Feasibility of Trash Removal at Pump Stations

Final Technical Report

Prepared for:

Santa Clara Valley
Urban Runoff
Pollution Prevention Program

Prepared by:

Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

July 30, 2009

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1.0 INTRODUCTION

Schaaf & Wheeler were asked to help evaluate existing trash management practices and the possibility of implementing additional trash controls at pump stations within the jurisdictions of the Santa Clara Valley Urban Pollution Prevention Program (SCVURPPP or Program). Since stormwater pump stations are being investigated as potential control point for trash, the evaluation also focused on determining the feasibility of implementing enhanced trash management practices to capture smaller pieces of trash for various flows, in terms of benefits, technical challenges and costs. This section introduces the issue of trash management at pump stations; provides specific questions that will be addressed; and provides the organization of the report.

Trash management at stormwater pump stations can have several benefits, including lengthening the lifespan of stormwater pumps; simplifying trash removal from stormwater conveyance systems; and reducing water quality impacts. Primarily for the last benefit, environmental regulatory agencies are requiring certain levels of trash management to minimize impacts to receiving waters. At the local level, the San Francisco Regional Water Quality Control Board (Water Board) will likely give the option of removing trash at different control points including stormwater pump stations. As a result, public agencies have a strong interest in determining the feasibility of controlling trash; and installing full trash capture devices at stormwater pump stations.

Specific questions that are addressed within this report include the following:

- **Q#1 -** What types of stations discharge to Lower South San Francisco Bay and its tributaries?
- **Q#2 -** How many pump stations discharge to the Bay and its tributaries, and where are they located?
- **Q#3 -** Who are the owners and operators of these stations?
- **Q#4 -** What are the existing trash management practices at pump stations?
- **Q#5 -** How much trash is typically captured at these stations?
- **Q#6 -** Which types of pump stations are more conducive to capturing trash?
- **Q#7 -** What feasible methods can be implemented to improve the capture of trash?
- **Q#8 -** What are the implications of trying to capture smaller trash items for various flows, in terms of benefits, technical challenges and costs?
- **Q#9 -** What are the varying feasibilities of retrofitting the different types of pump stations?
- **Q#10 -** What size trash can feasibly/reasonably be captured?

To answer these questions, the report is organized as follows:

- Section 2.0 provides the **Background** of trash management within the stormwater conveyance system, with a particular focus on pump stations within the Program's jurisdiction;
- Section 3.0 catalogs **Existing Pump Station Configurations and Operations,** including case studies based on recent field visits to existing pump stations within the Program's jurisdiction;
- Section 4.0 details **Potential Types of Retrofits for Trash Management**;
- Section 5.0 discusses the **Feasibility of the Various Retrofits**; and
- Section 6.0 presents **Conclusions** and recommendations regarding the implementation of enhanced trash management practices within the Program's jurisdiction.

2.0 BACKGROUND - TRASH MANAGEMENT BASICS

SCVURPPP actively works to understand the sources, extent and effects of urban runoff pollution within its jurisdiction; and develops and implements methods for pollution reduction and control. Since 2002, SCVURPPP has focused on assessing the accumulation and composition of trash in its urban watersheds and identifying existing and appropriate enhancements to management actions for reducing trash impacts on beneficial uses. Previous work conducted by SCVURPPP is mentioned within this report, as relevant. This section provides best management practices within the storm drain conveyance system, typical stormwater pump stations components related to trash management and general pump station design for trash management.

2.1 Best Management Practices within the Stormwater Conveyance System

Best Management Practices (BMPs) may be used to control trash at every level of the stormwater conveyance system. Implementation points of BMPs within the stormwater conveyance system are described in Table 1, ordered from their applicable level – starting at the pollutant source and going to “in the creek.”

Typical BMPs instituted at or near pump stations include trash racks (see Photos 1a and 1b), litter booms and detention basins. Trash racks are located at the intake to the pump station or inside the wet well. Litter booms and detention basins are located upstream of the pump station.

Photo 1 –Trash Racks - (a) Wrigley-Ford Creek culvert; (b) City of Sunnyvale Pump Station #1

Table 1 – Implementation Points of BMPs within the Stormwater Conveyance System

Implementation Point	Best Management Practice	Target
1. Source	Package reduction	Commercial/Industrial facilities
	Product bans (e.g., Styrofoam, bottled water)	General public
	Public education (litter campaigns)	General public
	Litter laws (and enforcement)	General public
2. In the Street	Street sweeping	Streets
	Manual litter pickup	Streets/Open spaces
	Biodegradation	Open spaces
3. Start of Pipe	Screening/inlet protection	Storm drain inlets
	Detention/retention basins	Storm drain system
	Storm drain stenciling	General public/system
	Other BMPs	Storm drain system
4.In Pipe	Vortex separation	Storm drain inlets
	In-line screening/removal	Storm drain system
5. End of Pipe	Trash Racks	Pump station debris
	End-of-pipe baskets	Storm drain system
	Netting Devices	Storm drain system
6. In Creek	Detention pond (area)	At or just upstream of outfall
	Retention pond (area)	At or just upstream of outfall
	Litter boom/net	In a detention/retention area
	Manual litter pickup	Small litter, trash from other sources (i.e., dumping, homeless camps)
	Biodegradation	Biodegradable trash

2.2 Typical Components of Stormwater Pumps and Pump Stations

Pumps are used to increase the static pressure of fluids by adding energy in various ways to the fluid. Most stormwater pumps add energy by increasing stormwater velocity from the inlet to the pump housing exit. The most common stormwater pump types are axial flow (propeller), radial flow (impeller) and mixed flow (combination of the two). Each pump type has operational advantages and disadvantages. In terms of debris and trash handling, radial flow pumps are the best at easily passing debris. Axial flow pumps, by contrast, can be damaged by relatively large, hard objects and by fibrous material wrapping around the propellers. Mixed-flow pumps handle debris at a level between the other two pump types (i.e., moderately well).

Figure 1 provides the major components of a "typical" stormwater pump station. These components, in the respective order that stormwater flows through the pump station, include an intake (culvert, pipeline or open channel), trash racks, forebay/wet well (sump), suction pipe, pump(s) and drive units (engines or electric motors) and discharge pipe. In addition, some local pump stations have a discharge box which leads to a gravity outfall (not shown in Figure I). The discharge box provides a relatively constant water surface elevation and pressure head (to the pumps) to promote more efficient pump operation.

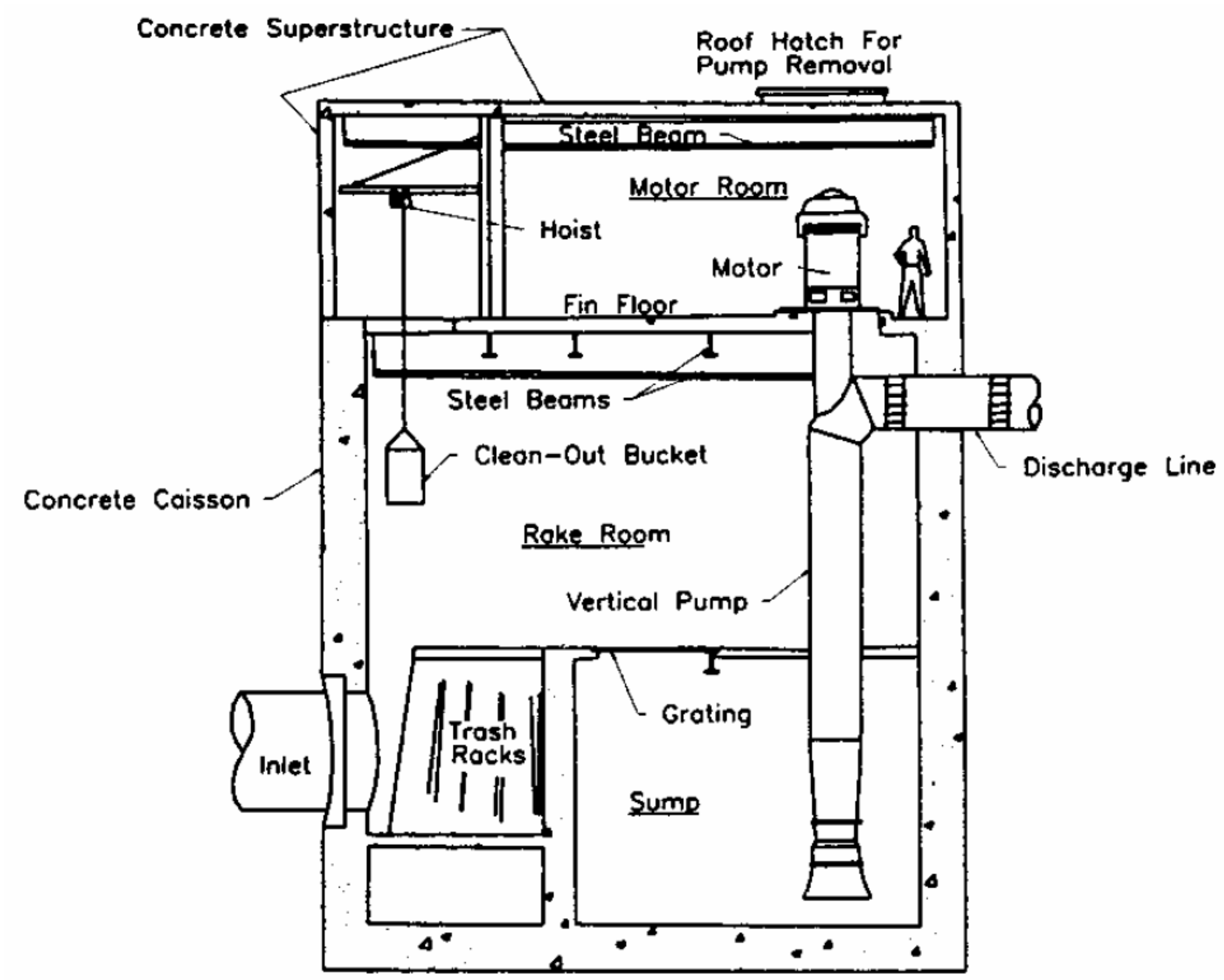

Figure 1 – "Typical" Stormwater Pump Station Configuration

The U.S. Department of Transportation (U.S. DOT), who is responsible for constructing pump stations along federally-maintained highways, recommends varying levels of trash management in pump station design. The recommended level depends on the size of the pump station. In essence, an increase in sophistication usually leads to an increase in capacity. Table 2 summarizes design recommendations.

Table 2 - U.S. DOT (1982) Pump Station Design Recommendations for Trash Management

Relative Station Size	Large (> 300 cfs)	Medium (100-300 cfs)	Small (< 100 cfs)
Recommended Trash Management Device	Elaborate built-in devices preferred (removable trash racks)	Simple built-in adequate (simple trash rack)	Vacuum trucks preferred.

When trash racks are installed in pump stations, they are placed at the upstream end within the forebay/wet well area (see Figure 1). Since the intake structure is designed to supply an even distribution of flow to the pumps, trash racks must be placed an adequate distance from the back wall of the wet well. This ensures smooth flow of stormwater to the pumps and helps distribute the incoming flow. Trash racks are designed with spacing to prevent large debris from entering the wet well since the pumps can usually pass relatively small solids with stormwater.

Stormwater pump stations intake stormwater from an open or closed drainage conduit (e.g., creek, lagoon or storm drain) and convey the stormwater through pressure to an outlet that could otherwise not be drained by gravity. In some cases, particularly in the Bay Area, stormwater pump stations are installed to convey urban drainage over protective levees near the banks of natural or engineered drainage channels. In other cases, urban drainage flows by gravity without the presence of levees or high backwater conditions in the channels. Some pump stations, including many in the Bay Area, allow for gravity bypass into the discharging channel when conditions allow (i.e., low backwater conditions).

Variables which factor into pump station design including:

- Type of pumps;
- Number and capacity of pumps;
- Sizing parameter: peak flow vs. storage;
- Force main vs. gravity discharge;
- Above grade (ground) vs. below grade;
- Need for monitoring systems;
- Need for standby/backup systems; and
- Maintenance requirements.

Most parameters are selected by their cost-effectiveness; and the judgment and experience of the design engineer. In terms of trash management, stormwater pumps must be designed with protective trash measures and/or with the ability to pass large items without substantially harming the pumping equipment. This is necessary due to the varied character of items found in stormwater runoff, including natural vegetation and anthropogenic trash,

2.3 General Stormwater Pump Station Design for Trash Management

Based on Schaaf & Wheeler's experience, stormwater pumps are designed and selected to pass solids as large as 2 to 3 inches. To protect the pumps, pump stations must be designed with trash management practices which screen out larger solids. It is expected, as the next section details, that most existing pump stations have trash management practices (i.e., trash racks) with at least 2 to 3 inches of space between bars. For example:

- The City of Sunnyvale's Baylands Pump Station was designed with a rack having ¼" bars at 1 ¾" spacing.
- The City of Palo Alto's Matadero Pump Station was originally designed with a rack having 3/8" bars at 4" spacing. It was later retrofitted, as discussed later, with additional trash racks that have apparently smaller spacing.
- The City of Palo Alto's San Francisquito Pump Station has been designed with 3/8" bars spaced at 2 3/8".

