20	1240	322	3.9	5	3.9
		40	1240	322	3.9	10	3.9
		60	1240	322	3.9	16	3.9

Pump Down at Delta 30 Switch to Delta 5 last 2000 feet ~ 20 hour pump down - Full Tunnel Assumes 15 MGD influent – not likely							
Pump Down @ Delta 20 Switch to Delta 5 last 1500 feet	Initial tunnel in flow - 15	20	470	322	1.5	14	1.5
		40	470	322	1.5	27	1.5
		60	470	322	1.5	41	1.5

Table 10 – 13 foot @ 35 MGD (not preferred)

13 Foot Tunnel / 20 - 40 - 60 Tons - Grit Delivery Rates / RLS Pumping @ 35 MGD							
Delta (MGD)	Flow Into Tunnel (MGD)	Grit (Tons)	Distance Between Free-Flow Point and Drop-Point (Feet) See flow	Rate at Which Free-Flow Location is Arriving at RLS (Feet/Hour) See Delta	Total Duration Between Drop-Point Arrival and Free-Flow Arrival at RLS (Hours)	Approximate Delivery Rate of Grit (Tons / Hour)	Hours Experiencing Grit Loading
20	15	20	900	914	1.0	20	1.0
		40	900	914	1.0	41	1.0
		60	900	914	1.0	61	1.0
15	20	20	1260	688	1.8	11	1.8
		40	1260	688	1.8	22	1.8
		60	1260	688	1.8	33	1.8
10	25	20	1400	475	2.9	7	2.9
		40	1400	475	2.9	14	2.9
		60	1400	475	2.9	20	2.9
5	30	20	1790	227	7.9	3	7.9
		40	1790	227	7.9	5	7.9
		60	1790	227	7.9	8	7.9

Pump Down at Delta 20 Switch to Delta 5 last 1500 feet ~28 hour pump down - Full Tunnel – Assumes 15 MGD influent – not likely							
Pump Down @ Delta 20 Switch to Delta 5 last 1500 feet	Initial tunnel in flow - 15	20	900	227	4.0	5	4.0
		40	900	227	4.0	10	4.0
		60	900	227	4.0	15	4.0

Conclusions

- Free-flow conditions above 5 MGD will ***always*** move grit and full-pipe conditions will ***never*** move grit, regardless of the currently accepted system flows applied to a full tunnel up to and including 105 MGD.

- The data in **Table 1** strongly indicate that a daily draining of the tunnel with a momentary tunnel flow of 20 MGD, when empty, will provide the sufficient flushing to remove any grit deposited during a diurnal storage episode. Assuming Diurnal storage occupying ~ 6000 feet of tunnel length and resuspension at 4 fps = 20 MGD @ 25 minutes will remove all grit.

- The **Table 1** scouring flows also apply to the section upstream from the San Carlos connection, indicating flows from Redwood City and West Bay may not be typically adequate to avoid accumulating grit in this section of the tunnel during dry weather conditions. That being said, if very short periodic maintenance flushing events (once a week or every couple weeks) can be implemented to get the grit just past the San Carlos connection (say 3500 ft. / 4 fps [20 MGD]) = 15 minutes, typical system flows down stream from the San Carlos connection should be adequate to remove dry weather grit on a daily basis.

- Daily dry weather diurnal storage shows that full-pipe cycles will settle and store grit and that free-flow cycles can re-suspend grit during a single diurnal cycle. Free-flows below ~5 MGD and full-pipe conditions will allow grit will settle from the liquid stream and will be re-suspended when experiencing free-flow flows of 20 MGD.

- As the tunnel is filling from a free-flow condition to a full-pipe condition, the grit entering the interceptor will settle out more or less along the entire length of that portion of the tunnel that achieves a full-pipe condition.

- The data seems to indicate that tunnel will not have significant fouling issues related to grit accumulation as the Free-Flow velocities generated by flows ***over*** 20 MGD are more than adequate to scour the tunnel. Calculations assuming 60 tons of wet fine silt indicates having enough grit concentrated in a single location to completely block the tunnel, as extremely unlikely.

- The rate of grit deposition, over a particular period of time during the filling phase, will distribute grit along the entire length of the tunnel that has been nearly filled. The rate of grit collection during the draining phase, will concentrate the total amount of stored grit and will deliver it at the RLS in a more concentrated fashion than had the grit arrived based on a distributed migration rate provided (by a typical or) the same storm event not using the tunnel for storage.

- Whenever draining the tunnel at maximum velocity (say 50 MGD into the tunnel and pumping 55 MGD from the RLS to the plant) this high flow - low delta combination will minimize grit loading (tons grit/hour) on the downstream processes by expanding the grit zone (lowering its concentration and slowing the grit zone introduction to the RLS. This method of draining will also cause the drain time to be extremely long.

- Conversely, draining the tunnel at lower velocities (say 20 MGD into the tunnel while pumping 40 MGD from the RLS) will maximize grit-loading spikes to downstream processes by concentrating the grit zone and introducing the grit zone at a faster rate even though this will drain the tunnel in a more reasonable time frame.

- The best method by which to manage the tunnel after a storm, in order to meet the top three objectives (stretching the grit zone, slowing the rate of grit loading, draining the tunnel as quickly as possible) is to follow the SOP provided in this report. ***Drain the tunnel rapidly at the beginning and slow the flow just before the grit load zone arrives***.

- The 13-foot diameter tunnel allows for lower grit loading rates on the RLS, and a slower drain rate than the 11-foot tunnel. The 11-foot tunnel allows for reasonable grit loading and the fastest drain times.

- Grit introduction to the RLS can be adjusted up or down by simply using a different delta setting. If it is desired that less grit be introduced over time, simply use a lower delta set point towards the end of the draining phase.

- Based on the data contained in this report the primary question that needs answering is:

How will the down stream processes be prepared to handle the impact of these grit loads being presented by this data?

(Those being the RLS pumping station, first, and the Headworks degritting process that follows, second.)

Acknowledgement and Disclaimer

This report would have been impossible to complete without the dedicated help of Kevin Kai at Brown and Caldwell who, working on the project and taking my calls on weekends, undauntedly fulfilled my numerous obscure requests for hydraulic information, in an always ever-pleasant fashion.

Robert Donaldson is a Grade V Operator certified in the State of California and a former Operations Manager and Project Manager at a Sub-Regional Wastewater Treatment Facility. Robert Donaldson is not an engineer nor does Collaborative Strategies Consulting provide engineering services. As such no design decisions should be made based on the information provided in this report unless a certified professional engineer validates it.

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Appendix H

SVCW Odor Control Workshop Minutes

CDM Smith

Meeting Minutes

To: *Bill Bryan*

From: *Bruce Singleton*

Date: *November 11, 2015*

Subject: *SVCW Odor Control Workshop*

Attendees: *Bill Bryan, Monte Hamamoto, Bob Huffstetler (SVCW)*
Bruce Singleton, Lynne Moss, Jan Davel, Ed Fernbach (CDM Smith)

Meeting Objectives

- Summarize for SVCW staff the current status of odor quantification methods for both specific odorous compounds and odor specifically, including single measurement approaches ("grab samples"), long-term sampling methods, and ambient air and perimeter monitoring equipment/methods.
- Discuss the current data presented to CDM Smith as it pertains to the design criteria for the Front of Plant (FOP) odor control equipment.
- Discuss the current understanding of the Receiving Lift Station (RLS) and tunnel design and its ramifications on ventilation and odor control design.
- Discuss current odor issues at the existing facility, in particular ambient H_2S levels and corrosion.

Discussion Items

- Slides were presented of H_2S monitoring equipment for both grab sampling and long term "logging" of H_2S. Devices covered included hand held instruments as well as permanent systems that log data, transmit data to SCADA, and in some cases provide offsite plume models as a function of the real time data.
- Odor measurement and its application was discussed, including the use of odor in dispersion modeling. Permanent odor sensors (E-nose) were discussed as a means to measure a specific odor from a specific source, and that it was not recommended for application at a fence-line to sense offsite odor excursions.
- Dispersion modeling and the data required was discussed as well as its application and value in summarizing the offsite effects of onsite odor sources. It was presented as a means to economize on odor control with predictable results rather than cover and treat every source with maximum treatment and/or demonstrate compliance with odor standards.

- The historical data set had been evaluated. However, since that data provided only ambient conditions both outside and within the control room, it provided little design value. SVCW staff also noted that the Jerome 631 that was used for onsite measurements may not be accurate. Notwithstanding, the effects of the levels shown in the data were indicative of fugitive emissions within the plant and it was discussed that perhaps some temporary (5-7 year duration) mitigation methods may be warranted until the new headworks and odor control is functional. Building ventilation with filtered air through Positive Pressurization Units (PPUs) was also discussed as a means to control electronics corrosion from both H_2S and chlorides dispersed as an aerosol from the bay. **Monte Hamamoto offered 3 years of historical data that had not been evaluated prior to this meeting.**

- Anecdotal information based on the historical data that had not yet reviewed indicated that concentrations in excess of 100 ppm have been measured at the influent coarse screens; the build-up of deep (>8") "mats" of grease at the screens was also discussed. The grease has been evaluated by SVCW and indications are that there are petroleum products that are not consistent with domestic sewage; there are known industrial contributions to the plant.

- The current offsite odor complaints were described as being from the collection system rather than from the treatment plant. Calcium nitrate is being used with a Versa Dose system in the collection system. However, it is described as a series of small force mains and 29 lift stations that are poorly ventilated, improperly ventilated, or ventilated without odor treatment. Odor release at the "dog park" was due to a break in the sewer that allowed gases to escape.

- CDM Smith advised that sampling at the influent chamber directly upstream of the new inlet screens would be prudent to document current conditions. The sampling should include both H_2S logging over several days as well as concurrent grab samples for dissolved sulfide, pH, ORP, Temperature, BOD, TRS_{air}, and $VOCs_{air}$. Following the meeting CDM Smith and Bill Bryan inspected the influent channel where sampling could be performed. **An outline of the recommended sampling protocol and analysis will be provided by CDM Smith.**

- The current understanding of the tunnel design was presented by CDM Smith and updated by SVCW. Currently storage in the tunnel is a strong consideration and to preclude pressurization of the upstream drop shafts the tunnel will be sized to allow for a gap at the RLS shaft with a d/D factor of 0.3 in the 12-ft diameter tunnel. The current tunnel slope is 1.5 ft/1,000 ft.

Action Items

- Monte: Provide 3 years of additional historical data not included in original data set.

- Bruce: Provide an outline of the recommended sampling protocol and required analysis.

cc: Meeting attendees.

Bill Schilling, Michael Zafer (CDM Smith)

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Appendix I

Influent Wastewater Odor Sampling and Analysis Plan

DRAFT TECHNICAL MEMORANDUM

Sampling and Analysis Guidance

1.1 Introduction

The Silicon Valley Clean Water (SVCW) WWTP Headworks and Screening Project - CIP #9160 will include facilities to mitigate odors. In preparation for future design efforts, existing hydrogen sulfide (H_2S) concentration data from the plant is being compiled for these facilities, but additional data is needed. This technical memorandum outlines supplemental sampling needs to support future odor control design efforts.

The data from the proposed sampling may also provide information that could assist in determining the cause of the extensive grease mat observed at the facilities coarse screens.

1.2 Sampling

A two-phase approach is recommended:

- Phase 1: H_2S survey. This survey would be performed to further the understanding of the sewer odor dynamics and any potential industrial effects on odors. OdaLog data loggers are recommended for this effort.

  Phase 2: Targeted Sampling. Sampling of: (1) wastewater for dissolved sulfide, pH, and oxidation reduction potential (ORP) and (2) atmospheric sampling for volatile organic compounds (VOCs) and Total Reduced Sulfur (TRS) compounds. Wastewater sampling and analysis can be performed on site, however air samples would need to be sent to an air laboratory for analysis. Recommended analyses are gas chromatography–mass spectrometry (GC-MS) to identify potential VOCs (via EPA Method TO-15), and ASTM-D5044 for TRS compounds.

  For the sake of economy Tedlar sample bags are proposed for air sample collection rather than Summa Canisters. Before sampling, local air labs should be consulted to determine which labs would do GC/MS for TO-15 parameters and TRS from Tedlar bags, and what size bag they would need; the lab should supply "pre-cleaned" bags with known background. Two bags (duplicates) are recommended for each analysis (VOC and TRS).

1.2.1 Equipment

- Odalogs with a range that will exceed the highest H2S levels expected, in this case 0-1000 ppm. Detection Instruments offers the LL-H2S-1000 with a 30 day deployment capability.
- Liquid sampler to collect a wastewater sample
- LaMotte dissolved sulfide kit
- Portable pH/ORP/temp probe (Hach HQ11d or equal) or transport to the plant lab for pH.

- Portable ORP probe (may be combined with the pH probe)
- Four Tedlar sampling bags as recommended by the lab
- Flux Chamber and tubing
- N_2 sweep gas
- SKC Sample pump or vacuum chamber

1.2.2 Procedures

1. Hang the OdaLog unit at the influent channel (to pre-screen H_2S levels) for 7-10 days to evaluate the data in order to determine what points in time are of interest. For example a point where the levels are peaking will provide the most concentrated data for VOCs and TRS.
2. After downloading initial data replace the Odalog for an additional 7 - 10 days.
3. At the time selected to measure VOCs/TRS (based on pre-screening above), draw air from the flux chamber into the Tedlar bags with either a vacuum chamber and SKC sampling pump (see attached). Record sample time and other information required on Chain of Custody forms (to be provided by labs). Also review Odalog data (once the unit is removed from its second deployment) to identify and note H_2S concentrations at the time of Tedlar bag sampling.
4. Concurrent with drawing air samples collect liquid samples for dissolved sulfide, temperature, pH, ORP measurements. A minimum of 2 samples should be collected.
5. Ship the air samples to the lab for VOC and TRS analysis.
6. Concurrent with sampling done above in items 3-5 the contribution from the Redwood residential area should be logged with dissolved sulfide grab samples.

1.3 Conclusion

Sampling should be scheduled during a period of time when flow is at an average and not affected by a storm event. The data collected will be integrated with historical data from the plant to support future odor control design efforts.

Appendix J

Influent Wastewater Odor Sampling Results

Odor Sampling Log for Silicon Valley Clean Water

Date: March 2, 2016 Completed by: Melissa Woo and Dane Whitmer

Weather Conditions: Sunny, partly cloudy, breezy to windy; temperatures in the 60's (deg F)

Preliminary Emission Sampling Locations and Methods

No.	Location	Vapor Phase				Liquid Phase				Time	Notes:
		H2S (Odalog)	TRS	VOCs	Velocity[2]	dS (mg/L)	ORP (mV)	pH	Temp (deg C)		
S-L-1	Influent Mix Box					0.3 - 0.4	-261	7.00	20.0	11:20 AM	
S-L-2	Influent Mix Box					-	-272	7.24	20.1	11:30 AM	DO (not calibrated) was at 2.1 mg/L
S-L-3	Influent Mix Box					1.3	-270	7.16	20.1	4:00 PM	DO (not calibrated) was at 1.1 mg/L
S-L-4	Influent Mix Box					1.6	-291	7.16	20.1	4:20 PM	DO (not calibrated) was at 1.9 mg/L
S-TRS-1	Influent Mix Box		Collected		Flux (5 lpm)					4:05 PM	Eurofins Air Toxics - ASTM D-5504
S-TRS-2	Influent Mix Box		Collected		Flux (5 lpm)					4:15 PM	
S-VOC-1	Influent Mix Box			Collected	Flux (5 lpm)					4:10 PM	Eurofins Air Toxics - EPA Method TO-15
S-VOC-2	Influent Mix Box			Collected	Flux (5 lpm)					4:20 PM	
S-H2S-1	Influent Mix Box	1 ppm (instantaneous)								11:20 AM	L2 - 0-1000, recording continuously
S-H2S-2	Influent Mix Box	3 ppm (instantaneous)								3:00 PM	L2 - 0-1000, recording continuously
S-H2S-2	Influent Mix Box	6 ppm (instantaneous)								3:20 PM	L2 - 0-1000, recording continuously

Notes:
1. For TRS and VOCs column, indicate: collected or not collected.
2. For Velocity column, indicate: enclosed, flux chamber, or recorded wind velocity

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3/9/2016
Ms. Melissa Woo
CDM Smith Inc.
12357-A Riata Trace Parkway, Suite 210

Austin TX 78727

Project Name: Silicon Valey Clean Water
Project #: 111171
Workorder #: 1603044A

Dear Ms. Melissa Woo

The following report includes the data for the above referenced project for sample(s) received on 3/3/2016 at Air Toxics Ltd.

The data and associated QC analyzed by TO-15 are compliant with the project requirements or laboratory criteria with the exception of the deviations noted in the attached case narrative.

Thank you for choosing Eurofins Air Toxics Inc. for your air analysis needs. Eurofins Air Toxics Inc. is committed to providing accurate data of the highest quality. Please feel free to the Project Manager: Brian Whittaker at 916-985-1000 if you have any questions regarding the data in this report.

Regards,

Brian Whittaker

Brian Whittaker
Project Manager

A Eurofins Lancaster Laboratories Company

Eurofins Air Toxics, Inc.
180 Blue Ravine Road, Suite B
Folsom, CA 95630
T | 916-985-1000
F | 916-985-1020
www.airtoxics.com

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WORK ORDER #: 1603044A

Work Order Summary

CLIENT:	Ms. Melissa Woo CDM Smith Inc. 12357-A Riata Trace Parkway, Suite 210 Austin, TX 78727	**BILL TO:**	Mr. Bruce Singleton CDM Smith Inc. 15 British American Blvd. Latham, NY 12000
PHONE:	512-346-1100	**P.O. #**	
FAX:	512-345-1483	**PROJECT #**	111171 Silicon Valey Clean Water
DATE RECEIVED:	03/03/2016	**CONTACT:**	Brian Whittaker
DATE COMPLETED:	03/09/2016		

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	FINAL PRESSURE
03A	S-VOC-1	TO-15	Tedlar Bag	Tedlar Bag
04A	S-VOC-2	TO-15	Tedlar Bag	Tedlar Bag
05A	Lab Blank	TO-15	NA	NA
06A	CCV	TO-15	NA	NA
07A	LCS	TO-15	NA	NA
07AA	LCSD	TO-15	NA	NA

CERTIFIED BY: Heidi Hayes (signature) DATE: 03/09/16

Technical Director

Certification numbers: AZ Licensure AZ0775, NJ NELAP - CA016, NY NELAP - 11291,
TX NELAP - T104704343-14-7, UT NELAP CA009332014-5, VA NELAP - 460197, WA NELAP - C935
Name of Accreditation Body: NELAP/ORELAP (Oregon Environmental Laboratory Accreditation Program)
Accreditation number: CA300005, Effective date: 10/18/2014, Expiration date: 10/17/2015.
Eurofins Air Toxics Inc.. certifies that the test results contained in this report meet all requirements of the NELAC standards

180 BLUE RAVINE ROAD, SUITE B FOLSOM, CA - 9563
(916) 985-1000 . (800) 985-5955 . FAX (916) 985-1020

LABORATORY NARRATIVE
EPA Method TO-15
CDM Smith Inc.
Workorder# 1603044A

Two 1 Liter Tedlar Bag samples were received on March 03, 2016. The laboratory performed analysis via EPA Method TO-15 using GC/MS in the full scan mode.

This workorder was independently validated prior to submittal using 'USEPA National Functional Guidelines' as generally applied to the analysis of volatile organic compounds in air. A rules-based, logic driven, independent validation engine was employed to assess completeness, evaluate pass/fail of relevant project quality control requirements and verification of all quantified amounts.

Receiving Notes

There were no receiving discrepancies.

Analytical Notes

All Quality Control Limit exceedances and affected sample results are noted by flags. Each flag is defined at the bottom of this Case Narrative and on each Sample Result Summary page.

Method TO-15 is validated for samples collected in specially treated canisters. As such, the use of Tedlar bags for sample collection is outside the scope of the method and not recommended for ambient or indoor air samples. It is the responsibility of the data user to determine the usability of TO-15 results generated from Tedlar bags.

Definition of Data Qualifying Flags

Eight qualifiers may have been used on the data analysis sheets and indicates as follows:

B - Compound present in laboratory blank greater than reporting limit (background subtraction not performed).

J - Estimated value.

E - Exceeds instrument calibration range.

S - Saturated peak.

Q - Exceeds quality control limits.

U - Compound analyzed for but not detected above the reporting limit, LOD, or MDL value. See data page for project specific U-flag definition.

UJ- Non-detected compound associated with low bias in the CCV

N - The identification is based on presumptive evidence.

File extensions may have been used on the data analysis sheets and indicates as follows:

a-File was requantified

b-File was quantified by a second column and detector

r1-File was requantified for the purpose of reissue

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Summary of Detected Compounds
EPA METHOD TO-15 GC/MS FULL SCAN

Client Sample ID: S-VOC-1

Lab ID#: 1603044A-03A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Freon 12	0.50	0.52	2.5	2.6
Ethanol	2.0	12	3.8	22
Acetone	5.0	6.9	12	16
Tetrahydrofuran	0.50	0.74	1.5	2.2
Chloroform	0.50	4.2	2.4	21
Trichloroethene	0.50	0.63	2.7	3.4
Toluene	0.50	6.0	1.9	23
Ethyl Benzene	0.50	0.52	2.2	2.2
m,p-Xylene	0.50	1.8	2.2	7.7
o-Xylene	0.50	0.63	2.2	2.7
4-Ethyltoluene	0.50	0.73	2.4	3.6
1,2,4-Trimethylbenzene	0.50	0.66	2.4	3.2

Client Sample ID: S-VOC-2

Lab ID#: 1603044A-04A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Ethanol	2.0	7.9	3.8	15
Toluene	0.50	3.2	1.9	12
m,p-Xylene	0.50	1.5	2.2	6.5
o-Xylene	0.50	0.59	2.2	2.6
4-Ethyltoluene	0.50	0.70	2.4	3.5
1,2,4-Trimethylbenzene	0.50	0.60	2.4	3.0

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Client Sample ID: S-VOC-1

Lab ID#: 1603044A-03A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**17030407**	**Date of Collection: 3/2/16 4:10:00 PM**
Dil. Factor:	**1.00**	**Date of Analysis: 3/4/16 02:13 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Freon 12	0.50	0.52	2.5	2.6
Freon 114	0.50	Not Detected	3.5	Not Detected
Chloromethane	5.0	Not Detected UJ	10	Not Detected UJ
Vinyl Chloride	0.50	Not Detected	1.3	Not Detected
1,3-Butadiene	0.50	Not Detected	1.1	Not Detected
Bromomethane	5.0	Not Detected	19	Not Detected
Chloroethane	2.0	Not Detected	5.3	Not Detected
Freon 11	0.50	Not Detected	2.8	Not Detected
Ethanol	2.0	12	3.8	22
Freon 113	0.50	Not Detected	3.8	Not Detected
1,1-Dichloroethene	0.50	Not Detected	2.0	Not Detected
Acetone	5.0	6.9	12	16
2-Propanol	2.0	Not Detected	4.9	Not Detected
Carbon Disulfide	2.0	Not Detected	6.2	Not Detected
3-Chloropropene	2.0	Not Detected	6.3	Not Detected
Methylene Chloride	5.0	Not Detected	17	Not Detected
Methyl tert-butyl ether	0.50	Not Detected	1.8	Not Detected
trans-1,2-Dichloroethene	0.50	Not Detected	2.0	Not Detected
Hexane	0.50	Not Detected	1.8	Not Detected
1,1-Dichloroethane	0.50	Not Detected	2.0	Not Detected
2-Butanone (Methyl Ethyl Ketone)	2.0	Not Detected	5.9	Not Detected
cis-1,2-Dichloroethene	0.50	Not Detected	2.0	Not Detected
Tetrahydrofuran	0.50	0.74	1.5	2.2
Chloroform	0.50	4.2	2.4	21
1,1,1-Trichloroethane	0.50	Not Detected	2.7	Not Detected
Cyclohexane	0.50	Not Detected	1.7	Not Detected
Carbon Tetrachloride	0.50	Not Detected	3.1	Not Detected
2,2,4-Trimethylpentane	0.50	Not Detected	2.3	Not Detected
Benzene	0.50	Not Detected	1.6	Not Detected
1,2-Dichloroethane	0.50	Not Detected	2.0	Not Detected
Heptane	0.50	Not Detected	2.0	Not Detected
Trichloroethene	0.50	0.63	2.7	3.4
1,2-Dichloropropane	0.50	Not Detected	2.3	Not Detected
1,4-Dioxane	2.0	Not Detected	7.2	Not Detected
Bromodichloromethane	0.50	Not Detected	3.4	Not Detected
cis-1,3-Dichloropropene	0.50	Not Detected	2.3	Not Detected
4-Methyl-2-pentanone	0.50	Not Detected	2.0	Not Detected
Toluene	0.50	6.0	1.9	23
trans-1,3-Dichloropropene	0.50	Not Detected	2.3	Not Detected
1,1,2-Trichloroethane	0.50	Not Detected	2.7	Not Detected
Tetrachloroethene	0.50	Not Detected	3.4	Not Detected
2-Hexanone	2.0	Not Detected	8.2	Not Detected

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Client Sample ID: S-VOC-1

Lab ID#: 1603044A-03A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**17030407**	**Date of Collection: 3/2/16 4:10:00 PM**
Dil. Factor:	**1.00**	**Date of Analysis: 3/4/16 02:13 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Dibromochloromethane	0.50	Not Detected	4.2	Not Detected
1,2-Dibromoethane (EDB)	0.50	Not Detected	3.8	Not Detected
Chlorobenzene	0.50	Not Detected	2.3	Not Detected
Ethyl Benzene	0.50	0.52	2.2	2.2
m,p-Xylene	0.50	1.8	2.2	7.7
o-Xylene	0.50	0.63	2.2	2.7
Styrene	0.50	Not Detected	2.1	Not Detected
Bromoform	0.50	Not Detected	5.2	Not Detected
Cumene	0.50	Not Detected	2.4	Not Detected
1,1,2,2-Tetrachloroethane	0.50	Not Detected	3.4	Not Detected
Propylbenzene	0.50	Not Detected	2.4	Not Detected
4-Ethyltoluene	0.50	0.73	2.4	3.6
1,3,5-Trimethylbenzene	0.50	Not Detected	2.4	Not Detected
1,2,4-Trimethylbenzene	0.50	0.66	2.4	3.2
1,3-Dichlorobenzene	0.50	Not Detected	3.0	Not Detected
1,4-Dichlorobenzene	0.50	Not Detected	3.0	Not Detected
alpha-Chlorotoluene	0.50	Not Detected	2.6	Not Detected
1,2-Dichlorobenzene	0.50	Not Detected	3.0	Not Detected
1,2,4-Trichlorobenzene	2.0	Not Detected	15	Not Detected
Hexachlorobutadiene	2.0	Not Detected	21	Not Detected

UJ = Analyte associated with low bias in the CCV and/or LCS.

