City and County of San Francisco
2030 Sewer System Master Plan

TASK 500
TECHNICAL MEMORANDUM NO. 503
REVIEW AND ASSESSMENT OF DRAINAGE CONTROL POLICIES, PROCEDURES, AND GUIDELINES

FINAL DRAFT
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CITY AND COUNTY OF SAN FRANCISCO
SEWER SYSTEM MASTER PLAN

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LIST OF TABLES

LIST OF FIGURES

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1.0 INTRODUCTION

The City and County of San Francisco collects sewage and stormwater in the same network of pipes. The collection system is referred to as a combined sewerage system and is part of the City's clean water utility. The San Francisco Public Utilities Commission (SFPUC), through its Wastewater Enterprise (WWE), is solely responsible for the management, operation, and maintenance of the clean water utility, including all clean water/sewer-related assets owned or maintained by the City and County of San Francisco. The City's combined sewerage system is characterized by "fail-safe" and self-cleansing principles. Fail-safe is a term which implies the system is designed and managed to minimize the risk to health and safety should any portion of the system fail. This is consistent with the mission of the SFPUC WWE which is *to protect public health, public safety, and the environment by providing safe, reliable, and cost-effective and efficient collection, treatment, and disposal of wastewater and stormwater and control of combined sewer discharges*. SFPUC activities, operations, and functions are all geared to accomplish this mission. In meeting this mission, SFPUC strives to provide maximum value relative to a "triple bottom line" of social, economic, and environmental standards.

This SFPUC is currently completing a comprehensive sewer system master plan. A master planning process is used by the City to identify, evaluate, and prioritize improvements to the combined sewer system that will allow the SFPUC to fulfill its mission. The process, which encompasses planning, engineering, and public participation, guides the development and implementation of a wastewater capital improvement program. The 2006 Master Plan is the fourth such long-range wastewater plan prepared by the City (previous ones were completed in 1899, 1935, and 1974).

A component of the 2006 Master Plan is the Detailed Drainage Modeling Plan (DDMP), which includes the development of computer models to support the analysis, evaluation, and design of improvement alternatives. The scope of the DDMP is to identify typical San Francisco drainage issues that, under certain conditions, may cause various types of drainage problems, to analyze alternatives, and to suggest improvements. The study is concentrated on seven focus areas within four of the city's eight major drainage basins (Richmond, Channel, Islais Creek, Lake Merced). The focus areas are described thoroughly in DDMP TM 5 *Existing Conditions and Needs Assessment*. The DDMP is being conducted and delivered under the premise that flooding can cause risk to public safety as well as public health and that reasonable management and reduction of flooding occurrences will contribute to meeting the SFPUC mission. Furthermore, it is to the economic benefit of the

City of San Francisco to protect private property that generates economic vitality and tax revenues.

Task 4 of the DDMP project involves assessing the City's current policies and procedures related to surface drainage and the combined sewer system, and evaluating them relative to the overall objectives of the DDMP. This can include formal and informal policies and procedures and may include guidelines that are not enforceable through regulatory process. This Technical Memorandum (TM) No. 4 comprises the product of Task 4.

2.0 PURPOSE

The purpose of the DDMP is to develop alternatives that will mitigate and improve known or estimated surface and combined sewage flow conditions in each of the seven focus areas. With the exception of the transport/storage facilities built for compliance with the clean water acts of the 1970s, the majority of main sewers in the City were designed based on information from only a few sources as to storm volumes and intensities. Over the years the amount of pervious area, especially in the residential areas, has been substantially reduced within the city, resulting in larger volumes of runoff that move faster over the surface. The DDMP is examining seven focus areas of the city to understand the impacts of changes in surface conditions. The ability to accomplish this effort is based on the recent history of dramatically expanded computerization capabilities in conjunction with expanded rainfall gauging and flow monitoring data. The DDMP also incorporates the ability to examine hydraulic aptitude of the main sewers and methods to improve performance.

The DDMP looks to the future to meet the mission statement and permit requirements with recommendations. It also looks to the existing conditions and the past to better understand how best to position the collection system for the future.

The purpose of this assessment of drainage control policies, procedures, and guidelines is to gain a thorough understanding of how well current and past practices have served the City, and to recommend, where appropriate, changes in design criteria and storm flow management practices. Recommendations are based on technological advances on the simulation of storm events and dry weather (sewage and infiltration) flows using computer models, and on rainfall and flow monitoring. Recommendations are also based on a current understanding of how the regulatory environment is likely to evolve, possible changes brought about by climate change, and the application of best management practices (BMPs).

Alternatives that will mitigate and improve known or estimated surface and combined sewage flow conditions in each of the seven focus areas may also address expected changes that may affect flow conditions in the future. Alternatives will need to be considered in the context of the various policies, procedures, and guidelines that relate to drainage and flooding. These generally pertain to one of the following two categories:

1. Sewer design philosophy (improvement, upgrade, realignment, augmentation).
2. Management of surface flow.

Policies, procedures, and guidelines for each of the above categories are discussed in the following sections. Some are relevant across categories. For example, design rainfall is pertinent for both sewer design and surface flow management. Where appropriate, recommendations are provided to modify, expand, or refine polices, procedures, and guidelines in the context of facilitating implementation of potential DDMP alternatives.