As Table 1 indicates, trash management at stormwater pump stations is implemented at the "end of pipe". However, trash racks and other trash management practices can serve multiple purposes. As a result, pump stations are a natural location for instituting enhanced trash management practices. These practices are instituted to achieve the following:

- Protect pumps from being damaged by large trash objects (e.g., wood, metal);
- Keep people and large animals out of the pump station, for safety;
- Protect fish and other objects from entering the pump station;
- Capture debris for water quality purposes; and
- Capture debris in a manner which allows easy removal/maintenance.

In serving these purposes, trash management practices must, above all, allow for adequate hydraulic operation of the pumps and pump station. Most trash racks are not precisely designed for trash control purposes; rather, they are designed for hydraulic operation and protection of the pumps. As a result, most trash racks are sized with some factor of safety to account for blockage of the trash rack while still maintaining adequate hydraulic pump capacity.

Typical recommendations for trash rack design and construction include:

- Design the maximum clear-space between bars should be 2 to 3 inches to prevent the passage of large solids (e.g., 2" by 4" lumber will not float on its minor axis);
- Use modules of similar screens/racks to facilitate removal for maintenance;

- Attach panels to base slab with corrosion resistant stainless steel bolts and bolt at top to a solid structural element;
- Pattern the trash racks and incline their faces to facilitate cleaning by raking from a readily accessible structure (e.g., catwalk); and
- Use mechanized cleaning systems, where feasible, to allow for the automatic removal of accumulated trash.

Besides trash racks, stormwater pump stations may be fitted with other trash management controls. Basins, channels or oversized pipelines can introduce detention into a stormwater system upstream of a pump station and serve to mitigate flow rates and capture trash. However, it must be justified to have such storage available. First, stormwater flow rates can vary over orders of magnitude throughout the life of a pump station; and pumps need to be cost-effective. Second, some pump stations are designed to limit outflow (i.e., to a pre-development outflow); with a storage volume which allows large flows to be stored while being released by the pumps at a lower, constant rate. Accordingly, a critical element in pump station design is often the amount of storage available upstream. If adequate storage is not available upstream, the pump station is often designed with multiple and variably-sized pumps to allow for varied output flow rates. Variable speed drive units are not generally used for high flow – low head stormwater pumps. To capture trash in detention basins or other upstream facilities, litter boom or nets may be used. These trash management practices are not currently widespread in the Bay Area, even at pump stations with upstream detention areas.

3.0 EXISTING PUMP STATION CONFIGURATIONS AND OPERATIONS

Q#1 through *Q#6* from the *Section 1.0 Introduction* are concerned with existing pump station configurations and trash management practices. An initial inventory of pump stations provided by SCVURPPP included pump station names, locations, catchment area tributary to the pump station, dominant land uses in the catchment area, names of receiving waters and the maximum pump station capacity for those stations within the Program's jurisdiction. Schaaf & Wheeler enhanced the inventory to include information from their files and details learned during two sets of field visits. **It is important to note that the final inventory does not include stormwater pump stations owned and operated by Caltrans.** Appendix 1: Table 9 summarizes critical trash management details from the inventory and includes an estimate of trash loading at each pump station, as discussed below. Appendix 2: Table 10 presents the full inventory of the eighty-three (83) pump stations reported within the Program's jurisdiction. (Note: Appendix 2: Table 10 is split into two sets of tables to fit on 11x17 sheets, with pump station names repeated at the left for clarification.). Summary tables are also provided below for quick reference. The intent of this section is to address the first six questions and focus on case studies which highlight trash management differences and similarities at pump stations located within the Program's jurisdiction.

3.1 Types/Numbers of Stormwater Pump Stations (Q#1/Q#2)

Q #1 asks what types of pump stations, which concerns the intake and discharge structures, types of pumps and general size of the pump. The inventory provides many of these details. Based on the inventory, the pump stations receive water directly from storm drains or through detention basins/open channels; discharge directly to San Francisco Bay or to waters (e.g., creeks, rivers, etc.) that flow to the Bay; use axial flow pumps; and vary in size from 100 gallons per minute (gpm) to over 300,000 gpm. Existing pump station configurations can be categorized as follows:

- **Gravity bypass stations**;
- **Stations with large upstream storage**;
- **Stations with a large downstream discharge structure/channel**; and
- **The "typical" configuration** – a pipeline connected directly to a wet well that leads to the pumps and discharges to a structure/outfall.

Freedom Circle Pump Station (35,200 gpm) within the City of Santa Clara is gravity bypass station, allowing stormwater to bypass the pumps when the receiving water (San Tomas Aquino Creek) is relatively low. However, at a high creek stage, corresponding with high local stormwater flow, stormwater is diverted into the pump station. Therefore, the pump station does not handle all flows from the catchment area. In contrast, the Matadero Pump Station (107,712 gpm) within the City of Palo Alto always receives stormwater from the upstream storm drain system prior to discharging to Matadero Creek.

Table 3 summarizes information on the number of pump stations within the Program's jurisdiction (*Q#2*), listed by discharge location (i.e., major creek/river system). In addition, the total reported discharge of the pump stations by major creek/river system, in cubic feet/second (cfs) is provided to further clarify the scale of pumping to each system. Pump stations which discharge to storm drain systems within the Program's jurisdiction eventually flow into one of the major creek/river systems listed or directly into the Bay.

Table 3 - Discharge Locations of Pump Stations (Q#2)

Major Creek/ River System	Tributaries	# Pump Stations	Reported Discharge (cfs)
Coyote Creek	Berryessa Creek	2	
	Calera Creek	1	
	Coyote Creek	5	
	Lower Penetencia Creek	3	
	Penetencia Creek	3	
		14	**2,507**
Guadalupe River	Alviso Marsh	1	
	Los Gatos Creek	1	
	Lower Guadalupe River – D/S of I-280	20	
	Upper Guadalupe River – U/S of I-280	3	
		25	**2,709**
Guadalupe Slough	Sunnyvale East Channel	1	
	Sunnyvale West Channel	2	
		3	**132**
Lower Peninsula Watersheds	Adobe Creek	1	
	Matadero Creek	3	
	Baylands	1	
	Permanente Creek	2	
	San Francisquito Creek	4	
	Stevens Creek	2	
		13	**1,228**
San Francisco Bay (directly)		**2**	**135**
San Tomas Aquino Creek	Calabazas Creek	2	
	San Tomas Aquino Creek	8	
		10	**691**
Other Storm Drain Systems (presumably closed conduit)		**15**	**129**
Palo Alto WWTP (Oregon/Alma)		**1**	**6**
All Reported Pump Stations		**83**	**7,537**

3.2 Summary of Existing Trash Management Practices at Pump Stations (Q#3/Q#4)

For this study, it is important to identify who is responsible for operating pumps stations within the Program's jurisdiction (*Q#3*) and determine what existing trash management practices have been implemented at these stations (*Q#4*). Table 4 summarizes pump stations by jurisdiction and details current trash management practices. As reported or mentioned in readily available documents, 31% of the pump stations have trash management practices, while 28% having trash racks and 12% having retention basins or lagoons. Since some of the pump stations within the Program's jurisdiction have forebays or large upstream reservoirs, these upstream systems can serve as detention basins and settle larger, heavier trash items. Since their original design and construction, the vast majority of pump stations have not been retrofitted for enhanced trash management practices. However, Matadero Pump Station, discussed below, was retrofitted with additional trash racks. Schaaf & Wheeler knows of no other local city or agency who has similarly upgraded their pump stations.

Table 4 – Summary of Pump Stations and Existing Trash Management Practices by Jurisdiction

Jurisdiction	Number of Reported Pump Stations				
	Geographic Location[1]	w/Trash Mgmt[2]	w/Trash Racks[2]	w/Lagoons/ Basins[2]	w/Other[2]
Milpitas	13	2	1	6	
San José[5]	27	N.R.[3]	N.R.	N.R.	
Santa Clara[6]	22	12	12	2	
Sunnyvale[7]	6	2	2	1	2 (gabions/ litter boom)
Mountain View	5	4	4	1	
Palo Alto[8]	10	6	4	0	2 (weirs)
Total	**83**	**26[4]**	**23**	**10**	**4**
Percentage		**31%**	**28%**	**12%**	**5%**

[1] Pump stations reported within each geographic location may not be owned and/or operated by each City.
[2] As reported or mentioned in readily available documents. Actual number may be higher.
[3] N.R. = None reported or mentioned in readily available documents.
[4] Some pump stations have both trash racks and other types of trash management practices (i.e., basins)
[5] Two pump stations located within the City of San Jose are operated by the County of Santa Clara.
[6] One pump station located within the City of Santa Clara is operated by the County of Santa Clara
[7] Two pump stations located within the City of Sunnyvale are operated by the County of Santa Clara.
[8] Two pump stations located within the City of Palo Alto are operated by the County of Santa Clara.

3.3 Bay Area Case Studies

Schaaf & Wheeler visited four pump stations within the Program's jurisdiction during the investigation of trash management practices, including the City of Palo Alto's Matadero and San Francisquito Pump Stations; and the City of San José's Oakmead and Rincon 2 Pump Stations.

General information and trash management practices at each pump station are discussed in the following subsections. Potential retrofits based on the field visits are discussed later.

3.3.1 City of Palo Alto - Matadero Pump Station

The City of Palo Alto's Matadero Pump Station, located at 1082 Colorado Avenue was built in 1968. It collects drainage and associated solids from over half of the City's total drainage area (>1,200 acres). The capacity of the Matadero Pump Station is approximately 107,792 gpm (240 cfs). In 2009, the San Francisquito Pump Station (see below) will be brought on-line resulting in a reduction of the Matadero Pump Station tributary area. The Matadero Pump Station receives inflow from the northwest through gravity pipeline and the southeast through an inverted siphon under Matadero Creek. Influent storm drainage collects in the wet well and is discharged into Matadero Creek (see Photo 2b) through the use of two small or three large pumps.

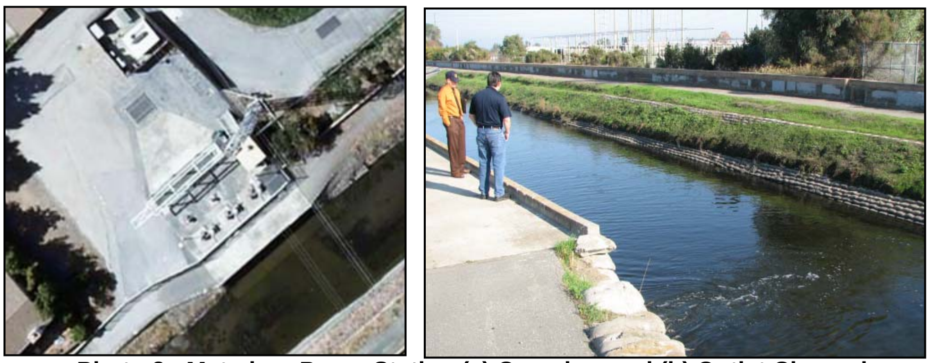

Photo 2 - Matadero Pump Station (a) Overview and (b) Outlet Channel

Although originally designed with one trash rack, Matadero Pump Station has been retrofitted with additional racks to reduce the burden on the original one. Photos 3a and 3b show the configuration of trash racks, including two smaller racks upstream of the larger one. Prior to installing the upstream racks, the original trash rack bent under heavy storms and trash loading.

Photo 3 – Matadero Pump Station – (a) Small and Large Trash Racks; (b) Close-up of Small Trash Rack

According to City of Palo Alto maintenance staff (personal communication, January 8, 2009), this station receives more trash than other stations. Collected debris consists of vegetation, trash, litter, wood and small dead animals. The trash racks are maintained prior to the wet season (usually September). If needed, a second, mid-winter cleaning is performed. City maintenance staff reported that approximately 13 cubic yards of trash and litter are removed during annual cleaning.

3.3.2 City of Palo Alto – San Francisquito Pump Station

The City of Palo Alto's San Francisquito Pump Station (see Figure 2), located at 2027 East Bayshore Road next to U.S. Highway 101, has recently been completed and conveys storm drainage from about 1,200 acres of tributary area with a capacity of approximately 135,000 gpm (300 cfs).