Container Type: 1 Liter Tedlar Bag

Surrogates	%Recovery	Method Limits
Toluene-d8	99	70-130
1,2-Dichloroethane-d4	91	70-130
4-Bromofluorobenzene	112	70-130

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Client Sample ID: S-VOC-2

Lab ID#: 1603044A-04A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**17030408**	**Date of Collection: 3/2/16 4:20:00 PM**
Dil. Factor:	**1.00**	**Date of Analysis: 3/4/16 02:40 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Freon 12	0.50	Not Detected	2.5	Not Detected
Freon 114	0.50	Not Detected	3.5	Not Detected
Chloromethane	5.0	Not Detected UJ	10	Not Detected UJ
Vinyl Chloride	0.50	Not Detected	1.3	Not Detected
1,3-Butadiene	0.50	Not Detected	1.1	Not Detected
Bromomethane	5.0	Not Detected	19	Not Detected
Chloroethane	2.0	Not Detected	5.3	Not Detected
Freon 11	0.50	Not Detected	2.8	Not Detected
Ethanol	2.0	7.9	3.8	15
Freon 113	0.50	Not Detected	3.8	Not Detected
1,1-Dichloroethene	0.50	Not Detected	2.0	Not Detected
Acetone	5.0	Not Detected	12	Not Detected
2-Propanol	2.0	Not Detected	4.9	Not Detected
Carbon Disulfide	2.0	Not Detected	6.2	Not Detected
3-Chloropropene	2.0	Not Detected	6.3	Not Detected
Methylene Chloride	5.0	Not Detected	17	Not Detected
Methyl tert-butyl ether	0.50	Not Detected	1.8	Not Detected
trans-1,2-Dichloroethene	0.50	Not Detected	2.0	Not Detected
Hexane	0.50	Not Detected	1.8	Not Detected
1,1-Dichloroethane	0.50	Not Detected	2.0	Not Detected
2-Butanone (Methyl Ethyl Ketone)	2.0	Not Detected	5.9	Not Detected
cis-1,2-Dichloroethene	0.50	Not Detected	2.0	Not Detected
Tetrahydrofuran	0.50	Not Detected	1.5	Not Detected
Chloroform	0.50	Not Detected	2.4	Not Detected
1,1,1-Trichloroethane	0.50	Not Detected	2.7	Not Detected
Cyclohexane	0.50	Not Detected	1.7	Not Detected
Carbon Tetrachloride	0.50	Not Detected	3.1	Not Detected
2,2,4-Trimethylpentane	0.50	Not Detected	2.3	Not Detected
Benzene	0.50	Not Detected	1.6	Not Detected
1,2-Dichloroethane	0.50	Not Detected	2.0	Not Detected
Heptane	0.50	Not Detected	2.0	Not Detected
Trichloroethene	0.50	Not Detected	2.7	Not Detected
1,2-Dichloropropane	0.50	Not Detected	2.3	Not Detected
1,4-Dioxane	2.0	Not Detected	7.2	Not Detected
Bromodichloromethane	0.50	Not Detected	3.4	Not Detected
cis-1,3-Dichloropropene	0.50	Not Detected	2.3	Not Detected
4-Methyl-2-pentanone	0.50	Not Detected	2.0	Not Detected
Toluene	0.50	3.2	1.9	12
trans-1,3-Dichloropropene	0.50	Not Detected	2.3	Not Detected
1,1,2-Trichloroethane	0.50	Not Detected	2.7	Not Detected
Tetrachloroethene	0.50	Not Detected	3.4	Not Detected
2-Hexanone	2.0	Not Detected	8.2	Not Detected

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Client Sample ID: S-VOC-2

Lab ID#: 1603044A-04A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**17030408**	**Date of Collection: 3/2/16 4:20:00 PM**
Dil. Factor:	**1.00**	**Date of Analysis: 3/4/16 02:40 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Dibromochloromethane	0.50	Not Detected	4.2	Not Detected
1,2-Dibromoethane (EDB)	0.50	Not Detected	3.8	Not Detected
Chlorobenzene	0.50	Not Detected	2.3	Not Detected
Ethyl Benzene	0.50	Not Detected	2.2	Not Detected
m,p-Xylene	0.50	1.5	2.2	6.5
o-Xylene	0.50	0.59	2.2	2.6
Styrene	0.50	Not Detected	2.1	Not Detected
Bromoform	0.50	Not Detected	5.2	Not Detected
Cumene	0.50	Not Detected	2.4	Not Detected
1,1,2,2-Tetrachloroethane	0.50	Not Detected	3.4	Not Detected
Propylbenzene	0.50	Not Detected	2.4	Not Detected
4-Ethyltoluene	0.50	0.70	2.4	3.5
1,3,5-Trimethylbenzene	0.50	Not Detected	2.4	Not Detected
1,2,4-Trimethylbenzene	0.50	0.60	2.4	3.0
1,3-Dichlorobenzene	0.50	Not Detected	3.0	Not Detected
1,4-Dichlorobenzene	0.50	Not Detected	3.0	Not Detected
alpha-Chlorotoluene	0.50	Not Detected	2.6	Not Detected
1,2-Dichlorobenzene	0.50	Not Detected	3.0	Not Detected
1,2,4-Trichlorobenzene	2.0	Not Detected	15	Not Detected
Hexachlorobutadiene	2.0	Not Detected	21	Not Detected

UJ = Analyte associated with low bias in the CCV and/or LCS.

Container Type: 1 Liter Tedlar Bag

Surrogates	%Recovery	Method Limits
Toluene-d8	100	70-130
1,2-Dichloroethane-d4	92	70-130
4-Bromofluorobenzene	113	70-130

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Client Sample ID: Lab Blank

Lab ID#: 1603044A-05A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**17030406**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis: 3/4/16 12:25 PM**	

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Freon 12	0.50	Not Detected	2.5	Not Detected
Freon 114	0.50	Not Detected	3.5	Not Detected
Chloromethane	5.0	Not Detected UJ	10	Not Detected UJ
Vinyl Chloride	0.50	Not Detected	1.3	Not Detected
1,3-Butadiene	0.50	Not Detected	1.1	Not Detected
Bromomethane	5.0	Not Detected	19	Not Detected
Chloroethane	2.0	Not Detected	5.3	Not Detected
Freon 11	0.50	Not Detected	2.8	Not Detected
Ethanol	2.0	Not Detected	3.8	Not Detected
Freon 113	0.50	Not Detected	3.8	Not Detected
1,1-Dichloroethene	0.50	Not Detected	2.0	Not Detected
Acetone	5.0	Not Detected	12	Not Detected
2-Propanol	2.0	Not Detected	4.9	Not Detected
Carbon Disulfide	2.0	Not Detected	6.2	Not Detected
3-Chloropropene	2.0	Not Detected	6.3	Not Detected
Methylene Chloride	5.0	Not Detected	17	Not Detected
Methyl tert-butyl ether	0.50	Not Detected	1.8	Not Detected
trans-1,2-Dichloroethene	0.50	Not Detected	2.0	Not Detected
Hexane	0.50	Not Detected	1.8	Not Detected
1,1-Dichloroethane	0.50	Not Detected	2.0	Not Detected
2-Butanone (Methyl Ethyl Ketone)	2.0	Not Detected	5.9	Not Detected
cis-1,2-Dichloroethene	0.50	Not Detected	2.0	Not Detected
Tetrahydrofuran	0.50	Not Detected	1.5	Not Detected
Chloroform	0.50	Not Detected	2.4	Not Detected
1,1,1-Trichloroethane	0.50	Not Detected	2.7	Not Detected
Cyclohexane	0.50	Not Detected	1.7	Not Detected
Carbon Tetrachloride	0.50	Not Detected	3.1	Not Detected
2,2,4-Trimethylpentane	0.50	Not Detected	2.3	Not Detected
Benzene	0.50	Not Detected	1.6	Not Detected
1,2-Dichloroethane	0.50	Not Detected	2.0	Not Detected
Heptane	0.50	Not Detected	2.0	Not Detected
Trichloroethene	0.50	Not Detected	2.7	Not Detected
1,2-Dichloropropane	0.50	Not Detected	2.3	Not Detected
1,4-Dioxane	2.0	Not Detected	7.2	Not Detected
Bromodichloromethane	0.50	Not Detected	3.4	Not Detected
cis-1,3-Dichloropropene	0.50	Not Detected	2.3	Not Detected
4-Methyl-2-pentanone	0.50	Not Detected	2.0	Not Detected
Toluene	0.50	Not Detected	1.9	Not Detected
trans-1,3-Dichloropropene	0.50	Not Detected	2.3	Not Detected
1,1,2-Trichloroethane	0.50	Not Detected	2.7	Not Detected
Tetrachloroethene	0.50	Not Detected	3.4	Not Detected
2-Hexanone	2.0	Not Detected	8.2	Not Detected

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Client Sample ID: Lab Blank

Lab ID#: 1603044A-05A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**17030406**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis: 3/4/16 12:25 PM**	

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Dibromochloromethane	0.50	Not Detected	4.2	Not Detected
1,2-Dibromoethane (EDB)	0.50	Not Detected	3.8	Not Detected
Chlorobenzene	0.50	Not Detected	2.3	Not Detected
Ethyl Benzene	0.50	Not Detected	2.2	Not Detected
m,p-Xylene	0.50	Not Detected	2.2	Not Detected
o-Xylene	0.50	Not Detected	2.2	Not Detected
Styrene	0.50	Not Detected	2.1	Not Detected
Bromoform	0.50	Not Detected	5.2	Not Detected
Cumene	0.50	Not Detected	2.4	Not Detected
1,1,2,2-Tetrachloroethane	0.50	Not Detected	3.4	Not Detected
Propylbenzene	0.50	Not Detected	2.4	Not Detected
4-Ethyltoluene	0.50	Not Detected	2.4	Not Detected
1,3,5-Trimethylbenzene	0.50	Not Detected	2.4	Not Detected
1,2,4-Trimethylbenzene	0.50	Not Detected	2.4	Not Detected
1,3-Dichlorobenzene	0.50	Not Detected	3.0	Not Detected
1,4-Dichlorobenzene	0.50	Not Detected	3.0	Not Detected
alpha-Chlorotoluene	0.50	Not Detected	2.6	Not Detected
1,2-Dichlorobenzene	0.50	Not Detected	3.0	Not Detected
1,2,4-Trichlorobenzene	2.0	Not Detected	15	Not Detected
Hexachlorobutadiene	2.0	Not Detected	21	Not Detected

UJ = Analyte associated with low bias in the CCV and/or LCS.

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
Toluene-d8	99	70-130
1,2-Dichloroethane-d4	91	70-130
4-Bromofluorobenzene	108	70-130

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Client Sample ID: CCV

Lab ID#: 1603044A-06A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**17030402**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 3/4/16 09:52 AM**

Compound	%Recovery
Freon 12	91
Freon 114	104
Chloromethane	63 Q
Vinyl Chloride	83
1,3-Butadiene	74
Bromomethane	103
Chloroethane	85
Freon 11	98
Ethanol	78
Freon 113	102
1,1-Dichloroethene	87
Acetone	85
2-Propanol	78
Carbon Disulfide	86
3-Chloropropene	86
Methylene Chloride	83
Methyl tert-butyl ether	87
trans-1,2-Dichloroethene	89
Hexane	78
1,1-Dichloroethane	84
2-Butanone (Methyl Ethyl Ketone)	86
cis-1,2-Dichloroethene	88
Tetrahydrofuran	79
Chloroform	88
1,1,1-Trichloroethane	91
Cyclohexane	85
Carbon Tetrachloride	98
2,2,4-Trimethylpentane	79
Benzene	88
1,2-Dichloroethane	93
Heptane	85
Trichloroethene	91
1,2-Dichloropropane	84
1,4-Dioxane	88
Bromodichloromethane	92
cis-1,3-Dichloropropene	92
4-Methyl-2-pentanone	82
Toluene	94
trans-1,3-Dichloropropene	92
1,1,2-Trichloroethane	91
Tetrachloroethene	106
2-Hexanone	79

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Client Sample ID: CCV

Lab ID#: 1603044A-06A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**17030402**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 3/4/16 09:52 AM**

Compound	%Recovery
Dibromochloromethane	97
1,2-Dibromoethane (EDB)	95
Chlorobenzene	98
Ethyl Benzene	97
m,p-Xylene	98
o-Xylene	96
Styrene	94
Bromoform	111
Cumene	97
1,1,2,2-Tetrachloroethane	88
Propylbenzene	96
4-Ethyltoluene	102
1,3,5-Trimethylbenzene	102
1,2,4-Trimethylbenzene	98
1,3-Dichlorobenzene	104
1,4-Dichlorobenzene	101
alpha-Chlorotoluene	93
1,2-Dichlorobenzene	102
1,2,4-Trichlorobenzene	93
Hexachlorobutadiene	108

Q = Exceeds Quality Control limits.

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
Toluene-d8	101	70-130
1,2-Dichloroethane-d4	86	70-130
4-Bromofluorobenzene	113	70-130

Client Sample ID: LCS

Lab ID#: 1603044A-07A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	17030403	Date of Collection: NA	
Dil. Factor:	1.00	Date of Analysis: 3/4/16 10:17 AM	

Compound	%Recovery	Method Limits
Freon 12	96	70-130
Freon 114	112	70-130
Chloromethane	78	70-130
Vinyl Chloride	87	70-130
1,3-Butadiene	73	70-130
Bromomethane	112	70-130
Chloroethane	87	70-130
Freon 11	102	70-130
Ethanol	84	70-130
Freon 113	102	70-130
1,1-Dichloroethene	88	70-130
Acetone	80	70-130
2-Propanol	84	70-130
Carbon Disulfide	77	70-130
3-Chloropropene	83	70-130
Methylene Chloride	80	70-130
Methyl tert-butyl ether	87	70-130
trans-1,2-Dichloroethene	92	70-130
Hexane	80	70-130
1,1-Dichloroethane	82	70-130
2-Butanone (Methyl Ethyl Ketone)	87	70-130
cis-1,2-Dichloroethene	87	70-130
Tetrahydrofuran	80	70-130
Chloroform	88	70-130
1,1,1-Trichloroethane	92	70-130
Cyclohexane	87	70-130
Carbon Tetrachloride	99	70-130
2,2,4-Trimethylpentane	83	70-130
Benzene	91	70-130
1,2-Dichloroethane	94	70-130
Heptane	89	70-130
Trichloroethene	94	70-130
1,2-Dichloropropane	87	70-130
1,4-Dioxane	93	70-130
Bromodichloromethane	96	70-130
cis-1,3-Dichloropropene	89	70-130
4-Methyl-2-pentanone	86	70-130
Toluene	97	70-130
trans-1,3-Dichloropropene	94	70-130
1,1,2-Trichloroethane	94	70-130
Tetrachloroethene	110	70-130
2-Hexanone	86	70-130

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Client Sample ID: LCS

Lab ID#: 1603044A-07A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**17030403**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 3/4/16 10:17 AM**

Compound	%Recovery	Method Limits
Dibromochloromethane	102	70-130
1,2-Dibromoethane (EDB)	99	70-130
Chlorobenzene	101	70-130
Ethyl Benzene	100	70-130
m,p-Xylene	100	70-130
o-Xylene	101	70-130
Styrene	101	70-130
Bromoform	119	70-130
Cumene	102	70-130
1,1,2,2-Tetrachloroethane	93	70-130
Propylbenzene	103	70-130
4-Ethyltoluene	109	70-130
1,3,5-Trimethylbenzene	109	70-130
1,2,4-Trimethylbenzene	109	70-130
1,3-Dichlorobenzene	109	70-130
1,4-Dichlorobenzene	108	70-130
alpha-Chlorotoluene	103	70-130
1,2-Dichlorobenzene	108	70-130
1,2,4-Trichlorobenzene	109	70-130
Hexachlorobutadiene	118	70-130

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
Toluene-d8	102	70-130
1,2-Dichloroethane-d4	92	70-130
4-Bromofluorobenzene	113	70-130

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Client Sample ID: LCSD

Lab ID#: 1603044A-07AA

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**17030404**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 3/4/16 10:42 AM**

Compound	%Recovery	Method Limits
Freon 12	97	70-130
Freon 114	112	70-130
Chloromethane	81	70-130
Vinyl Chloride	88	70-130
1,3-Butadiene	74	70-130
Bromomethane	114	70-130
Chloroethane	89	70-130
Freon 11	104	70-130
Ethanol	85	70-130
Freon 113	104	70-130
1,1-Dichloroethene	89	70-130
Acetone	83	70-130
2-Propanol	84	70-130
Carbon Disulfide	77	70-130
3-Chloropropene	82	70-130
Methylene Chloride	81	70-130
Methyl tert-butyl ether	89	70-130
trans-1,2-Dichloroethene	91	70-130
Hexane	82	70-130
1,1-Dichloroethane	83	70-130
2-Butanone (Methyl Ethyl Ketone)	87	70-130
cis-1,2-Dichloroethene	88	70-130
Tetrahydrofuran	80	70-130
Chloroform	89	70-130
1,1,1-Trichloroethane	93	70-130
Cyclohexane	88	70-130
Carbon Tetrachloride	101	70-130
2,2,4-Trimethylpentane	84	70-130
Benzene	90	70-130
1,2-Dichloroethane	94	70-130
Heptane	89	70-130
Trichloroethene	93	70-130
1,2-Dichloropropane	87	70-130
1,4-Dioxane	93	70-130
Bromodichloromethane	96	70-130
cis-1,3-Dichloropropene	88	70-130
4-Methyl-2-pentanone	88	70-130
Toluene	97	70-130
trans-1,3-Dichloropropene	93	70-130
1,1,2-Trichloroethane	93	70-130
Tetrachloroethene	110	70-130
2-Hexanone	87	70-130

eurofins | Air Toxics

Client Sample ID: LCSD

Lab ID#: 1603044A-07AA

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**17030404**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 3/4/16 10:42 AM**

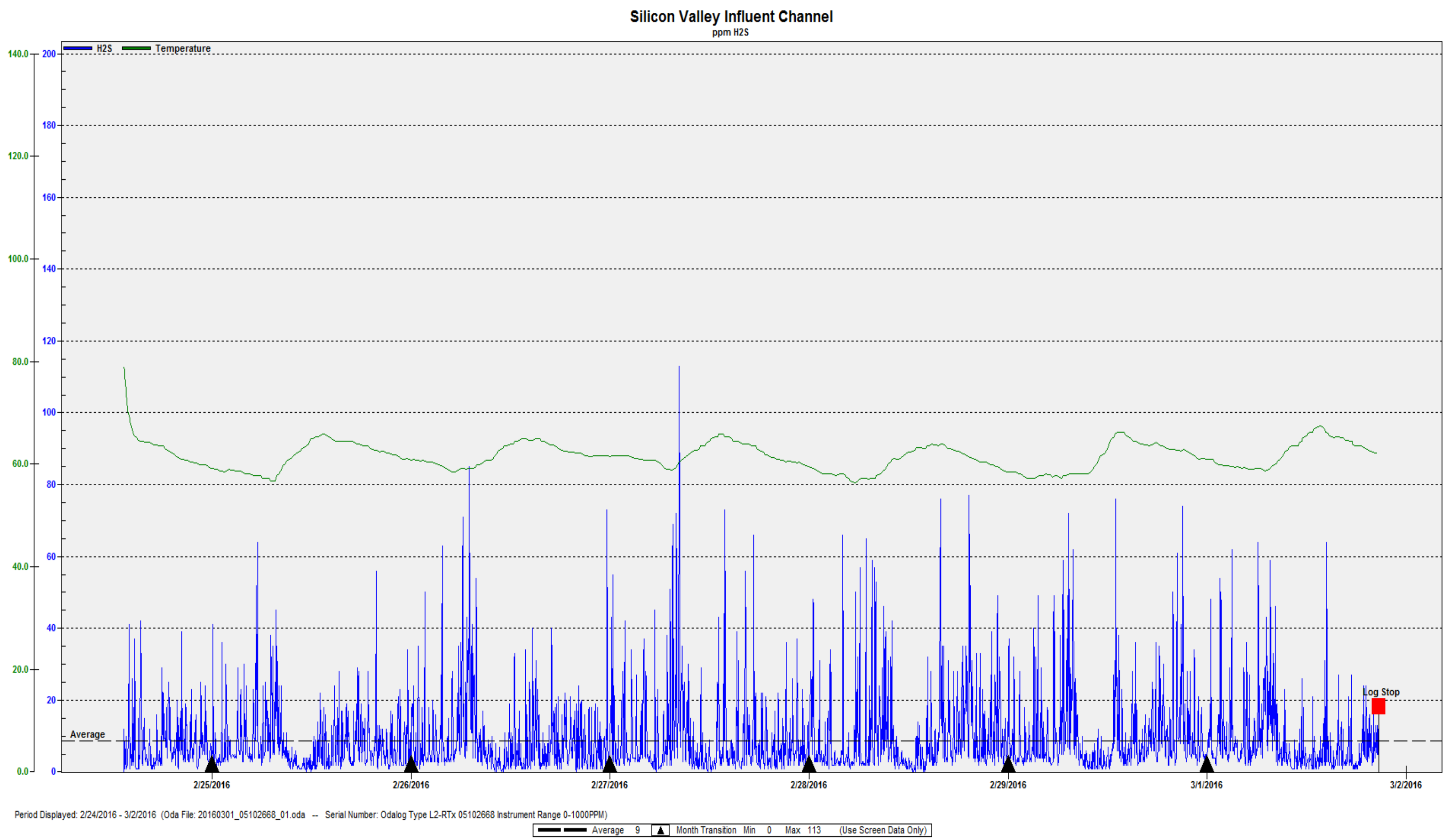
Compound	%Recovery	Method Limits
Dibromochloromethane	102	70-130
1,2-Dibromoethane (EDB)	99	70-130
Chlorobenzene	102	70-130
Ethyl Benzene	100	70-130
m,p-Xylene	101	70-130
o-Xylene	103	70-130
Styrene	101	70-130
Bromoform	119	70-130
Cumene	102	70-130
1,1,2,2-Tetrachloroethane	93	70-130
Propylbenzene	103	70-130
4-Ethyltoluene	111	70-130
1,3,5-Trimethylbenzene	108	70-130
1,2,4-Trimethylbenzene	110	70-130
1,3-Dichlorobenzene	111	70-130
1,4-Dichlorobenzene	109	70-130
alpha-Chlorotoluene	104	70-130
1,2-Dichlorobenzene	110	70-130
1,2,4-Trichlorobenzene	120	70-130
Hexachlorobutadiene	129	70-130

Container Type: NA - Not Applicable

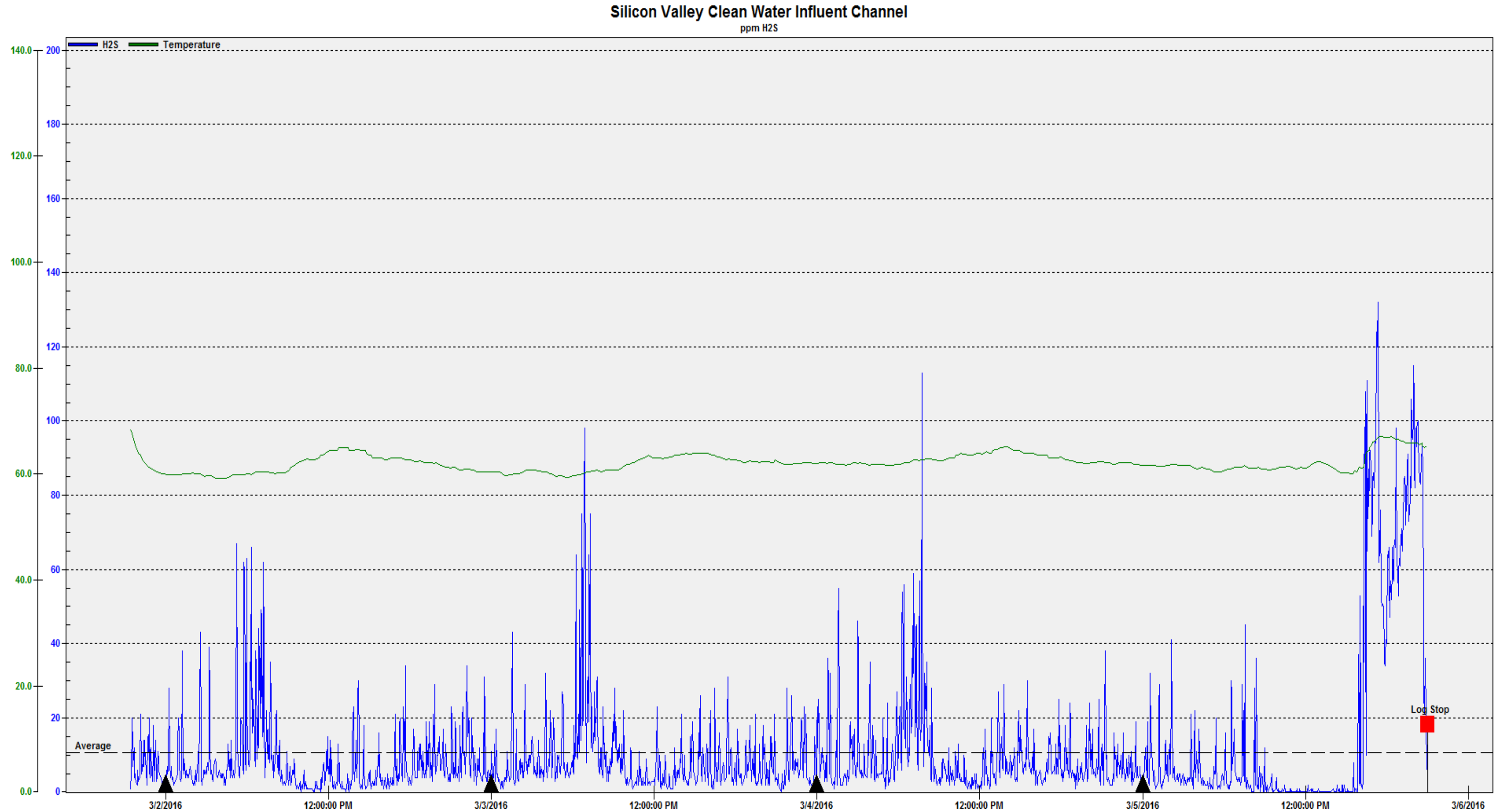
Surrogates	%Recovery	Method Limits
Toluene-d8	102	70-130
1,2-Dichloroethane-d4	92	70-130
4-Bromofluorobenzene	113	70-130