3.0 SEWER DESIGN PHILOSOPHY

San Francisco's combined sewer system serves the dual function of continually conveying wastewater to treatment plants and providing drainage of storm runoff to minimize the risk of urban flooding. Sewerage system design is largely driven by the latter function, as stormwater flow comprises a far more significant portion of the total flow conveyed by the pipes.

On the assumption that there is no system we could afford to build that will protect against all storm events, the sewer designs should incorporate fail-safe features to the maximum reasonable extent. All drainage, whether it is on the surface, within the sewers, or within the soil, should be controlled in the safest manner possible. The main sewer design objective should be to control and dissipate energy and move flow along rapidly to prepare for the next storm surge. The tributary sewers design objective should be to slow storm flow down as safely as possible. Standards should be generally reflective of these objectives. Examples of tools to help meet objectives are controlled turbulence for main sewers to absorb energy at higher elevations, reducing runoff coefficient for tributary sewers and increasing the friction factor for low-elevation major sewers.

3.1 Historic Overview

3.1.1 1899 Grunsky Report[1]

The Grunsky Report was the first systematic look at the entire city with drainage recommendations essentially collecting untreated dry-weather sanitary flow and discharging into the northern waterfront into bay waters with the best local flushing characteristics. Interceptor sewers on each side of the city, the North Point Main in the east and the Mile Rock Sewer in the west, drained south to north, collecting tributary dry-weather flow and allowing higher wet-weather flows to flow over and into the closest receiving water. Essentially, this was the City's first attempt at wet-weather fail-safe design.

The Grunsky Report accepted the "dendritic" nature of the City's drainage into larger trunk sewers, which were formerly stream beds sized to accommodate branch main sewers based on inch-per-hour rainfall and the time of concentration for the flow to reach any particular point. It was noted that in the records of the 19th century, the city never experienced as much as 1 inch per hour of rainfall.

3.1.2 1930 – 1950s Treatment Plants

Treatment plants were the main focus of the 1930–50s. There were to be three primary treatment plants — Richmond-Sunset on the west in Golden Gate Park and southeast in the Bayview and North Point in the North Beach areas on the east. Smaller interceptor sewers and pumping stations were included to direct dry-weather flow to the plants to fit existing conditions and were primarily located near the perimeter of the city. The interceptor system further incorporated fail-safe design in allowing excess to flow directly to the receiving water. Approximately 40 outfalls were incorporated in the system and the 5-year storm became the basis of main sewer design.

3.1.3 1970s Clean Water Acts

In 1969, the California Legislature enacted the Porter-Cologne Water Quality Act to preserve, enhance and restore the quality of the State's water resources. Porter-Cologne established the State Water Resources Control Board and nine Regional Water Quality Control Boards as the principle state agencies with the responsibility for controlling water quality in California. Under this Act, water quality policy is established, water quality standards are enforced for both surface and ground water, and the discharges of pollutants from point and non-point sources are regulated. Porter-Cologne authorizes the State Control Board to establish water quality principles and guidelines for long range resource planning including ground water and surface water management programs and control and use of recycled water.

The Federal Water Pollution Control Act of 1948 was the first major U.S. law to address water pollution. Growing public awareness and concern for controlling water pollution led to sweeping amendments in 1972. As amended in 1977, the law became commonly known as the Clean Water Act (CWA). The 1977 amendments:

- Established the basic structure for regulating pollutants discharges into the waters of the United States.
- Gave the U.S. Environmental Protection Agency (EPA) the authority to implement pollution control programs such as setting wastewater standards for industry.
- Maintained existing requirements to set water quality standards for all contaminants in surface waters.
- Made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions.
- Funded the construction of sewage treatment plants under the construction grants program.

- Recognized the need for planning to address the critical problems posed by nonpoint source pollution.

San Francisco’s response to the state and federal acts was to construct perimeter transport/ storage systems that connected to on-shore or shoreline outfalls and which amounted to expanded interceptors that would store and transport all tributary flow. The transport/ storage systems provide gravitational primary treatment and baffling for all flows greater than the capacity of the treatment facilities.

The new transport/storage systems were an environmental improvement unmatched by any other community in the country at the time, including those communities with separate sewer and storm water systems. The portion of transport/storage system built lower than tide level as a part of the 1970s plan emphasized fail-safe wet-weather and self-cleaning dry-weather characteristics.

Design criteria evolved during this period. The new transport/storage, treatment, and outfall structures were sized on the principle of reasonable minimum total cost of both storage volume and processing rate to keep the number of emergency overflows (discharge of untreated waters) within the range stipulated by the City’s discharge permits. The variables of storage volume and processing rate are still the dominant control variables and were used for the design of the Oceanside Treatment Plant completed in 1993.