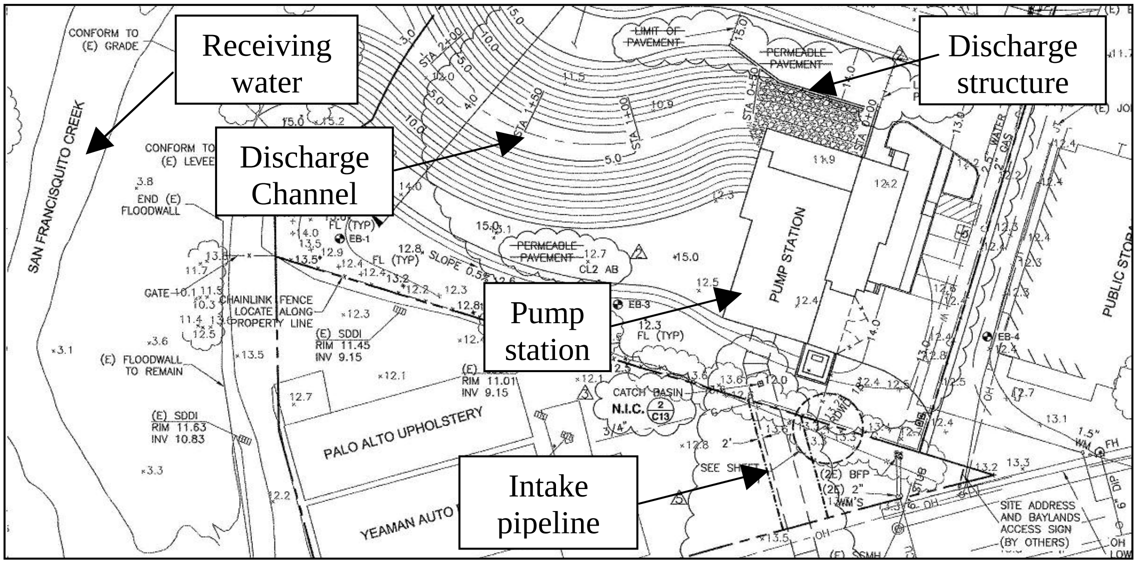

Figure 2 - Layout of San Francisquito Pump Station

The new station receives inflow from an 8' by 8' culvert connected to an upstream 96-inch diameter pipeline crossing under U.S. Highway 101. Stormwater collects in the wet well and discharges to an open-air discharge box structure; dissipation rip-rap and a short vegetated channel leading to San Francisquito Creek (see Photo 4b and 4c). Photo 4a shows the trash racks which are designed to straighten the entering flow and retain relatively large trash. The spacing of the trash rack bars is indicated by scale with the ladder steps in the picture.

During the design phase, the hydraulic losses through the trash racks were explicitly calculated since it was determined that the upstream culvert storage would supplement forebay storage and be essential for adequate pump cycling. Furthermore, Schaaf & Wheeler's design report for the San Francisquito Pump Station discusses the importance of keeping the trash racks clean to ensure satisfactory pump station operation.

Photo 4 - San Francisquito Pump Station (a) Trash Rack; (b) Discharge Structure; and (c) Discharge Channel

3.3.3 City of San José – Rincon 2 Pump Station

San José's Rincon 2 Pump Station, which is located west of the Trimble Road and Orchard Parkway intersection next to the Guadalupe River, was finished in 2003. It has a capacity of 269,000 gpm (600 cfs) and collects drainage from almost 840 acres. This capacity allows for conveyance of about a 10-year storm from the receiving area. The layout of Rincon 2 (see Photo 5) is fairly standard with a 12' by 12' intake culvert under Trimble Road leading into the wetwell. Stormwater is discharged through submersible axial flow pumps, which flow through a concrete structure and rip-rap leading to the Lower Guadalupe River.

Photo 5 indicates the scale of the pumps (cars in the background) and the configuration of the discharge structure. Photo shows closer views of the pumps and discharge structure.

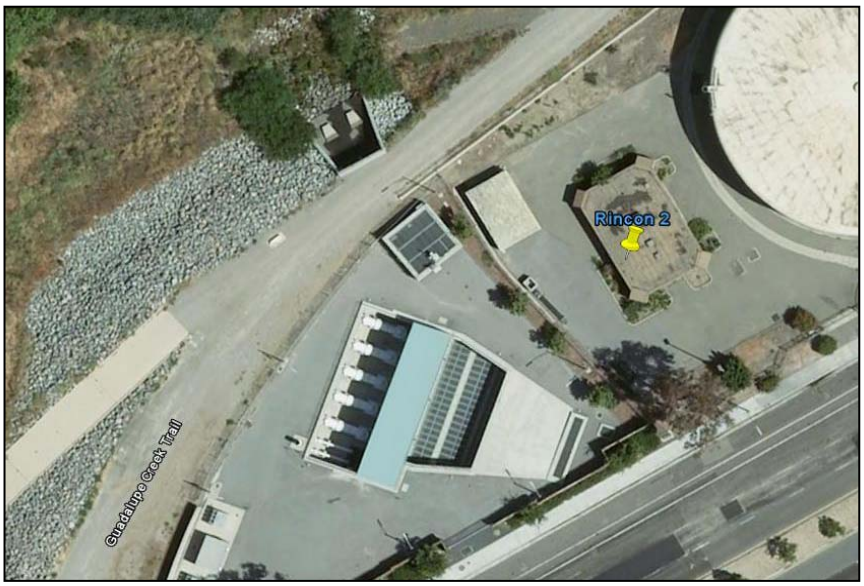

Photo 5- Aerial Overview of Rincon 2 Pump Station

Photo 6 – Rincon 2 Pump Station (a) View of Pumps; (b) Discharge Structure

Photo shows how trash is managed at the Rincon 2 Pump Station. Trash racks are at the intake to the station (Photo a) and screens are at the station's discharge point (Photo b). Discharge screens were most likely installed to prevent people and animals from entering the pump station during non-operation. They also serve to retain any large solids that have passed the upstream trash racks and pumps. Based on discussions with City of San Jose maintenance staff, the Rincon 2 Pump Station is not regularly cleaned because its deep configuration does not allow for normal vactor truck maintenance. During a site visit on January 8, 2009, small amounts of trash were observed at the upstream face of the pump station's trash racks.

Photo 7 – Rincon 2 Pump Station Trash Management at (a) Intake; (b) Discharge

3.3.4 City of San José – Oakmead Pump Station

The City of San José's Oakmead Pump Station, located at Lisa Lane off of Renaissance Drive was built around 1982. It has a capacity of approximately 329,868 gpm (735 cfs) and supports a 1,485-acre catchment area. The configuration of the Oakmead Pump Station is fairly standard (see Photo 8). It consists of a large intake culvert, a wetwell, pumps, a discharge culvert and rip-rap. To maintain a relatively constant head on the pumps, the discharge structure maintains a relatively constant discharge water surface as it weirs over into the erosion protection discharge structure (see Photo 9).

Trash management practices at the Oakmead Pump Station consist of trash racks having roughly 3-inch spacing upstream of the pumps in the wet well (Photo 10). The City of San José removes trash from this station once a year.

The pumps at the Oakmead Pump Station can be turned on automatically. During the field visit, one of the pumps was turned on to demonstrate the operation of the discharge structure. Photo 11 shows the water flowing from the discharge structure into the Guadalupe River just downstream of the pump station discharge. Photo and visual observations indicated that little to no visible trash is being discharged from the pump station.

Photo 8 – Aerial Overview of Oakmead Pump Station

Photo 9 – Oakmead Pump Station Discharge Structure

Photo 10 – Trash Racks at Intake to Oakmead Pump Station

Photo 5- Water Flowing from Oakmead Pump Station

3.3.5 Other Pump Stations within the Program's Jurisdiction

Through previous work, Schaaf & Wheeler have collected pictures of trash management at other pump stations within the Program's jurisdiction. Representative pictures from one pump station are provided below. Photos 12a and 12b show the trash rack and pump area at the City of Santa Clara's Rambo Pump Station. This pump station has a drainage area of 347 acres and a capacity of 61,200 gpm (136 cfs). Photo 12a show various types of trash collected at the trash rack. Photo 12b shows relatively large amount of trash which reached the pump. It is important to note that the Rambo Pump Station has a gravity outfall that normally allows stormwater to bypass the pump station when the receiving water (i.e., San Tomas Aquino Creek) is low. This is also common for several other pump stations within the Program's jurisdiction.

Photo 6 – (a) Trash rack and (b) Pump at the City of Santa Clara's Rambo Pump Station

4.0 POTENTIAL TYPES OF PUMP STATION RETROFITS FOR TRASH CONTROL (Q#7)

Two major tasks of this analysis include determining the overall feasibility of retrofitting pump stations and determining the independent feasibility of implementing different trash management options. Completing these tasks requires an understanding of existing trash management practices and an evaluation of potential trash management options that may be implemented.

Pump station configurations may require different types of retrofits to improve trash capture rates. Given the various configurations of stormwater pump stations in Santa Clara County (*Q#1*); several potential trash management retrofits may be feasible. For example, trash racks may be installed or enhanced at pump stations with gravity bypasses; or netting systems may be used to filter out solids at pump stations with large upstream basins. General types of retrofits discussed within this section include:

- **Adding mesh screens on top of existing (coarser) trash rack devices;**
- **Installing louver screens in a similar manner to trash racks;**
- **Installing end-of-pipe trash nets/screens at or near pump station outfalls;**
- **Installing litter booms upstream of pump stations;**
- **Installing in-stream netting in upstream basins;**
- **Installing fish screen-type filters in the wet well or forebay of pump stations;**
- **Adding alternative trash rack coatings or materials; and**
- **Installing mechanical trash rack cleaning devices (as a supplement to other devices).**

Potential pump station configurations to which these options would be applicable; and the advantages and disadvantages of these retrofits are summarized in Table 5.

Table 5 - Summary of Trash Management Retrofits

Retrofit Type	Pump Station Applicability	Advantages	Disadvantages
Mesh screens attached to upstream side of trash rack	Those with existing trash racks.	• Relatively easy installation/low cost • Better protection of pumps	• May not work with pump station hydraulics • Mesh may clog pump impellers • May require confined space entry permit/additional maintenance
Mesh screens downstream of trash rack	Those with existing trash racks and wet wells large enough to accommodate.	• Trash rack serves as a pre-filter • Relatively low cost • No station entry required for installation/maintenance	• May not work with pump station hydraulics • Would require some sort of backing (i.e., structural support) • Installation not straightforward
Solids separation screens/Louver screens	Broadly applicable (replace a trash rack, in upstream detention, in wet well with enough space)	• Multiple placement opportunities • Relatively easy installation/low cost • Readily available and tested technology • Good removal of small trash items	• May not work with pump station hydraulics (i.e., increase upstream hydraulic grade line) • Can trap water under low flows • Can be aesthetically unattractive
End-of-pipe nets/screens	Those with adequately-sized discharge boxes or outfall channels.	• Generally large areas available • Relatively easy installation/low cost • Maintenance more straightforward • Small effect on pump station hydraulics	• Increased maintenance. • May drastically reduce hydraulic capacity of influent storm drain • Permits required in jurisdictional waters
Litter booms with in-stream netting	Those with adequately-sized upstream basins or lagoons.	• Relatively low capital costs • Readily available	• Not considered effective in capturing smaller trash items • Potentially high costs • Difficult to clean and maintain • Can be aesthetically unattractive
Alternative materials/coatings	Those with existing trash racks.	• Relatively inexpensive • Relatively easy installation	• May not be very effective • Only a supplemental method
Mechanical cleaners	Those with existing trash racks or those retrofitted with enhanced devices at the trash racks.	• Reduces manual maintenance requirements • Maintains pump station hydraulics	• Relatively expensive • Difficult installation • Only a supplemental method

4.1 Mesh Screens

In addition to existing trash racks at pump stations, finer mesh screens could be added upstream of the pumps to filter smaller solids from incoming stormwater. With 5-mm spacing, these screens are similar in appearance to a window screen or netting. Mesh screens could be placed upstream or downstream of existing trash racks. If placed downstream, the existing trash racks would serve as a “pre-filter” to remove large solids, while the mesh screens remove finer materials. This configuration would extend the time between maintenance. If placed upstream, mesh screens would replace the trash rack as the primary trash management control mechanism. The latter configuration is similar to the setup at the City of Palo Alto’s Matadero Pump Station.

Mesh screens require some sort of structural backing. It may be possible to use the existing trash racks as the backing if they are placed on the upstream side of the trash rack. If the mesh screens have a separate structural support, they could be placed downstream or further upstream of the trash racks.

Since many pump stations have one or more closed-conduit intake pipelines, it may be possible to retrofit the pipelines with a mesh screen or device similar to what is shown in Figure 3. This type of device may be useful in gravity bypasses or stormwater systems that drain directly to receiving waters. In the case of gravity bypasses, adding trash management devices to intake pipelines would likely force stormwater and solids towards the pump station.

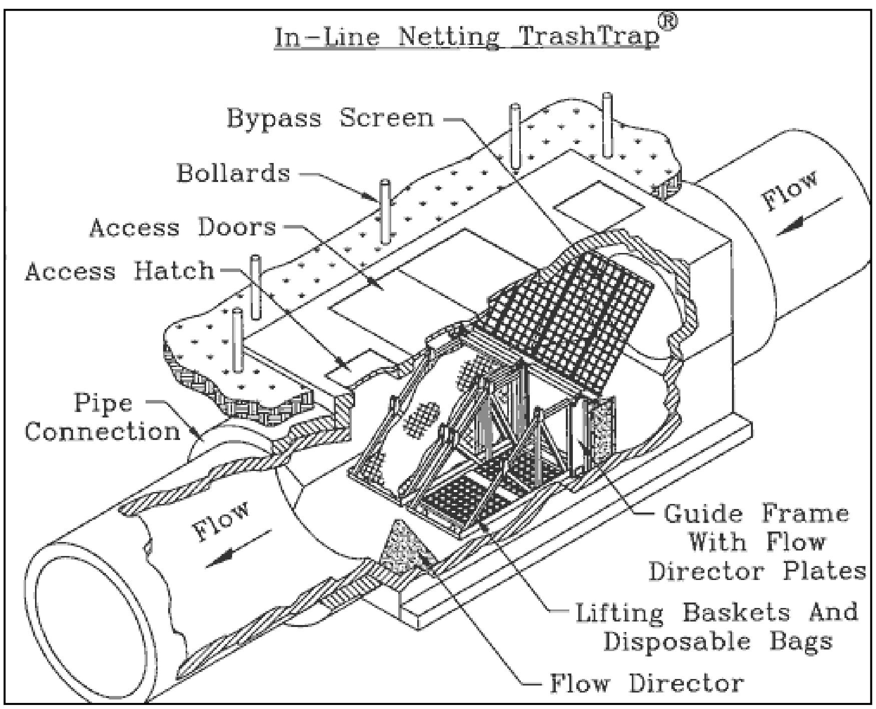

Figure 3 - In-Line Trash Management Device

Advantages of adding mesh screens to existing pipelines or trash racks include the relative ease of installation and maintenance; as well as the removal of additional trash leading to increased pump protection.