LABSAMPID	LABCODE	MATRIX	METHOD	CLIENTSAMPID	SAMPDATE	ANALDATE	ANALTIME	LABCTLID	DILUTION	REPLMT	UNITS	RESULTS	DATAFLAGS	COMPOUND NAME	CASNUM	COMMENTS
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV	110		Hydrogen Sulfide	7783-06-4	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	Carbonyl Sulfide	463-58-1	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV	11		Methyl Mercaptan	74-93-1	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	Ethyl Mercaptan	75-08-1	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	Dimethyl Sulfide	75-18-3	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	20	PPBV		ND	Carbon Disulfide	75-15-0	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	Isopropyl Mercaptan	75-33-2	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	tert-Butyl Mercaptan	75-66-1	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	n-Propyl Mercaptan	107-03-9	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	Ethyl Methyl Sulfide	624-89-5	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	Thiophene	110-02-1	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	Isobutyl Mercaptan	513-44-0	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	Diethyl Sulfide	352-93-2	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	n-Butyl Mercaptan	109-79-5	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	Dimethyl Disulfide	624-92-0	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	3-Methylthiophene	616-44-4	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	Tetrahydrothiophene	110-01-0	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	2-Ethylthiophene	872-55-9	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	2,5-Dimethylthiophene	638-02-8	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	4.0	PPBV		ND	Diethyl Disulfide	110-81-6	
1603044B-01A	ATL	AIR	ASTM D-5504	S-TRS-1	03/02/2016	03/03/2016	1123	gck03Mar2016	1.00	20	PPBV	130		Total Reduced Sulfur ref. to H2S (MW=34)	NA	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV	1400		Hydrogen Sulfide	7783-06-4	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	Carbonyl Sulfide	463-58-1	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV	72		Methyl Mercaptan	74-93-1	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	Ethyl Mercaptan	75-08-1	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	Dimethyl Sulfide	75-18-3	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	120	PPBV		ND	Carbon Disulfide	75-15-0	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	Isopropyl Mercaptan	75-33-2	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	tert-Butyl Mercaptan	75-66-1	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	n-Propyl Mercaptan	107-03-9	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	Ethyl Methyl Sulfide	624-89-5	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	Thiophene	110-02-1	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	Isobutyl Mercaptan	513-44-0	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	Diethyl Sulfide	352-93-2	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	n-Butyl Mercaptan	109-79-5	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	Dimethyl Disulfide	624-92-0	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	3-Methylthiophene	616-44-4	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	Tetrahydrothiophene	110-01-0	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	2-Ethylthiophene	872-55-9	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	2,5-Dimethylthiophene	638-02-8	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	24	PPBV		ND	Diethyl Disulfide	110-81-6	
1603044B-02A	ATL	AIR	ASTM D-5504	S-TRS-2	03/02/2016	03/03/2016	1300	gck03Mar2016	6.00	120	PPBV	1400		Total Reduced Sulfur ref. to H2S (MW=34)	NA	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	Hydrogen Sulfide	7783-06-4	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	Carbonyl Sulfide	463-58-1	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	Methyl Mercaptan	74-93-1	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	Ethyl Mercaptan	75-08-1	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	Dimethyl Sulfide	75-18-3	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	20	PPBV		ND	Carbon Disulfide	75-15-0	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	Isopropyl Mercaptan	75-33-2	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	tert-Butyl Mercaptan	75-66-1	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	n-Propyl Mercaptan	107-03-9	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	Ethyl Methyl Sulfide	624-89-5	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	Thiophene	110-02-1	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	Isobutyl Mercaptan	513-44-0	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	Diethyl Sulfide	352-93-2	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	n-Butyl Mercaptan	109-79-5	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	Dimethyl Disulfide	624-92-0	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	3-Methylthiophene	616-44-4	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	Tetrahydrothiophene	110-01-0	
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016	2226	gck03Mar2016	1.00	4.0	PPBV		ND	2-Ethylthiophene	872-55-9	

1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016 2226	gck03Mar2016	1.00	4.0	PPBV		ND	2,5-Dimethylthiophene	638-02-8
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016 2226	gck03Mar2016	1.00	4.0	PPBV		ND	Diethyl Disulfide	110-81-6
1603044B-03A	ATL	AIR	ASTM D-5504	Lab Blank	00:00	03/02/2016 2226	gck03Mar2016	1.00	20	PPBV		ND	Total Reduced Sulfur ref. to H2S (MW=34)	NA
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	118		Hydrogen Sulfide	7783-06-4
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	81		Carbonyl Sulfide	463-58-1
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	100		Methyl Mercaptan	74-93-1
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	92		Ethyl Mercaptan	75-08-1
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	96		Dimethyl Sulfide	75-18-3
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	99		Carbon Disulfide	75-15-0
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	95		Isopropyl Mercaptan	75-33-2
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	96		tert-Butyl Mercaptan	75-66-1
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	99		n-Propyl Mercaptan	107-03-9
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	101		Ethyl Methyl Sulfide	624-89-5
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	96		Thiophene	110-02-1
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	96		Isobutyl Mercaptan	513-44-0
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	98		Diethyl Sulfide	352-93-2
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	97		n-Butyl Mercaptan	109-79-5
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	103		Dimethyl Disulfide	624-92-0
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	103		3-Methylthiophene	616-44-4
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	108		Tetrahydrothiophene	110-01-0
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	119		2-Ethylthiophene	872-55-9
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	120		2,5-Dimethylthiophene	638-02-8
1603044B-04A	ATL	AIR	ASTM D-5504	LCS	00:00	03/02/2016 2135	gck03Mar2016	1.00		%R	122		Diethyl Disulfide	110-81-6
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	110		Hydrogen Sulfide	7783-06-4
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	81		Carbonyl Sulfide	463-58-1
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	97		Methyl Mercaptan	74-93-1
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	97		Ethyl Mercaptan	75-08-1
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	97		Dimethyl Sulfide	75-18-3
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	98		Carbon Disulfide	75-15-0
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	94		Isopropyl Mercaptan	75-33-2
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	95		tert-Butyl Mercaptan	75-66-1
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	99		n-Propyl Mercaptan	107-03-9
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	103		Ethyl Methyl Sulfide	624-89-5
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	96		Thiophene	110-02-1
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	96		Isobutyl Mercaptan	513-44-0
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	100		Diethyl Sulfide	352-93-2
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	101		n-Butyl Mercaptan	109-79-5
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	104		Dimethyl Disulfide	624-92-0
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	107		3-Methylthiophene	616-44-4
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	110		Tetrahydrothiophene	110-01-0
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	120		2-Ethylthiophene	872-55-9
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	120		2,5-Dimethylthiophene	638-02-8
1603044B-04AA	ATL	AIR	ASTM D-5504	LCSD	00:00	03/02/2016 2159	gck03Mar2016	1.00		%R	123		Diethyl Disulfide	110-81-6



Silicon Valley Influent Channel
ppm H2S
H2S
Temperature
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
200
180
160
140
120
100
80
60
40
20
0
Average
Log Stop
2/25/2016
2/26/2016
2/27/2016
2/28/2016
2/29/2016
3/1/2016
3/2/2016
Period Displayed: 2/24/2016 - 3/2/2016 (Oda File: 20160301_05102668_01.oda -- Serial Number: Odalog Type L2-RTx 05102668 Instrument Range 0-1000PPM)
Average 9
Month Transition Min 0 Max 113 (Use Screen Data Only)



Period Displayed: 3/1/2016 - 3/6/2016 (Oda File: 20160305_05102668_01.oda -- Serial Number: Odalog Type L2-RTx 05102668 Instrument Range 0-1000PPM)

Average 11 ▲ Day Transition Min 0 Max 132 (Use Screen Data Only)

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Appendix K

Multi-Stage Chemical Scrubber Brochure

LO/PRO® Packaged Odor Control System

Evoqua Water Technologies offers a full range of chemical scrubber odor control systems for municipal and industrial odor control.

LO/PRO Multi-Stage Scrubber

The patented LO/PRO® multi-stage scrubber system is the most efficient and versatile chemical odor control system available. By promoting different chemical reactions in each stage, the LO/PRO system can target a range of compounds in a single scrubber system.

The LO/PRO can treat up to 30,000 cfm (50,000 m^3/h) of odorous air in a single scrubber with very compact footprint. Because of the low profile it may easily be installed indoors or outdoors.

Standard Configuration

In the standard configuration, the first stage uses NaOH to remove 70% of the H_2S. The second and third stages use NaOH and NaOCl to remove the remaining H_2S and organic odors. This multi-chemistry system reduces chemical costs to less than half that required by conventional packed tower scrubbers.

Special Configurations

The LO/PRO system may also be configured to remove ammonia and amines in the first stage using H_2SO_4, and then remove H_2S and organic odors in the second and third stages using NaOH and NaOCl. This configuration is well suited to dewatering and solids handling operations , where lime stabilization causes ammonia and amine odors.

When operating at high ORP levels the LO/PRO is very efficient at oxidizing mercaptans and organic sulfides. In such systems a final NaOH stage may be used to prevent any residual chlorine odors.

Standard Features

- Patented Multi-stage Odor Control Process
- Removes H2S, Mercaptans, Organic Sulfides, Ammonia and Amines in One System
- Low Profile enables indoor installations
- Factory Assembled for near "Plug & Play" Installation
- FRP Construction
- Service and Support

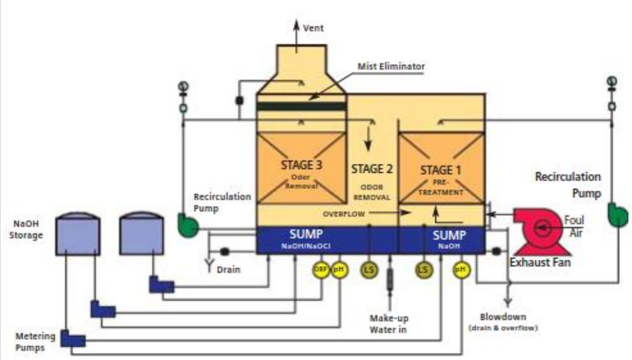
evoqua
WATER TECHNOLOGIES

The LO/PRO Design Information

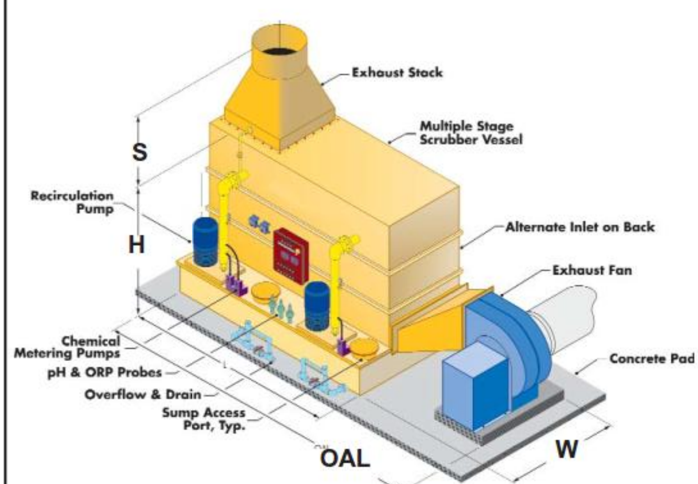
Model	Airflow Rate*	Dimensions LxWxH	Overall Length (OAL)	Shipping Wt	Operating Wt	Fan Motor	Recirc Pump Motors
Unit	cfm	ft	ft	lbs	lbs	HP	HP
LP-1500	1,000	4.50 x 4.00 x 8.50	9.0	1,000	3,500	5.0	3.5
LP-1750	1,300	5.25 x 4.25 x 9.25	10.0	1,600	4,500	5.0	5.0
LP-2000	1,700	6.00 x 4.50 x 9.25	11.0	2,200	6,000	7.5	7.0
LP-2250	2,200	6.75 x 4.75 x 9.25	12.5	2,500	7,000	7.5	8.0
LP-2500	2,700	7.50 x 5.00 x 9.50	13.0	1,100	8,000	7.5	8.0
LP-2750	3,300	8.25 x 5.25 x 9.50	15.0	3,700	9,500	7.5	10.0
LP-3000	4,000	9.00 x 5.50 x 10.50	15.5	4,400	11,000	10	10.0
LP-3500	5,500	8.75 x 6.00 x 11.00	16.0	5,000	12,000	15	10.0
LP-4000	7,100	10.00 x 6.50 x 11.00	17.5	5,600	14,500	15	12.5
LP-4500	9,100	11.25 x 7.00 x 11.25	19.5	6,200	17,000	20	12.5
LP-5000	11,200	12.50 x 7.50 x 11.50	20.5	6,800	19,500	25	15.0
LP-5500	13,600	13.75 x 8.00 x 11.75	22.0	7,500	22,000	30	17.5
LP-6000	16,200	15.00 x 8.50 x 12.00	24.0	8,300	22,500	40	17.5
LP-6500	20,000	16.25 x 9.00 x 12.25	26.0	9,100	28,500	50	25.0
LP-7000	24,500	17.50 x 9.50 x 12.50	27.0	10,000	32,000	60	35.0
LP-7000Q	30,000	28.00 x 9.50 x 12.50	38.0	16,000	51,000	100	35.0

** Standard Exhaust Stack "S" is six feet*

Process Flow Diagram



Isometric Drawing



Evoqua
Water Technologies
12316 World Trade Drive, Suite 100
San Diego, California 92128
Phone: 858-487-2200

OC-RJLOUSAdr-DS-0108

Subject to change without prior notice.

The United States and Trademark Office has recognized the novelty of the design of the LO/PRO with the award of two patents (U.S. Patent Nos. 5,876,662 & 6,174,498) An additional patent is now pending.

The information provided in this literature contains merely general descriptions or characteristics of performance which in actual case of use do not always apply as described or which may change as a result of further development of the products. An obligation to provide the respective characteristics shall only exist if expressly agreed in the terms of the contract.

Appendix L

Chemical Demand Calculations

Odor Control Front of Plant (FoP) Chemical Calculations

CLIENT: **SVCW**

PROJECT **Silicon Valley**

JOB NO.:

FILE NAMI **FOP Chemcial Calcs**

FILE LOC/ **PW**

COMPUTE **BJS** DATE: **12/1/3016**

CHECKED BY: DATE:

REVIEWED BY: DATE:

Location: **FOP**

CALCULATIONS:

DESCRIPTION:

Chemical calculations for NaOH and NaOCl for the chemical scrubbers at the FOP

30,000 cfm at 10 ppm H2S

Fop Calculations

Q =	Air Flow/Scrubber*	30,000	cfm				
y1 =	H2S in	10	ppm	1.59375	lb/hr	38.25	lb/day
y2 =	H2S out	0.1	ppm	0.015938	lb/hr	0.38	lb/day
	TRS in	2	ppm	0.674009	lb/hr	16.18	lb/day
	TRS out	1	ppm	0.000112	lb/hr	0.00	lb/day
	NH3 in	0	ppm	0	lb/hr	0.00	lb/day
	NH3 Out	0	ppm	0	lb/hr	0.00	lb/day
n =	H2S Removal	99.00%		1.577813	lb/hr	37.87	lb/day
	Blowdown rate =	2.00%					
	Liquid loading (recycle) =	260	gpm				

H_2S - Caustic Use

H_2S + 2 NaOH ---> Na_2S + 2 H_2O
1 mole H_2S reacts with 2 moles NaOH
34 lb H_2S reacts with 80 lb NaOH
or 2.35 lb NaOH per lb H_2S

H2S removal % 99

NaOH = 88.99 lb_{NaOH}/day

Assume 25% caustic is used — density = 2.7 $lb_{NaOH}/gal_{25\%}$

$NaOH_{25}$ = 33 gal/day

1.37 gph

CO_2 - Caustic Use

Per Waltrip, 1984

Assume 10% CO_2 removed at pH 11.5
Assume atmospheric CO_2 = 400 ppm
Equates to approx 0.4 lb $NaOH_{25}$ per lb CO_2 applied

2NaOH + CO_2 = Na_2CO

CO_2 removed	8	lb/hr
NaOH @ 0.55lb_{CO2}/lb_{NaOH}	4.54	lb_{NaOH}/hr
$NaOH_{25}$ =	18.15	lb/hr
$NaOH_{25}$ =	6.72	gph

Assume 2500 mg/L in the sump and a blowdown rate given above as % and recycle rate.

NaOH =	156.12	lb/day
NaOH =	6.51	lb/hr
$NaOH_{25}$ =	26.02	lb/hr
$NaOH_{25}$ =	9.64	gph

Total Caustic Use **17.73 gph** as 25% NaOH

Caustic Use - Second Stage

Assume only 90% removed in first stage (Conservative)
Assume CO_2 does not consume any NaOH because pH is less than 9

NaOH =	8.94	lb/day
$NaOH_{25}$ =	35.78	lb/day
$NaOH_{25}$ =	**0.55**	**gph**

Assume 2500 mg/L in the sump and a blowdown rate given above as % and recycle rate.

NaOH =	156.12	lb/day
NaOH =	6.51	lb/hr
$NaOH_{25}$ =	26.02	lb/hr
$NaOH_{25}$ =	9.64	gph

Waste rate governs **10.19 gph**

Hypochlorite Use

H_2S + 4NaOCl + 2 NaOH --> Na_2SO_4 + 4NaCl+2 H_2O
1 mole H_2S reacts with 4 moles NaOCl
34 lb H_2S reacts with 298 lb NaOCl
or 8.76 lb NaOCl per lb H_2S

Assume 90% H_2S removal and 10% TRS Compound removal in first stage (conservative for sizing)

H_2S in =	0.16 lb/hr	
TRS in=	0.67 lb/hr	
NaOCl =	7.30 lb/hr	second stage

Assume 12.5% hypo is used density = 10.56 lb/gal

$NaOCl_{12.5}$ =	58 lb/hr	second stage
$NaOCl_{12.5}$ =	**5.5 gph**	**second stage**

Assume 2500 mg/L in the sump and a blowdown rate given above as % and recycle rate.

NaOCl =	156.12 lb/day
NaOCl =	6.51 lb/hr
$NaOCl_{12.5}$ =	52.04 lb/hr
$NaOCl_{12.5}$ =	4.93 gph

Note, if the blowdown from the first stage scrubber is returned to the plant ahead of the aeration basins, some hydrogen sulfide may be released to the atmosphere in order to prevent this, the blowdown stream should be fully or partially oxidized. Under the worst case condition, all of the hydrogen sulfide removed by the system would be oxidized by hypochlorite. Hypochlorite feed would then have to be:

8.3 **first stage max.**

This flow rate will not be sufficient to oxidize blowdown under maximum conditions
I consider such a condition too conservative and the pump will not be able to
turn down to dose under average conditions or anything less than average.

Specify first stage pumps at this rate, which will be equivalent to second stage
stage pumps at design peak.

Caustic Storage

Design for 14 days consumption under average conditions, but no less than 1000 gal
as this is a stand-alone facility

Average consumption - all uses @ 25% strength

27.92	gph	
670.1	gpd	
9381.9	gal	for 14 day's storage

Use	**9,000**	**gal**
Providing	**13.4**	**days of storage under average conditions**

Hypochlorite Storage

Design for 14 days consumption at average conditions assuming that hypochlorite is added to
the first stage. This will account for oxidizing the blow-down, if it is needed to prevent re-release.

5.5	gph	
132.7	gpd	
1858.3	gal	for 14 day's storage

Use	**3,000**	**gal**
Providing	**22.6**	**days of storage under average conditions**

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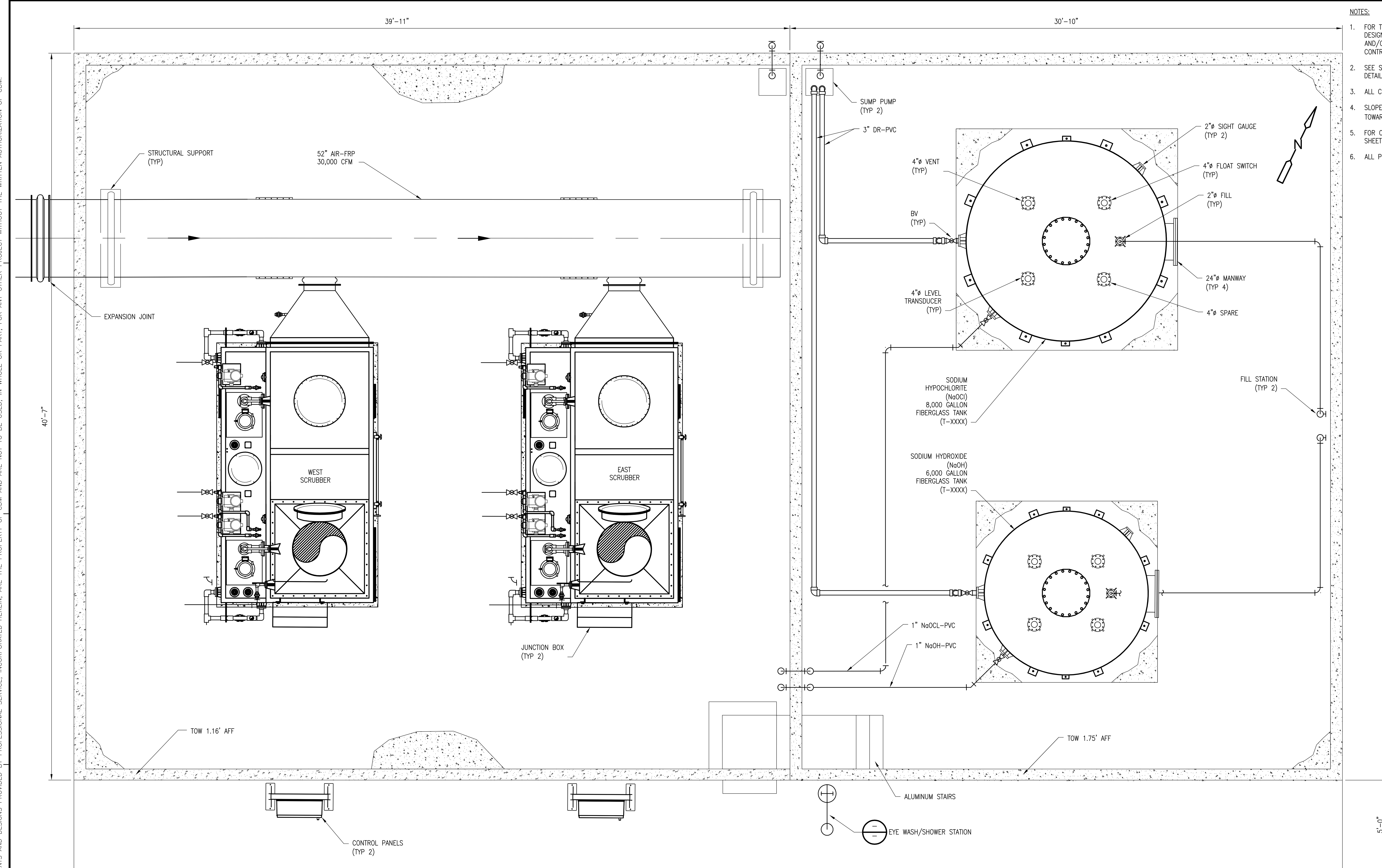
Appendix M

FoP Odor Control Facility Conceptual Mechanical Layout



NOTES:

1. FOR THE ASSOCIATED SEISMIC AND WIND LOADING DESIGN DATA AND INSPECTION REQUIREMENTS, DESIGNER AND/OR MANUFACTURE'S ENGINEER SHALL SEE THE CONTRACT STRUCTURAL DRAWINGS.
2. SEE STRUCTURAL DRAWINGS FOR STRUCTURAL SUPPORT DETAILS ON ____.
3. ALL CHEMICAL PIPING SHALL BE DOUBLE WALLED.
4. SLOPE AREAS WITHIN SECONDARY CONTAINMENT TOWARDS SUMPS AT MIN SLOPE OF 1/8" PER FOOT.
5. FOR CANOPY OVER CHEMICAL STORAGE TANKS, SEE SHEET ____.
6. ALL PRESSURE SENSOR TUBING SHALL BE 316SS.

PRELIMINARY - NOT FOR CONSTRUCTION

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY:
DRAWN BY:
SHEET CHK'D BY:
CROSS CHK'D BY:
APPROVED BY:
DATE: SEPTEMBER 2015

CDM Smith
100 Pringle Ave, Suite 300
Walnut Creek, CA 94596
Tel: (925) 933-2900
Fax (925) 933-4174

SVCW Silicon Valley Clean Water

Silicon Valley Clean Water
Redwood City, California

HEADWORKS ODOR CONTROL
DRAFT LAYOUT 1

PROJECT NO. 76558-XXXXXX
FILE NAME: SVCWOC01
SHEET NO.
OC-1

Appendix N

Headworks Early Startup Technical Memorandum

Technical Memorandum

To: *Bill Bryan, SVCW*

From: *Jan Davel*

Prepared By: *Dane Whitmer, CDM Smith*
Bill Schilling, CDM Smith

Date: *December 13, 2016*

Subject: *Headworks Facility Project - Early Startup of Headworks Facility*

1.0 Introduction

Silicon Valley Clean Water (SVCW) is implementing a Capital Improvement Program (CIP) to improve the reliability of their conveyance system and wastewater treatment plant (WWTP). The CIP includes rehabilitation and repurposing of several collection system pump stations and installation of the following facilities:

- Gravity Pipeline to replace the existing 54-inch forcemain that conveys wastewater to the treatment plant
- Receiving Lift Station (RLS) located on the treatment plant site at the end of the new Gravity Pipeline
- Headworks Facility to remove screenings and grit from influent wastewater
- Influent Connector Pipes (ICP) to convey flow from the Headworks Facility to the primary clarifiers
- Odor control facilities to treat foul air venting from the gravity tunnel, RLS and Headworks Facility, referred to as the Front of Plant (FoP) Odor Control Facilities

SVCW is evaluating the feasibility of constructing, testing and accepting the Headworks Facility approximately 18 months before the other facilities listed above. The purpose of this memo is to summarize the conceptual approach for an early startup of the Headworks Facility and to discuss the advantages challenges and costs of the early startup.

2.0 Existing Conditions

Figures 1 and 2 below, show the current configuration of the influent conveyance and preliminary treatment facilities at the SVCW WWTP. The influent conveyance and preliminary treatment facilities consist of a 54-inch reinforced concrete force main, an Influent Lift Station (ILS), an Influent Mix Box, and a Screen Facility. The Influent Mix Box is located at the outlet of the 54-inch force main and the suction pipes for the ILS pipe are connected to the 54-inch force main, just upstream of the Influent Mix Box. These facilities are also shown in Figure 5 at the end of this TM.