The storage/treatment criteria provide a tradeoff between treatment capacity and operating costs. Storage volume is more difficult to come by but does represent an increase in capacity with low maintenance and operation costs. Increased processing capacity at the plants comes with higher maintenance and operation costs.

3.2 Sewer Design Instigators

In general, new sewer design and construction in San Francisco is instigated by one or more of the following:

1. **The need to repair, replace, or otherwise hydraulically improve sewers.** As sewers age, they naturally become more susceptible to deterioration and failure. Today, construction standards in San Francisco typically expect an approximate 100-year lifespan. Many sewers in San Francisco were built to fairly high standards and are lasting beyond their original life expectancy. However, due to normal aging, many sewers reaching or exceeding their life expectancy are in need of repair or replacement. This is evidenced through routine inspection that identifies deterioration and other evidence of potential degraded performance or failure.
2. **The need to accommodate new development or redevelopment of land.** Changing the conditions in either the area contributing to the flow in a sewer or the street/right-of-way in which the sewer is located may instigate a need to upgrade, realign, or augment an existing sewer. Redevelopment (infill) is considered to be the

primary impetus for this type of work, although there are limited cases of new development that trigger a need for new sewers or upgrades (e.g., Mission Bay).

3. **The need to manage, mitigate, or improve flooding and drainage issues related to:**

   a. **Changed land use conditions.** There may be sewer drainage areas that have experienced more intensive development than originally planned. This has resulted in more impervious areas and larger peak runoffs, rendering the sewer hydraulically unable to drain the area adequately during design event storm conditions.

   b. Topographically low areas that are naturally low lying or constructed on bay fill (that has consolidated and may continue to do so) that are experiencing subsidence. Property in these areas may be below both the City's official grade and the hydraulic grade of nearby sewers, making them more susceptible to flooding and drainage problems.

   c. **Changed functions.** Some of San Francisco's sewers were designed and constructed prior to the advent of the city's wastewater treatment facilities. When the new treatment facilities came on-line, sewers previously designed to provide direct offshore disposal of untreated wastewater were reconfigured to route wastewater to treatment facilities. For example, the North Point Main and the Mile Rock Main were originally designed to convey wastewater northward along the bay and ocean sides of the city from as far south as Daly City. The objective was to move wastewater from the entire city to outfalls in the mouth of the San Francisco Bay where tidal action and flushing is most vigorous. Transporting wastewater over this significant distance required sewer grades much flatter than what may normally have been designed. The 1899 Grunsky Report, which presented the basis for the North Point Main, states: "*North Point was found to be about as far west on the northern frontage of the city as an intercepting sewer could be made to discharge successfully by gravity flow*." When wastewater treatment facilities were brought on-line, these sewers were reconfigured and/or intercepted. Consequently, the operating conditions such as velocity and hydraulic grade, under which the sewers operate, were affected, potentially leading to greater surcharging, deposition, and accumulation of biological and chemical constituents on the pipe walls. The reduced capacity and greater deterioration potential may have led to new failures and flooding issues.

   d. **Blockage of historical overland drainage.** Historical flood management in San Francisco consisted of managing drainage from moderate storms through a pipe drainage network. Larger storms that exceeded the capacity of the pipe network were managed by flow conveyance and volume storage within the roadway. In several locations in the city, the drainage functions of the roadways have been compromised in the interest of other public works objectives (e.g., paving, bus/rail public transport, curb/gutter configuration, etc.). This has resulted in more frequent pooling and inundation of properties adjacent to roadways whose drainage capabilities have been compromised. In order to protect the interests of private property owners, and owners of properties that have experienced settling, the City has not actively engaged in raising or reconfiguring roadways to improve overland drainage.

In response to the triggers listed above, the City of San Francisco must design new sewers and implement the designs by others. Two City agencies are involved with collection system repair, replacement, maintenance, and management. The SFPUC owns the sewer system and is solely responsible for its management, operation, and maintenance including all sewer-related assets owned or maintained by the City and County of San Francisco. The San Francisco Department of Public Works (SFDPW) is responsible for the design and maintenance of the roadway as well as the management of the public right-of-way.

The SFDPW Bureau of Engineering (BOE) Hydraulic Section is responsible for the engineering and reconnaissance associated with repairing, replacing, and improving the sewers as a service provided to SFPUC. Sewer design is typically provided by BOE. An exception is when redevelopment projects are controlled and implemented by a developer, other governmental agency, or other City agencies. Typically the SFPUC must approve these redevelopments and will inherit the final developed utilities, including sewers, at a later date. The approval process is subject to political or developmental considerations and does not always guarantee that SFPUC or BOE have complete control of their final design and construction. Furthermore, BOE is not tasked with performing engineering calculations/analysis as part of the review.

Policy, procedure, and guideline components associated with typical sewer design are discussed below.