A potential *disadvantage* includes a negative influence on pump station or storm drain system hydraulics, such as increasing the hydraulic grade line upstream of the trash control and encouraging flooding upstream; or lowering the observed upstream head on the pumps and altering their operation. Another significant *disadvantage* includes the possibility of the mesh screens deteriorating or breaking off into the pump impellers. Stormwater pumps can pass larger solids but do not usually pass stringy, cloth-like material due to it potentially wrapping around the pump shaft and interfering with pump operation. In addition, trash racks with a finer mesh most likely require more frequent maintenance. Finally, due to their limited entry and nature, confined space permitting may be required for access and cleaning of the screens.

4.2 Solids Separation Screens and Louver Screens

Another potential trash management practice is the installation of some type of metallic screen, such as solids separation screens or louver screens, originally developed as water well screens. These types of screens can be used in various forms, such as the cylindrical form for an in-line trash management device, similar to what is shown in Figure 3. The cylindrical form may also be useful for placement within pump station wet wells. Another form, the inclined flat form, has also been used with louver screens, as shown in Photo 13.

Photo 13- Inclined Louver Panel Screens within Caltrans Detention Basin, Pasadena, CA (Photo courtesy of Kevin McGillicuddy, Roscoe Moss Company, Los Angeles, CA)

The inclined flat form involves installing individual louver panel screens side-by-side to span the width of the detention basin and/or forebay. Commercially available louvers have slot widths of 3” and openings of 0.200” that would permit passage of stormwater but retain trash and debris measuring 0.200” (5mm) and larger. This design meets the Los Angeles Regional Water Quality Control Board definition of a "full capture system". A full capture system is any single device or series of devices that traps all particles retained by a 5 mm mesh screen and has a design treatment capacity of not less than the peak flow rate (Q) resulting from a one-year, one-hour, storm in the subdrainage area. Panel sections can be mounted horizontally and vertically to cover the area designed for treatment. The panels are mounted on H-beam supports that are anchored in concrete at the base. Individual panel dimensions shown in Photo 13 are 8 ft x 5 ft with a $^1/_4$" thickness (personal communication, Kevin McGillicuddy, Roscoe Moss Company, July 9, 2009). Individual panels may be custom made up to 8 ft x 10 ft with a $^3/_8$" thickness.

Trash and debris collected in front of the solids separation screens and louver screens could be removed with a vactor truck or small loader, similar to maintenance of trash racks.

A*dvantages* of the metallic screens include the option of installing them at multiple places, including intake pipelines, wet wells, and upstream detention basins; relatively easy installation and low cost; readily available and reliable; and their ability to trap relatively small trash items (e.g., 5 mm) and large quantities of floatable materials. The reliability of these screens is indicated by their successful, long-term use in other types of water resource-related projects.

Disadvantages of using the metallic screens, particularly in wet wells, is that they are not usually designed with excess capacity. As a result, the use of excess capacity may negatively affect pump station hydraulics, including pump cycling and hydrodynamic complications at the pump intakes (i.e., increased vortices). Their placement in upstream detention basins or intake pipelines could increase hydraulic grade lines and have negative consequences in terms of upstream flooding. To avoid flooding, the height of the screens should be pre-determined to allow for by-pass. In some instances, metallic screens may be difficult to install in working pump stations which have limited space. As a result, installation costs may be expensive. Other *disadvantages* of the metallic screens include the temporary storage of water behind the screens during low flows due to blockage; and causing unaesthetic views if in public view.

4.3 End -of-Pipe Trash Nets/Screens

Almost all pump stations have some sort of discharge structure, such as a box culvert. It may be possible to retrofit discharge structures with end-of-pipe trash nets or screens, similar to what is shown in Photo 14. Before and after photos demonstrate the performance of trash nets.

Some pump stations also have discharge channels where end-of-pipe netting may be installed. The City of Palo Alto's San Francisquito Pump Station has both a rip-rap area and a downstream channel just off of the main San Francisquito Creek where the installation of netting may be feasible. Maintenance crews would clean or replace the netting periodically to maintain adequate operation of the pump station and prevent excessive backwater effects. Trash nets could also be installed at the City of San Jose's Oakmead Pump Station. However, it may not be practical to place the nets within the adjacent flood plain since they could potentially block the channel during high flood flows.

Photo 14 – Sample End-of-Pipe Trash Nets (a) Empty and (b) Full of Trash

Some *advantages* of end-of-pipe nets is that they do not normally affect pump station hydraulics; may be placed downstream of any discharge box that gives a control surface to the pumps; and may be installed without entering the pump station. The pump station can also be manually shut-down to prevent flows during installation and maintenance.

Disadvantages to installing end-of-pipe trash nets include the lack of an adequate attachment area on the discharge structure and the presence of flood channels or other obstructions downstream. To allow adequate pump station operation, end-of-pipe nets/screens would need to be sized large enough to ensure reasonable flow velocities given a certain level of blockage. In addition, obtaining regulatory permits for net installation within jurisdictional waters may be problematic. Although nets would reduce the amount of trash discharged to receiving waters, there is the possibility of net breakage. This could have critical aesthetic and regulatory consequences, particularly if a full net caused the blockage of a flood channel.

4.4 Litter Booms

A potential trash management practice for capturing trash at pump stations is the installation of litter booms with drop-down netting. Litter booms, which are flotation structures with suspended nets/curtains used to capture floating trash, are best suited at pump stations with detention basins/lagoons, large wet wells or large downstream water bodies. Photo 15 shows the level and types of trash usually captured by litter booms upstream of a pump station.

Photo 7 – Los Angeles River Litter Boom System

Alternatively, a device similar to Fresh Creek Technologies' Floating Netting TrashTrap®, represented in Figure 4, could be used at the discharge channel of a pump station. This device, which is similar to the end-of-pipe netting described above, can accommodate downstream water level changes of up to 25 feet. However, this device is not suitable for channels unless standing water is present at all times. Since the device is placed within a channel, maintenance (e.g., replacing trash nets) is usually difficult due to access limitations.

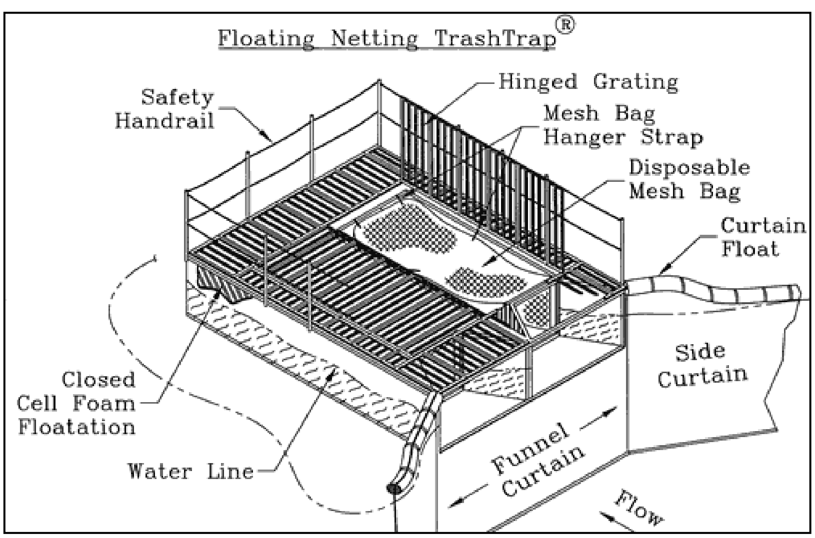

Figure 4 - Floating Trash Management Device

Some *advantages* of litter booms include and netting include their relatively easy installation and a wide range of sizes and models to accommodate different situations. Litter booms can trap large quantities of floatable materials. Maintenance is relatively simple and does not require any confined space entry.

Some disadvantages of litter booms include poor performance and their unaesthetic appearance. In terms of performance, they are designed to capture only the floatable portion of gross solids loading, which may be a very low fraction of the total loading. Even with attached netting, suspended nets/curtains may break away and reintroduce trash into the channel. With large flows, litter booms and nets could be overwhelmed resulting in relatively intensive maintenance requirements.

4.5 Alternative Materials and Coatings

Trash rack materials and coatings that resist adhesion of solids could reduce trash rack maintenance. The intent of using alternatives materials or coatings would be to preserve the *amount* of trash collected but reduce the clogging and maintenance requirements of trash racks. Accordingly, using alternative materials may not enhance trash management but could supplement the methods discussed above by increasing their feasibility.

Most trash rack materials are ferrous metal. Epoxy or paint coatings can be selected to resist adhesion of expected trash materials. The use of alternate materials and coatings is useful in preventing trash from accumulating on the surface of trash racks or other trash management devices; and facilitates the cleaning of these devices thus reducing maintenance costs.

Some *advantages* of alternate materials and coatings are their relative low cost when compared to other enhanced trash management devices or practices; and the relative ease of replacing existing uncoated trash racks with epoxy-treated ones.

Disadvantages may include little effectiveness in enhancing trash management due to additional and smaller trash not being captured. Even with minimized adhesion, the direction and level of incoming flow will serve to impinge materials on the trash rack. This may decrease the effective flow area, block stormwater flow and increase head losses. This practice should only be used as a supplement to other devices or practices.

4.6 Mechanical Trash Rack Cleaners

Mechanical trash rack cleaning devices are useful in keeping trash racks clean even if rack spacing is reduced. These devices can be automatic or semi-manual, thus requiring some human operation. Cleaning device types include rake-like (see Photo 16) or conveyer-type devices. The use of cleaners requires setting aside or installing trash storage areas since additional trash accumulates and is removed from cleaning procedures.

Photo 8 - Automatic Trash Rack Rake

The major *advantage* of mechanical cleaning devices is the reduced need of maintenance staff to visit and clean trash management devices. Cleaning devices are able to maintain adequate hydraulics across trash management devices, even under heavy trash loading.

Potential *disadvantages* of mechanical cleaning devices include relatively high installation costs and difficulties with installation upstream of the pumps. The cost of installing mechanical devices, which require electrical power, would need to be weighed against potential maintenance cost savings to help determine their utility.

5.0 FACTORS INFLUENCING FEASIBILITY OF PUMP STATION RETROFITS

To determine the feasibility of retrofitting pump stations for enhanced trash management, potential retrofit costs and implementation requirements need to be determined. This section looks at these factors.

To answer the last three questions on the feasibility of retrofitting pump stations, the following factors need to be analyzed:

- Existing pump station trash management practices;
- Existing pump station configurations (particularly at the inlet works);
- Details of trash management retrofit devices/practices;
- Effects of trash management retrofits on pump station operations, including hydraulics and maintenance;
- Composition and size distribution of trash;
- Expected trash loading rate; and
- Stormwater flow rates.

The first three factors have been previously discussed above. The fourth factor – effects of retrofits on pump station operations, including hydraulics and maintenance – was briefly discussed within the last section. A more detailed analysis is provided below with a discussion of the last three factors – composition and size distribution of trash, expected trash loading rates and stormwater flow rates.

5.1 Effects of Trash Management Retrofits – Benefits, Challenges, Costs (Q#8)

In addition to the benefits of reducing trash runoff into receiving waters, retrofitting pump stations with trash management devices has several challenges. The retrofits will have certain costs that may or may not be offset by the expected benefits. Overall, a pump station has been designed for specific hydraulic purposes and must continue to operate adequately while not adversely affecting any upstream storm drain system. In particular, head losses through the trash management device should be minimized. Maintenance, while critical to keeping the devices operating properly, must also be minimized to reduce operation and maintenance (O&M) costs.

5.1.1 Benefits

The retrofit of existing pump stations with relatively few or no trash management practices may result in the following benefits:

- Extended service life of pump station components;
- Easier maintenance of pump stations; and

- Improved stormwater conveyance through the pump station.

Since the pumps at most pump stations are designed to handle some solids, trash management does not necessarily improve pump performance. However, it could help protect the pumps from wear and tear. As the size of trash being removed gets smaller, the benefits would likely shrink proportionally. In addition, retrofits may significantly improve trash management at pump stations that have a gravity bypass.

The overarching benefit of retrofitting pump stations currently with or without existing trash management practices is a reduction of trash entering the receiving waters.

5.1.2 Challenge #1 – Head losses

To ensure adequate pump station operations, trash management devices should be designed to carry a certain design flow rate at a reasonable velocity without significant head losses. Stormwater pump stations have a design flow rate and desired velocity range.