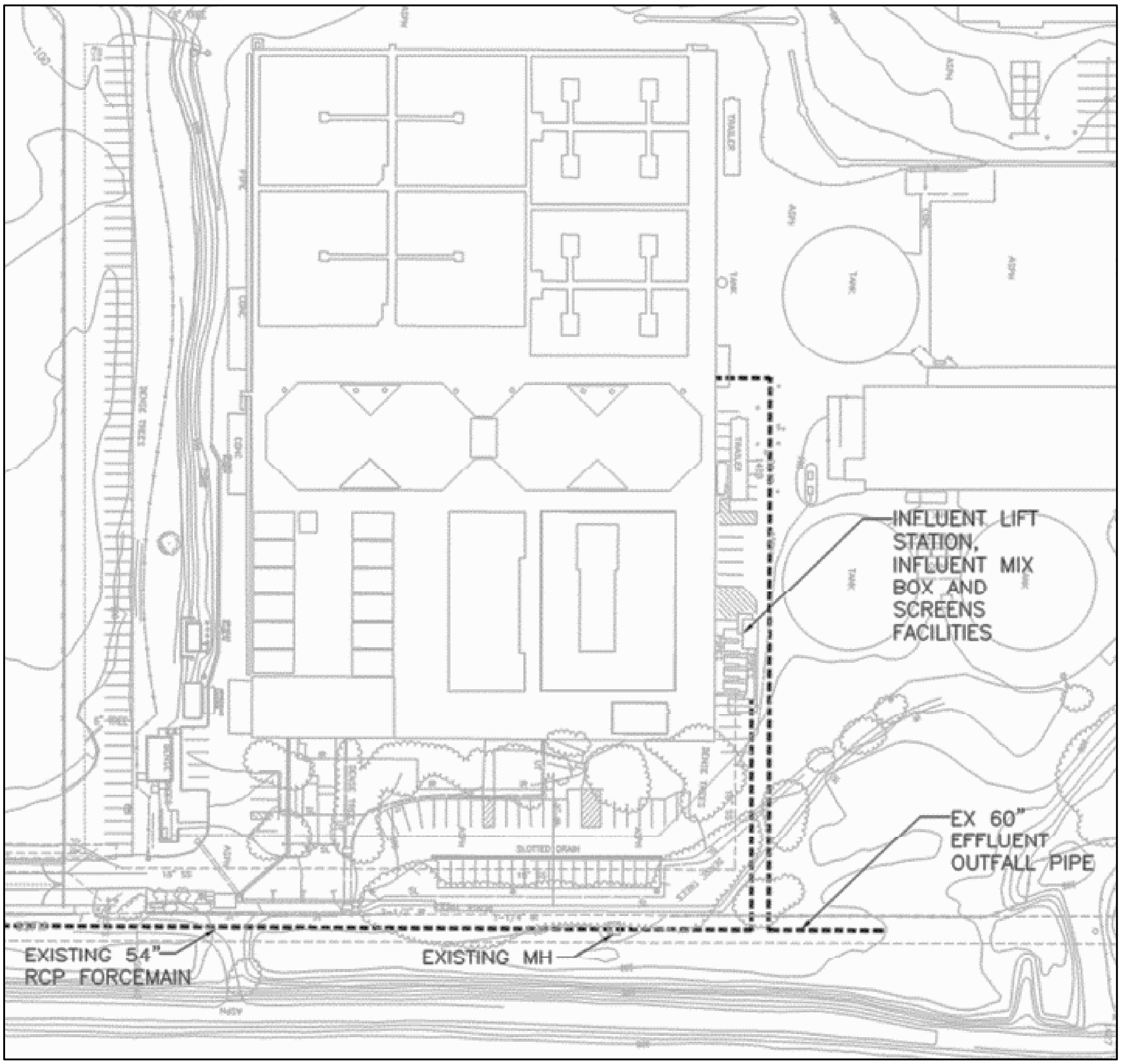


Figure 1
Existing SVCW Influent Conveyance Facilities Site Plan

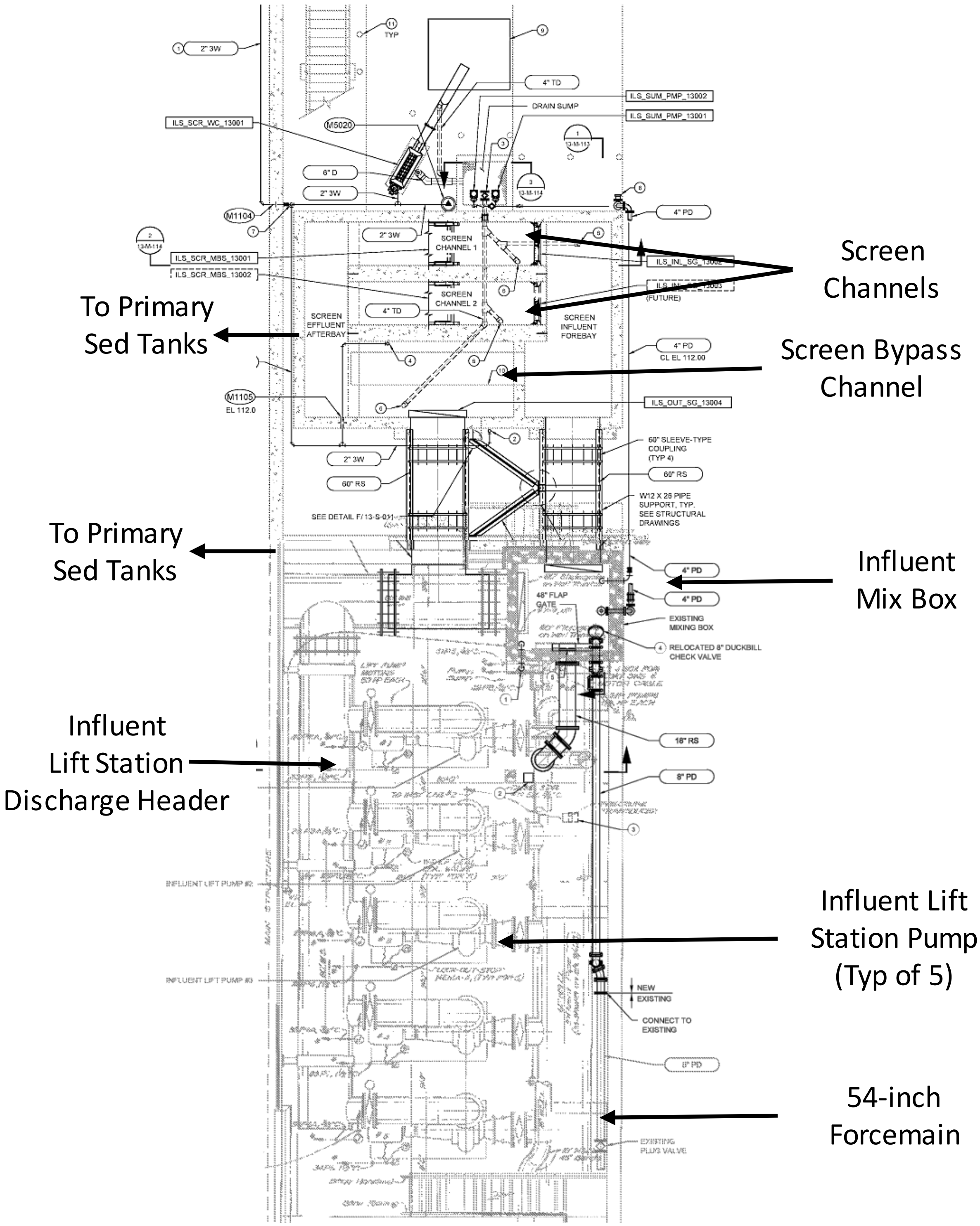


Figure 2
Existing SVCW Influent Conveyance Facilities Mechanical Plan

Under dry weather conditions, raw sewage is pumped through the existing 54-inch force main, past the suction pipes for the ILS pumps, which are normally off, directly to the existing Influent Mix Box. The Influent Mix Box then directs flow to either the Screen Facility or the Primary Settling Tanks. Flow is normally sent to the Screen Facility, but can be diverted to the Primary Settling Tanks when the Screen Facility needs to be shut down for maintenance, high flow wet weather events or other reasons.

Under wet weather conditions, the ILS pumps are started, causing a knuckle valve (flap gate) to be drawn closed inside the Influent Mix Box. Under these conditions, the ILS pumps withdraw sewage from the 54-inch force main and discharge it directly to the Primary Settling Tanks. The influent conveyance and preliminary treatment facilities are operated in this manner during wet weather conditions to reduce the pressure in the existing 54-inch force main. The ILS pumps are manually started and typically turned to protect the influent forcemain when the influent flow causes pressures in the existing forcemain to rise and typically are used to maintain influent pressures in the existing forcemain below 16 psig at the Redwood City Pump Station.

3.0 Proposed Improvements

As discussed in Section 1.0, SVCW requires several improvements to their influent conveyance and preliminary treatment facilities. Figure 3, below, shows the conceptual layout of these facilities including the RLS, Headworks Facility, FoP Odor Control Facility, and the ICP. After the facilities shown in Figure 3 are constructed, raw sewage will be conveyed through the Gravity Pipeline to the RLS, which will pump it up to the new Headworks Facility. The raw sewage will flow through the Headworks and the ICP to the existing WWTP. The existing 54-inch forcemain will no longer be needed and it will be abandoned in place. The proposed facilities are also shown in Figure 6 at the end of this TM.

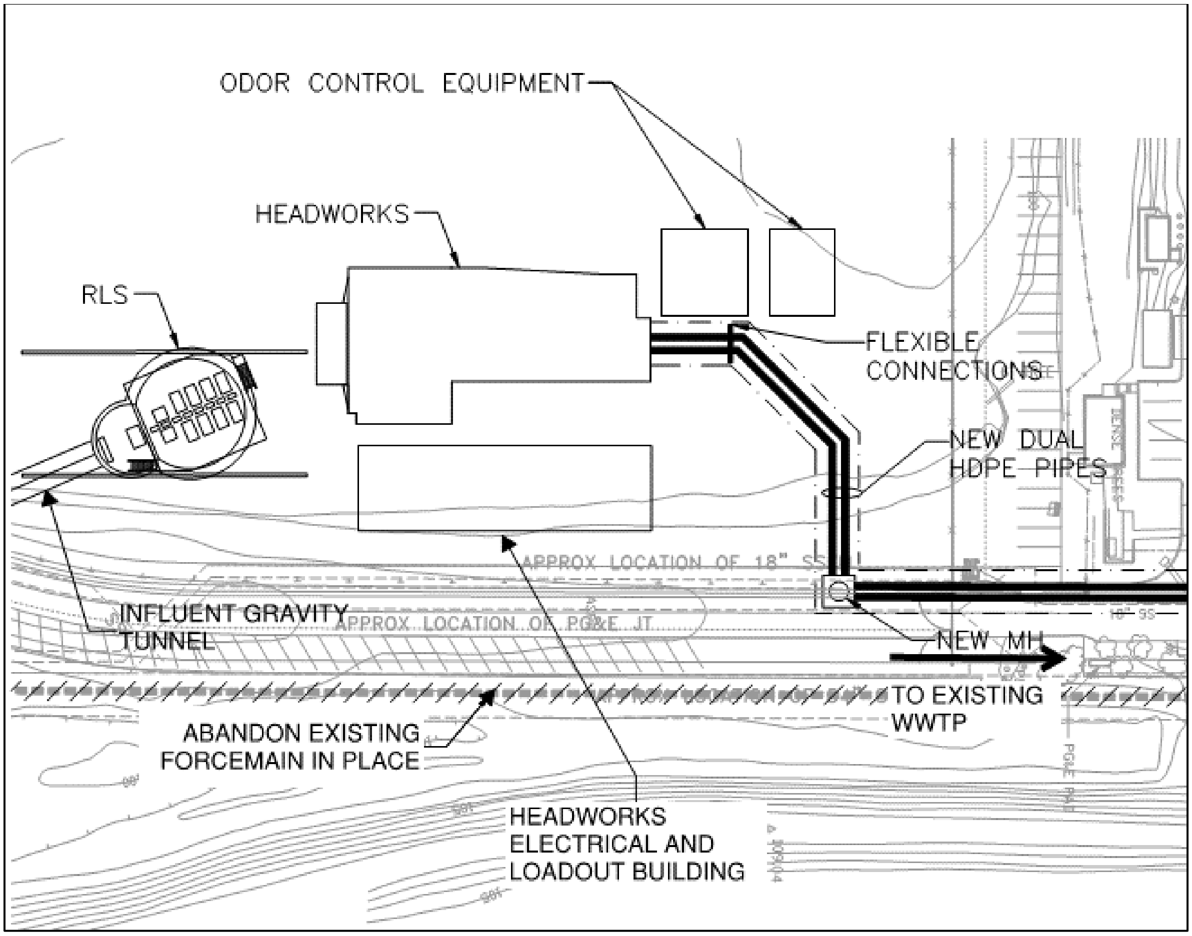


Figure 3
SVCW Proposed Conveyance System and Preliminary Treatment Improvements

4.0 Early Connection of Headworks

SVCW is considering constructing the Headworks Facility before construction of the Gravity Pipeline, RLS, and ICP is complete. This would allow SVCW to realize the benefits of improved screenings and grit removal much earlier than if construction of the Headworks Facility were delayed until after the Gravity Pipeline, RLS, and ICP are constructed. According to the latest CIP schedule, constructing the Headworks and FoP Odor Control Facilities prior to completing construction of the Gravity Pipeline, RLS, and ICP would allow the Headworks and FoP Odor Control Facilities to be constructed 18 months earlier.

Figure 4, below, shows a conceptual layout of the influent conveyance and preliminary treatment facilities under the scenario where the Headworks Facility is constructed and started up before the Gravity Pipeline, RLS, and ICP. The layout is also shown in Figure 7 at the end of this TM. The conceptual layout shown in Figure 4 and 7 is discussed in detail in Section 4.1. The capital costs and operational impacts associated with starting up the Headworks early are discussed in Sections 4.2 and 4.3, respectively.

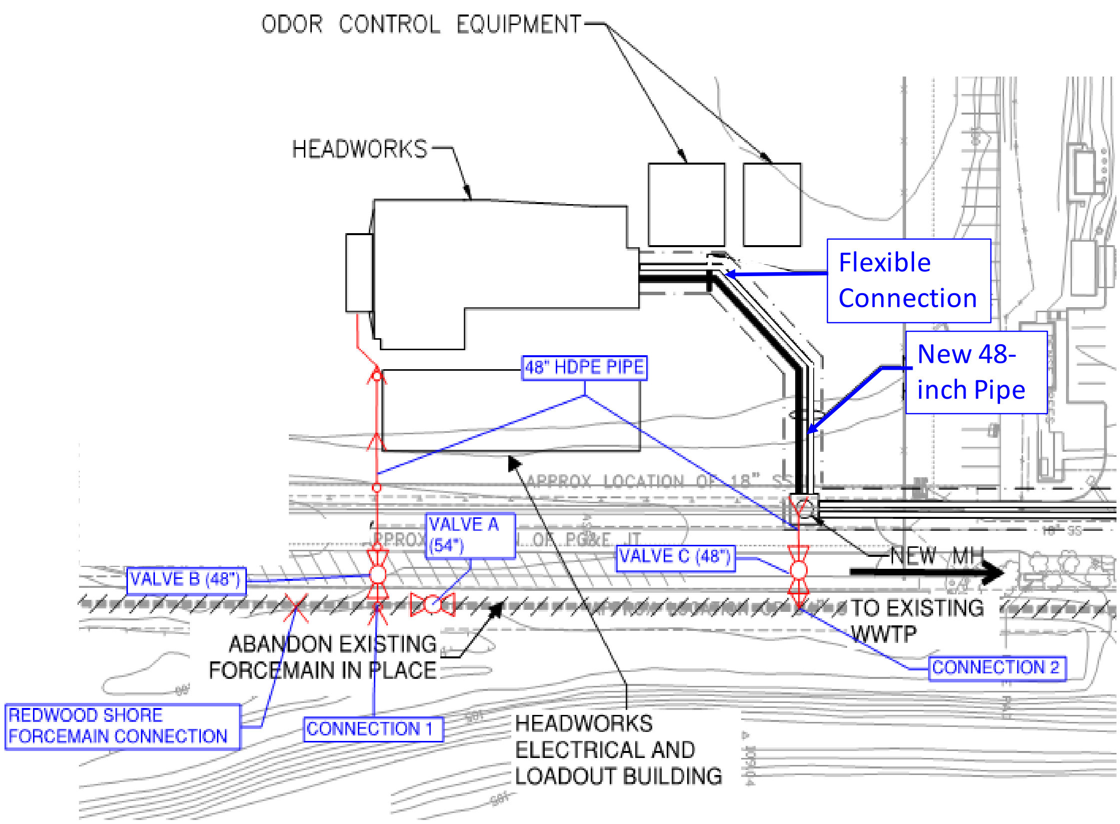


Figure 4
Conceptual Layout of Early Startup of Headworks and FoP Odor Control Facilities

4.1 Conceptual Layout

The conceptual layout shown in Figure 4 includes the following facilities:

- The proposed Headworks Facility and FoP Odor Control Facilities.
- A portion of one of the ICP between the Headworks Facility and a manhole located near the existing entrance gate to the plant.
- New piping to connect the 18-inch Redwood Shores forcemain to the existing 54-inch forcemain.
- A new 48-inch HDPE pipe to convey raw sewage from the existing 54-inch forcemain at Connection Point 1 to the influent channel of the Headworks Facility.

- A new 48-inch HDPE pipe to convey screened and de-gritted sewage from the manhole at the end of the ICP back into the existing 54-inch forcemain.
- Connection Point 1 – This connection point includes a new 54" x 54" x 48" tee, a 54-inch valve on the existing 54-inch forcemain (Valve A), and a new 48-inch valve on the new 48-inch pipe (Valve B). The new valves and tee will need to be pile-supported.
- Connection Point 2 – This connection point includes a new 54" x 54" x 48" tee, and a new 48-inch valve on the new 48-inch pipe (Valve C). The new valve and tee will need to be on a pile-supported concrete pad.

Under the configuration shown in Figure 4, the Headworks Facility would operate as follows:

- During dry weather conditions, raw sewage from the existing 54-inch forcemain will be diverted to the new Headworks Facility for preliminary treatment. Effluent from the Headworks will be sent back into the 54-inch forcemain using a portion of the ICP, where it will be conveyed to the Influent Mix Box. This will be accomplished by closing Valves A and opening Valves B and C.
- During wet weather conditions, raw sewage will not be diverted to the Headworks Facility. Since the Headworks Facility is at a higher elevation than the Influent Mix Box, sending wet weather flows to the Headworks Facility during interim operation would increase the pressure in the existing 54-inch force main most likely beyond its pressure rating. Therefore, wet weather flows will be conveyed through the existing 54-inch forcemain directly to the Influent Mix Box, bypassing the Headworks Facility. Under this scenario, operation of the influent conveyance and preliminary treatment facilities will match the existing operations. This will be accomplished by opening Valves A and closing Valves B and C.

Consideration was given to using the full length of the ICP to convey effluent from the Headworks Facility to the Influent Mix Box, rather than utilizing a portion of the existing 54-inch forcemain. This idea was eliminated from further consideration because it would require significant piping modifications at the Influent Mix Box and would require installation of several pieces of pipe and valves that would become obsolete after the Gravity Pipeline and RLS were constructed.

4.2 Capital Costs

The facilities shown in red in Figure 4 are only needed during the Headworks early start-up and operation period prior to construction of the Gravity Pipeline and the RLS. These facilities are referred to as Interim Facilities, and include the new 48-inch HDPE pipes and the fittings and valves required at Connection Point 1 and Connection Point 2. The other facilities shown in Figure 4 will remain functional after construction of the Gravity Pipeline and RLS.

The Level 5 Opinion of Probable Construction Cost associated with the interim facilities is summarized in Table 1, included at the end of this TM. As shown, the cost of constructing the interim facilities is estimated to be approximately $1,050,000 (+50%, -30%). The costs shown in

Table 1 were developed using aspects of the previously submitted OPCC for the ICP and Headworks Facility Projects. The following assumptions were made in developing the costs:

- Pipes will be constructed using open trench with sheet piling, similar to the approach for the outfall replacement project currently under construction
- Three plant shutdowns will be required to install new piping and valves

4.3 Operational Impacts and Costs

The operational impacts and costs associated with the configuration shown in Figure 3 and discussed above are as follows:

- The existing pump stations pumping flow to the plant will need to discharge to a higher elevation during dry weather operations after the new Headworks Facility is started up. This will increase the discharge pressure on the pumps and therefore increase the amount of energy required to operate the pumps. The water surface elevation in the new Headworks Facility will be approximately 117 feet during dry weather flows. The water surface elevation in the existing Influent Mix Box is approximately 109.0 feet at a dry weather flow of 12.8 mgd. Therefore, the discharge pressure on the pumps will be increased by 8 ft. The combined increased energy cost to operate the conveyance system pumps under the higher discharge pressure is approximately $25,000/year, assuming an energy cost of $0.13/kilowatt hour.
- Currently, the maximum pressure in the 54-inch force main occurs when influent flows to the plant are approximately 50 mgd and the ILS pumps are not operating. Under the configuration shown in Figure 3, the maximum pressure in the 54-inch force main will occur when peak dry weather flows (approximately 23 mgd) are being sent to the Headworks Facility. Based on a preliminary review of the hydraulic conditions under both of these scenarios, the maximum pressure in the 54-inch force main under the configuration shown in Figure 3 will be approximately 2.5 psi higher than the maximum system pressure under the current configuration.

5.0 Advantages and Disadvantages

The advantages of bringing the headworks online early include the following:

- The total project cost (construction cost plus contingency and soft costs) of the Headworks Facility and FoP Odor Control Facility is estimated to be $52,700,000 (see Headworks Facility Opinion of Probable Construction Cost TM). Constructing these facilities early eliminates approximately 18 months of escalation from the project. At annual escalation rate of 4.5%, this is a savings of approximately $3,700,000.
- Opens up space for other FoP projects that would have been occupied by the headworks construction contractor. This will significantly reduce congestion in the FoP area.

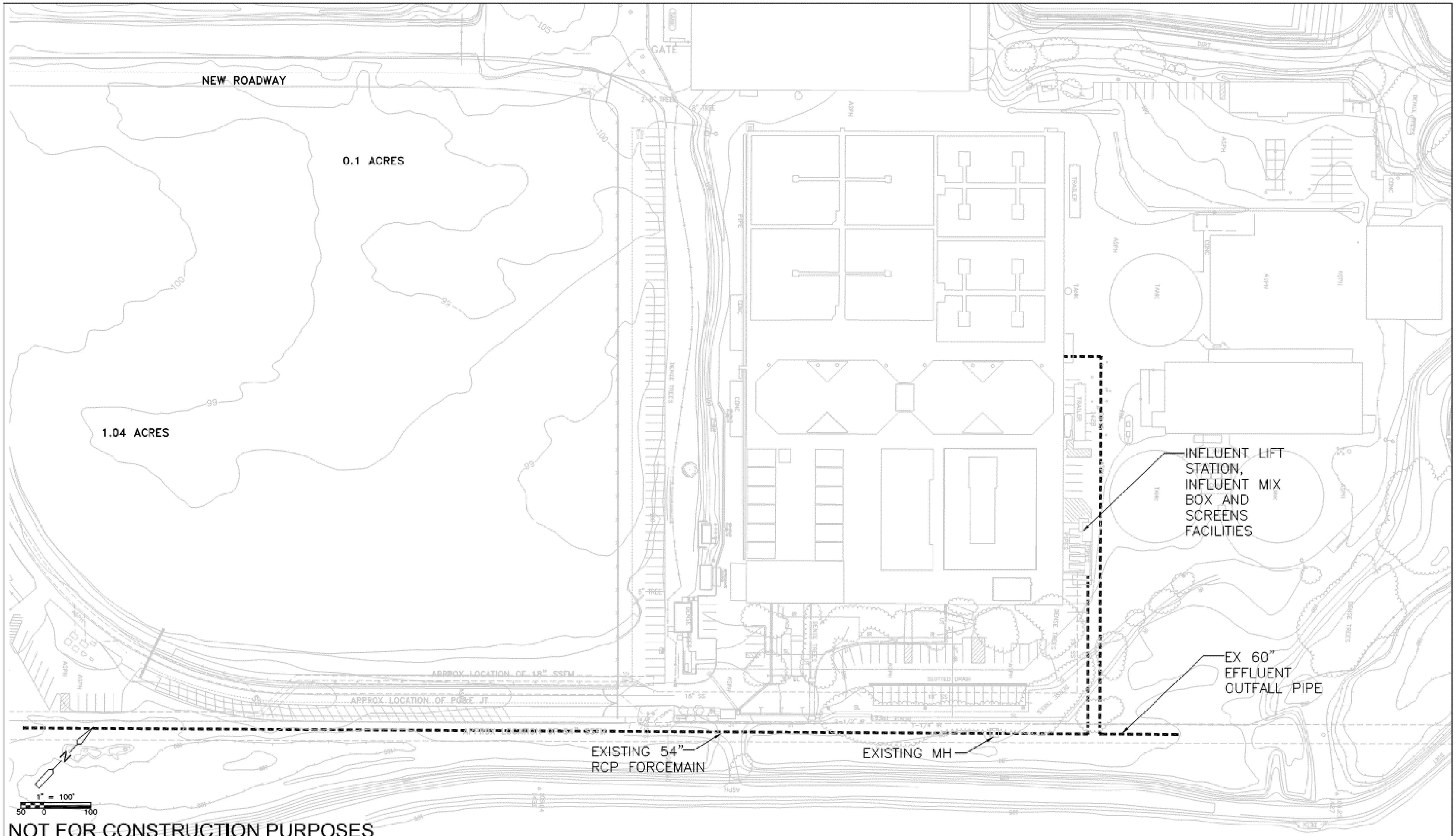
- Significantly eliminates complexity of startup by not having to go through concurrent testing of the proposed Receiving Lift Station and gravity tunnel at the same time.
- Provides 18 months of operation for plant staff to become familiar with the facility, fine tune equipment, and adjust operational procedures prior to the addition of even more complex issues of the gravity sewer storage and operation, and acceptance of the RLS.
- Provides the added process reliability of flow equalization at the plant by providing a connection to the drying beds. Currently, SVCW can only equalize a portion of the collection system flows at the Menlo Park Flow Equalization Facility. With this HW to Drying bed connection SVCW could extend its complete plant shutdown window from only several hours in the middle of the night to almost two days, which is an exceptional increase in repair and operational windows for in plant repairs.
- Provides an additional 18 months, and perhaps longer, of screening and grit removal, reducing impacts to downstream equipment and processes.