3.3 Summary of Existing Sewer Design Policies, Procedures, and Guidelines

Because San Francisco's sewers convey both stormwater and sanitary sewage, sewer design must address both types of flow. The City's procedures and guidelines for sewer design are outlined in the *Subdivision Regulations*[2] published by BOE in 1982. The publication governs the design criteria for HGL in the combined sewer system. The criteria from this publication is still widely used internally at SFDPW as well as externally by engineers, developers, and other individuals of the public for determining appropriate sewer sizes within the City and County of San Francisco. Sections 13, 14, and 15 of the Regulations deal specifically with sewer design. The content of these sections is outlined in Table 1.

Table 1 Sewer Design Procedures and Guidelines from *Subdivision Regulations*
2030 Sewer System Master Plan
City and County of San Francisco

Topic	Parameter/Characteristic	Procedure/Guideline
Section 13 – Recommended Standards of Design for Sewer Systems		
General		Remove all sewage and storm water
Sewers	Location	Center of street
	Depth and cover	6 feet or 4 feet with special permit; backflow preventers in all streets below grade
	Sizes	6-inch diameter and up
	Materials	Vitrified clay or reinforced concrete
	Types of joints	Compression type or bell and spigot
	Alignment and curves	Generally straight, some curvature allowed on reinforced concrete pipes, no compound curves allowed
	Encasement, bedding and piling	Based on size, grade, soil conditions
Manholes	Spacing	No more than 350 feet apart
Tapers and Junction Structures		At all changes in size or shape
Culverts		10-inch diameter vitrified clay pipe
Catch Basins and Storm Water Inlets:		At all corners of an intersection
Sewer Connections		6 inches in residential areas, 8 inches in commercial and industrial
Side Sewers		6 inches in residential areas, 8 inches in commercial and industrial
Section 14 – Required Capacity of Storm and Combined Sewers		
Design Basis	Runoff	Computed storm runoff based on ultimate development
	Minimum Size	12 inches
	Minimum Velocity	3 feet per second (fps) when flowing full (storm) 2 fps under average sanitary flows (sewage)
	Invert Lining	Required for 10 fps or greater under average sanitary flows
Hydraulic Considerations	Hydraulic grade line	In general, 4 feet below ground, never less than 2 feet
	Tidal elevation	-3.5 feet (City datum) to be used in hydraulic calculations
	Bend losses	To be considered for velocities of 7 fps or greater
	Runoff	To be computed by Rational Formula
	Rainfall intensity	To be 5-year storm (rainfall intensity-time of concentration curve from 1941 provided)
	Runoff Coefficient	According to table provided
	Time of Concentration	Inlet time plus time of travel in sewer from most distant point
	Roughness Coefficient	In accordance with table provided

Table 1 Sewer Design Procedures and Guidelines from *Subdivision Regulations*
2030 Sewer System Master Plan
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Topic	Parameter/Characteristic	Procedure/Guideline
Section 15 – Sanitary Flow Criteria		
Design Basis	Capacity	Capacity to convey sanitary plus infiltration flows at ¾ full for pipes 18 inches in diameter and larger, ½ full for smaller pipes
	Minimum Size	12 inches
	Velocity	2 fps under average sanitary flow conditions
	Depth	Same as for combined sewers
	Selection of Sewer Sizes	Use roughness value from table provided
	Quantity of Flow	Maximum ultimate sanitary flow or 180 gallons per capita per day

The following section discusses some of the relevant issues associated with sewer design in San Francisco.

3.3.1 Dry Weather Flow

The overarching consideration in sewer design is the flow that a pipe will need to convey under design conditions. The flow generally comprises dry-weather, and wet-weather flow. Dry-weather flow is pertinent to wastewater quality, including sediment and odor management. For the purposes of this discussion, dry-weather flow will be assumed to include residential, commercial, industrial, and institutionally produced flow, as well as seasonal shallow subsurface and groundwater inflow. For combined sewers, the wet-weather flow component is a much larger component of the total design condition flow. Dry-weather flow is therefore not particularly quantitatively pertinent to combined sewer design except in situations where there is a large increase in dry-weather flow in association with development or redevelopment.

An example would be the development of a high-rise residential building on land that was previously a warehouse. Assuming the impervious area on the site does not change with development and no additional stormwater management or retention/detention measures are implemented, there would be little to zero change in wet-weather flow response. The dry-weather contribution would increase significantly. It would be incumbent on the City and/or the developer to evaluate the proportion of the sewer capacity serving the site taken up by increased dry-weather peak flows that is now unavailable for wet-weather drainage.

Section XV of the 1982 SFDPW *Subdivision Regulations* publication (See Table 1) is titled *Sanitary Flow Criteria in the City and County of San Francisco*. A subsection of this section, *Design Basis*, states on page 42 that "*Sanitary or Interceptor sewers shall be designed to carry the ultimate maximum sanitary flow plus infiltration…"* The ultimate flow is then specified to be carried by a pipe running ½ or ¾ full for pipes 12 to 18 inches and 18 inches and greater, respectively. The ultimate flow is calculated based on standard per-capita wastewater generation rates.