Since the flow rate is equivalent to the velocity multiplied by cross sectional flow area (Q= vA), specifying the flow rate and velocity requires a specific flow area. Flow area influences the size of the trash management device depending on the effective area of the device (i.e., the actual area through its slots which allows flow). Trash racks and other trash management devices must have large enough openings to prevent partial plugging which adversely restrict stormwater flows. While there are no universal guidelines on trash rack sizing, a rule-of-thumb is to have the trash rack area at least ten times larger than the control outlet orifice or pipeline feeding the pump station. Manufacturers will usually report the open or effective area of the trash rack or screen. If this area is not provided, it may be calculated. When the effective area is known, hydraulic calculations can be performed and trash management devices can be sized to pass adequate flow.

Head losses through trash management devices are generally proportional to the square of the velocity through the device. The U.S. Army Corps of Engineers and others have developed head loss equations of the following form:

$$H_L = K*V^2/ (2*g) = K*h_v$$

Where "H_L" is the head loss (in feet), K is a dimensionless loss coefficient dependent on the parameters of the grate, "V" is the flow velocity (in ft/sec) through the grate, "g" is the gravitational constant (in ft/sec^2), and "h_v" represents the velocity head.

Typical values of K range from 0.3 to 0.8, which account for various trash rack configurations and also include a factor for partial blocking.

There are more sophisticated equations to calculate head loss. These equations are based on actual gross and effective cross sectional area; or on wire/bar thickness, slot opening, and the angle of the trash device.

Şentürk's *Hydraulics of Dams and Reservoirs* (1995) presents an equation of the former variety:

$$K = 1.45 – 0.45*A_N/A_g – (A_N/A_g)^2,$$

Where "A_N" is the effective (net) area through the trash bars and A_g is the gross area; and an equation of the latter variety as:

$$K = B*(S/y)^{4/3} * \sin(d),$$

where "B" is a coefficient defined in the book, "S" is the thickness of the trash bars, "y" is the clearance between the bars, and "d" is the slope angle of the trash device. For bars/wires much longer than they are thick, "B" becomes equivalent to "S."

Since the Santa Clara Valley Water District references the former equation in their *1996 Hydrology Procedures*, it will be used in this analysis. Manufacturers also report values of effective area for small opening screens. Screen Services lists their mesh with 5 mm (0.1960 in) openings as having an open area of 61.5%. Therefore, A_N/A_g = 0.615 and K = 0.795. Assuming 50% blockage, A_N/A_g = 0.308 and K = 1.22. For small velocities (e.g., 2 fps), the K value for 50% blockage would give a negligible headloss of 0.076 feet (< 1 in). For larger velocities (e.g., 8 fps), headloss would be more than an order of magnitude greater, equaling 0.99 feet (11.9 in).

Schaaf & Wheeler designed the San Francisquito Pump Station and had substantial background engineering information on the pump station. With such information, estimates can be made to show the effects of increased hydraulic losses on upstream flooding within the City of Palo Alto. These estimates indicate potential adverse impacts, such as increased pump cycling or upstream flooding, from one method of enhanced trash management (i.e., finer screen mesh).

These estimations are calculated by using an Excel spreadsheet to estimate the effective trash rack area, based on the size of spacing and level of blockage; and a USEPA hydraulic model (SWMM) that simulates the pump station and upstream stormdrain system operation under a specified flow rate. The result of the Excel spreadsheet is used with the equations above to estimate a loss coefficient. This estimate is put into the hydraulic model.

Given a flow rate, water level and parameters of the trash rack (e.g., bar spacing and width); an estimation of the expected hydraulic losses and effects on pump station operation can be made. Storm data from December 2005, the fourth largest storm on record, was used in the predictive hydraulic model to compare different levels of effective trash rack area.

The estimated maximum hydraulic losses through the trash rack with either 2.5-inch or 5-mm (0.196") spacing are listed in Table 6 for various levels of trash rack blockage. These results are based on a maximum inflow rate of 285 cfs, which requires all four pumps to run, and a design depth of water at the trash rack of 3.5 feet.

Table 6 - San Francisquito Pump Station Headloss Comparison

Blockage	Spacing			
	2.5”		0.196” (5 mm)	
	Headloss (ft)	Velocity (fps)	Headloss (ft)	Velocity (fps)
0%	0.04	2.7	0.10	3.2
25%	0.16	3.7	0.26	4.3
50%	0.50	5.5	0.75	6.4
75%	2.44	11.0	3.42	12.9

The results in Table 6 indicate that the smaller spacing would increase head losses a maximum of 200% with no blockage; and a minimum of 40% with 75% blockage. These ratios are for direct comparison at each level of blockage. However, it is likely that the smaller spacing would reach a higher level of blockage, on average. Therefore, it is more useful to compare the effects of the 5-mm (0.196”) spacing at 75% blockage to the 2.5-inch spacing at a lower blockage, say 50%.

The hydraulic model estimates surface flooding induced for 50% blockage of the existing trash racks at 141.40 ac-ft. With enhanced trash management and 75% blockage, surface flooding would increase to 147.97 ac-ft, a difference of 6.54 ac-ft or over 2.1 million gallons of additional flooding. It would be useful for the City of Palo Alto to examine whether the benefits of trash management enhanced to the 5-mm (0.196”) level would offset the cost of increased flooding.

The results for the San Francisquito Pump Station may not be applicable to other pump stations, particularly if the pump station does not have significant upstream flooding. Some pump stations may have excess upstream capacity that can accommodate increased head losses from enhanced trash management practices. Each Permittee would need to analyze the hydraulics of their pump stations to estimate the hydraulic effects of enhanced trash management.

5.1.3 Challenge #2 – Maintenance

An important aspect of trash rack/screen operation is maintaining an adequate flow rate of stormwater through the trash device. Most pump station trash racks are designed perpendicular to the flow. When enough trash has been collected on the racks, it starts to block stormwater flow. Since most trash accumulation occurs during high-flow events, it is not always possible to clean and prevent significant blockage of the trash racks. Generally, a design criterion of 50% blockage without detrimental loss of hydraulic performance is used.

Undoubtedly, the enhanced trash management will require increased pump station maintenance. To maintain adequate trash rack operation, the following cleaning methods may be used:

- Mechanical cleaning with a scraper;
- Mechanical cleaning with a brush device;
- Mechanical vibration (experimental);
- Backflushing with water jets; and
- Manual cleaning (raking).

As discussed above, alternative trash rack materials and automatic trash rack cleaners would mitigate the maintenance burden but would increase overall maintenance requirements at pump stations. Many of these methods must be repeated at frequent intervals, particularly during periods of high stormwater flow, when large volumes of trash are conveyed to the pump station.

Typical design velocities for trash racks range from 0.5-3 ft/sec depending if the trash management device doubles as a solids separation screen. As mentioned above, smaller-spaced trash racks are more likely to become blocked at a faster rate since they capture more solids over a given amount of time. Maintenance requirements of trash management devices vary due to trash loading, device effectiveness and the effects of blockage on performance.

Inline screening devices are typically reported as requiring 12-24 person-hours of cleaning/maintenance time per storm season, which is considered to be one year. Assuming existing pump stations are maintained once/year, the required maintenance could increase to 3-5 times a year per pump station, or a 300-500% increase.

5.1.4 Costs of Pump Station Retrofits

The cost of pump station retrofits depends on the type of retrofit and the factors detailed below. Design and construction costs are estimated to be between $200,000 and $1,500,000 per pump station. Total twenty year costs of the retrofits are estimated to be $400,000 to $1,700,000 per pump station, including increased costs for O&M over the time period. Table 7 provides estimates of costs associated with pump station retrofits.

Table 7 - Estimated Costs of Retrofits per Pump Station

Cost Category	Elements in Category	Costs Per Pump Station
Design/Planning	Engineering, Environmental, Agency Permitting	\$50,000 - \$100,000
Capital	Concrete, Nets, Mechanical cleaning devices, Additional vehicles	\$50,000 - \$1,000,000
Other Construction	Labor, Administration, CM	\$100,000 - \$400,000
Operation & Maintenance	Cleaning, Net replacement, Trash hauling	\$9,000 (annually); ~\$200,000 (20-year total)
Design and Construction		\$0.2 - \$1.5 million
Total 20-year Cost		\$0.4 - \$1.7 million

As is typical for construction projects, **design and planning costs** should be relatively minor compared to the other costs. This is due to many proprietary devices rolling their design costs into the purchase cost.

Capital costs for construction are likely the most significant costs for implementing enhanced trash management practices. These costs could include:

- Concrete and materials for trash management device construction;
- Disposable trash nets and litter booms;
- Mechanical cleaning devices; and
- Additional vehicles and storage containers used to manage the increased trash load.

Depending on the difficulty of construction, capital costs are estimated to vary from \$50,000 to \$1,000,000 per pump station.

Other construction costs, which include labor, administration and construction management costs could be a significant percentage of total project costs. These costs may be 25-50% of total construction costs. An estimate of non-capital construction costs for retrofitting one pump station is \$100,000 to \$400,000.

The increase in **annual O&M costs** could also be a significant portion of the long-term enhanced trash management costs. As discussed above, increased maintenance is expected due to additional trash loading. Assuming a 300 % increase in operator labor at \$120 an hour (including benefits) and a current expenditure of 24 hours per year, the increase in O&M costs for labor would be approximately $9,000 per pump station. If a Permittee has ten pump stations within its jurisdiction, the estimated annual O&M cost is approximately $90,000. This number represents the salary of on full time O&M staff person.

5.2 Trash Composition and Distribution

Another important aspect of trash accumulation is the composition of the captured trash. Different types of trash have different buoyancies and weights, as well as different sizes. The disparate parameters affect how much and where various types of trash accumulate within the storm drain system. These factors can also influence the efficacy of any trash management practice.

A 2007 SCVURPPP study indicated that 60% of trash observed within San Francisco Bay area creeks were made of plastic (e.g., bottles and bags). No other material category comprised a proportion greater than 13%. The reported percentages are:

- 60% - plastic;
- 13% - biodegradable;
- 7% - glass;
- 7% - metal;
- 5% - miscellaneous;
- 3% - construction;
- 2% - fabric/cloth;
- 1% - toxic;
- 1% - large; and
- 1% - biohazard.

The SCVURPPP study does not indicate the size of trash pieces observed, other than noting that "large" pieces of trash were 1% of the observed trash. Certain assumptions can be made from the composition to understand the size of trash involved. For example, if biodegradable products are mainly composed of paper, it is safe to assume that the observed paper likely varies from napkin pieces and wrappers to cardboard box pieces with accompanying sizes (a few inches square to a couple feet square).

The City of Los Angeles conducted a study of catch basins that yielded the following composition of trash:

- 33% soil;
- 31% yard trimmings;

- 26% paper; and
- 10% plastic wastes.

This study also found that observed plastic waste was a smaller proportion in residential areas; paper waste was greater in commercial areas; and soil and yard waste were greater in residential and open space areas. Caltrans has conducted studies of vortex units (e.g., Continuous Deflective Separation (CDS) units) installed adjacent to freeways. Study results indicated that the CDS units collected a high percentage of vegetative material (93%), trash and litter.

Due to limited studies, it is difficult to estimate what types of trash would reach urban pump stations. Based on recent observations within the Program's jurisdiction, it can be assumed that street tree debris/leaf litter is more prevalent in residential areas; and plastic and paper wastes are more prevalent in commercial areas. However, street tree debris/leaf litter is also common within commercial areas due to the presence of a significant number of street trees.

One of the outstanding questions of interest is "What is the size distribution of trash expected at the pump stations?"

5.3 Trash Loading Rate

The rate at which trash accumulates in a drainage area varies with some quantifiable factors including:

- Land use and
- Proximity to public and high-traffic areas.

However, various other factors are difficult to quantify including:

- Income level of the community and
- Environmental awareness of the community.

There are also temporary factors that can play a major role in trash loading and composition. These include:

- Climate (i.e., rainfall and tree debris) and
- Construction activity.

With all of these diverse factors, it is difficult to estimate a trash loading rate into a storm drain system from first principles. Several field investigations have been conducted to determine trash loading and accumulation at various urban land uses. SCVURPPP has conducted some of these investigations and summarized others.

- The Program's *Trash BMP Tool Box* describes a study performed on catch basin inserts within a 123.5 acre urban watershed in Australia. This study found an average of 250 kg dry weight of trash collected per month. Assuming a trash density of 1 lb/gal, the estimated trash accumulation rate is approximately 0.05 ft^3/ac/yr (0.17 kg/acre/year).

- The City of Calabasas, CA collected solids from stormwater runoff using a CDS unit. It was estimated that the annual trash loading rate for the urban watershed area is 640 gallons/square mile. This equates to an annual trash accumulation rate of 0.13 ft^3/ac/yr.

- Net-type trash traps were installed within a tributary drainage area of 172.8 acres in Signal Hill, CA. These nets are expected to capture approximately 175 gallons of trash per year. This equates to an average trash accumulation rate of 0.14 ft^3/ac/yr.

- The City of Los Angeles collected 160 gallons of trash per cleaning from a 1,366-acre basin and a 2,267-acre basin. Over a 2.5 year period, these areas were cleaned approximately nine times. The annual trash accumulation rate for these areas is 0.021 ft^3/ac/yr.