The disadvantages of bring the headworks online early include the following:

- Increases construction cost of approximately $1,050,000 (+50%/-30%)
- Increases annual system pumping cost by approximately $25,000 to pump wastewater to the elevation of the new headworks facility. (Assumes $0.13/kWh and average flow of 12.8 mgd)

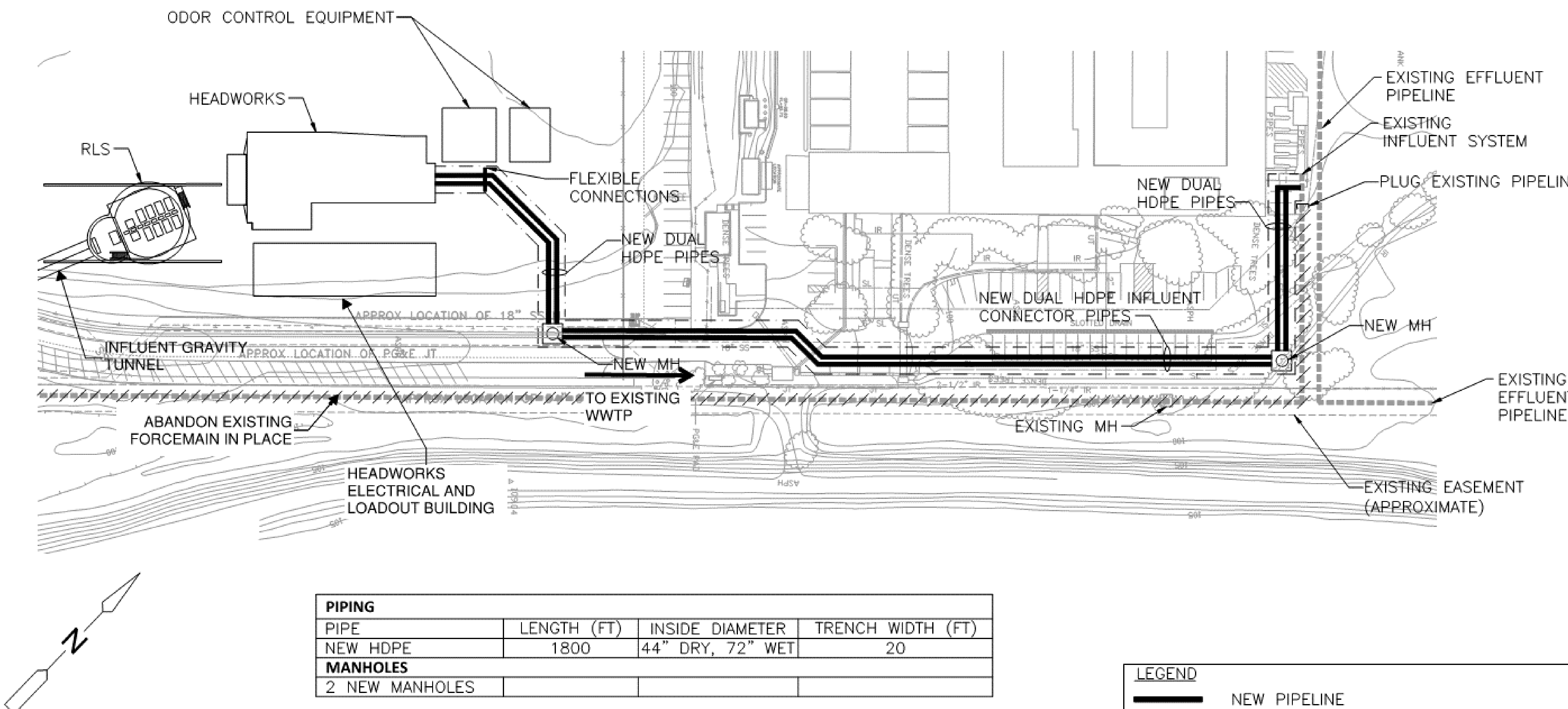
In conclusion, the increased construction and O&M costs associated with early startup of the Headworks and FoP Odor Control Facilities will be offset by the savings realized by avoiding 18 months of escalation in construction costs. Therefore, there will be an overall net savings realized by bringing the Headworks Facility online early. The net savings will be approximately $2,612,500 ($3,700,000 - $1,050,000 – 1.5 yrs x $25,000/yr of increased electricity costs). This does not include the additional O&M savings associated with 18 additional months of improved screenings and grit removal.

cc: [Click here to enter name]



CDM Smith

FIGURE 5 EXISTING PLANT SITE PLAN



PIPING			
PIPE	LENGTH (FT)	INSIDE DIAMETER	TRENCH WIDTH (FT)
NEW HDPE	1800	44" DRY, 72" WET	20
MANHOLES			
2 NEW MANHOLES			

1" = 80'

40 0 80

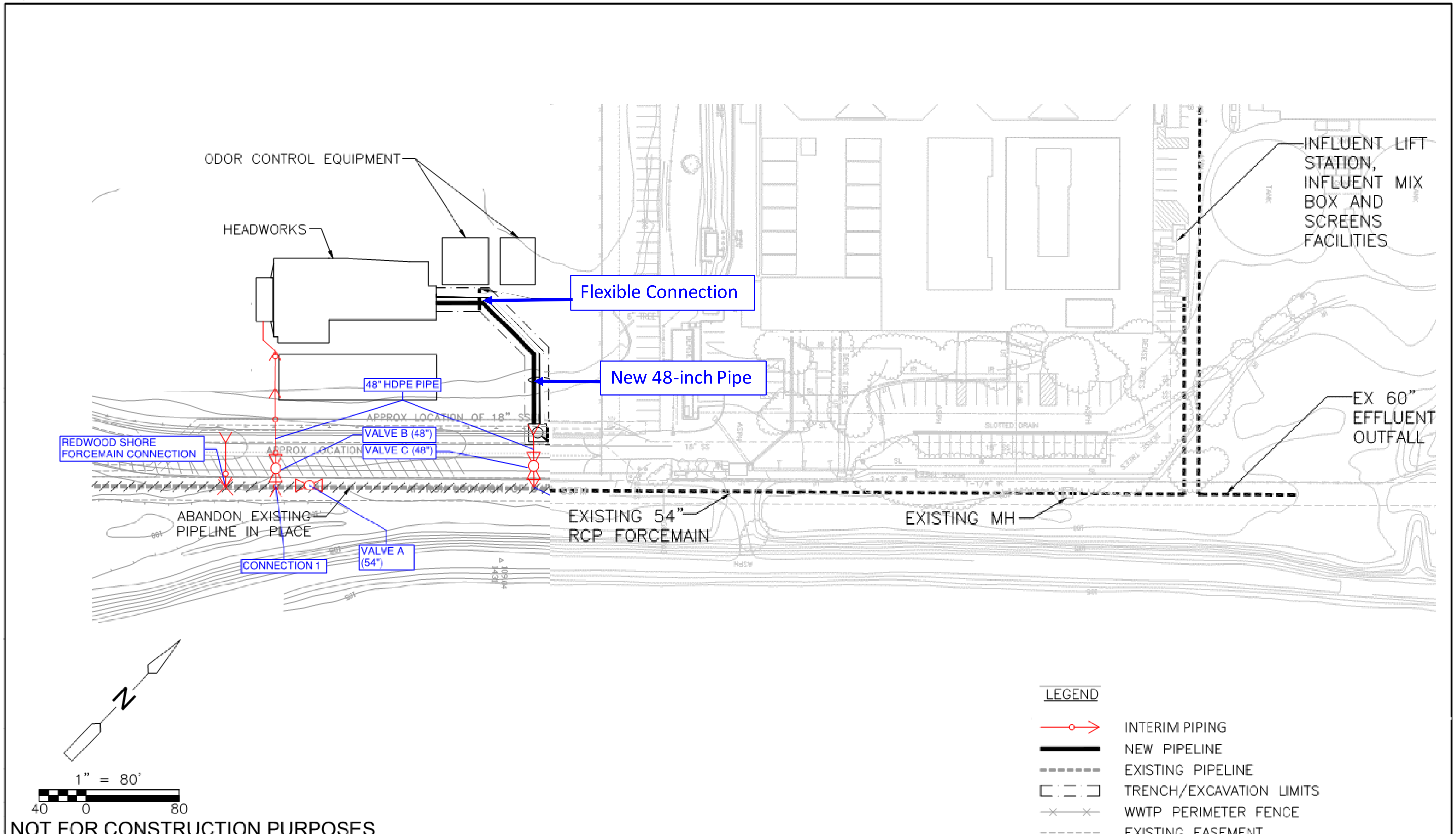
NOT FOR CONSTRUCTION PURPOSES

LEGEND

- NEW PIPELINE
- EXISTING PIPELINE
- TRENCH/EXCAVATION LIMITS
- WWTP PERIMETER FENCE
- EXISTING EASEMENT

CDM Smith

FIGURE 6 CONCEPTUAL FACILITY LAYOUT



CDM Smith

FIGURE 7 HEADWORKS EARLY STARTUP TEMPORARY PIPING

Table 1: SVCW Proposed Headworks Interim Piping OPCC					
ITEM	**UNITS**	**QUANTITY**	**UNIT COST**	**COST (Rounded)**	**COMMENTS**
48" HDPE Pipe and trench	lf	225	$775	$174,000	Unit cost taken from 02/24/2016 OPCC for dual 66" ICP of $775/lf. Excluding cost for restrained flexible couplings. Cost is conservative when compared to 48" HDPE pipe.
6" Tremie Seal Slab	cy	25	$175	$4,000	Unit cost taken from 02/24/2016 OPCC for dual 66" ICP.
Dresser Couplings (48"/54")	ls	6	$14,000	$84,000	Unit cost taken from 02/24/2016 OPCC for dual 66" ICP. Cost is for 60" dresser coupling and SS hardware.
Pipe Shoring	lf	225	$555	$125,000	Unit cost taken from 02/24/2016 OPCC for dual 66" ICP. Cost is for dual 66" pipes. Cost is similar.
Piles	-	16	$10,355	$166,000	Unit Cost taken from 04/04/2016 OPCC for Headworks. 135' of pile supported pipe and piles at interconnections/valves.
Valves (44"/54")	ls	2	$75,000	$150,000	Unit cost taken from 02/24/2016 OPCC for dual 66" ICP of $75,000 for 60 inch BFV. SVCW to provide 1 of 3 valves.
48" Connection to Existing 54" RCP	ea	2	$35,000	$70,000	Assumed that the connection will be made via concrete collar over new section of pipe.
	Sub Cost			**$770,000**	
Building Permits	1% of sub cost		$7,700		
Bldr's Risk Ins	1% of sub cost		$7,700		
Gen Liab Ins	1.5% of sub cost		$11,550		
GC Bonds	2% of sub cost		$15,400		
Sales Tax	9% of sub cost		$69,300		
	Total			**$882,000**	
GC General Conditions	10% of Total		$77,000		Excludes escalation and contingencies. Does not reflect any shut down costs carried by the district, night work, and engineering costs.
Contractor Total OH&P	12% of Total		$92,400		Relocation of Redwood Shores FM carried under ICP cost estimate
	Grand Total			**$1,050,000**	

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Appendix O

Life Cycle Cost Analysis Guidelines Technical Memorandum

Brown AND Caldwell
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Technical Memorandum

Prepared for: Silicon Valley Clean Water

Project Title: PS Predesign Project – CIP#7010

Project No.: 142399

Technical Memorandum No. 11.3 - FINAL

Subject: Task 11 – Life Cycle Cost Analysis Guidelines

Date: July 13, 2016

To: Kim Hackett, Engineering Director, South Bayside System Authority

From: Charles Joyce, Project Manager, Brown and Caldwell

Copy to: Roanne Ross, Whitley Burchett and Associates

Prepared by: ______________________
Bernadette Visitacion-Sumida, P.E., Project Engineer
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Charles Joyce, P.E., Quality Control
California License No. C33166

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Table of Contents

List of Tables

List of Abbreviations

BC	Brown and Caldwell
BPS	Belmont Pump Station
CEQA	California Environmental Quality Act
CSMP	Conveyance System Master Plan
EQ	Equation
FEF	Flow Equalization Facilities
FoP	Front of Plant
FRP	Fiberglass Reinforced Plastic
FTE	Full-Time Equivalent
LCC	Life Cycle Cost
LF	Linear Feet
MCC	Motor Control Center
MPPS	Menlo Park Pump Station
NPDES	National Pollutant Discharge Elimination System
NPV	Net Present Value
O&M	Operation and Maintenance
PWWF	Peak Wet Weather Flow
RCPS	Redwood City Pump Station
RLS	Receiving Lift Station
SCPS	San Carlos Pump Station
SRF	California State Revolving Fund
SVCW	Silicon Valley Clean Water
TM	Technical Memorandum
WWTP	Wastewater Treatment Plant
$	Dollars

Executive Summary

In May 2015, the Silicon Valley Clean Water (SVCW) Commissioners approved Alternative 4BE as the recommended conveyance system alternative to proceed with California Environmental Quality Act (CEQA) documentation and predesign. Alternative 4BE includes a deep gravity tunnel from the San Carlos Pump Station (SCPS) to the Wastewater Treatment Plant (WWTP), varying combinations of pump station rehabilitation, Receiving Lift Station (RLS) and new Headworks facility with Influent Connector Pipe. Since the Commissioners' approval, the project components were refined and updated costs were developed.

The purpose of this technical memorandum (TM) is to summarize the methods and guidelines for performing a life cycle cost (LCC) analyses of the various conveyance system components for Alternative 4BE. Brown and Caldwell (BC) performed the original LCC model used as part of the process to evaluate the conveyance system alternatives that resulted in the Alternative 4BE selection. SVCW requested that each of the SVCW conveyance system consultants perform an LCC on their individual project components using the updated construction costs developed by each team. SVCW will compile the costs to develop the updated 50-year LCC. The major considerations in developing each project component's LCC include capital cost, annual operation and maintenance (O&M) running costs, replacement/rehabilitation costs and overall project schedule.

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Section 1: Introduction

The purpose of this technical memorandum (TM) is to summarize the assumptions, sources of information and methodology of the LCC analyses originally performed by Brown and Caldwell (BC) for the various conveyance system components to use as a guideline for the project-specific LCC analyses. The project components consist of varying combinations of pump stations, gravity tunnels, Flow Diversion Structure and force mains to convey wastewater from SVCW's Member Agencies to their WWTP.

Each of the SVCW's conveyance system consultants (consultants) will perform LCCs for their individual project components. The LCC models developed by each consultant should include an economic analysis that accounts for the current and future costs of facilities over the course of its lifetime; including initial capital, O&M, and rehabilitation/replacement costs.

1.1 Background

SVCW decided to consider several alternatives to the conveyance system upgrades that were identified in the 2011 Conveyance System Master Plan (CSMP). The CSMP included replacement of the existing 54-inch force main that transports wastewater from the San Carlos Pump Station (SCPS) to the WWTP with a new 63-inch force main located through Redwood Shores. After meeting with the public in Redwood Shores, SVCW looked at other pipeline alignments and construction methods to reduce the construction impact to the Redwood Shores area businesses and residents. This evaluation resulted in the development of several alternatives to eliminate the force main that would be installed by open-cut methods through Redwood Shores.

BC performed the original LCC analysis for the recommendation of Alternative 4BE that was approved by the Commissioners in May 2015 to proceed to the environmental entitlements phase. The original Alternative 4BE included the following components:

- Tunnel and Gravity Pipeline
- Belmont Force Main Improvements
- Belmont Pump Station Rehabilitation
- Menlo Park Pump Station Rehabilitation
- Redwood City Pump Station Replacement
- Elimination of the Existing San Carlos Pump Station
- Receiving Lift Station
- Flow Equalization Facility
- Headworks Facility

Since May 2015, each of these components have been refined during conceptual design and the construction costs updated. Additional projects have also been added to the overall conveyance system improvements program. The following is a list of current projects included within the program with a short description of changes that occurred over the past year:

- **Tunnel and Gravity Pipeline.** The Gravity Pipeline was originally designed to be 6 ft in diameter. The current inner diameter is 11 ft within a maximum 15 ft exterior diameter tunnel. The reason for the change is to allow wet weather flow storage within the tunnel and reduce the Receiving Lift Station pumping capacity.
- **Belmont Force Main Improvements.** The Belmont Force Main will be reused and convey flows back to the San Carlos Pump Station site and combine with the incoming flows from the City of San Carlos before discharge into the Gravity Pipeline.

- **Belmont Pump Station Rehabilitation.** No major updates – remains as a rehabilitation project.
- **Menlo Park Pump Station Rehabilitation.** The Menlo Park Pump Station will be designed to convey dry weather flows to the Bair Island Drop Shaft for discharge into the Gravity Pipeline. During wet weather, the pumps are designed to convey flows to the Redwood City Pump Station where it will be combined within the screenings building and pumped to the Bair Island Drop Shaft.
- **Redwood City Pump Station Replacement.** The wet weather capacity of the Redwood City Pump Station increases to 60 MGD (combination of Menlo Park and Redwood City flows) from the original 38 MGD that accounted only for Redwood City flows.
- **Elimination of the Existing San Carlos Pump Station.** The San Carlos Pump Station will be repurposed to include flow metering for Belmont and San Carlos flows, trash rack and odor control for the Gravity Pipeline.
- **Receiving Lift Station.** The Receiving Lift Station will be designed to convey 80 MGD Peak Wet Weather Flow (PWWF) instead of the 102.9 MGD PWWF originally proposed.
- **Flow Equalization Facility.** The Flow Equalization Facility has been eliminated from the program, replaced by storage in the tunnel.
- **Headworks Facility.** The Headworks Facility will be designed for a capacity of 80 MGD and will house electrical equipment and odor control equipment associated with the Receiving Lift Station and Gravity Tunnel.

Additional projects added to the program include the following:

- **Influent Connector Pipe.** The Influent Connector Pipe will connect the Headworks to the primary sedimentation basins and serve as a bypass during wet weather events when flows exceed the Headworks Facility capacity.
- **Front of Plant Civil Improvements.** The Front of Plant Civil Improvements will include ground improvements to accommodate the Receiving Lift Station and Headworks Facility, including a pipeline from the Headworks to Sludge Drying Bed A for emergency wastewater storage. It will also include a storm drain pump station for storm water conveyance offsite.

Detailed descriptions and consultant teams assigned to each project are included in Section 2. LCC model runs will be required for each project by the respective consultant teams for use in the upcoming California State Revolving Fund (SRF) application process.

1.2 LCC Model Requirements

Each consultant will develop/complete a LCC calculation/model to perform an economic analysis for each consultant's respective project components that includes the following:

- Net Present Value (NPV) analysis including appropriate discount and escalation rates, established by SVCW as presented in this TM.
- Capital costs
- Annual operation and maintenance (O&M) costs, established by each project team.
- Replacement and rehabilitation costs, established by each project team.
- Construction schedules, established by each project team.

The following sections describe the assumptions, sources, development, and guidelines for developing the LCC model.

Section 2: Conveyance System Components

SVCW selected four consultants to work on various components of the Conveyance System upgrades. The four consultants are Brown and Caldwell (BC), CDM Smith (CDM), Freyer and Laureta (F+L) and Kennedy Jenks (K/J). The consultant assigned to each project is designated in the project headers below. The major project components are briefly summarized below. These project components are the most current project elements that were included in the May 2016 construction cost estimates submitted by each consultant team.

2.1 Tunnel and Gravity Pipeline (K/J)

The Tunnel and Gravity Pipeline (referred to as Gravity Pipeline herein) component consists of a new 17,600-linear foot pipeline constructed by a tunnel boring machine between the SVCW WWTP and the north end of Inner Bair Island. The Gravity Pipeline will store wastewater during wet weather when flows exceed the WWTP capacity. The new 11-foot inside diameter pipeline will be installed within a 13-foot inside diameter concrete tunnel (up to 15-foot outside diameter) in two separate sections of tunnel. Costs include the pipeline, tunneling, tunnel launch and receiving shafts. This project includes the new drop structure connection at the San Carlos Pump Station location. The connection for the leachate discharge will be directly into the drop structure as part of this project.

2.2 Receiving Lift Station (RLS; BC)

The RLS will be located at the terminus of the Gravity Pipeline at the WWTP. The RLS will be used to pump raw sewage from the Gravity Pipeline to the Headworks. The RLS will consist of an inlet area, isolation gates and channels followed by two trench-style wet wells that will each house three submersible pumps for a total of six pumps. Cost components included in the RLS May 2016 construction cost estimate are summarized in Table 1. Additional items to be designed/constructed by others are also included in this table.

Table 1. RLS Cost Components	
Consultant	**Components**
BC	• Shaft interior improvements including plastic lining. • Slide gates. • Tunnel to inlet channel transition. • Flushing lines at each pump and slide gate. • Pumps and associated mechanical and piping. • RLS interior walls and structures (e.g., components to form inlet channel separation, trench wet wells, ogee ramp, etc.) • Exhaust ducting within the RLS routed to just outside of the Headworks building. • Two supply air blowers and associated ducting. • Pump control cabinets. • Variable frequency drives. • Instrumentation systems. • Motor Control Centers (MCCs). • Electrical and instrumentation cable/conduit and duct banks from the pumps to just outside of the Headworks building. • Pipe gallery and pile supports.
CDM as part of the Headworks	• Odor Control Ducting within the Headworks Building. • Odor Control System. • Exhaust fans.

Table 1. RLS Cost Components	
Consultant	Components
	• Electrical and Instrumentation cable/conduit within the Headworks Building. • Flow Distribution Structure located at the RLS pump discharges.
F+L as part of the Civil Improvements	• Ground improvements surrounding the RLS to accommodate heavy equipment during construction and long-term maintenance. • RLS access and paving. • General site civil in the RLS area. Drainage is assumed to be away from the RLS and pipe galleries.
K/J as part of the Gravity Pipeline	• Tunnel shaft. • Gravity Pipeline connection.

Electrical and operational costs associated with the RLS, including supply air to the RLS for odor control, will be developed by BC.

2.3 Headworks Facility (CDM)

The Headworks will be constructed upstream of the existing primary treatment process areas and downstream of the RLS. It will consist of grit and screening processing equipment, odor control facilities, electrical room, and standby generator. The electrical room and odor control facilities will service the RLS, Tunnel exhaust, and Headworks. See Section 2.2 for RLS components that will be included as part of the Headworks Facility.

2.4 Influent Connector Pipe (CDM)

The Influent Connector Pipe currently includes two parallel pipes, 44-inch diameter and 72-inch diameter that connect the Headworks at Flow Distribution Box No. 2 to the existing influent system. Each of the pipes are ~900 ft long and are sized to accommodate a range of flows while maintaining adequate flushing velocity. The Headworks Facility is considered a separate project component from the Influent Connector Pipe.

2.5 Front of Plant (FoP) Civil Improvements (F+L)

Civil improvements are needed for the front of the plant area to accommodate the new RLS, Headworks, and support construction activities. These improvements include: soil stabilization, flow diversion pipe from Headworks Facility to Sludge Drying Bed A, general setting of the site elevations to allow access to new facilities and for proper drainage away from the RLS and Headworks facilities; storm drainage improvements to prevent site flooding; driveway and roadway improvements to create safe vehicle routing; walls and fencing for site securing and screening; and tree planting for further site screening and visual improvements. In addition, a storm water pump station collects and conveys rainwater and storm water that falls on the FoP portion of the WWTP site for treatment as required by the plant's National Pollution Discharge Elimination System (NPDES) permit. This work will occur across three construction phases and each of these three phases needs to be developed separately in the LCC.

2.6 Belmont Force Main Improvements (BC)

The Belmont Force Main component will consist of rehabilitating the existing force main that conveys the wastewater flow from the City of Belmont to the SVCW system, back to the existing San Carlos Pump Station (SCPS) location. The project will include rehabilitation of an existing ~1,150 foot 24-inch segment of the force main; and slipline of ~3,550 feet of the 54-inch force main to transport the Belmont flow to the new gravity wastewater pipeline in the vicinity of the SCPS.

2.7 Belmont Pump Station (BPS) Rehabilitation (BC)

The Belmont Pump Station Rehabilitation includes rehabilitation of the pump station and replacement of the three existing pumps with new pumps that accommodate future flow rates and pressures. The existing electrical equipment, diminutor, controls, and standby generator have reached the end of their useful and will be replaced with new equipment.

2.8 SCPS Repurposing (BC)

The SCPS Improvements will include the installation of the piping and improvements on the site to take the existing pump station off line, provide individual metering and sampling of the San Carlos and Belmont flows, and connect the two pipelines to the Gravity Pipeline at a drop structure connection (drop structure is part of the Gravity Pipeline project). Piping improvements include extending the San Carlos sanitary sewer to the proposed Gravity Pipeline; extending the Belmont force main to connect to the proposed Gravity Pipeline; relocating the 10-inch San Carlos force main to connect to the San Carlos inlet sewer; installing flow metering and sampling structures; and installing a Belmont/San Carlos Combination Structure and 42-inch diameter pipe at the drop structure stub-out to connect to the Gravity Pipeline. On the San Carlos inlet to the Belmont/San Carlos Combination Structure, a trash rack will be placed to remove large debris and to connect the relocated 10-inch San Carlos force main upstream of the San Carlos flow meter.

2.9 San Carlos Odor Control Facility (CDM)

An odor control facility at the San Carlos Connection will be installed to contain and treat foul air venting from the Gravity Pipeline drop shaft. Equipment includes chemical scrubbers, storage tanks for chemicals used in the scrubbers, metering pumps, secondary containment piping, electrical equipment, and other ancillary equipment that will be located in the existing San Carlos Pump Station building. The installation of the new odor control equipment includes removal of existing equipment (only needed for odor control equipment space) and interior walls, and other building or site upgrades/renovations to maintain the long-term operation of the odor control facility.

2.10 Redwood City Pump Station (RCPS) Replacement (BC)

At the location of the existing Redwood City Pump Station, a new pump station will be built to pump the wastewater flow from Redwood City into the SVCW Conveyance System. The current pump station building will be repurposed to house odor control, standby generator and electrical/control facilities. A new pump station facility will be constructed adjacent and to the west of the existing RCPS building and will include two new trench-style wet wells that will contain two dry weather and two wet weather pumps for a total of eight pumps. In addition, a new screenings building will be built to the north of the new pump station wet well that includes coarse screens to remove large solids, rags and debris from the Redwood City flows.

2.11 Menlo Park Pump Station (MPPS) Rehabilitation (BC)

Improvements to the pump station include both above ground and below ground modifications. The above-grade improvements include exterior façade upgrades to the existing pump station building, a new 18-inch exterior perimeter wall and access ramps for flood protection/access, onsite storm water management, new security fencing and lighting, landscaping, new vacuum relief valves, a new odor control system, seismic upgrades to the existing building, and an upgraded HVAC system. In addition, five new 5.5 MGD, 75-HP pumps, new pump discharge manifold and valves, flow meter, grinders, and related equipment will be installed below grade. The existing pump station building will be reused and will house electrical/control equipment, standby power, odor control, and other ancillary equipment needed to operate and maintain the rehabilitated pump station. The proposed improvements, with the exception of the flow meter, will be located within the existing MPPS building. Vehicle access to the site will be from the existing gate on Marsh Road.

Section 3: Cost Components

The following sections discuss the assumptions and sources of information for the cost components to be incorporated into the LCC model. The LCC model primarily considers three types of costs: construction, annual O&M, and rehabilitation/replacement costs. Assumptions and sources of these cost components are discussed in the following sections. Salvage costs for equipment and benefits will not be considered in this analysis since it was not included in the original LCC analysis completed for the Conveyance System.

3.1 Construction Costs

Construction costs were developed by SVCW's consultants following a set of guidelines prepared by Joe Covello and The Covello Group. The construction costs must be converted into capital costs by applying soft costs, project contingencies, and market fluctuations to each individual cost component using Equation (EQ) 3-1.

$$\textit{Capital Cost} = \textit{Construction Cost} \times [1 + \textit{Project Contingency} + \Sigma(\textit{Soft Costs}) + \textit{Market Fluctuations}] \quad \text{[EQ 3-1]}$$

The construction contingencies, soft costs, and market fluctuations are summarized in Table 2. Market fluctuations are applied to capture the range of costs that could potentially occur over the construction period for the entire conveyance system program upgrade.

Table 2. Capital Cost Factors	
Cost Factor	**Markup**
Construction Contingency[1]	
Tunnel	20%
All Other Projects	25%
Soft Costs[2]	
Construction Management, Engineering Services During Construction, Testing, Inspection	15% (Tunnel and Pipeline Projects) 18% (All Other Projects)
Contract Change Orders (CCO)	5%
Planning	5%
Design	10%
Project Management	5%
Soft Cost Subtotal	
Tunnel and Pipeline	40%
All Other Projects	43%
Market Fluctuations[3]	
Low	-5%
High	15%

Notes:

[1,2]Construction contingency developed by SVCW as presented in the comparison of construction cost estimates during the June 2, 2016 Department Head Meeting.

[3]Market fluctuations developed by SVCW. Source: SVCW Conveyance System Construction Cost Analysis, Front of Plan, Revision Date: April 22, 2015, Revision 28b.

3.1.1 Operation and Maintenance Costs

O&M costs for each alternative are grouped by the type of facility. The types of O&M costs are described below. O&M for the existing conveyance facilities will not be included in this LCC analysis. Rehabilitation and replacement costs are accounted for separately from O&M costs in Section 3.1.2 below. The following list includes the assumptions that were made during the LCC analysis that was done as part of the Alternative Analysis process. **The project teams should verify either that these assumptions are still correct or propose new assumptions for the development of O&M costs for their projects.**

- **Tunnel and Gravity Pipeline.** During the initial LLC analysis, the annual O&M costs for the tunnel were assumed to negligible as most O&M for the gravity pipeline will be included conveyance system pump station O&M costs; therefore, annual O&M costs do not need to be included in the Gravity Pipeline LCC model. Tunnel cleaning and inspection and associated cycles will be included per the Gravity Pipeline consultant team's recommendation.
- **Receiving Lift Station.** The RLS costs are based on the operation of submersible pumps within trench-style wet wells. During the initial LLC analysis, the RLS annual O&M cost were equal to one Full-Time Equivalent (FTE) employee at a cost of $150,000/year/employee. Additional costs for pump inspection and electrical use should be included as separate O&M cost items. Electrical power and equipment for the RLS (pumps, valve operators, supply air blowers, etc. at the RLS site or part of the RLS in the Headworks building) should be incorporated into the RLS life cycle cost.