The cited regulations were established prior to dynamic hydraulic models being commonly used in sewer design. Current design practice enables the engineer to analyze the peak diurnal patterns in conjunction with peak stormwater flows as well as the routing and synchronizing effects of these peaks.

3.3.2 Design Rainfall

Pipes are designed to convey and/or store a certain peak and/or volume of flow. Peak flow and volume is generated by dry- and wet-weather flow components. The wet-weather flow component is generated by the rainfall-runoff hydrologic process. Engineers and planners must decide the magnitude of storm, and the consequent runoff peak and volume, to form the basis for pipe design. The magnitude of a storm is typically characterized by an intensity-duration-frequency (IDF) storm. Each combination of intensity over a specific duration equates to a frequency, e.g., 3 inches over six hours with an average intensity of 0.5 inches per hour. Storm frequencies are described as the probability of occurring in any given year. For example, the frequency of a storm might be 20%, in which case there is a 20% chance of a storm of given intensity and duration occurring in any given year. Storm frequencies are also commonly referred to by the reciprocal of their probability of occurrence in any given year. For example, a 20% storm may also be referred to as a 5-year storm. The fallacy of referring to a storm (or any other probabilistic event) as a 5-year storm, for example, is the potential interpretation that an event of such magnitude should occur only once every five years when in fact it could just as likely occur once in each of several successive years.

Section XIV of the 1982 SFDPW *Subdivision Regulations* publication (See Table 1), *Required Capacity of Storm and Combined Sewers*, contains a subsection, *Run-off*, which states on page 39: "*Rainfall rate or intensity used in the design shall be taken from the tabulation entitled San Francisco Rainfall Rate Table 1941, Plan L-3903.4 dated February 1941, or subsequent revisions thereof, and is defined as a 5-year storm*.*"* The IDF curve from this table is presented in Figure 1. The 3-hour storm from this IDF curve is commonly used in design calculations as the 5-year design storm. A 3-hour duration was chosen because it is believed that within a 3-hour period, water from the most upstream portions of the city will make its way through the system to either a treatment plant or a combined sewer discharge location (time of concentration). The longest pathway for water falling on a catchment in the city to discharge is estimated to be approximately four miles. Most of the catchments in the city are of high imperviousness. Water travels faster over impervious surfaces than pervious ones.

Compelling reasons to consider design storm durations longer than 3-hours would be in analyzing storage/treatment systems, combined sewer discharge (CSD) frequencies, and if the effects of significant antecedent rainfall on soil moisture content were being considered as part of a hydrologic analysis.