- The Los Angeles County Department of Public Works installed a trash netting system within a 1,029 acre drainage area. During the first year of installation, over 35,000 pounds of trash were collected. Subsequent years had lower yields. In FY 2006-2007, approximately 7,700 pounds of trash were collected. Assuming a trash density of 1 lb/gal, the trash accumulation rate for this watershed ranged from 1 to 5 ft^3/ac/yr.

- Professor Len Ortolano of Stanford University summarizes in his book entitled *Environmental Planning and Decision Making* that various values of "accumulated solids loading" exist for urban runoff. While these solids are not defined in terms of size, presumably they include trash and other non-dissolved solids. Professor Ortolano discusses previous studies on solids loadings, even categorizing loading by various land uses. For residential and commercial areas, a maximum value of 600 pounds/curb mile of street surface is reported. For industrial areas, a maximum of 1,200 pounds/curb mile is reported. Using similar assumptions of trash density, the 600 pounds/curb mile is equivalent to approximately 0.03 ft^3/ac/yr. This number may be underestimated since a density of 1 lb/gal may be an order of magnitude or more smaller than actual solid slurry densities.

The reported results of trash capture vary over two orders of magnitude even though most studies report an average trash accumulation rate of about **0.2 ft^3/ac/yr.**

The City of Los Angeles has determined that the highest litter generation per acre (i.e., trash loading rate) occurs in commercial and industrial areas. Typical sources of trash within these areas include: debris from large, open trucks; commercial/industrial loading/unloading and other operations; and expansive parking lot areas. Residential areas tend to generate trash from yard maintenance, illegal dumping, inadequate waste container management and homeless encampments.

5.4 Stormwater Flow Rates

There are two stormwater flow rates of importance when designing and implementing trash management devices. They include the pump station design (operational) flow rate and the low (water quality) flow rate. Stormwater pump stations are generally designed for a 10-year flood flow or larger flow rates. The low (water quality) flow rate is the condition when most solid pollutants are expected to be mobilized through the storm drain system. Therefore, it is important to design trash management devices with adequate performance between water quality and design flow rates. Full-capture trash systems are required to have a design treatment capacity of not less than the peak flow rate resulting from a one-year, one-hour storm.

To estimate the low-flow and design flow rates, the Rational Formula can be used:

$$Q = CIA$$

where Q is the calculated flow rate in cubic feet per second (cfs), “C” is the dimensionless runoff coefficient of the drainage area, “I” is the rainfall intensity for the storm of interest in inches per hour (in/hr), and “A” is the basin’s drainage area in acres. The Rational Formula is generally applicable to drainage areas of less than 200 acres which do not have significant detention basins or other storage reservoirs. Even for larger drainage areas, which include pump stations within the Program’s jurisdiction, the Rational Formula should be accurate enough for the current analysis.

Drainage areas to pump stations have been reported by various cities. These drainage areas will be used in the flow calculations. In addition, predominant land uses within the catchment areas have also been reported. These land uses will be used to estimate the runoff coefficients. Based on the Santa Clara County *Drainage Manual 2007*, the following “C” values will be used to reflect the predominant land use:

- Commercial = 0.80;
- Industrial = 0.75;
- Residential = 0.60; and
- Underpass (paved) = 0.90.

Based on various methods, the rainfall intensity, “I”, can be calculated using the Santa Clara County *Drainage Manual 2007* or the Santa Clara Valley Water District *Hydrology Procedures*. These methods include the Global Regional equation, the TDS Regional equation and Intensity-Duration-Frequency (IDF) curves. Results from these methods are summarized in Table 8.

Table 8 - Rainfall Intensity Results

Method	Intensity (in/hr)	
	1-year, 1-hour	10-year, 30-min
Global Regional	0.52	1.08
TDS Regional	0.47*	1.05
IDF Curve	0.48*	1.05
Average	0.49	1.06
Std. Deviation	0.03 (5.4%)	0.02 (1.6%)
*1-year data not available. 2-year, 1-hour storm results are presented as conservative estimates.		

Using a partial duration series, the one-year storm can be better estimated. This procedure yields an estimate of the 1-year storm for a mean annual precipitation of 20 inches at 0.48 in/hr, which is similar to the results above. Using this same procedure, the 2-year storm is estimated at 0.57 in/hr.

For the 10-year storm, a 30-minute duration has been used. This is estimated to be equivalent to the average time-of-concentration (T_c) for the various drainage areas. This T_c is estimated from an assumed 100 acre, square drainage area (2,000 feet on each side) with a typical overland flow velocity of 2 feet per second (fps). This velocity would give about a 20-minute flow time across the basin. When combined with a roof-to-gutter time (i.e., initial T_c) of 10 minutes, the total T_c is 30 minutes.

6.0 CONCLUSIONS

6.1 Ideal Situation(s) for Enhanced Trash Management Retrofits at Pump Stations

Based on available literature and the analysis discussed above, the following steps are beneficial in implementing trash management retrofits in an efficient manner:

- Perform adequate up-front planning on a site-specific basis;
- Involve O&M staff from the beginning to add their practical experience and buy-in;
- Use sound engineering with attention to detail and close project management to ensure on-time and on-budget completion;
- Ensure proper system operation; and
- Adequately maintain reporting paperwork (i.e., pound or yards of trash removed, removal frequency, etc.) to analyze efficacy of trash management options.

The ideal situation for enhanced trash management retrofits at pump stations is selecting a pump station which has an adequate wet well or upstream storage capacity. Some of this additional capacity could be used for trash capture and storage. In addition, the use of a mechanical trash rack rake requires the additional storage of trash above or near the trash racks.

6.2 Outstanding Questions (Data Gaps)

There are several outstanding questions which need to be answered to refine the analysis of trash management retrofits at pump stations. These questions include:

1. What is the typical size distribution of trash that enters pump stations (*Q#5*)?
2. What is the size range of proposed trash management devices (especially the maximum size)?
3. Will the trash management device fit in the pump station? Does the pump station have excess storage capacity (for trash storage) within the wet well and surrounding surface areas?
4. Is it feasible to cease operations and dewater pump stations when installing and maintaining trash management devices?

Answering these questions and the remaining questions below would be useful in tailoring an appropriate trash management retrofit for a specific pump station:

5. What are the specific costs and benefits of various retrofits, particularly in terms of capital and maintenance?
6. Which retrofits are applicable to the pump station of interest?
7. Which retrofits have relatively more value for the pump station of interest?

8. How can retrofits be implemented without adversely affecting pump station hydraulics?

6.3 Recommendations

Even with some outstanding questions, the analysis detailed in this report can lead to several recommendations on enhanced trash management at stormwater pump stations:

- Each jurisdiction will need to examine their specific pump stations and configurations to determine the means and feasibility of enhanced trash management; and determine the costs and benefits of implementing these actions versus improvements in trash management at other points in the stormwater conveyance system.
- Most existing pump stations likely screen out trash as small as 2-3 inches (50-75 mm) in size (smallest dimension). Pump stations which do not have existing trash management practices should be further evaluated for potential retrofits.
- Pump stations with gravity bypasses would be particularly conducive to enhanced trash management since the benefit of removing additional trash is potentially larger than maintaining the gravity discharge and allowing trash to reach the receiving water.
- Existing pump stations with large forebays or other upstream ponding areas are particularly conducive to retrofitting with screens or nets to achieve full trash capture.
- Pump stations without significant upstream storage are more conducive to downstream capture (e.g., outfall netting) unless unfavorable for the discharge structure or channel.
- Specific head losses through the enhanced trash management devices are difficult to accurately estimate. However, when velocities are kept low enough (i.e., by maximizing screening surface area), head losses could be minor resulting in storm drain system performance not being compromised.
- Commercially available low-velocity floating trash management devices or solids separation/louver screens may be an effective for additional trash control. This option would not significantly affect pump station hydraulics.
- Use of readily available and tested materials, even if currently used for other purposes, is likely to be relatively cost effective and timely. Manufacturers of such materials already have plans and specifications that could be readily transferred to pump station trash management practices.

In summary, there are some challenges to implementing full trash capture. However, many pump stations may feasibly be retrofitted for enhanced trash management. Specific trash management devices will need to be tailored to individual pump stations depending on all factors discussed within this report.

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APPENDICES

Appendix 1: Table 9 – Trash Device Flowrates (1-year, 1-hour) and Trash Accumulation Rates

Pump Station	City	Catchment Area (acres)	Dominant Land Use	Estimated "C"	$Q_{1,1}$ (cfs)	$Q_{1,1}$ (gpm)	Trash* (lbs)
San Francisquito	Palo Alto	1,250	Residential	0.60	360.00	161,579	1,870
Matadero	Palo Alto	1,200	Residential	0.60	345.60	155,116	1,795
Sunnyvale P.S. # 2	Sunnyvale	700	Residential and commercial	0.60	201.60	90,484	1,047
Fairway Glen	Santa Clara	632	Residential	0.60	182.02	81,694	946
Lick Mill	Santa Clara	598	Residential	0.60	172.22	77,299	895
Sunnyvale P.S. # 1	Sunnyvale	500	Industrial	0.75	180.00	80,789	748
Airport	Palo Alto	400	Commercial	0.80	153.60	68,940	598
West Side Retention basin	Santa Clara	366	Industrial	0.75	131.76	59,138	548
Adobe	Palo Alto	350	Residential	0.60	100.80	45,242	524
Rambo	Santa Clara	347	Residential	0.60	99.94	44,854	519
Laurelwood	Santa Clara	335	Industrial	0.75	120.60	54,129	501
East Side Retention Basin	Santa Clara	284	Industrial/ Residential	0.75	102.24	45,888	425
Freedom Circle	Santa Clara	200	Industrial	0.75	72.00	32,316	299
Lakeside	Santa Clara	170	Industrial	0.75	61.20	27,468	254
Nelo/Victor	Santa Clara	154	Industrial	0.75	55.44	24,883	230
Gianera	Santa Clara	99	Residential	0.60	28.51	12,797	148
Santa Clara Golf Course	Santa Clara	60	Industrial	0.75	21.60	9,695	90
Colorado	Palo Alto	50	Residential	0.60	14.40	6,463	75
Twin Creeks Sports Cmplx	Sunnyvale	46		0.40	8.83	3,964	69
University	Palo Alto	10	Underpass	0.90	4.32	1,939	15
Lake Santa Clara	Santa Clara	6	Residential	0.60	1.73	776	9
Embarcadero	Palo Alto	5	Underpass	0.90	2.16	969	7
De La Cruz	Santa Clara	5	Industrial	0.75	1.80	808	7
Homer	Palo Alto	1	Underpass	0.90	0.43	194	1
Bowers Ave.	Santa Clara	1	Industrial/ Residential	0.75	0.36	162	1
City Hall (East Wing)	Santa Clara	1	Industrial	0.75	0.36	162	1
City Hall (West Wing)	Santa Clara	1	Industrial	0.75	0.36	162	1
Lafayette	Santa Clara	1	Industrial	0.75	0.36	162	1
Lafayette Subway	Santa Clara	1	Industrial	0.75	0.36	162	1
Police Pistol range	Santa Clara	1	Industrial	0.75	0.36	162	1
Lockheed Pump Station	Sunnyvale			#N/A	#N/A	#N/A	0
Shulman	Santa Clara	0	Industrial	0.75	0.00	0	0
Tasman Outfall Storm St.	Santa Clara	0	Residential	0.60	0.00	0	0

*Trash loading based on loading rate of 0.2 ft^3/acre/year and a density of 1 lb/gal.