- **Headworks Facility.** During the initial LLC analysis, the annual O&M costs for the Headworks facility were equal to one FTE at a cost of $150,000/year/employee that included screening, grit removal and standby generator (generator maintenance is no longer required for this updated LCC) maintenance. In addition to the annual O&M costs, odor control costs, electrical costs, and equipment inspection costs should be included. Odor control costs include costs for electrical power, chemical and water to operate the system on an annual basis. RLS O&M costs and electrical costs will be included by BC as part of the RLS LCC analysis.
- **Influent Connector Pipe.** CDM shall coordinate with SVCW regarding the annual O&M costs for the influent connector pipe. The influent connector pipe was not included as part of the original LCC analysis. Cleaning, inspection and associated activity cycles will be included per the influent connector pipe consultant team's recommendation.
- **FoP Civil Improvements.** Annual maintenance costs and storm water pumping power requirements will need to be determined by F+L.
- **Belmont Force Main.** During the initial LLC analysis, the annual O&M costs for the force main were assumed to part of the annual conveyance system pump station O&M costs. The Belmont design team should determine whether they need to be accounted for in the Belmont Force Main LCC model for this phase of estimating. Additional force main O&M costs include internal pipe inspection with inspection intervals to be determined by the force main consultant team.
- **BPS Rehabilitation.** During the original LCC analysis, the BPS O&M annual costs were included as part of the MPPS and RCPS general maintenance costs. Odor control costs, electrical costs and pump inspection costs should be included in this LCC analysis. Odor control costs include costs for chemical and water to operate the system on an annual basis. Pump inspection and electrical costs to operate each pump station should also be included as separate O&M cost items.
- **RCPS Replacement.** During the initial LCC analysis, the annual O&M cost for RCPS was equal to one FTE employee at a cost of $150,000/year/employee. The annual O&M cost for RCPS assumes costs for screens, cranes, standby generator, and surge control maintenance. Additional costs for water, odor control chemicals, pump inspection and electrical use should be included as separate cost items. The pumps for this LCC analysis are assumed to submersible pumps within trench-style wet wells.
- **MPPS Rehabilitation.** The annual O&M cost for MPPS was equal to one FTE employee at a cost of $150,000/year/employee in the initial LCC analysis. This annual O&M cost for MPPS assumes costs for cranes, standby generator, and surge control maintenance. Additional costs for water, odor control chemicals, pump inspection and electrical use should be included as separate cost items. The pumps for this LCC analysis are assumed to dry-pit submersible.
- **SCPS Repurposing.** Annual O&M costs will be accounted for in the San Carlos Odor Control Facility Project.
- **San Carlos Odor Control Facility.** San Carlos Odor Control Facility annual O&M costs shall be coordinated with SVCW. Two separate O&M cost items should be included to account for power requirements to run the odor control facility and for providing chemical and water to support the odor control facility.

Electrical costs should be calculated using the location of the facility and the electrical rates displayed in Table 3. These electrical costs are based on current SVCW electrical bills with the exception of the FoP rate. The FoP rate was based on the WWTP winter time rate.

Table 3. Electrical Rates	
City	Electrical Rate
Belmont	$0.163/KWh
FoP	$0.129/KWh
Menlo Park	$0.150/KWh
Redwood City	$0.161/KWh
San Carlos	$0.196/KWh

A summary of the O&M cost items applicable to each project are displayed below in Table 4. O&M items not identified above or in Table 4 should not preclude the consultant team from including it in their LCC analysis, unless specifically stated not to include.

Table 4. O&M Cost Component Summary[1]

Conveyance System Component	General O&M Allowance[2]	Pipe Cleaning	Pipe Inspection	Mechanical Equipment Inspection	Power Requirements[3]	Odor Control (Chemical and Water)
Tunnel and Gravity Pipeline		✓	✓			
Receiving Lift Station	✓			✓	✓	
Headworks Facility	✓			✓	✓	✓
Influent Connector Pipe		✓	✓			
FoP Civil Improvements	✓			✓	✓	
Belmont Force Main Improvements			✓			
BPS Rehabilitation				✓	✓	✓
SCPS Repurposing					✓	
San Carlos Odor Control Facility	✓				✓	✓
RCPS Replacement	✓			✓	✓	✓
MPPS Rehabilitation	✓			✓	✓	✓

Notes:

[1]*Check marks denote O&M cost item to be included as part of conveyance system component LCC analysis.*

[2]*General O&M Allowance is one FTE for the pump stations and Headworks, and one-half FTE for the FoP Site Civil and Flow Diversion Basin Projects. The cost for a FTE is $150,000/year.*

[3]*Power requirements should be calculated using the electrical rates displayed in Table 3.*

3.1.2 Rehabilitation and Replacement Costs

Rehabilitation and replacements costs for each facility were developed based on the following general assumptions:

- **Facility Design Life.** The following design life should be assumed for each facility based on discussions with SVCW:
  - Force Main – 75 years for new pipelines.
  - Tunnel/Gravity Pipeline – 100 years.
  - Conveyance System Pump Stations, RLS, Headworks, and Odor Control Facilities – various based on component, see below.
- **Component Rehabilitation/Replacement Costs.** Rehabilitation and/or replacement costs should be accounted for the various system components below. The rehabilitation/replacement intervals and costs should be assigned at the discretion of the facilities' design teams.
  - **Pump Refurbishing.** Includes pump refurbishing for the conveyance system pump stations, RLS, FoP storm water pump station.
  - **Mechanical Equipment Replacement.** Pump replacement costs should be accounted for the conveyance system pump stations, RLS, FoP storm water pump station and Flow Diversion return pumps. Replacement costs for odor control, screens, grit removal systems, etc. should also be accounted for in the LCC analyses.
  - **Structural Rehabilitation.** Structural rehabilitation includes piping, valves, HVAC, odor control and building rehabilitation or replacement.
  - **Electrical and Instrumentation Rehabilitation/Replacement.** Electrical equipment replacement is assumed at 25 year intervals, and instrumentation and control equipment replacement at 15 year intervals for all applicable facilities.

Section 4: Net Present Value Analysis

The LCC is based on a net-present-value (NPV) analysis. NPV analysis summarizes the present value of cash flow over a set period. All anticipated cost items for each project component should be estimated in 2016 dollars. The following sections discuss the escalation rates, discount rates and equations for applying these rates in the LCC analysis. Additionally, years of analysis and year of expenditure occurrence are discussed.

4.1 Escalation Rate, Discount Rates and Equations

Escalation and discount rates are displayed in Table 5. Each capital cost, O&M cost, and rehabilitation/replacement cost item should be escalated at a rate of four percent to determine the future value. To determine the present value of these items in the Year of Analysis, their values were adjusted at a discount rate of seven percent for capital projects and rehabilitation/replacement items and three percent for operation and maintenance items. The discount rates were developed by SVCW based on current and projected investment return rates.

Table 5. Escalation and Discount Rates	
Factor	Rate
Escalation	4%
Capital Project and Rehabilitation/Replacement Discount	7%
O&M Discount	3%

Escalation should be applied to each cost item using EQ 4-1 below to determine the future cost of each cost item.

$$FV = PV \cdot (1+i)^{(Y_n - Y_{2016})}$$ *[EQ 4-1]*, where

- FV = Future Value
- PV = Present Value
- i = Escalation (4%)
- Y_n = Year of Capital Outlay/Occurrence
- Y_{2016} = Present Year = 2016

After escalating all cost items to future values, using Year 2016 as the present year, the 50-Year LCC should be determined at the Year of Beneficial Use. The Year of Beneficial Use was determined to be the year that the major facilities (i.e., Tunnel, RLS and Headworks) start up. Based on the current program-wide schedule (Version 13 dated June 23, 2016) developed by SVCW, the Year of Beneficial Use is the Year 2022.

To determine the costs at the Year of Beneficial Use, discounting is applied to place the different costs that occur on different timelines on a comparable basis. Discounting also facilitates the determination of how much funds SVCW will need to invest today to pay for future assets and expenses. Each consultant should use the sum of cost items calculated by EQ 4-1 and EQ 4-2 over a 50-year period to determine the 50-Year LCC at the Year of Beneficial Use.

Costs items occurring before 2022 are considered sunk costs; therefore, the costs can simply be calculated using EQ 4-1 without any discount factors applied. For costs that occur after 2022, EQ 4-2 should be used to account for assets and expenses incurred at the time of Beneficial Use.

$$Z_i = FV_i \cdot (1+r)^{-(Y_n - Y_{2022})}$$ *[EQ 4-2]*, where

- Z_i = Future Cost at Year of Beneficial Use
- FV_i = Future Value as calculated by EQ 4-1
- r = Discount Rate (Per Table 4)
- Y_n = Year of Capital Outlay/Occurrence
- Y_{2022} = Year of Beneficial Use = 2022

All cost components should be summed over a 50-Year Period ending in the Year 2066, which will provide the overall LCC for each project. SVCW will compile the LCCs from each project team to determine the program-wide LCC value. A simplified, example calculation for determining the LCC of a particular project is included in Attachment A.

4.2 Construction Schedules

Construction schedules were established based on the timing and scheduling of permitting, design and construction on a program-wide level. Each consultant team should use the current program-wide schedule (Version 13 dated June 23, 2016) developed by SVCW. A midpoint year and an end year of construction were established for each capital cost component. Capital costs should be entered into the LCC model at the midpoint year of construction. For example, if the tunnel and Gravity Pipeline's midpoint of construction occurs in the Year 2020, the capital outlay or sunk cost for that facility is placed in the Year 2020. The end year of construction should be used to establish abandonment years for existing facilities and to establish O&M, replacement, and rehabilitation for new facilities. Recurring O&M or rehabilitation/replacement costs should occur at the scheduled maintenance and/or rehabilitation/replacement intervals determined by each consultant team.

Section 5: LCC Analysis Deliverable

In addition to SVCW, the audience for the LCC reports is the State's SRF staff. They will be conducting a detailed due-diligence review of the LCC assumptions, calculations and estimated costs. To support the SRF application each consultant team needs to prepare a separate LCC analysis for each project identified within this TM. Each project package will need to include a cover letter describing the LCC analysis assumptions. The cover letter should include the following assumptions:

- Construction cost components including assumed structures, facilities, equipment and construction activities to be included in the project.
- Markups (project contingency, soft costs and market fluctuations) assumed to convert construction costs into capital costs.
- Midpoint year of construction.
- Year of construction completion.
- O&M costs.
- Rehabilitation and replacement costs.
- Escalation and discount rates.

Calculations should be included as an attachment. The calculations should clearly show all equations, costs and markups used in the analysis.

Attachment A: LCC Example Calculation

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SVCW Life Cycle Cost (LCC) Example Calculation

A. Purpose: This sheet provides a simplied, example LCC calculation for a 50-year analysis period. The equations used below are further explained in TM 11-3: Life Cycle Cost Analysis Guidelines. This example is based on the Belmont Force Main Project.

All user inputs are highlighted below in green.

B. Step 1: Conversion from Construction Cost to Capital Cost: Equation 3-1 from TM 11-3 is used to convert the construction cost developed by each team into a capital cost. Contingency, soft cost and market fluctuation cost factors are displayed below.

Capital Cost = Construction Cost x [1 + Project Contingency + Σ(Soft Costs) + Market Fluctuations] [EQ 3-1]

1. Project Contingency (all projects except Gravity Pipeline), Cont: $\text{Cont} := 25\%$

2. Soft Costs, SC:

- Construction Management and Engineering Service for Pipeline Projects: $SC_{CM} := 15\%$
- Conract Change Orders: $SC_{CCO} := 5\%$
- Planning: $SC_{Plan} := 5\%$
- Design: $SC_{Design} := 10\%$
- Project Management $SC_{PM} := 5\%$

3. Market Fluctuation, MF:

$MF_{low} := -5\%$

$MF_{base} := 0\%$

$MF_{high} := 15\%$

4. Capital Cost, CC: For the Belmont Force Main Project, the construction cost is $3,200,000 and occurs in the midyear of construction.

Display Unit of Dollars: $\text{dollars} := 1$

$\text{Cost}_{Construction} := 3.2 \cdot 10^{6} \text{dollars}$ *Note: From Consultant's Construction Cost Estimate, May 2016*

$$\text{Cost}_{Capital\_low} := \text{Cost}_{Construction} \cdot \left(1 + \text{Cont} + SC_{CM} + SC_{CCO} + SC_{Plan} + SC_{Design} + SC_{PM} + MF_{low}\right) = 5.12 \times 10^{6} \cdot \text{dollars}$$

$$\text{Cost}_{Capital\_base} := \text{Cost}_{Construction} \cdot \left(1 + \text{Cont} + SC_{CM} + SC_{CCO} + SC_{Plan} + SC_{Design} + SC_{PM} + MF_{base}\right) = 5.28 \times 10^{6} \cdot \text{dollars}$$

$$Cost_{Capital\_high} := Cost_{Construction} \cdot (1 + Cont + SC_{CM} + SC_{CCO} + SC_{Plan} + SC_{Design} + SC_{PM} + MF_{high}) = 5.76 \times 10^{6} \cdot dollars$$

$Y_{capital}$ = Midpoint Year of Construction $Y_{capital} := 2022$

C. Step 2: Calculate Operation and Maintenance (O&M) Costs: The following O&M assumptions are made for the Belmont Force Main:

1. Future Annual O&M Costs are assumed to be included in the conveyance system pump stations; therefore, do not need to be accounted for in this analysis.
2. The force main does not require regular cleaning; therefore, there are no cleaning costs associated with the Belmont Force Main.
3. Inspections are completed by acoustic doppler technology every 10 years after rehabilitation at the cost shown below.

Consultant should determine the project specific O&M elements for Step 2.

1. Pipe Inspections

- Construction Finish Year, $Y_{EndConst}$: $Y_{EndConst} := 2023$
- Inspection Cost, $Cost_{Unit\_Inspect}$: $Cost_{Unit\_Inspect} := \frac{10dollars}{ft}$
- Length of Belmont Force Main, L_{FM}: $L_{FM} := 4700ft$

Annual cost for pipe inspections is calculated as follows:

$$Cost_{Annual\_Inspect} := L_{FM} \cdot Cost_{Unit\_Inspect} = 47000 \cdot dollars$$

Inspection occurs every 10 years under a 50-year cycle; therefore, inspections occur in the following years:

$$Y_{OM\_1} := Y_{EndConst} + 10 = 2033$$

$$Y_{OM\_2} := Y_{EndConst} + 20 = 2043$$

$$Y_{OM\_3} := Y_{EndConst} + 30 = 2053$$

$$Y_{OM\_4} := Y_{EndConst} + 40 = 2063$$

D. Step 3: Calculate Rehabilitation and Replacement Costs: The anticipated design life for new force mains is 75 years; thus, no rehabilitation or replacement costs need to be calculated for the force main since the design life occurs outside of the analysis window of 50 years.

Consultant should determine the project specific Rehabilitation and Replacement Costs for Step 3.

E. Step 4: Calculate the Future Value of All Costs:

- Current Year, $Y_{current}$: $Y_{current} := 2016$
- Escalation, i: $i := 4\%$
- Calculate future values, FV using TM 11-3, EQ 4-1:
  $FV = PV \times (1+i)^{Yn-Ycurrent}$,
  where Y_n is the year the cost occurs and PV = present value.

$$FV_{capital\_low} := Cost_{Capital\_low} \cdot (1+i)^{Y_{capital}-Y_{current}} = 6.48 \times 10^{6} \cdot dollars$$

$$FV_{capital\_base} := Cost_{Capital\_base} \cdot (1+i)^{Y_{capital}-Y_{current}} = 6.68 \times 10^{6} \cdot dollars$$

$$FV_{capital\_high} := Cost_{Capital\_high} \cdot (1+i)^{Y_{capital}-Y_{current}} = 7.29 \times 10^{6} \cdot dollars$$

$$FV_{OM\_1} := round\left[Cost_{Annual\_Inspect} \cdot (1+i)^{Y_{OM\_1}-Y_{current}}, -4\right] = 90000 \cdot dollars$$

$$FV_{OM\_2} := round\left[Cost_{Annual\_Inspect} \cdot (1+i)^{Y_{OM\_2}-Y_{current}}, -4\right] = 140000 \cdot dollars$$

$$FV_{OM\_3} := round\left[Cost_{Annual\_Inspect} \cdot (1+i)^{Y_{OM\_3}-Y_{current}}, -4\right] = 200000 \cdot dollars$$

$$FV_{OM\_4} := round\left[Cost_{Annual\_Inspect} \cdot (1+i)^{Y_{OM\_4}-Y_{current}}, -4\right] = 300000 \cdot dollars$$

F. Step 5: Calculate Present Value at Year of Beneficial Use:

- Year of Beneficial Use, Y_{BFU}: $Y_{BFU} := 2022$
- Discount Rate for O&M, r_{OM}: $r_{OM} := 3\%$
- Discount Rate for Capital and Rehab/Replace, $r_{capital}$: $r_{capital} := 7\%$
- Calculate Present Values for all Years above Year of Beneficial Use using TM 11-3, EQ 4-2:

  Z = FV x (1+r)^(Y_{BFU}-$Y_{current}$),
  where Z is the cost at the Year of Beneficial Use and FV is the future value calcuated in Step 4.

- For all costs occuring before Year of Beneficial Use, assume these costs are sunk costs in the year it occurs. Therefore, the future value as calculated in Step 4 will be used.

$$Z_{capital\_low} := \text{if}\left[Y_{capital} \le Y_{BFU}, FV_{capital\_low}, FV_{capital\_low}\cdot(1 + r_{capital})^{-(Y_{capital}-Y_{BFU})}\right] = 6.48 \times 10^{6}\cdot\text{dollars}$$

$$Z_{capital\_base} := \text{if}\left[Y_{capital} \le Y_{BFU}, FV_{capital\_base}, FV_{capital\_base}\cdot(1 + r_{capital})^{-(Y_{capital}-Y_{BFU})}\right] = 6.68 \times 10^{6}\cdot\text{dollars}$$

$$Z_{capital\_high} := \text{if}\left[Y_{capital} \le Y_{BFU}, FV_{capital\_high}, FV_{capital\_high}\cdot(1 + r_{capital})^{-(Y_{capital}-Y_{BFU})}\right] = 7.29 \times 10^{6}\cdot\text{dollars}$$

$$Z_{OM\_1} := \text{round}\left[\text{if}\left[Y_{OM\_1} \le Y_{BFU}, FV_{OM\_1}, FV_{OM\_1}\cdot(1 + r_{OM})^{-(Y_{OM\_1}-Y_{BFU})}\right], -4\right] = 70000\cdot\text{dollars}$$

$$Z_{OM\_2} := \text{round}\left[\text{if}\left[Y_{OM\_2} \le Y_{BFU}, FV_{OM\_2}, FV_{OM\_2}\cdot(1 + r_{OM})^{-(Y_{OM\_2}-Y_{BFU})}\right], -4\right] = 80000\cdot\text{dollars}$$

$$Z_{OM\_3} := \text{round}\left[\text{if}\left[Y_{OM\_3} \le Y_{BFU}, FV_{OM\_3}, FV_{OM\_3}\cdot(1 + r_{OM})^{-(Y_{OM\_3}-Y_{BFU})}\right], -4\right] = 80000\cdot\text{dollars}$$

$$Z_{OM\_4} := \text{round}\left[\text{if}\left[Y_{OM\_4} \le Y_{BFU}, FV_{OM\_4}, FV_{OM\_4}\cdot(1 + r_{OM})^{-(Y_{OM\_4}-Y_{BFU})}\right], -4\right] = 90000\cdot\text{dollars}$$

G. Step 6: Calculate the Total Cost for the Year of Beneficial Use by Summing the Adjusted Values in Step 5:

$$Z_{total\_low} := Z_{capital\_low} + Z_{OM\_1} + Z_{OM\_2} + Z_{OM\_3} + Z_{OM\_4} = 6.8 \times 10^{6} \cdot dollars$$

$$Z_{total\_base} := Z_{capital\_base} + Z_{OM\_1} + Z_{OM\_2} + Z_{OM\_3} + Z_{OM\_4} = 7 \times 10^{6} \cdot dollars$$

$$Z_{total\_high} := Z_{capital\_high} + Z_{OM\_1} + Z_{OM\_2} + Z_{OM\_3} + Z_{OM\_4} = 7.61 \times 10^{6} \cdot dollars$$

The total 50-Year LCC for the Year of Beneficial Use is $7.00 million for the Belmont Force Main with a range of $6.80 million to $7.61 million accounting for market fluctuations.

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Appendix P

Headworks Facility Opinion of Probable Construction Cost

Opinion of Probable Cost - Feb - 2016- Preliminary Design

Project name	SVCW Headworks Project
Estimator	KJ,SH,SM
Labor rate table	CA16 San Francisco
Equipment rate table	00 15 Equip Rate BOF
Bid date	2/19/2016
Notes	This is an Opinion of Probable Construction Cost only, as defined by the documents provided at the level of design indicated above. CDM has no control over the cost of labor, materials, equipment, or services furnished, over schedules, over contractor's methods of determining prices, competitive bidding (at least 3 each - both prime bidders and major subcontractors), market conditions or negotiating terms. CDM does not guarantee that this opinion will not vary from actual cost, or contractor's bids. There are not any costs provided for: Change Orders, Design Engineering, Construction Oversight, Client Costs, Finance or Funding Costs, Legal Fees, Land Acquisition or temporary/permanent Easements, Operations, or any other costs associated with this project that are not specifically part of the bidding contractor's proposed scope. Assumptions: No rock excavation is required. No Dewatering is included No consideration for contaminated soils or hazardous materials (e.g. asbestos, lead) Based on a 40 hour work week with no overtime.
Report format	Sorted by 'Area/95CSI Sctn/Element' 'Detail' summary Allocate addons

Spreadsheet Level	Takeoff Quantity	Labor Amount	Material Amount	Equip Amount	Sub Amount	Other Amount	Total Cost/Unit	Total Amount
002 Site Work								
02740 Asphalt Paving								
02740.48002 Site Paving (Assumed 6" over 8")	30,950.00 sf	72,745	115,731	48,479	29,525		8.61 /sf	266,479
02740 Asphalt Paving		72,745	115,731	48,479	29,525			266,479
02800 Site Improvements								
02800.48002 Site Sidewalk, Curb & Cutter	3,200.00 sf				14,472		4.52 /sf	14,472
02800.48004 Site Valley Gutter	80.00 lf				1,126		14.07 /lf	1,126
02800.48006 Site Curb & Gutter	800.00 lf				16,884		21.11 /lf	16,884
02800.48008 Site Signage & Striping	1.00 ls		7,236		7,136		14,371.50 /ls	14,372
02800.48010 Site Bollards	20.00 ea	5,950	2,554	960			473.19 /ea	9,464
02800 Site Improvements		5,950	9,790	960	39,617			56,317
02900 Planting								
02900.48002 Lanscaping Allownace	1.00 ls					175,875	175,875.00 /ls	175,875
02900 Planting						175,875		175,875
002 Site Work		**78,695**	**125,520**	**49,439**	**69,142**	**175,875**		**498,671**
010 Diversion Box 1 (Influent)								
02304 Structural Excavation & Fill								
02304.48102 Structural Excavation & Backfill	77.00 cy	1,534		2,258			49.24 /cy	3,791
02304 Structural Excavation & Fill		1,534		2,258				3,791
02305 Structural Import								
02305.48104 Structural Rock Section	56.00 cy	679	2,131	687	618		73.48 /cy	4,115
02305 Structural Import		679	2,131	687	618			4,115
02455 Driven Piles								
02455.48102 14" SQ Driven Concrete Piles (100' In Depth)	23.00 ea	57,149	146,301	28,942	5,725		10,352.90 /ea	238,117
02455 Driven Piles	23.00 ea	57,149	146,301	28,942	5,725		10,352.90 /ea	238,117
03000 CONCRETE								
03000.4502 1.5' Thick Concrete Mat Slab on Grade - 25.42cy	25.42 cy	7,933	9,102	908			705.83 /cy	17,942
03000.4508 Concrete Walls Running E-W 10.19' Tall - 2ea @ 14.32cy/ea	28.64 cy	15,321	11,578	1,894			1,005.37 /cy	28,794
03000.4509 Added Concrete Wall to Support Elevated Slab 10.19' Tall - 1ea 13.6cy	13.60 cy	7,276	5,498	900			1,005.37 /cy	13,673
03000.4510 Concrete Walls Running N-S 10.19' Tall - 2ea @ 4.22cy/ea	8.44 cy	4,515	3,412	558			1,005.37 /cy	8,485
03000.4522 1'-3" Thick Concrete Elevated Slab w/ Sacraficial Forms - 21.11cy	21.11 cy	11,294	17,556	1,396			1,432.78 /cy	30,246
03000.4524 Concrete Walls at the Diversion Structure 6.56' Tall - 23.78cy	23.78 cy	12,722	9,613	1,573			1,005.37 /cy	23,908
03000.4526 12" Thick Concrete Elevated Slab w/ Sacraficial Forms - 17.09cy	17.09 cy	9,143	14,212	1,130			1,432.72 /cy	24,485
03000 CONCRETE	138.00 cy	68,203	70,970	8,360			1,069.08 /cy	147,533
03151 Concrete Embedes & LIning								
03150.4572 T-Lok Liner for Diversion Box #1 Walls - 1,786sf	1,786.00 sf	12,789	12,686	248			14.40 /sf	25,722
03151 Concrete Embedes & LIning		12,789	12,686	248				25,722
13400 MEASUREMENT & CONTROL INSTRUMENTATION								
13400.0010 Instruments	1.00 ls				9,161		9,161.18 /ls	9,161
13400 MEASUREMENT & CONTROL INSTRUMENTATION					9,161			9,161
15220 Steel Pipe								
15220.2202 66" Wall Pipes w/ Blind Flanges	2.00 ea	13,950	57,292	2,291			36,767.03 /ea	73,534
15220 Steel Pipe		13,950	57,292	2,291				73,534
16000 Electrical Allowance/Miscellaneous								
16000.0032 Equipment Connections	2.00 ea				5,025		2,512.50 /ea	5,025
16000.0120 Power Feeders for LIghting, Recept, and Control, Avg	800.00 lf				13,805		17.26 /lf	13,805
16000 Electrical Allowance/Miscellaneous					18,830			18,830
010 Diversion Box 1 (Influent)		**154,303**	**289,381**	**42,785**	**34,334**			**520,803**
020 Screening Facility								
02304 Structural Excavation & Fill								
02304.48202 Structural Excavation & Backfill	440.00 cy	8,257		12,416			46.98 /cy	20,673
02304 Structural Excavation & Fill		8,257		12,416				20,673
02305 Structural Import								
02305.48204 Structural Rock Section	327.00 cy	3,964	12,444	4,010	3,609		73.48 /cy	24,028
02305 Structural Import		3,964	12,444	4,010	3,609			24,028
02455 Driven Piles								