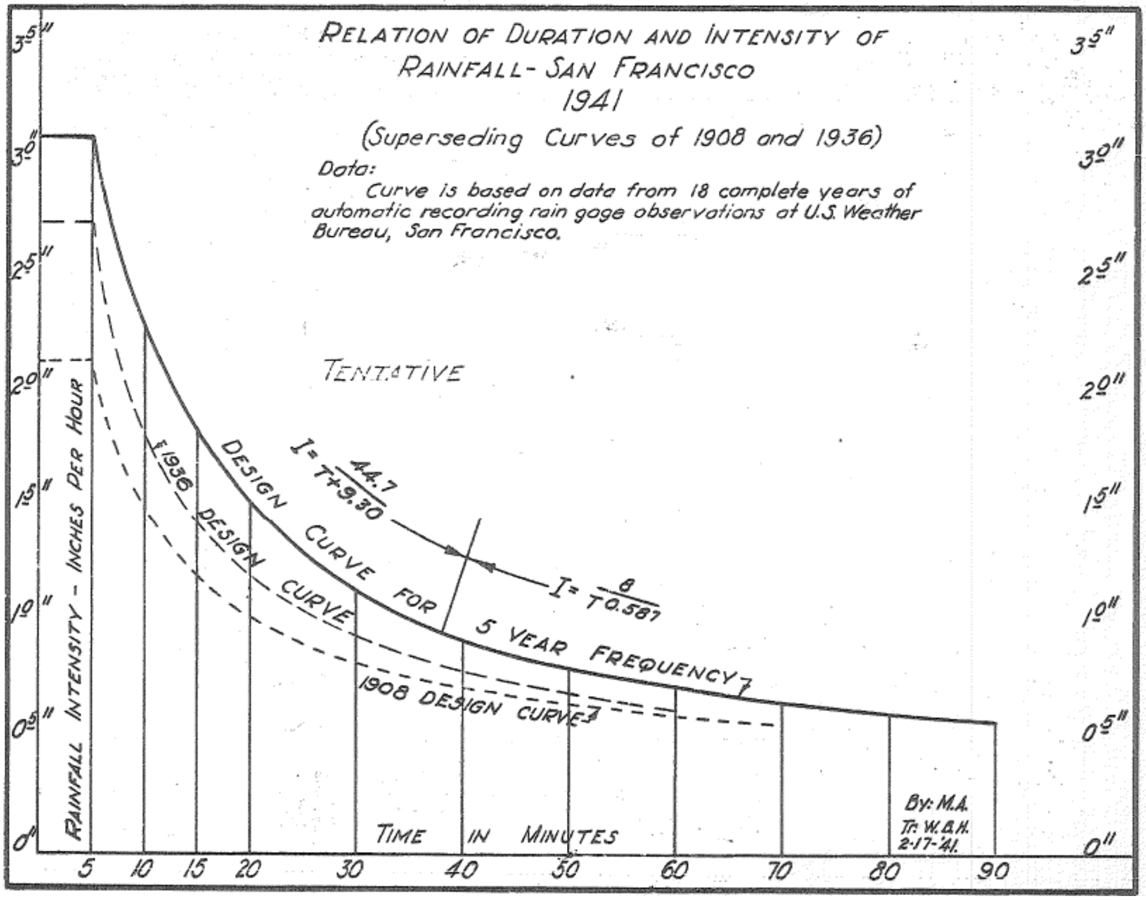

Figure 1 5-Year Intensity-Duration-Frequency Curve Used by City of San Francisco

The City's 1971 Wastewater Master Plan cites the following relative to design storm criteria on Page VII-6 of the *Preliminary Comprehensive Report* dated September 15, 1971: *"The City's design criteria provides a 5-year storm hydraulic grade line about 1 foot below gutter level at any point in the sewerage system."* This statement specifies a 5-year storm as the rainfall design criteria.

In 2007, as part of the City's Sewer System Master Plan, the City and consultants jointly looked at historical rainfall intensities and rainfall periods over the last 30 years. The analysis is thoroughly documented in the Sewer System Master Plan Document PMC2A, *Rainfall Analysis Technical Memorandum*[3]. The Technical Memorandum included a comparison between the rainfall data over the last 30 years and the 1941 curve current used by the City. Results of the comparison are presented in Figure 2. The *Currently Used* plotline on Figure 2 is the curve shown in Figure 1 plotted on $\log_{10}/\log_{10}$ scale with durations beyond 90 minutes extrapolated. For durations less than 30 minutes, the revised storm based on the last 30 years of rainfall shows lower intensities than the City's adopted 5-year storm; however, for durations greater than 30 minutes, the opposite is true.

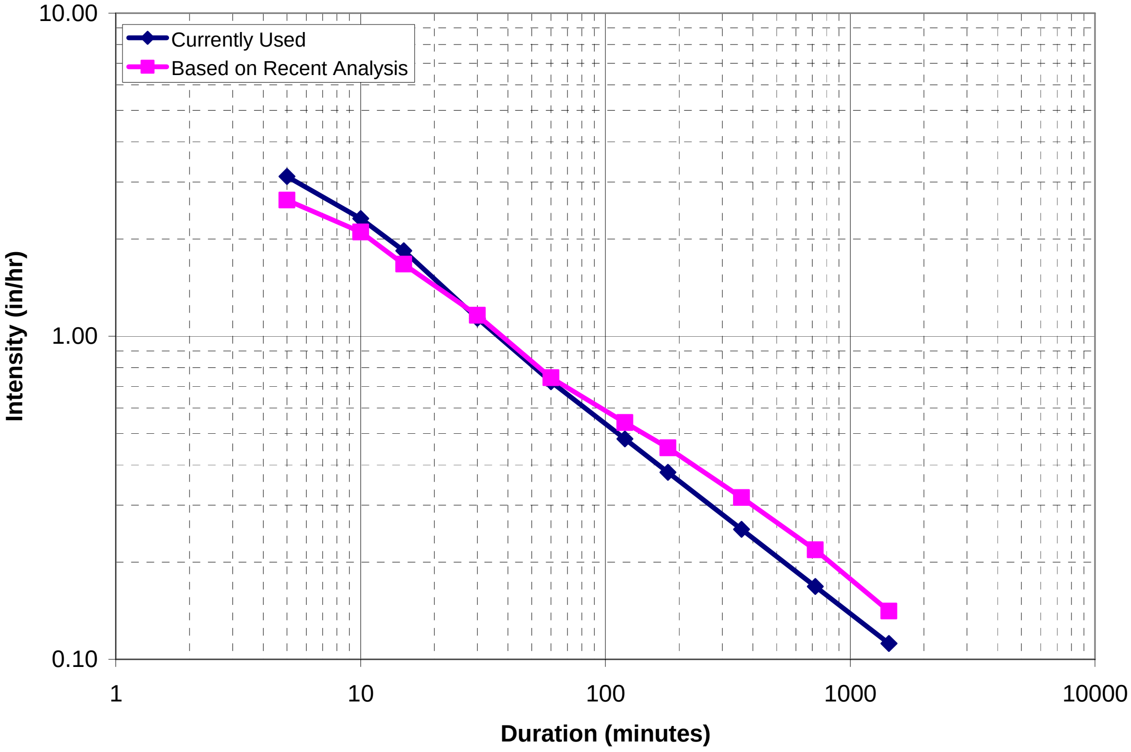

Figure 2 Analysis of Past 30 Years of Rainfall Versus 1941 IDF Curve

This analysis raises the question of whether, statistically, the storm intensities and volumes associated with a 5-year recurrence, or a 20 percent chance of occurrence in any given year, will continue to increase over time in association with global climate change. However, the available data on rainfall changes due to global climate change are widely varying, making it difficult to incorporate into planning assumptions.