Appendix 2: Table 10 (Part I) – Stormwater Pump Station Inventory – Organized by Jurisdiction

P.S. Name	City	Catchment Area (acres)	Dominant Land Use(s)	Receiving Water for Discharge	Wet Well Storage Capacity (units vary)	Trash Control (Y/N)?	Type of Trash Control	# Main Pumps	# Low-flow pumps	Type of Pumps	MaxPump Capacity of Station (gpm)	Flow Measurable (Y/N)?	Method of flow measurement:	Wet Weather Discharge (gpm)	Gravity Bypass (Y/N)?
Abbott Avenue	Milpitas	53.0	Park/Industrial	Lower Penetencia Ck	27 ac-ft			2	0	Axial flow	10,776				N
Bellew	Milpitas	270.0	Industrial	Coyote Ck				3	1	Axial flow	168,375				N
Berryessa	Milpitas	550.0	Commercial/Residential	Berryessa Ck	52 ac-ft			3	1	Axial flow	67,350				N
California Circle	Milpitas	410.0	Residential/Freeway	Lower Penetencia Ck	2.5 acre (10.8 ft deep)	Y	retention pond/trash rack	3	0	Axial flow	52,533				N
Jurgens	Milpitas	430.0	Mixed residential	Lower Penetencia Ck	1 ac-ft	Y	detention pond	4	1	Axial flow	67,350				N
Manor	Milpitas	150.0	Commercial/Residential	Penetencia Ck				2	1	Axial flow/submersible centrifugal	26,940				Y
McCarthy Ranch	Milpitas	185.0	Mixed use	Coyote Ck	N.R.			3	1	Axial flow	179,600				N
Minnis Circle	Milpitas	30.0	Commercial/Residential	Calera Ck				2	0	Rail-mounted Submersible electric	13,470				N
Murphy	Milpitas	130.0	Industrial	Coyote Ck				3	1	Axial flow	89,800				N
Oak Creek	Milpitas	280.0	Industrial	Coyote Ck				3	1	Axial flow	143,680				N
Penitencia	Milpitas	215.0	Residential	Penetencia Ck	3.6 acre			3	1	Axial flow	29,185				Y
Spence Creek	Milpitas	60.0	Commercial/Residential	Penetencia Ck				2	1	Submersible axial/submersible centrifugal	40,410				Y
Wrigley-Ford	Milpitas	550.0	Industrial	Berryessa Ck				3	1	Axial flow/submersible	193,968				Y
Amphitheatre	Mountain View			Permanente Ck N of Amphth. Pkwy. (tidal)		Y	trash rack				74,000			66,000	
Charleston	Mountain View			Stevens Ck N of Hwy 101(tidal)		Y	Intake trash rack				5,727				
Crittenden	Mountain View			Stevens Ck D/S from Charleston P.S. (tidal)		N	(wet well, sump)	3			71,808			67,320	
High Level Ditch	Mountain View			Perm. Ck D/S from Amphth. P.S. (tidal)		Y	trash rack				4,200				
Coast-Casey	Mountain View			Palo Alto Baylands Slough	30 ac-ft	Y	trash rack				66,000			66,000	
Santa Clara Cnty Oregon/Alma	Palo Alto			City Treatment - Sewer							2,494				
Santa Clara Cnty Oregon/Alma	Palo Alto			Matadero Ck							3,200				
Adobe	Palo Alto	350	Residential	Adobe Ck	?	Y	Trash rack	3			67,320	Y	Pump run times (hours)	varies	
Airport	Palo Alto	400	Commercial	San Francisco Bay	?	Y	Trash rack	3			40,392	Y	Pump run times (hours)	varies	
Colorado	Palo Alto	50	Residential	Matadero Ck	?	N		1			11,220	Y	Pump run times (hours)	varies	
Embarcadero	Palo Alto	5	Underpass	San Francisquito Ck	?	Y	Weir	2			1,795	Y	Pump run times (hours)	varies	
Homer	Palo Alto	1	Underpass	San Francisquito Ck	?	N		2			673	Y	Pump run times (hours)	varies	

P.S. Name	City	Catchment Area (acres)	Dominant Land Use(s)	Receiving Water for Discharge	Wet Well Storage Capacity (units vary)	Trash Control (Y/N)?	Type of Trash Control	# Main Pumps	# Low-flow pumps	Type of Pumps	MaxPump Capacity of Station (gpm)	Flow Measurable (Y/N)?	Method of flow measurement:	Wet Weather Discharge (gpm)	Gravity Bypass (Y/N)?
Matadero	Palo Alto	1200	Residential	Matadero Ck	?	Y	Trash rack	5			107,712	Y	Pump run times (hours)	varies	
San Francisquito	Palo Alto	1250	Residential	San Francisquito Ck	?	Y	Trash rack	3			134,640	Y	Pump run times (hours)	varies	
University	Palo Alto	10	Underpass	San Francisquito Ck	?	Y	Weir	2			2,693	Y	Pump run times (hours)	varies	
Santa Clara Cnty Celco	San Jose			Stormdrain							3,080				
Santa Clara Cnty Chula Vista Ct.	San Jose			Stormdrain							2,345				
87/Taylor	San Jose			Lower Guadalupe R.							3,200				
Alma	San Jose			Upper Guadalupe R.							3,200				
Almaden	San Jose			Stormdrain							2,000				
Bascom	San Jose			Stormdrain							2,800				
Bird	San Jose			Stormdrain							6,500				
Capitol	San Jose			Upper Guadalupe R.							2,000				
Chynoweth	San Jose			Stormdrain							15,280				
Delmas	San Jose			Stormdrain							800				
Forest	San Jose			Stormdrain							1,400				
Gateway	San Jose			Lower Guadalupe R.							3,142				
Gold	San Jose			San Francisco Bay							20,196				
Golden Wheel	San Jose			Coyote Ck							42,000				
Hedding	San Jose			Stormdrain							**10,000**				
Hester	San Jose			Stormdrain							100				
Hope Street	San Jose			Alviso Marsh							135				
Julian	San Jose			Stormdrain							**900**				
Liberty	San Jose			Lower Guadalupe R.							90				
Oakmead	San Jose	1485.0		Lower Guadalupe R.							329,868				
Park	San Jose			Los Gatos							1,740				
Rincon	San Jose	512.0		Lower Guadalupe R.				2	1		161,568				
Rincon 2	San Jose	838.0		Lower Guadalupe R.				4	1		269,280				
River Oaks	San Jose			Lower Guadalupe R.							30,070				
Skyport	San Jose			Lower Guadalupe R.							2,600				
Taylor	San Jose			Stormdrain							2,000				
Willow	San Jose			Upper Guadalupe R.							1,800				

P.S. Name	City	Catchment Area (acres)	Dominant Land Use(s)	Receiving Water for Discharge	Wet Well Storage Capacity (units vary)	Trash Control (Y/N)?	Type of Trash Control	# Main Pumps	# Low-flow pumps	Type of Pumps	MaxPump Capacity of Station (gpm)	Flow Measurable (Y/N)?	Method of flow measurement:	Wet Weather Discharge (gpm)	Gravity Bypass (Y/N)?
Bowers Ave.	Santa Clara	1 (Note #1)	Industrial/ Residential	San Tomas Aquino Ck.	Note #4	N	Trash Racks	2			2,750	Note #2		Note #3	
City Hall (East Wing)	Santa Clara	1 (Note #1)	Industrial	Guadalupe R.	Note #4	N		2			dewatering	Note #2		Note #3	
City Hall (West Wing)	Santa Clara	1 (Note #1)	Industrial	Guadalupe R.	Note #4	N		2			dewatering	Note #2		Note #3	
De La Cruz	Santa Clara	5 (Note #1)	Industrial	Guadalupe R.	Note #4	N		2			not known	Note #2		Note #3	
East Side Retention Basin	Santa Clara	284 (Note #1)	Industrial/ Residential	Guadalupe R.	Note #4 - 6.5 ac-ft in retention basin.	Y	Trash Rack; retention basin	3			50,000	Note #2		Note #3	
Fairway Glen	Santa Clara	632 (Note #1)	Residential	Guadalupe R.	Note #4	Y	Trash Rack	5			111,500	Note #2		Note #3	
Freedom Circle	Santa Clara	200 (Note #1)	Industrial	San Tomas Aquino Ck.	Note #4	Y	Trash Rack	4			35,200	Note #2		Note #3	
Gianera	Santa Clara	99 (Note #1)	Residential	San Tomas Aquino Ck.	Note #4	Y	Trash Rack	5			17,500	Note #2		Note #3	
Lafayette	Santa Clara	1 (Note #1)	Industrial	Guadalupe R.	Note #4	N		2			2,300	Note #2		Note #3	
Lafayette Subway	Santa Clara	1 (Note #1)	Industrial	Guadalupe R.	Note #4	N		2			200	Note #2		Note #3	
Lake Santa Clara	Santa Clara	6 (Note #1)	Residential	San Tomas Aquino Ck.	Note #4	N		2			not known	Note #2		Note #3	
Lakeside	Santa Clara	170 (Note #1)	Industrial	Calabazas Cr.	Note #4	Y	Trash Rack	4			30,000	Note #2		Note #3	
Laurelwood /Victor	Santa Clara	335 (Note #1)	Industrial	Guadalupe R.	Note #4	Y	Trash Rack	4			59,150	Note #2		Note #3	Y - dry season
Lick Mill	Santa Clara	598 (Note #1)	Residential	Guadalupe R.	Note #4	N		4			**105,500**	Note #2		Note #3	
Nelo/Victor	Santa Clara	154 (Note #1)	Industrial	Guadalupe R.	Note #4	Y	Trash Rack	4			78,150	Note #2		Note #3	Y - dry season
Police Pistol range	Santa Clara	1 (Note #1)	Industrial	San Tomas Aquino Ck.	Note #4	Y	Trash Rack	1			not known	Note #2		Note #3	
Rambo	Santa Clara	347 (Note #1)	Residential	San Tomas Aquino Ck.	Note #4	Y	Trash Rack	4			61,200	Note #2		Note #3	Y - dry season
Santa Clara Cnty Central/De La Cruz	Santa Clara			Stormdrain							1,700				

P.S. Name	City	Catchment Area (acres)	Dominant Land Use(s)	Receiving Water for Discharge	Wet Well Storage Capacity (units vary)	Trash Control (Y/N)?	Type of Trash Control	# Main Pumps	# Low-flow pumps	Type of Pumps	MaxPump Capacity of Station (gpm)	Flow Measurable (Y/N)?	Method of flow measurement:	Wet Weather Discharge (gpm)	Gravity Bypass (Y/N)?
Santa Clara Golf Course	Santa Clara	60 (Note #1)	Industrial	San Tomas Aquino Ck.	Note #4	Y	Trash Rack	3			11,100	Note #2		Note #3	
Shulman	*Santa Clara*	*0 (Note #1)*	*Industrial*	*Guadalupe R.*	*Note #4*	*N*		*1*			*600*	*Note #2*		*Note #3*	
Tasman Outfall Storm St.	Santa Clara	0 (Note #1)	Residential	Guadalupe R.	Note #4	N/A		1			not known	Note #2		Note #3	
West Side Retention basin	Santa Clara	366 (Note #1)	Industrial	San Tomas Aquino Ck.	Note #4	Y	Trash Rack; Retention Basin	5			64,500	Note #2		Note #3	Y - dry season
Lockheed Pump Station	Sunnyvale	*500.0*		Sunnyvale West Channel			Lagoon/channel				*130,000*				
Santa Clara Cnty Central/Fair Oaks	Sunnyvale			Stormdrain							9,000				
Santa Clara Cnty Central/Lawrence	Sunnyvale			Stormdrain							<1700				
Twin Creeks Sports Complex	Sunnyvale	46.0		Sunnyvale East Channel											
Sunnyvale Pump Station # 1	Sunnyvale	500.0	Moffett Industrial Park/Tech firms and commercial businesses	West Channel to Guadalupe Slough (tidal)	Not available	Y	Trash rack @ forebay	3			59,250	N	Not available	Variable	
Sunnyvale Pump Station # 2	Sunnyvale	700.0	Residential and commercial	Calabazas Ck (tidal)	Not available	Y	Gabions and trash rack.	6			87,700	N	Not available	Variable	

Notes:

1 Catchment area provided is for general perspective only (not to be relied upon).

2 Pump start and stop time is known for larger pump stations. GPM is not measurable, but could be approximated by calculation. Variable speed pumps require additional approximation. No flow information is available for smaller pump stations.

3 Wet weather discharge rate similar to dry weather rate, difficult to quantify. Inflow determines number of pumps operating. Lag/lead pumps may be of different size or type (variable speed).

4 Wet well storage capacity depends on depth of water in wet well. Need further detail. Is calculation to be from high alarm, low water cutoff, etc.?

5 Trash control measures limited to trash racks, with the addition of retention basins at Eastside and Westside.

6 Pump station operation (e.g. number & timing of pump starts, wet well level, pump run times, etc.) tracked and recorded

7 Geocoded from street address/description

APPENDIX 2: Table 10 (Part II) - Stormwater Pump Station Inventory – Organized by Jurisdiction (continued)