Spreadsheet Level	Takeoff Quantity	Labor Amount	Material Amount	Equip Amount	Sub Amount	Other Amount	Total Cost/Unit	Total Amount
02455.48202 14" SQ Driven Concrete Piles (100' In Depth)	67.00 ea	165,856	411,621	82,766	5,725		9,939.82 /ea	665,968
02455 Driven Piles	67.00 ea	165,856	411,621	82,766	5,725		9,939.82 /ea	665,968
03000 CONCRETE								
03000.4504 1.5' Thick Concrete Mat Slab on Grade - 170.15cy	170.15 cy	53,098	60,922	6,078			705.83 /cy	120,098
03000.4512 12" Concrete Wing Walls from Diversion Box to Screening - 8.23cy	8.23 cy	5,870	3,327	544			1,183.69 /cy	9,742
03000.4514 12" Concrete Walls Running E-W 10.19' Tall - 2ea @ 22.94cy/ea	45.88 cy	24,544	18,547	3,035			1,005.37 /cy	46,126
03000.4516 12" Concrete Walls Running N-S 10.19' Tall - 6ea @ 14.69cy/ea	88.13 cy	47,149	35,628	5,830			1,005.41 /cy	88,607
03000.4518 12" Concrete Walls E&W at Screens Effluent Channel - 2ea @ 1.8cy/ea	3.60 cy	1,926	1,455	238			1,005.36 /cy	3,619
03000.4520 18" Concrete Wall E&W Between Screening and Grit - 1ea @ 34.5cy/ea	34.53 cy	18,474	13,960	2,284			1,005.45 /cy	34,718
03000.4532 1'-3" Thick Concrete Elevated Slab w/ Sacraficial Forms - 141.82cy	141.82 cy	75,869	117,938	9,381			1,432.72 /cy	203,188
03000.4534 Concrete Screen Channel Walls 6.56' Tall - 146.8cy	146.80 cy	78,533	59,344	9,710			1,005.37 /cy	147,588
03000.4536 12" Concrete Walls E&W at Screens Effluent Channel - 2ea @ 1.36cy/ea	2.72 cy	1,455	1,100	180			1,005.36 /cy	2,735
03000.4538 12" Concrete Wing Walls from Diversion Box to Screening - 5.66cy	5.66 cy	4,037	2,288	374			1,183.69 /cy	6,700
03000.4540 18" Concrete Wall E&W Between Screening and Grit - 1ea @ 22.26cy/ea	22.26 cy	11,908	8,999	1,472			1,005.37 /cy	22,379
03000.4542 12" Thick Concrete Elevated Slab w/ Sacraficial Forms - 83.38cy	83.38 cy	44,606	69,339	5,515			1,432.72 /cy	119,460
03000 CONCRETE	753.00 cy	367,470	392,846	44,642			1,069.00 /cy	804,959
03151 Concrete Embedes & LIning								
03150.4502 T-Lok Liner for Screen Channel Walls - 5ea @ 511.68sf/ea	2,558.40 sf	18,319	18,173	355			14.40 /sf	36,847
03150.4504 T-Lok Liner for Screens Effluent Channel - 968.5sf	968.50 sf	6,935	6,880	134			14.40 /sf	13,949
03151 Concrete Embedes & LIning		25,254	25,052	489				50,795
05120 Structural Steel								
05120.4520 Exterior Metal Stairs and Landings - 5 ea - Assumed	5.00 ea	111,178	60,291	43,552			43,004.28 /ea	215,021
05120 Structural Steel		111,178	60,291	43,552				215,021
05140 Aluminum								
05140.4502 Alum Cover Plate and Support at Screen Chnls- 5ea @ 164.25sf/ea	821.25 sf	4,713	56,913	1,846			77.29 /sf	63,471
05140.4504 Alum Cover Plate and Support Screen Eff Chnl- 283.6sf	283.60 sf	1,627	19,653	637			77.29 /sf	21,918
05140 Aluminum		6,340	76,566	2,484				85,390
05520 Handrail/Railing								
05120.4520 Exterior Metal Stairs and Landings - 5 ea - Assumed	5.00 ea	5,848	5,775				2,324.57 /ea	11,623
05520.4522 Guardrail at Second Level - 193lf	193.00 lf	4,515	26,750				161.99 /lf	31,264
05520 Handrail/Railing		10,362	32,525					42,887
05585 Formed Metal Fabrications								
05585.4502 Floor Door Hatch - 1ea	1.00 ea	337	7,103				7,440.08 /ea	7,440
05585 Formed Metal Fabrications		337	7,103					7,440
11251 Mechanical Multi Rake Screen								
11251.2202 Multi Rake Bar Screens - Supply	4.00 ea		739,200				184,800.00 /ea	739,200
11251.2204 Multi Rake Bar Screens - Install	4.00 ea	12,041	5,198	2,608		1,802	5,412.10 /ea	21,648
11251 Mechanical Multi Rake Screen		12,041	744,398	2,608		1,802		760,848
11252 Manual Screen								
04-11280.2603 Manual Screen in Channel	1.00 ea	7,246	35,462	701			43,409.28 /ea	43,409
11252 Manual Screen		7,246	35,462	701				43,409
11281 Stop Logs								
11281.2202 Stop Log Plates in Channel	1.00 ea	3,409	22,176	96		404	26,085.17 /ea	26,085
11281 Stop Logs		3,409	22,176	96		404		26,085
11284 Sluiceway and Gates								
04-11280.2600 Sluiceway Channel Isolation Gates	20.00 ea	101,258	509,586				30,542.19 /ea	610,844
11200.2208 316 SS Sluiceway - Supply	1.00 ls		277,200				277,200.00 /ls	277,200
11200.2209 316 SS Sluiceway - Install	1.00 ls	14,872	1,733	1,931		845	19,381.03 /ls	19,381
11284 Sluiceway and Gates		116,130	788,519	1,931		845		907,425
13400 MEASUREMENT & CONTROL INSTRUMENTATION								
13400.0010 Instruments	1.00 ls				54,967		54,967.07 /ls	54,967
13400 MEASUREMENT & CONTROL INSTRUMENTATION					54,967			54,967
15241 PVC Pipe & Fittings								
15241.2202 Overflow PIping	1.00 ls	4,087	2,121				6,207.75 /ls	6,208
15241.2209 Drain Piping	1.00 ls	6,648	7,580				14,227.96 /ls	14,228
15241 PVC Pipe & Fittings		10,735	9,701					20,436
16000 Electrical Allowance/Miscellaneous								

Spreadsheet Level	Takeoff Quantity	Labor Amount	Material Amount	Equip Amount	Sub Amount	Other Amount	Total Cost/Unit	Total Amount
16000.0032 Equipment Connections	38.00 ea				95,475		2,512.50 /ea	95,475
16000.0060 Grounding & Lightning protection	1.00 ls				5,025		5,025.00 /ls	5,025
16000.0090 Building Lighting	58.00 ea				58,290		1,005.00 /ea	58,290
16000.0091 Motor Starters, DIsconnects, Control Panels Connections	38.00 ea				41,398		1,089.42 /ea	41,398
16000.0120 Power Feeders for LIghting, Recept, and Control, Avg	13,250.00 lf				228,640		17.26 /lf	228,640
16000.0290 Electrical Allowance (NOC)	1.00 ls					28,875	28,875.00 /ls	28,875
16000 Electrical Allowance/Miscellaneous					428,828	28,875		457,703
020 Screening Facility		**848,580**	**2,618,704**	**195,694**	**493,130**	**31,926**		**4,188,034**
030 Screening Building								
03600 Grout								
08110.4522 Single Man Door - 2ea	2.00 ea	654	77				365.30 /ea	731
03600 Grout		654	77					731
04200 Masonry								
04200.4522 12" CMU Exterior Wall - Split Faced Assumed - 3,260.4sf	3,260.40 sf				117,961		36.18 /sf	117,961
04200 Masonry					117,961			117,961
05120 Structural Steel								
05120.4510 Metal Stairs and Landings - 2 ea	2.00 ea	44,471	24,116	17,421			43,004.29 /ea	86,009
05120.4525 Metal Deck Support Angle - 167lf	167.00 lf	958	5,339	375			39.96 /lf	6,673
05120.4533 Structural Steel Channel - 1 ea @ 36'/ea	1.00 ea	546	1,913	214			2,672.66 /ea	2,673
05120.4562 Structural Steel Beams - 8ea @ 36'/ea	8.00 ea	8,737	46,570	3,423			7,341.16 /ea	58,729
05120 Structural Steel		54,713	77,938	21,433				154,083
05300 Steel Deck								
05300.4526 Roof Metal Decking - 1,709sf	1,709.00 sf	1,961	5,922	768			5.06 /sf	8,651
05300 Steel Deck		1,961	5,922	768				8,651
05510 Metal Ladders								
05510.4502 Roof Access Ladder - Assumed 1ea @ 15lf	1.00 ea	702	866				1,567.99 /ea	1,568
05510 Metal Ladders		702	866					1,568
05520 Handrail/Railing								
05120.4510 Metal Stairs and Landings - 2 ea	2.00 ea	2,339	2,310				2,324.56 /ea	4,649
05520 Handrail/Railing		2,339	2,310					4,649
07530 Elastomeric Membrane Roofing								
07530.4522 Building Roof - 1,709sf	1,709.00 sf	6,293	12,023				10.72 /sf	18,316
07530 Elastomeric Membrane Roofing		6,293	12,023					18,316
07630 Roof Drains								
07710.4502 Roof Drainage - Assumed 4ea Downspouts	1.00 ls	976	7,900				8,876.06 /ls	8,876
07630 Roof Drains		976	7,900					8,876
07720 Roof Accessories								
07720.4502 Roof Hatches - Assumed 1ea	1.00 ea	364	1,964				2,327.23 /ea	2,327
07720 Roof Accessories		364	1,964					2,327
08110 Metal Doors & Frames								
08110.4522 Single Man Door - 2ea	2.00 ea	1,182	4,620				2,901.06 /ea	5,802
08110 Metal Doors & Frames		1,182	4,620					5,802
08510 Windows								
08510.4522 Windows Assumed 4'x4' - 8ea	8.00 ea		8,870				1,108.80 /ea	8,870
08510 Windows			8,870					8,870
09910 Architectural Painting								
09910.4502 Finish Interior Painting - Assumed	8,144.00 sf	14,344	9,299				2.90 /sf	23,642
09910 Architectural Painting		14,344	9,299					23,642
09981 Special & High Performance Coatings								
09981.4507 Concrete Sealer Elevated Floor - 957sf	957.00 sf	2,466	1,091				3.72 /sf	3,557
09981 Special & High Performance Coatings		2,466	1,091					3,557
10210 Wall Louvers								
10210.4522 Fixed Louvers - 4'x4' - 2ea	2.00 ea	1,031	1,531				1,280.82 /ea	2,562
10210 Wall Louvers		1,031	1,531					2,562
15500 HVAC								
15500.2203 HVAC Allowance	1.00 ls				76,380		76,380.00 /ls	76,380

Spreadsheet Level	Takeoff Quantity	Labor Amount	Material Amount	Equip Amount	Sub Amount	Other Amount	Total Cost/Unit	Total Amount
15500.2209 HVAC Allowance	1.00 ls	32,557	32,557	32,557	28,329	32,557	158,557.50 /ls	158,558
15500 HVAC		32,557	32,557	32,557	104,709	32,557		234,938
16000 Electrical Allowance/Miscellaneous								
16000.0090 Building Lighting	58.00 ea				58,290		1,005.00 /ea	58,290
16000 Electrical Allowance/Miscellaneous					58,290			58,290
030 Screening Building		**119,581**	**166,967**	**54,758**	**280,960**	**32,557**		**654,824**
040 Grit Removal Facility								
02250 Sheeting, Shoring & Bracing								
02250.48402 Sheeting @ Grit Removal Building	300.00 lf	66,368	173,250	27,674			890.97 /lf	267,292
02250 Sheeting, Shoring & Bracing		66,368	173,250	27,674				267,292
02304 Structural Excavation & Fill								
02304.48402 Structural Excavation & Backfill	1,800.00 cy	30,667		47,144			43.23 /cy	77,811
02304 Structural Excavation & Fill		30,667		47,144				77,811
02305 Structural Import								
02305.48404 Structural Rock Section	598.00 cy	7,248	22,758	7,333	6,601		73.48 /cy	43,940
02305 Structural Import		7,248	22,758	7,333	6,601			43,940
02455 Driven Piles								
02455.48402 14" SQ Driven Concrete Piles (100' In Depth)	144.00 ea	356,094	875,931	176,957	5,725		9,824.36 /ea	1,414,708
02455 Driven Piles	144.00 ea	356,094	875,931	176,957	5,725		9,824.36 /ea	1,414,708
03000 CONCRETE								
03000.4550 2' Thick Concrete Mat Slab on Grade - 266.2cy	266.20 cy	83,072	95,313	9,508			705.83 /cy	187,893
03000.4552 1'-10" Concrete Walls at Grit Infl Channel 15.5' Tall - 72.86cy	72.86 cy	38,978	29,454	4,819			1,005.37 /cy	73,251
03000.4554 1'-6" Concrete Walls at Grit Infl Channel 15.5' Tall - 88.76cy	88.76 cy	47,484	35,881	5,871			1,005.37 /cy	89,236
03000.4556 1'-6" Concrete Walls at Grit Separators 15.5' Tall - 5ea @ 23.15cy/ea	115.75 cy	61,923	46,792	7,656			1,005.37 /cy	116,371
03000.4558 1'-6" Concrete Walls at Grit Eff Channel 13' Tall - 104.82cy	104.82 cy	56,075	42,373	6,934			1,005.37 /cy	105,382
03000.4560 2' Concrete Walls at Grit Eff Channel 13' Tall - 68.36cy	68.36 cy	36,570	27,635	4,522			1,005.37 /cy	68,727
03000.4562 18"x24" Concrete Beams - 4ea @ 1.63cy/ea	6.52 cy	3,486	2,709	431			1,016.29 /cy	6,626
03000.4564 12" Thick Concrete Elevated Slab w/ Sacraficial Forms - 45.86cy	45.86 cy	24,534	38,137	3,033			1,432.72 /cy	65,704
03000.4565 12" Thick Concrete Elevated Slab w/ Sacraficial Forms - 19.52cy	19.52 cy	10,443	16,233	1,291			1,432.72 /cy	27,967
03000.4566 12" Concrete Walls at Grit Eff Channel 12.33' Tall - 35cy	35.00 cy	18,724	14,149	2,315			1,005.37 /cy	35,188
03000.4567 1'-6" Concrete Walls at Grit Eff Channel 12.33' Tall - 81cy	81.00 cy	43,332	32,744	5,358			1,005.37 /cy	81,435
03000.4568 2' Concrete Walls at Grit Eff Channel 12.33' Tall - 64cy	64.00 cy	34,238	25,872	4,233			1,005.37 /cy	64,343
03000.4569 12" Concrete Walls at Grit Infl Channel 9.33' Tall - 54.6cy	54.60 cy	29,209	22,072	3,612			1,005.37 /cy	54,893
03000.4571 1'-6" Concrete Walls at Grit Infl Channel 9.33' Tall - 51.6cy	51.60 cy	27,604	20,859	3,413			1,005.37 /cy	51,877
03000.4573 1'-10" Concrete Walls at Grit Infl Channel 9.33' Tall - 43.25cy	43.25 cy	23,137	17,484	2,861			1,005.37 /cy	43,482
03000.4575 8" Thick Concrete Elevated Slab w/ Sacraficial Forms - 45.24cy	45.24 cy	24,202	37,622	2,992			1,432.72 /cy	64,816
03002.4502 Grit Separator Concrete Fill 6.25' Thick - 4ea @ 59.25cy/ea	237.00 cy	42,262	38,323	1,568			346.64 /cy	82,153
03000 CONCRETE	1,400.00 cy	605,273	543,652	70,419			870.96 /cy	1,219,344
03151 Concrete Embedes & LIning								
03150.4510 T-Lok Liner for Grit Influent Channel Walls - 2232.15sf	2,232.15 sf	15,983	15,856	309			14.40 /sf	32,148
03150.4512 T-Lok Liner for Grit Separator Walls - 16ea @ 316sf/ea	5,056.00 sf	36,203	35,914	701			14.40 /sf	72,818
03150.4514 T-Lok Liner for Grit Effluent Channel Walls - 1867.71sf	1,867.71 sf	13,374	13,267	259			14.40 /sf	26,899
03151 Concrete Embedes & LIning		65,560	65,036	1,269				131,865
05120 Structural Steel								
05120.4510 Metal Stairs and Landings - 2 ea	2.00 ea	44,471	24,116	17,421			43,004.29 /ea	86,009
05120.4520 Exterior Metal Stairs and Landings - 5 ea - Assumed	5.00 ea	111,178	60,291	43,552			43,004.28 /ea	215,021
05120 Structural Steel		155,649	84,407	60,973				301,030
05140 Aluminum								
05140.4512 Alum Cover Plate and Support Grit Infl Chnl - 467.5sf	467.50 sf	2,683	32,398	1,051			77.29 /sf	36,131
05140.4514 Alum Cover Plate and Support Grit Separators - 4ea @ 260sf	1,040.00 sf	5,968	72,072	2,338			77.29 /sf	80,378
05140.4516 Alum Cover Plate and Support Grit Eff Chnl - 328.67sf	328.67 sf	1,886	22,777	739			77.29 /sf	25,402
05140 Aluminum		10,536	127,247	4,127				141,910
05520 Handrail/Railing								
05120.4510 Metal Stairs and Landings - 2 ea	2.00 ea	2,339	2,310				2,324.56 /ea	4,649
05120.4520 Exterior Metal Stairs and Landings - 5 ea - Assumed	5.00 ea	5,848	5,775				2,324.57 /ea	11,623
05520.4523 Guardrail at Second Level - 230.5lf	230.50 sf	5,392	31,947				161.99 /sf	37,339

Spreadsheet Level	Takeoff Quantity	Labor Amount	Material Amount	Equip Amount	Sub Amount	Other Amount	Total Cost/Unit	Total Amount
05520 Handrail/Railing		13,579	40,032					53,611
05585 Formed Metal Fabrications								
05585.4512 Floor Door Hatch - 2ea Assumed	2.00 ea	674	14,207				7,440.08 /ea	14,880
05585 Formed Metal Fabrications		674	14,207					14,880
09980 Paint Pipe/Valve/Equip/Structural Steel								
09980.2202 Pipe Painting	1.00 ls	15,823	1,418			61	17,302.08 /ls	17,302
09980 Paint Pipe/Valve/Equip/Structural Steel		15,823	1,418			61		17,302
11210 PUMPS								
11210.2202 Grit Pumps - Supply	4.00 ea		92,400				23,100.00 /ea	92,400
11210.2204 Grit Pumps - Install	4.00 ea	11,074	3,465	2,818		1,599	4,738.85 /ea	18,955
11210 PUMPS		11,074	95,865	2,818		1,599		111,355
11320 Grit Systems								
11320.2210 Vortex Grit Separator, Tray - Supply	4.00 ea		1,062,600				265,650.00 /ea	1,062,600
11320.2211 Vortex Grit Separator, Tray - Install	4.00 ea	62,358	9,933	5,216		1,460	19,741.75 /ea	78,967
11320 Grit Systems		62,358	1,072,533	5,216		1,460		1,141,567
13400 MEASUREMENT & CONTROL INSTRUMENTATION								
13400.0010 Instruments	1.00 ls				64,128		64,128.25 /ls	64,128
13400 MEASUREMENT & CONTROL INSTRUMENTATION					64,128			64,128
14630 OH Traveling Bridge Crane								
14630.2202 Bridge Crane Supply and Install	1.00 ea	777		47	40,200		41,024.74 /ea	41,025
14630 OH Traveling Bridge Crane		777		47	40,200			41,025
15111 Plug Valves								
15210.2203 Valves for Grit Piping	10.00 ea	5,975	7,854				1,382.87 /ea	13,829
15111 Plug Valves		5,975	7,854					13,829
15210 Ductile Iron Pipe								
15210.2202 Grit Piping	200.00 lf	18,358	23,552	997			214.53 /lf	42,906
15210.2210 Drain Piping for Grit 12"	200.00 lf	29,583	44,960	1,055			377.99 /lf	75,598
15210.2212 Drain Piping for Grit 10"	100.00 lf	11,996	15,495	514		9	280.14 /lf	28,014
15210 Ductile Iron Pipe		59,936	84,007	2,566		9		146,519
15220 Steel Pipe								
15220.2204 66" Piping under Grit Channel	75.00 lf	39,865	76,988	2,755		643	1,603.35 /lf	120,251
15220.2205 Piping under Effluent Channel	150.00 lf	85,953	190,899	5,286		858	1,886.64 /lf	282,996
15220 Steel Pipe		125,818	267,887	8,041		1,501		403,247
15241 PVC Pipe & Fittings								
15241.2201 Plant Water Piping Allowance	300.00 ls	6,648	7,580				47.43 /ls	14,228
15241.2202 Overflow PIping	150.00 ls	4,087	2,121				41.39 /ls	6,208
15241 PVC Pipe & Fittings		10,735	9,701					20,436
15248 FRP Pipe								
15248.2206 Odor Control Pipe -	200.00 lf	13,734	18,935	1			163.35 /lf	32,670
15248 FRP Pipe		13,734	18,935	1				32,670
16000 Electrical Allowance/Miscellaneous								
16000.0029 Connection to existing 12KV MV	1.00 ea				20,100		20,100.00 /ea	20,100
16000.0030 Duct Bank 12kv to Electrical Gear	50.00 lf				8,492		169.85 /lf	8,492
16000.0032 Equipment Connections	9.00 ea				22,613		2,512.50 /ea	22,613
16000.0040 Switch Gear	1.00 ls				60,300		60,300.00 /ls	60,300
16000.0060 Grounding & Lightning protection	1.00 ls				5,025		5,025.00 /ls	5,025
16000.0070 Stie Lighting	1.00 ls				20,100		20,100.00 /ls	20,100
16000.0091 Motor Starters, DIsconnects, Control Panels Connections	38.00 ea				41,398		1,089.42 /ea	41,398
16000.0120 Power Feeders for LIghting, Recept, and Control, Avg	13,250.00 lf				228,640		17.26 /lf	228,640
16000.0290 Electrical Allowance (NOC)	1.00 ls					28,875	28,875.00 /ls	28,875
16000 Electrical Allowance/Miscellaneous					406,668	28,875		435,543
040 Grit Removal Facility		**1,617,879**	**3,504,720**	**414,588**	**523,322**	**33,504**		**6,094,013**
050 Diversion Box 2 (Effluent)								
02250 Sheeting, Shoring & Bracing								
02250.48502 Sheeting @ Diversion Box 2 (Deep Sheet Shoring)	60.00 lf	11,618	41,580	4,844			967.36 /lf	58,042
02250 Sheeting, Shoring & Bracing		11,618	41,580	4,844				58,042
02304 Structural Excavation & Fill								

Spreadsheet Level	Takeoff Quantity	Labor Amount	Material Amount	Equip Amount	Sub Amount	Other Amount	Total Cost/Unit	Total Amount
02304.48502 Structural Excavation & Backfill	105.00 cy	1,717		2,707			42.13 /cy	4,424
02304 Structural Excavation & Fill		1,717		2,707				4,424
02305 Structural Import								
02305.48504 Structural Rock Section	66.00 cy	1,061	2,512	1,073	729		81.42 /cy	5,374
02305 Structural Import		1,061	2,512	1,073	729			5,374
02455 Driven Piles								
02455.48502 14" SQ Driven Concrete Piles (100' In Depth)	29.00 ea	76,838	182,481	38,812	5,725		10,477.80 /ea	303,856
02455 Driven Piles	29.00 ea	76,838	182,481	38,812	5,725		10,477.80 /ea	303,856
03000 CONCRETE								
03000.4570 2' Thick Concrete Mat Slab on Grade - 69.3cy	69.30 cy	21,626	24,813	2,475			705.83 /cy	48,914
03000.4572 1'-6" Concrete Walls Diversion Box #2 26.33' Tall - 95.81cy	95.81 cy	51,255	38,731	6,338			1,005.37 /cy	96,324
03000.4574 2' Concrete Walls Diversion Box #2 26.33' Tall - 9.53cy	9.53 cy	5,098	3,852	630			1,005.36 /cy	9,581
03000.4576 1'-6" Concrete Walls Diversion Box #2 13' Tall - 70.55cy	70.55 cy	37,742	28,520	4,667			1,005.37 /cy	70,929
03000.4577 2' Concrete Walls at Diversion Box #2 13' Tall - 11.17cy	11.17 cy	5,976	4,515	739			1,005.37 /cy	11,230
03000.4578 12" Thick Concrete Elevated Slab w/ Sacraficial Forms - 15.87cy	15.87 cy	8,490	13,197	1,050			1,432.72 /cy	22,737
03000.4580 12" Concrete Walls at Diversion Box #2 9.33' Tall - 7cy	7.00 cy	3,745	2,830	463			1,005.36 /cy	7,038
03000.4582 1'-6" Concrete Walls at Diversion Box #2 9.33' Tall - 27.45cy	27.45 cy	14,685	11,097	1,816			1,005.37 /cy	27,597
03000.4584 8" Thick Concrete Elevated Slab w/ Sacraficial Forms - 23.4cy	23.40 cy	12,518	19,459	1,548			1,432.72 /cy	33,526
03000 CONCRETE	330.00 cy	161,135	147,015	19,725			993.56 /cy	327,875
03151 Concrete Embedes & LIning								
03150.4520 T-Lok Liner for Diversion Structure - 4031.83sf	4,031.83 sf	28,870	28,639	559			14.40 /sf	58,068
03151 Concrete Embedes & LIning		28,870	28,639	559				58,068
16000 Electrical Allowance/Miscellaneous								
16000.0032 Equipment Connections	4.00 ea				10,050		2,512.50 /ea	10,050
16000.0120 Power Feeders for LIghting, Recept, and Control, Avg	5,300.00 lf				91,456		17.26 /lf	91,456
16000 Electrical Allowance/Miscellaneous					101,506			101,506
050 Diversion Box 2 (Effluent)		**281,238**	**402,227**	**67,720**	**107,960**			**859,145**
060 Flow Meter Vault								
02250 Sheeting, Shoring & Bracing								
02250.48602 Sheeting @ Flow Meter Vault	64.00 lf	14,158	36,960	5,904			890.97 /lf	57,022
02250 Sheeting, Shoring & Bracing		14,158	36,960	5,904				57,022
02304 Structural Excavation & Fill								
02304.48602 Structural Excavation & Backfill	215.00 cy	2,943		4,228			33.35 /cy	7,171
02304 Structural Excavation & Fill		2,943		4,228				7,171
02305 Structural Import								
02305.48604 Structural Rock Section	112.00 cy	1,856	4,262	1,878	1,236		82.43 /cy	9,232
02305 Structural Import		1,856	4,262	1,878	1,236			9,232
02455 Driven Piles								
02455.48602 14" SQ Driven Concrete Piles (100' In Depth)	25.00 ea	60,144	158,361	30,376	5,725		10,184.24 /ea	254,606
02455 Driven Piles	25.00 ea	60,144	158,361	30,376	5,725		10,184.24 /ea	254,606
03000 CONCRETE								
03002.4520 1'-4" Thick Concrete Mat Slab - 23.15cy	23.15 cy	7,224	8,289	827			705.83 /cy	16,340
03002.4522 12" Concrete Walls Flow Meter Box 8.5' Tall - 27.9cy	27.90 cy	14,926	11,279	1,846			1,005.37 /cy	28,050
03002.4524 1'-6" Thick Concrete Elevated Slab - 26.11cy	26.11 cy	13,968	15,079	1,727			1,178.62 /cy	30,774
03000 CONCRETE	77.00 cy	36,118	34,646	4,399			976.15 /cy	75,163
05120 Structural Steel								
05120.4511 Metal Stairs and Landings - 1 ea	1.00 ea	22,236	12,058	8,710			43,004.29 /ea	43,004
05120 Structural Steel		22,236	12,058	8,710				43,004
05520 Handrail/Railing								
05120.4511 Metal Stairs and Landings - 1 ea	1.00 ea	1,170	1,155				2,324.57 /ea	2,325
05520 Handrail/Railing		1,170	1,155					2,325
07720 Roof Accessories								
07720.4502 Roof Hatches - Assumed 1ea	1.00 ea	364	1,964				2,327.23 /ea	2,327
07720 Roof Accessories		364	1,964					2,327
13420 I&C Instruments								
13420.2202 Flow Meter 48"	1.00 ea	4,159	35,175				39,334.01 /ea	39,334