3.3.3 Design Condition Hydraulic Grade Line

A key parameter or design condition associated with sewer design is the maximum allowable design condition hydraulic grade. The most restrictive design condition hydraulic grade line (HGL) would be to specify that it not exceed the crown of the sewer pipe being designed during the peak hydrographic flow response from the design storm event. The least restrictive design HGL condition that prevents flooding would be to allow the HGL to rise to just below the ground surface or the elevation that would cause surface flooding or lateral sewer backup.

Section XIV of the 1982 SFDPW *Subdivision Regulations* publication (See Table 1*)*, *Required Capacity of Storm and Combined Sewers*, contains a subsection, *Hydraulic Considerations*, which states: "*Sewer sizes shall be selected so that the HGL shall, in general, be four feet below the pavement or ground surface, and at no point less than two feet.*" The flexibility to apply a design HGL of either 2 or 4 feet below ground surface and the inclusion of the term "in general" allows flexibility to be applied according to the situation at hand. However, it may result in some inconsistency in the application and enforcement of the design HGL specifications.

In potential conflict with the *Subdivision Regulations* is the City's 1971 Wastewater Master Plan, which cites the following on Page VII-6 of the *Preliminary Comprehensive Report* dated September 15, 1971: *"The City's design criteria provides a 5-year storm hydraulic grade line about 1 foot below gutter level at any point in the sewerage system."* However, "1 foot below gutter level" is close to "2 feet below pavement or ground surface" of the *Subdivision Regulations* if one considers the roadway crown elevation as the reference point.

The selection of design HGL generally hinges on the acceptance of a safety factor. A deeper design HGL provides a greater safety factor. That is, there is less chance it will exceed the ground surface or otherwise cause flooding or sewer connection backup. Once the pipes in the sewer system are flowing full, it takes little additional flow to significantly increase the HGL. This is because there is generally slight marginal increase in storage volume (in the connecting manholes) as the HGL rises.

In certain situations the difference between a design HGL of 2 versus 4 feet below ground surface can result in large differences in sewer facility sizing. The selection of a deeper design HGL elevation may result in the inefficient use of the storage capacity in contiguous (upstream or downstream) reaches. For example, a design HGL of 4 feet below ground may constrain an upstream or downstream facility from filling to its acceptable level. A similar situation may occur when there is an abrupt transition from steep to mildly sloped pipes. In these instances, more conservative, deeper HGL criteria may result in significantly greater financial costs for sewer upgrades and may require sewer upgrades in adjacent areas.

For some of the city's existing sewer infrastructure, it may be prohibitively expensive to meet current HGL design criteria. This is likely where there are large equivalent diameter facilities with a crown that is a relatively short distance from the ground surface. For tributary side sewers that connect to these large facilities, the HGL in the connecting sewers will be completely dominated by the water surface elevation in the large pipes. A designer of a connecting sewer will have minimal ability to influence the HGL for the facility being designed.

A corollary consideration is the congestion of the city's underground utility infrastructure. Larger and more extensive sewer piping may conflict with a number of other utilities, including fiber optic conduits, gas and electric facilities, and other San Francisco government and non-government underground facilities.

3.3.4 <u>Official Grade</u>

The design HGL elevation for sewer sizing discussed above relates to the hydraulic grade elevation of the sewer, which is typically an elevation some distance below ground surface. The term "official grade" refers to the elevation of streets at intersections with respect to the

San Francisco Datum that was established many years ago to set surface elevations for future development. San Francisco Datum is 8.61 feet above mean sea level, with mean sea level referenced to the 1929 Net Geodetic Vertical Datum (NGVD). The City's official reference for ground surface is maintained on the *Official Grade Map* comprising 354 pages covering most of the city streets. It is maintained and updated by the survey section, Bureau of Street Use and Mapping (BSM). Updates have been added from time to time. Figure 3 presents an excerpt of the *Official Grade Map*.

Many parts of the city were built on fill. Under the fill is a soft ground condition that is mostly consolidated. In these areas, the land surface has subsided and may experience additional consolidation in the future in response to stressors such as significant development. Figure 4 is a schematic of liquefaction zones; much of the liquefaction zones are the areas of the city built on fill.

The *Official Grade Map* for the areas of the City built on fill may not represent actual conditions. The consolidation of fill process has lowered the city's roadway elevations in some areas to a point where they no longer correspond to the official grade reference as well as to a point where the local sewer system's HGL may be above the ground surface elevations during some storms. Also, some streets in commercial areas were not properly constructed by developers to official grade criteria and are consequently prone to flooding. Many of these streets that exhibit flooding and drainage issues are now, for various reasons and as a result of various processes, under the jurisdiction of the City to maintain and protect against flooding even though the City was not involved in their development.