P.S. Name	City	Dry Weather Discharges (Y/N)?	Dry Weather Discharge (gpm)	Date P.S. Built	Date P.S. Last Updated	Additional notes on management regime	Operating Agency	P.S. Address / Location	Lat	Long	Origin of Coordinates	Notes
Abbott Avenue	Milpitas	N					City of Milpitas	1225 N Abbott (@ San Andreas)	37.44426	-121.91497	Note #7	Lagoon; 30 hp vertical electric
Bellew	Milpitas	N					City of Milpitas	481 Murphy Ranch Road (@ Technology Drive)	37.41890	-121.92742	Note #7	600 hp, 40 hp electric jockey
Berryessa	Milpitas	N					City of Milpitas	Folsom Circle @ Hidden Lake Park	37.44005	-121.90385	Note #7	Hidden Lake provides detention; 150 hp diesel engines, 7.5 hp electric jockey
California Circle	Milpitas	N					City of Milpitas	California Circle @ Dixon Landing Road	37.45450	-121.92120	Note #7	U/S retention pond (lagoon); 175 hp diesel engines
Jurgens	Milpitas	N					City of Milpitas	Jurgens @ Larkwood Court	37.45120	-121.91630	Note #7	25 hp electric jockey; 150 hp diesel
Manor	Milpitas	N					City of Milpitas	Marylinn Drive @ Barker Street	37.43430	-121.91370	Note #7	85 hp; 5 hp jockey
McCarthy Ranch	Milpitas	N		1995?			City of Milpitas	1005 N. McCarthy Blvd (~3/4 mi S Dixon Landing Road)	37.41334	-121.92177	Note #7	750 hp diesel , 30 hp electric jockey
Minnis Circle	Milpitas	N					City of Milpitas	1125 N Milpitas Blvd @ Hanson Court	37.44626	-121.90893	Note #7	
Murphy	Milpitas	N					City of Milpitas	801 Murphy Ranch Road (@ Sumac Drive)	37.41591	-121.92480	Note #7	250 hp, 25 hp electric jockey
Oak Creek	Milpitas	N					City of Milpitas	1521 McCarthy Blvd (@ Sycamore Drive)	37.40756	-121.92024	Note #7	600 hp, 25 hp electric jockey
Penitencia	Milpitas	Y					City of Milpitas	La Honda Drive @ Hall Memorial Park	37.44320	-121.91285	Note #7	Lagoon; 60 hp, 7.5 hp electric jockey
Spence Creek	Milpitas	N					City of Milpitas	11 Butler Street @ Spence Avenue	37.42927	-121.91067	Note #7	215 hp, 3 hp jockey
Wrigley-Ford	Milpitas	Y		1991			City of Milpitas	Levee across from Marylinn Drive	37.42636	-121.90562	Note #7	Forebay and channel storage; 150 hp electric motors, 5 hp electric jockey
Amphitheatre	Mountain View	Y	8,000	1987		minimal dry		North side of Amphitheatre Parkway on the east bank of Permanente Creek	37.38535	-122.08145	Note #7	3-204-hp pumps, 1-25-hp pump
Charleston	Mountain View	Y	3,727	1980	1988			East end of Charleston retention pond – end of Charleston Avenue cross street Shoreline Blvd.	37.38535	-122.08145	Note #7	2-150 hp pumps, 1-50-hp pump
Crittenden	Mountain View	N	4,489	1999	1999			East edge of Shoreline Amphitheatre Parking Lot E	37.38535	-122.08145	Note #7	66" SD intake, 3-200 hp pumps (room for 1 more), 1 smaller pump
High Level Ditch	Mountain View	Y			1994	minimal dry		North side of Shoreline Amphitheatre/Vista Slope on the east bank of Permanente Creek	37.38535	-122.08145	Note #7	
Coast-Casey	Mountain View	Y		1980	1995			End of San Antonio Rd. at Terminal Avenue	37.38535	-122.08145	Note #7	Receives from a retention basin. Approx. size given. 125-hp pump
Santa Clara Cnty Oregon/Alma	Palo Alto	Y					County of Santa Clara	Oregon Expwy and Alma St.	37.42900	-122.14090	Note #7	
Santa Clara Cnty Oregon/Alma	Palo Alto	Y					County of Santa Clara	Oregon Expwy and Alma St.	37.42900	-122.14090	Note #7	
Adobe	Palo Alto	Y	varies	1968	1996	Note #6.	City of Palo Alto	East Meadow Drive near Fabian Way	37.42910	-122.10540	City of Palo Alto	
Airport	Palo Alto	Y	varies	1996	1996	Note #6.	City of Palo Alto	Embarcadero Rd. at Palo Alto Airport	37.45630	-122.11320	City of Palo Alto	
Colorado	Palo Alto	Y	varies	1960	1996	Note #6.	City of Palo Alto	West Bayshore Rd. at Colorado Ave.	37.44070	-122.11510	City of Palo Alto	
Embarcadero	Palo Alto	N	N/A	1936	1996	Note #6.	City of Palo Alto	Embarcadero Rd. at Alma St./CalTrain Tracks -Underpass	37.43840	-122.15590	City of Palo Alto	
Homer	Palo Alto	N	N/A	2005	2005	Note #6.	City of Palo Alto	Homer Ave. bicycle/pedestrian tunnel at CalTrain Tracks-Underpass	37.44070	-122.16060	City of Palo Alto	

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Matadero	Palo Alto	Y	varies	1968	1996	Note #6.	City of Palo Alto	Colorado Ave. near West Bayshore Rd.	37.43900	-122.11570	City of Palo Alto	
San Francisquito	Palo Alto	Y	varies	2008	2008	Note #6.	City of Palo Alto	East Bayshore Rd. at San Francisquito Ck	37.45280	-122.12650	City of Palo Alto	
University	Palo Alto	N	N/A	1940	1996	Note #6.	City of Palo Alto	University Ave. at Alma Street/CalTrain tracks - Underpass	37.44320	-122.16460	City of Palo Alto	
Santa Clara Cnty Celco	San Jose	Y					County of Santa Clara	Celeco Lane	37.34038	-121.89218	Note #7	
Santa Clara Cnty Chula Vista Ct.	San Jose	Y					County of Santa Clara	Chula Vista Ct.	37.39322	-121.82502	Note #7	
87/Taylor	San Jose	Y						West side of Highway 87 under SE quadrant of Taylor	37.34038	-121.89218	Note #7	
Alma	San Jose	Y						Alma @ SPRR	37.31300	-121.87880	Note #7	
Almaden	San Jose	Y						Almaden Road @ SPRR	37.31120	-121.87850	Note #7	
Bascom	San Jose	Y						Bascom Avenue Under Xing at Highway 880	37.34038	-121.89218	Note #7	
Bird	San Jose	Y						Bird Undrcrossing of RXR between Virginia and Fuller	37.34038	-121.89218	Note #7	
Capitol	San Jose	Y						Capitol Expressway @ Old Almaden Road	37.27570	-121.87710	Note #7	
Chynoweth	San Jose	Y						890 Chynoweth Ave, Undercrossing at 87 e/o Pearl Ave	37.34038	-121.89218	Note #7	
Delmas	San Jose	Y						RxR Undercrossing between Jerome and Fuller	37.34038	-121.89218	Note #7	
Forest	San Jose	Y						Forest Avenue Under Xing at Highway 880	37.34038	-121.89218	Note #7	
Gateway	San Jose	Y						Guadalupe Freeway 1050' n/o Airport Parkway	37.34038	-121.89218	Note #7	
Gold	San Jose	Y						N/E corner of Gold Street @ Elizabeth Street	37.34038	-121.89218	Note #7	
Golden Wheel	San Jose	Y						East P/L of Golden Wheel Mobile Home Park, 1450 Oakland Rd	37.34038	-121.89218	Note #7	
Hedding	San Jose	Y						Hedding Street Under Xing at Highway 880	37.34038	-121.89218	Note #7	
Hester	San Jose	N						Ped Xing on The Alameda @ Hester Avenue	37.34038	-121.89218	Note #7	
Hope Street	San Jose	N						E/S Hope Street 100' n/o Elizabeth	37.34038	-121.89218	Note #7	
Julian	San Jose	Y						Julian @ SPRR east of Stockton Ave	37.34800	-121.87815	Note #7	
Liberty	San Jose	Y						South End of Liberty Street	37.34038	-121.89218	Note #7	
Oakmead	San Jose	Y					City of San Jose	Lisa Lane off of Renaissance Drive	37.34038	-121.89218	Note #7	Diesel engines
Park	San Jose	Y						Park Avenue @ Los Gatos Creek	37.32630	-121.90400	Note #7	
Rincon	San Jose	Y					City of San Jose	N/S Montague Expressway w/o N. 1st Street	37.34038	-121.89218	Note #7	
Rincon 2	San Jose	Y					City of San Jose	N/S Trimble Road w/o N. 1st Street	37.34038	-121.89218	Note #7	
River Oaks	San Jose	Y						900' w/o west end of River Oaks Place	37.34038	-121.89218	Note #7	
Skyport	San Jose	Y						Skyport Ave under Highway 87	37.34038	-121.89218	Note #7	
Taylor	San Jose	Y						RxR Undercrossing between Coleman and Stockton	37.34038	-121.89218	Note #7	
Willow	San Jose	Y						Willow @ SPRR	37.31645	-121.88645	Note #7	

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Bowers Ave.	Santa Clara	Y	Note #3	1974	N/A			2800 Mead (between Chromite & Kifer) Underpass	37.37156	-121.98223	Note #7	
City Hall (East Wing)	Santa Clara	Y	Note #3	1964	N/A			1500 Warburton Ave.	37.35500	-121.95183	Note #7	
City Hall (West Wing)	Santa Clara	Y	Note #3	1964	N/A			1500 Warburton Ave.	37.35500	-121.95183	Note #7	
De La Cruz	Santa Clara	Y	Note #3	1975	N/A			1701 De La Cruz Blvd. (South of Reed St.) - Underpass	37.35500	-121.95183	Note #7	
East Side Retention Basin	Santa Clara	Y	Note #3	1973	2005			5611 Lafayette (South of 237)	37.35954	-121.94778	Note #7	(Catchment area seems low by a factor of 2)
Fairway Glen	Santa Clara	Y	Note #3	1989	N/A			4751 Lick Mill Blvd.	37.39806	-121.94476	Note #7	(Catchment Area seems Factor of 2 high?)
Freedom Circle	Santa Clara	Y	Note #3	2001	N/A			3905 Freedome Circle at Mission College Blvd.	37.39070	-121.97240	Note #7	
Gianera	Santa Clara	Y	Note #3	1978	1996			2337 Gianera St.	37.39981	-121.96790	Note #7	
Lafayette	Santa Clara	Y	Note #3	1976	N/A			3301 Bassett St (North of Laurelwood Rd.)	37.38200	-121.95024	Note #7	
Lafayette Subway	Santa Clara	Y	Note #3	1963	1995			1890 Lfayette St. (south of Reed St.)	37.35803	-121.94744	Note #7	
Lake Santa Clara	Santa Clara	Y	Note #3	1986	N/A			4266 Lake Santa Clara	37.39181	-121.96759	Note #7	
Lakeside	Santa Clara	Y	Note #3	1998	N/A			3298 Lakeside Dr.	37.38812	-121.98727	Note #7	
Laurelwood /Victor	Santa Clara	N	Note #3	1986	N/A			3401 Victor St.	37.38628	-121.93844	Note #7	
Lick Mill	Santa Clara	Y	Note #3	1988	N/A			449 Montague Expwy at Guadalupe River	37.35500	-121.95183	Note #7	
Nelo/Victor	Santa Clara	N	Note #3	1986	2005			3575 Victor St.	37.38852	-121.93994	Note #7	
Police Pistol range	Santa Clara	Y	Note #3	1979	N/A			1990 Walsh Ave.	37.35500	-121.95183	Note #7	
Rambo	Santa Clara	N	Note #3	1986	2002			4526 lakeshre at Rambo	37.39640	-121.96750	Note #7	
Santa Clara Cnty Central/De La Cruz	Santa Clara	Y					County of Santa Clara	Central Expwy and De La Cruz	37.37330	-121.94350	Note #7	

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Santa Clara Golf Course	Santa Clara	Y	Note #3	1987	N/A			2501 Stars & Stripes	37.35500	-121.95183	Note #7	
Shulman	*Santa Clara*	*Y*	*Note #3*	*1979*	*N/A*			*5099 Lick Mill Blvd. at Shulman*	*37.40834*	*-121.96127*	*Note #7*	*Pump station no longer operational. Does not discharge to creek.*
Tasman Outfall Storm St.	Santa Clara	Y	Note #3	1990	N/A	Does not discharge to Guad. R.		5099 Lick Mill Blvd. at Tasman	37.40834	-121.96127	Note #7	
West Side Retention basin	Santa Clara	N	Note #3	1975	2001			2900 Old Mt. View Alviso Rd.	37.41037	-121.97787	Note #7	
Lockheed Pump Station	Sunnyvale							West end of Carl Road (drainage area over 500 ac), recently underwent remediation by Navy/other agencies to remove accumulated contaminated sediments	37.36902	-122.03502	Note #7	Channel storage
Santa Clara Cnty Central/Fair Oaks	Sunnyvale	Y					County of Santa Clara	Central Expwy and Fair Oaks	37.38055	-122.01875	Note #7	
Santa Clara Cnty Central/Lawrence	Sunnyvale	Y					County of Santa Clara	Central Expwy and Lawrence Expwy	37.37770	-121.99600	Note #7	
Twin Creeks Sports Complex	Sunnyvale							969 Caribbean Drive	37.41278	-122.00074	Note #7	
Sunnyvale Pump Station # 1	Sunnyvale	Y	Wet basin - electric pumps operate year round due to shallow groundwater in this part of the City.	1961	2007	Cleaned regularly per URMP SOPs.	City of Sunnyvale	Between WPCP at Borregas and Smart Station at Carl Rd.	37.41889	-122.01257	City of Sunnyvale	7,750 gpm; 21,500 gpm; 30,000 gpm. 2007-Emergency engine replacement. Emergency engines operate during the wet season.
Sunnyvale Pump Station # 2	Sunnyvale	N		1967	1990	Gabions catch trash before trash rack. Regularly cleaned per URMP - SOPs.	City of Sunnyvale	Baylands Park	37.41287	-121.99401	City of Sunnyvale	1-2,700 gpm; 5-17,000 gpm. Dry basin. Prior to electical pump turning on, entire basin must be covered w/2' water. Operates as a wet basin in wet season, when water level drops to 1', pumps are inactivated.

Notes:

1. Catchment area provided is for general perspective only (not to be relied upon).
2. Pump start and stop time is known for larger pump stations. GPM is not measurable, but could be approximated by calculation. Variable speed pumps require additional approximation. No flow information is available for smaller pump stations.
3. Wet weather discharge rate similar to dry weather rate, difficult to quantify. Inflow determines number of pumps operating. Lag/lead pumps may be of different size or type (variable speed).
4. Wet well storage capacity depends on depth of water in wet well. Need further detail. Is calculation to be from high alarm, low water cutoff, etc.?
5. Trash control measures limited to trash racks, with the addition of retention basins at Eastside and Westside.
6. Pump station operation (e.g. number & timing of pump starts, wet well level, pump run times, etc.) tracked and recorded
7. Geocoded from street address/description