Spreadsheet Level	Takeoff Quantity	Labor Amount	Material Amount	Equip Amount	Sub Amount	Other Amount	Total Cost/Unit	Total Amount
13420.2204 Flow Meter 54"	1.00 ea	4,159	45,225				49,384.01 /ea	49,384
13420 I&C Instruments		8,318	80,400					88,718
15210 Ductile Iron Pipe								
15210.2215 48" Piping to Flow Meter	40.00 lf	17,902	79,627	1,015			2,463.61 /lf	98,544
15210.2230 54" Piping to Flow Meter	40.00 lf	22,793	117,047	1,208			3,526.19 /lf	141,048
15210 Ductile Iron Pipe		40,696	196,674	2,222				239,592
16000 Electrical Allowance/Miscellaneous								
16000.0032 Equipment Connections	2.00 ea				5,025		2,512.50 /ea	5,025
16000.0120 Power Feeders for LIghting, Recept, and Control, Avg	2,650.00 lf				45,728		17.26 /lf	45,728
16000 Electrical Allowance/Miscellaneous					50,753			50,753
060 Flow Meter Vault		**188,002**	**526,480**	**57,718**	**57,714**			**829,914**
070 Screenings/ Grit Handling Facility								
02304 Structural Excavation & Fill								
02304.48702 Structural Excavation & Backfill	372.00 cy	5,092		7,315			33.35 /cy	12,407
02304 Structural Excavation & Fill		5,092		7,315				12,407
02305 Structural Import								
02305.48704 Structural Rock Section	323.00 cy	3,915	12,292	3,961	3,565		73.48 /cy	23,734
02305 Structural Import		3,915	12,292	3,961	3,565			23,734
02455 Driven Piles								
02455.48702 14" SQ Driven Concrete Piles (100' In Depth)	62.00 ea	147,665	381,471	73,612	5,725		9,814.08 /ea	608,473
02455 Driven Piles	62.00 ea	147,665	381,471	73,612	5,725		9,814.08 /ea	608,473
03000 CONCRETE								
03000.4563 18"x24" Concrete Beams - 3ea @ 4.22cy/ea	12.66 cy	6,773	5,264	837			1,016.92 /cy	12,874
03002.4560 Screenings/Grit Handling Grade Beam Foundation - 37.76cy	37.76 cy	11,784	14,392	1,349			728.93 /cy	27,525
03002.4562 Pile Caps - 62ea @ 0.68cy/ea	42.16 cy	18,795	15,582	1,506			851.13 /cy	35,883
03002.4564 12" Thick Concrete Slab on Grade - 124.25cy	124.25 cy	38,774	44,488	4,438			705.83 /cy	87,700
03002.4566 12" Thick Concrete Elevated Slab - 64.58cy	64.58 cy	34,548	37,295	4,272			1,178.62 /cy	76,115
03000 CONCRETE	281.00 cy	110,674	117,021	12,402			854.44 /cy	240,097
03600 Grout								
08110.4502 Single Man Door - 3ea	3.00 ea	980	116				365.29 /ea	1,096
08110.4504 Double Man Door - 2ea	2.00 ea	654	77				365.30 /ea	731
03600 Grout		1,634	193					1,826
04200 Masonry								
04200.4502 12" CMU Exterior Wall - Split Faced Assumed - 7,289.5sf	7,289.50 sf				263,734		36.18 /sf	263,734
04200.4504 12" CMU Interior Wall - Smooth Faced Assumed - 5,132.4sf	5,132.40 sf				180,532		35.18 /sf	180,532
04200 Masonry					444,266			444,266
05120 Structural Steel								
05120.4503 Metal Deck Support Angle - 225lf	225.00 lf	1,291	7,214	506			40.05 /lf	9,010
05120.4510 Metal Stairs and Landings - 2 ea	2.00 ea	44,471	24,116	17,421			43,004.29 /ea	86,009
05120.4522 Structural Steel Beams - 11ea @ 37'-10"/ea	416.13 lf	12,624	67,288	4,945			203.92 /lf	84,858
05120.4532 Structural Steel Channel - 1 ea @ 37'-10"/ea	37.83 lf	574	2,010	225			74.24 /lf	2,809
05120 Structural Steel		58,960	100,628	23,097				182,685
05300 Steel Deck								
05300.4506 Roof Metal Decking - 2820.5sf	2,820.50 sf	3,237	9,773	1,268			5.06 /sf	14,278
05300 Steel Deck		3,237	9,773	1,268				14,278
05520 Handrail/Railing								
05120.4510 Metal Stairs and Landings - 2 ea	2.00 ea	2,339	2,310				2,324.57 /ea	4,649
05520.4502 Guardrail at Second Level - 37.83lf	37.83 lf	885	5,243				161.99 /lf	6,128
05520 Handrail/Railing		3,224	7,553					10,777
07530 Elastomeric Membrane Roofing								
07530.4502 Building Roof - 2,880sf	2,880.00 sf	10,605	20,261				10.72 /sf	30,866
07530 Elastomeric Membrane Roofing		10,605	20,261					30,866
07630 Roof Drains								
07710.4502 Roof Drainage - Assumed 4ea Downspouts	1.00 ls	976	7,900				8,876.07 /ls	8,876
07630 Roof Drains		976	7,900					8,876
08110 Metal Doors & Frames								

Spreadsheet Level	Takeoff Quantity	Labor Amount	Material Amount	Equip Amount	Sub Amount	Other Amount	Total Cost/Unit	Total Amount
08110.4502 Single Man Door - 3ea	3.00 ea	1,773	6,930				2,901.06 /ea	8,703
08110.4504 Double Man Door - 2ea	2.00 ea	1,455	6,930				4,192.46 /ea	8,385
08110 Metal Doors & Frames		3,228	13,860					17,088
08360 Overhead Doors								
08360.4502 Rollup Doors - 24'Wx12'H - 2ea	2.00 ea	1,746	173		34,733		18,325.90 /ea	36,652
08360 Overhead Doors		1,746	173		34,733			36,652
08510 Windows								
08510.4502 Windows Assumed 4'x4' - 7ea	7.00 ea		7,762				1,108.80 /ea	7,762
08510 Windows			7,762					7,762
09910 Architectural Painting								
09910.4502 Finish Interior Painting - Assumed	18,398.00 sf	32,070	20,269				2.85 /sf	52,340
09910 Architectural Painting		32,070	20,269					52,340
09981 Special & High Performance Coatings								
09981.4504 Concrete Sealer Base Floor - 2,841.5sf	2,841.50 sf	7,323	3,238				3.72 /sf	10,561
09981.4506 Concrete Sealer Elevated Floor - 1,743.64sf	1,743.64 sf	4,494	1,987				3.72 /sf	6,481
09981 Special & High Performance Coatings		11,817	5,225					17,042
10210 Wall Louvers								
10210.4502 Fixed Louvers - 4'x4' & 6'x6' - 3ea	3.00 ea	2,191	3,253				1,814.49 /ea	5,443
10210 Wall Louvers		2,191	3,253					5,443
10880 Scales								
10880.2202 Scales for Waste Bins - Allowance	2.00 ea				160,800		80,400.00 /ea	160,800
10880 Scales					160,800			160,800
11000 Miscellaneous Equipment and Materials								
04-11000.2605 Screening Dumpster	2.00 ea		12,060				6,030.00 /ea	12,060
04-11000.2610 Grit Dumpster	2.00 ea		12,060				6,030.00 /ea	12,060
11200.2200 Dumpster Loading Troughs - Supply	3.00 ea		75,375				25,125.00 /ea	75,375
11200.2201 Dumpster Loading Troughs - Install	3.00 ea		2,261		10,553		4,271.25 /ea	12,814
11000 Miscellaneous Equipment and Materials			101,756		10,553			112,309
11172 Washer Compactor								
11172.2202 Screenings Washer Compactor - Supply	3.00 ea		173,250				57,750.00 /ea	173,250
11172.2204 Screenings Washer Compactor - Install	3.00 ea	15,407	3,465	3,912		1,573	8,118.97 /ea	24,357
11172 Washer Compactor		15,407	176,715	3,912		1,573		197,607
11320 Grit Systems								
11320.2202 Grit Washers - Supply	4.00 ea		637,560				159,390.00 /ea	637,560
11320.2204 Grit Washers - Install	4.00 ea	57,701	8,778	5,216		1,358	18,263.33 /ea	73,053
11320 Grit Systems		57,701	646,338	5,216		1,358		710,613
11351 Screw Conveyor								
11200.2202 Dumpster Conveyors - Supply	4.00 ea		683,400				170,850.00 /ea	683,400
11200.2204 Dumpster Conveyors - Install	4.00 ea	144,680	4,620	36,770		3,400	47,367.79 /ea	189,471
11351.2202 Grit Screw Conveyors - Supply (with gates)	1.00 ls		785,400				785,400.00 /ls	785,400
11351.2204 Grit Screw Conveyors - Install	1.00 ls	119,285	4,620	25,718		2,292	151,914.24 /ls	151,914
11351 Screw Conveyor		263,965	1,478,040	62,488		5,692		1,810,185
13400 MEASUREMENT & CONTROL INSTRUMENTATION								
13400.0010 Instruments	1.00 ls				36,645		36,644.71 /ls	36,645
13400 MEASUREMENT & CONTROL INSTRUMENTATION					36,645			36,645
14630 OH Traveling Bridge Crane								
14630.2202 Bridge Crane Supply and Install	1.00 ea	777		47	40,200		41,024.75 /ea	41,025
14630 OH Traveling Bridge Crane		777		47	40,200			41,025
15500 HVAC								
15500.2207 HVAC Allowance	1.00 ls				118,791		118,791.00 /ls	118,791
15500 HVAC					118,791			118,791
16000 Electrical Allowance/Miscellaneous								
16000.0032 Equipment Connections	22.00 ea				55,275		2,512.50 /ea	55,275
16000.0060 Grounding & Lightning protection	1.00 ls				5,025		5,025.00 /ls	5,025
16000.0090 Building Lighting	58.00 ea				58,290		1,005.00 /ea	58,290
16000.0091 Motor Starters, DIsconnects, Control Panels Connections	38.00 ea				29,597		778.88 /ea	29,597

Spreadsheet Level	Takeoff Quantity	Labor Amount	Material Amount	Equip Amount	Sub Amount	Other Amount	Total Cost/Unit	Total Amount
16000.0120 Power Feeders for LIghting, Recept, and Control, Avg	8,000.00 lf				138,047		17.26 /lf	138,047
16000.0290 Electrical Allowance (NOC)	1.00 ls					28,875	28,875.00 /ls	28,875
16000 Electrical Allowance/Miscellaneous					286,234	28,875		315,109
070 Screenings/ Grit Handling Facility		**734,884**	**3,110,484**	**193,318**	**1,141,512**	**37,498**		**5,217,697**
080 Odor Control								
02304 Structural Excavation & Fill								
02304.48802 Structural Excavation & Backfill @ Scrubber Pad	198.00 cy	2,710		3,894			33.35 /cy	6,604
02304.48803 Structural Excavation & Backfill @ Chemical Storage Pad	148.00 cy	2,026		2,910			33.35 /cy	4,936
02304 Structural Excavation & Fill		4,736		6,804				11,540
02305 Structural Import								
02305.48804 Structural Rock Section @ Scrubber Pad	165.00 cy	2,225	6,279	2,251	1,821		76.22 /cy	12,577
02305.48805 Structural Rock Section @ Chemical Storage Pad	131.00 cy	1,767	4,985	1,787	1,446		76.22 /cy	9,985
02305 Structural Import		3,992	11,265	4,038	3,267			22,562
02455 Driven Piles								
02455.48802 14" SQ Driven Concrete Piles (100' In Depth) @ Scrubber Pad	16.00 ea	46,666	104,091	23,922	5,725		11,275.24 /ea	180,404
02455.48804 14" SQ Driven Concrete Piles (100' In Depth) @ Chemical Storage Pad	20.00 ea	52,656	128,211	26,790	5,725		10,669.13 /ea	213,383
02455 Driven Piles	36.00 ea	99,321	232,302	50,712	11,450		10,938.51 /ea	393,787
03000 CONCRETE								
03002.4530 16" Thick Concrete Mat Slab Scrubber Pad- 79cy	79.00 cy	24,653	28,286	2,822			705.83 /cy	55,761
03002.4531 16" Thick Concrete Mat Slab Chemical Storage Area- 58.5cy	58.50 cy	18,256	20,946	2,090			705.83 /cy	41,291
03002.4532 8" Wide Concrete Containment Curb - Scrubber Pad - 6.88cy	6.88 cy	5,521	2,940	910			1,362.10 /cy	9,371
03002.4533 8" Wide Concrete Containment Curb - Chem Storage Area - 6.36cy	6.36 cy	5,104	2,718	841			1,362.09 /cy	8,663
03002.4534 6" Thick Equipment Scrubber Pads - 2 ea - 11.68cy	11.68 cy	5,207	4,452	773			893.10 /cy	10,431
03002.4535 10" Thick Equipment Chem Tank Pads - 2 ea - 7cy	7.00 cy	3,121	2,668	463			893.10 /cy	6,252
03000 CONCRETE	169.00 cy	61,861	62,010	7,899			779.70 /cy	131,770
09981 Special & High Performance Coatings								
09981.4552 Concrete Coatings for Odor Control Chemical Area	1,600.00 sf	6,185	21,437				17.26 /sf	27,622
09981 Special & High Performance Coatings		6,185	21,437					27,622
11218 Chemical Sample/Transfer/Metering Pumps								
11218.2202 Chemical Pumps - Install, Supply with Odor Control	1.00 ls	5,123	3,465	1,739		712	11,038.31 /ls	11,038
11218 Chemical Sample/Transfer/Metering Pumps		5,123	3,465	1,739		712		11,038
11375 Aeration Equipment								
11375.2202 Install Odor Control Blower (Supply with Odor Control)	1.00 ls	6,924	3,465	1,487		521	12,397.22 /ls	12,397
11375 Aeration Equipment		6,924	3,465	1,487		521		12,397
13123 Pre-Engineered Canopy								
13123.2202 Canopy - Cover Chemical Tanks	300.00 sf				7,688		25.63 /sf	7,688
13123 Pre-Engineered Canopy					7,688			7,688
13200 Tanks								
13200.2200 Sodium Hydroxide Tank (NaOH) 6,000 gal	1.00 ea		17,286				17,286.00 /ea	17,286
13200.2201 Sodium Hypo Tank (NaOCl) 8,000 gal	1.00 ea		24,623				24,622.50 /ea	24,623
13200.2202 Install Sodium Hydroxide Tank (NaOH)	1.00 ea	9,384		1,470		96	10,949.61 /ea	10,950
13200.2204 Install Sodium Hypo Tank (NaOCl)	1.00 ea	9,384		1,470		96	10,949.61 /ea	10,950
13200 Tanks		18,767	41,909	2,939		193		63,808
13400 MEASUREMENT & CONTROL INSTRUMENTATION								
13400.0010 Instruments	1.00 ls				18,322		18,322.35 /ls	18,322
13400 MEASUREMENT & CONTROL INSTRUMENTATION					18,322			18,322
15060 Hangers & Supports								
15060.2202 Odor Control Duct Pipe Supports	35.00 ea	25,119	21,587				1,334.45 /ea	46,706
15060 Hangers & Supports		25,119	21,587					46,706
15248 FRP Pipe								
15248.2202 Odor Control Duct Main Header and Screening	200.00 lf	23,102	55,452	1			392.78 /lf	78,556
15248 FRP Pipe		23,102	55,452	1				78,556
15900 HVAC Control								
15900.2202 Multi Stage Scrubber - LO/PRO - Supply (16,200 cfm)	2.00 ea		623,700				311,850.00 /ea	623,700
15900.2204 Multi Stage Scrubber - LO/PRO - Install	2.00 ea	78,330		28,581	2,412	1,294	55,308.38 /ea	110,617
15900 HVAC Control		78,330	623,700	28,581	2,412	1,294		734,317
16000 Electrical Allowance/Miscellaneous								

Spreadsheet Level	Takeoff Quantity	Labor Amount	Material Amount	Equip Amount	Sub Amount	Other Amount	Total Cost/Unit	Total Amount
16000.0032 Equipment Connections	2.00 ea				5,025		2,512.50 /ea	5,025
16000.0091 Motor Starters, DIsconnects, Control Panels Connections	38.00 ea				28,833		758.78 /ea	28,833
16000.0120 Power Feeders for LIghting, Recept, and Control, Avg	2,700.00 lf				46,591		17.26 /lf	46,591
16000 Electrical Allowance/Miscellaneous					80,449			80,449
080 Odor Control		**333,461**	**1,076,591**	**104,201**	**123,589**	**2,719**		**1,640,561**
085 Plant Drain Pump Station								
02304 Structural Excavation & Fill								
02304.48081 Structural Excavation & Backfill	80.00 cy	1,095		1,573			33.35 /cy	2,668
02304 Structural Excavation & Fill		1,095		1,573				2,668
02305 Structural Import								
02305.48081 Structural Rock Section	57.00 cy	691	2,169	699	629		73.48 /cy	4,188
02305 Structural Import		691	2,169	699	629			4,188
02455 Driven Piles								
02455.48081 14" SQ Driven Concrete Piles (100' In Depth)	10.00 ea	25,809	61,061	12,870	3,738		10,347.86 /ea	103,479
02455 Driven Piles	10.00 ea	25,809	61,061	12,870	3,738		10,347.86 /ea	103,479
11210 PUMPS								
99-11210.2630 Packaged Plant Water Pump Station	1.00 ls	15,748	186,549	6,476			208,772.58 /ls	208,773
11210 PUMPS		15,748	186,549	6,476				208,773
15241 PVC Pipe & Fittings								
15241.2207 Plant Water Piping Allowance, incl Valves	1.00 ls	10,906	9,385				20,291.05 /ls	20,291
15241 PVC Pipe & Fittings		10,906	9,385					20,291
085 Plant Drain Pump Station		**54,249**	**259,164**	**21,618**	**4,367**			**339,399**
090 Electrical / Mechanical Building								
02304 Structural Excavation & Fill								
02304.48902 Structural Excavation & Backfill	222.00 cy	3,039		4,365			33.35 /cy	7,404
02304 Structural Excavation & Fill		3,039		4,365				7,404
02305 Structural Import								
02305.48904 Structural Rock Section	203.00 cy	2,461	7,725	2,489	2,241		73.48 /cy	14,916
02305 Structural Import		2,461	7,725	2,489	2,241			14,916
02455 Driven Piles								
02455.48902 14" SQ Driven Concrete Piles (100' In Depth)	49.00 ea	116,155	303,081	58,026	5,725		9,856.90 /ea	482,988
02455 Driven Piles	49.00 ea	116,155	303,081	58,026	5,725		9,856.90 /ea	482,988
03000 CONCRETE								
03000.4563 18"x24" Concrete Beams - 3ea @ 4.22cy/ea	12.66 cy	6,773	5,264	837			1,016.92 /cy	12,874
03002.4550 Electrical Building Grade Beam Foundation - 25.54cy	25.54 cy	7,970	9,735	912			728.93 /cy	18,617
03002.4552 Pile Caps - 49ea @ 0.68cy/ea	33.32 cy	14,854	12,315	1,190			851.13 /cy	28,360
03002.4554 12" Thick Concrete Slab on Grade - 92.69cy	92.69 cy	28,925	33,188	3,311			705.83 /cy	65,424
03002.4567 12" Thick Concrete Elevated Slab - 81.23cy	81.23 cy	43,455	46,910	5,373			1,178.62 /cy	95,739
03000 CONCRETE	245.00 cy	101,978	107,412	11,624			902.10 /cy	221,013
03600 Grout								
08110.4502 Single Man Door - 3ea	3.00 ea	980	116				365.29 /ea	1,096
08110.4504 Double Man Door - 2ea	2.00 ea	654	77				365.30 /ea	731
03600 Grout		1,634	193					1,826
04200 Masonry								
04200.4512 12" CMU Exterior Wall - Split Faced Assumed - 5,885.06sf	5,885.06 sf				212,921		36.18 /sf	212,921
04200 Masonry					212,921			212,921
05120 Structural Steel								
05120.4513 Metal Deck Support Angle - 191.5lf	191.50 lf	1,099	6,122	430			39.95 /lf	7,651
05120.4523 Structural Steel Beams - 8ea @ 37'-10"/ea	332.90 lf	10,099	53,831	3,956			203.92 /lf	67,886
05120.4532 Structural Steel Channel - 1 ea @ 37'-10"/ea	37.83 lf	574	2,010	225			74.24 /lf	2,809
05120.4542 Misc. Framing	50.00 lf	141	566	55			15.23 /lf	762
05120 Structural Steel		11,913	62,528	4,667				79,107
05300 Steel Deck								
05300.4516 Roof Metal Decking - 2198sf	2,198.00 sf	2,523	7,616	988			5.06 /sf	11,127
05300 Steel Deck		2,523	7,616	988				11,127
05510 Metal Ladders								

Spreadsheet Level	Takeoff Quantity	Labor Amount	Material Amount	Equip Amount	Sub Amount	Other Amount	Total Cost/Unit	Total Amount
05510.4502 Roof Access Ladder - Assumed 1ea @ 15lf	1.00 ea	702	866				1,568.00 /ea	1,568
05510 Metal Ladders		702	866					1,568
07530 Elastomeric Membrane Roofing								
07530.4512 Building Roof - 2,198sf	2,198.00 sf	8,094	15,463				10.72 /sf	23,557
07530 Elastomeric Membrane Roofing		8,094	15,463					23,557
07630 Roof Drains								
07710.4502 Roof Drainage - Assumed 4ea Downspouts	1.00 ls	976	7,900				8,876.06 /ls	8,876
07630 Roof Drains		976	7,900					8,876
07720 Roof Accessories								
07720.4502 Roof Hatches - Assumed 1ea	1.00 ea	364	1,964				2,327.23 /ea	2,327
07720 Roof Accessories		364	1,964					2,327
08110 Metal Doors & Frames								
08110.4502 Single Man Door - 3ea	3.00 ea	1,773	6,930				2,901.06 /ea	8,703
08110.4504 Double Man Door - 2ea	2.00 ea	1,455	6,930				4,192.46 /ea	8,385
08110 Metal Doors & Frames		3,228	13,860					17,088
08510 Windows								
08510.4512 Windows Assumed 4'x4' - 10ea	10.00 ea		11,088				1,108.80 /ea	11,088
08510 Windows			11,088					11,088
09910 Architectural Painting								
09910.4502 Finish Interior Painting - Assumed	15,453.00 sf	27,017	17,059				2.85 /sf	44,075
09910 Architectural Painting		27,017	17,059					44,075
09981 Special & High Performance Coatings								
09981.4514 Concrete Sealer Base Floor - 2,193.3sf	2,193.30 sf	5,652	2,499				3.72 /sf	8,152
09981.4516 Concrete Sealer Elevated Floor - 2,193.3sf	2,193.30 sf	5,652	2,499				3.72 /sf	8,152
09981 Special & High Performance Coatings		11,305	4,999					16,304
10210 Wall Louvers								
10210.4502 Fixed Louvers - 4'x4' & 6'x6' - 3ea	3.00 ea	2,191	3,253				1,814.49 /ea	5,443
10210 Wall Louvers		2,191	3,253					5,443
13400 MEASUREMENT & CONTROL INSTRUMENTATION								
13400.0020 Instrumentation Commissioning	10.00 day				32,160		3,216.00 /day	32,160
13400.0050 Hardware/Servers/PLC	1.00 ls				140,700		140,700.00 /ls	140,700
13400.0060 Software & Programming	1.00 ls				80,400		80,400.00 /ls	80,400
13400.0070 Fire Alarm	1.00 ls				35,175		35,175.00 /ls	35,175
13400 MEASUREMENT & CONTROL INSTRUMENTATION					288,435			288,435
15500 HVAC								
15500.2204 Hot Water Boiler & Piping		14,474	14,582	2,310				31,366
15500 HVAC		14,474	14,582	2,310				31,366
16000 Electrical Allowance/Miscellaneous								
16000.0031 Duct Bank Low Voltage to Facilities	300.00 lf				51,255		170.85 /lf	51,255
16000.0032 Equipment Connections	4.00 ea				10,050		2,512.50 /ea	10,050
16000.0050 MCC 1,2,3,4	4.00 ea				241,200		60,300.00 /ea	241,200
16000.0060 Grounding & Lightning protection	1.00 ls				5,025		5,025.00 /ls	5,025
16000.0090 Building Lighting	58.00 ea				58,290		1,005.00 /ea	58,290
16000.0120 Power Feeders for LIghting, Recept, and Control, Avg	5,300.00 lf				91,456		17.26 /lf	91,456
16000.0140 Security System	1.00 ls				20,100		20,100.00 /ls	20,100
16000.0160 Electrical Testing & Commissioning	12.00 day				38,592		3,216.00 /day	38,592
16000.0290 Electrical Allowance (NOC)	1.00 ls					28,875	28,875.00 /ls	28,875
16000 Electrical Allowance/Miscellaneous					515,968	28,875		544,843
090 Electrical / Mechanical Building		**308,051**	**579,588**	**84,470**	**1,025,290**	**28,875**		**2,026,274**
100 Generators (Deleted)								
16000 Electrical Allowance/Miscellaneous								
16000.4502 Generators not in Cost - Removed from Scope	1.00 ea						/ea	

Estimate Totals

Description	Amount	Totals	Hours	Rate
Labor	4,718,924		54,264 hrs	
Material	12,659,828			
Subcontract	3,861,320			
Equipment	1,286,309		11,871 hrs	
Other	342,955			
	22,869,336	22,869,336		

Subtotal Direct Cost		22,869,336		
Building Permits(% total cost)	435,525			1.00 %
Bldr's Risk Ins (% total cost)	435,525			1.00 %
Gen Liab Ins (% total cost)	653,288			1.50 %
GC Bonds (% total cost)	871,050			2.00 %
Sales Tax	1,166,217			9.00 %
Subtotal Prior to OH&P	3,561,605	26,430,941		
GC General Conditions	2,104,402			10.00 %
Contractor Total OH&P	5,226,303			12.00 %
Subtotal with OH&P	7,330,705	33,761,646		
Construction Contingency	6,752,329			20.00 %
Total Cost at:	6,752,329	40,513,975		
Escalation to Mid Point 2018 Based on ENR 3% per year	3.038.548			7.50 %
	3,038,548	43,552,523		
Total		***43,552,523***		

"This Opinion of Probable Construction Cost is produced in accordance with CDM Smith's Firmwide Quality policies and best practices as described in CDM Smith's Estimating Manual Dated 01/03/12 Section 10 titled Quality Control. I hereby attest that the Cost Estimating policies and procedures were followed in preparation of the Opinion of Probable Cost"

Lead Estimator initials: KJ,SH,SM *Date: 2/19/2016*

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