The unreliability of the *Official Grade Map* in certain areas complicates the regulation of commercial developers, contractors, homebuilders, and existing property owners constructing or rebuilding their respective plumbing facilities. Development and redevelopment in areas where the official grade is no longer accurate may leave these areas exposed to surcharging and possible flooding. The design HGL criteria of the sewer system may no longer protect the properties. Any portion of a property below ground elevation may be susceptible to backflow (sewage backing up into a property). Areas that have subsided may also be susceptible to surface ponding because the catchbasins and local sewers are below the main sewer's design HGL.

The City is limited in its ability to bring subsided areas into conformance with official grade. It is possible, and within the City's jurisdiction, to bring subsided areas within the public right-of-way such as streets and sidewalks up to official grade. However, the City is limited in its ability to do so for private properties. Raising land surface in the public right-of-way may only exacerbate problems to adjacent private properties that are left below official grade. In addition, work in the right-of-way may impede or complicate access to private properties.

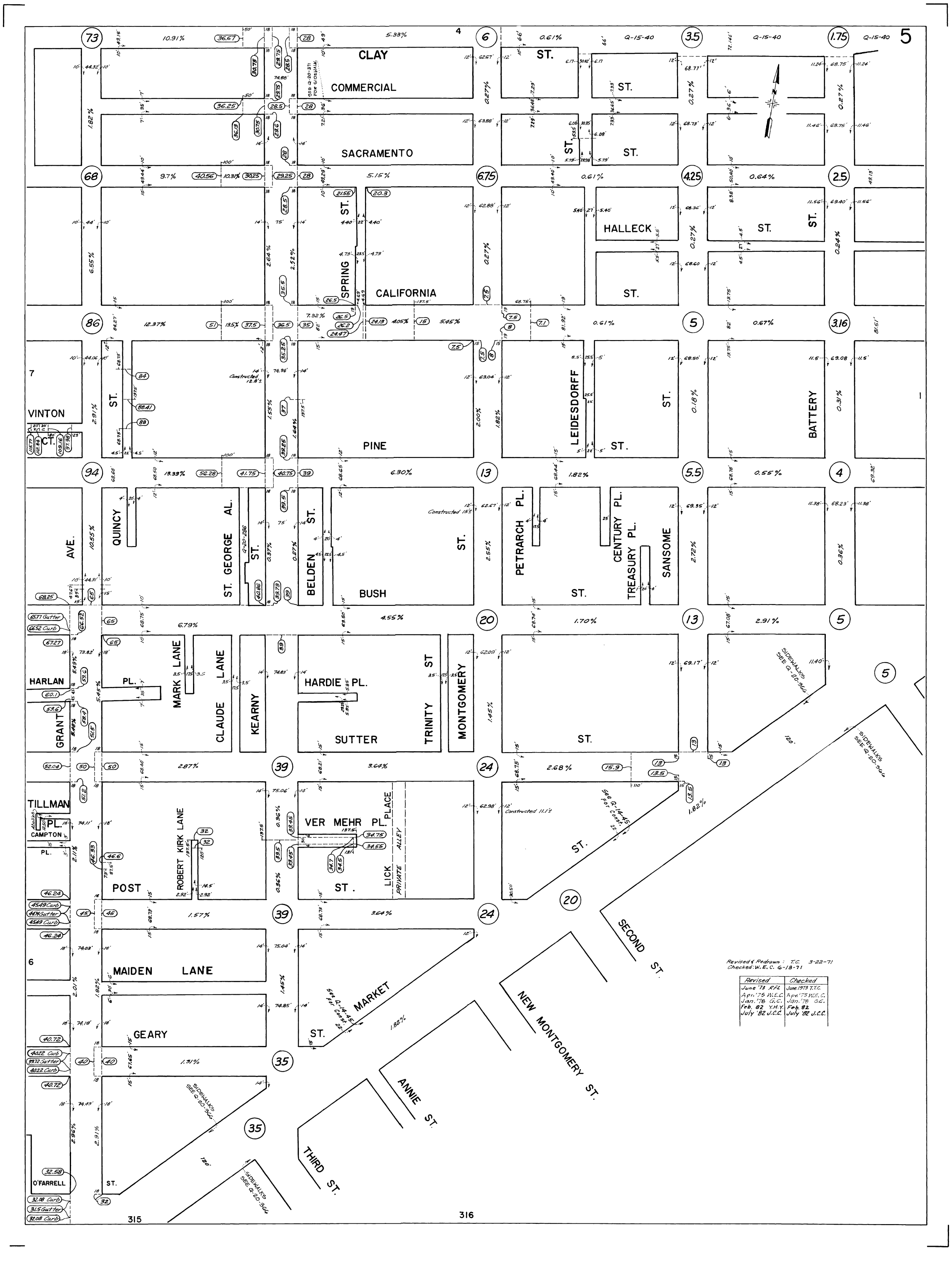

Figure 3 Excerpt from City of San Francisco Official Grade Map

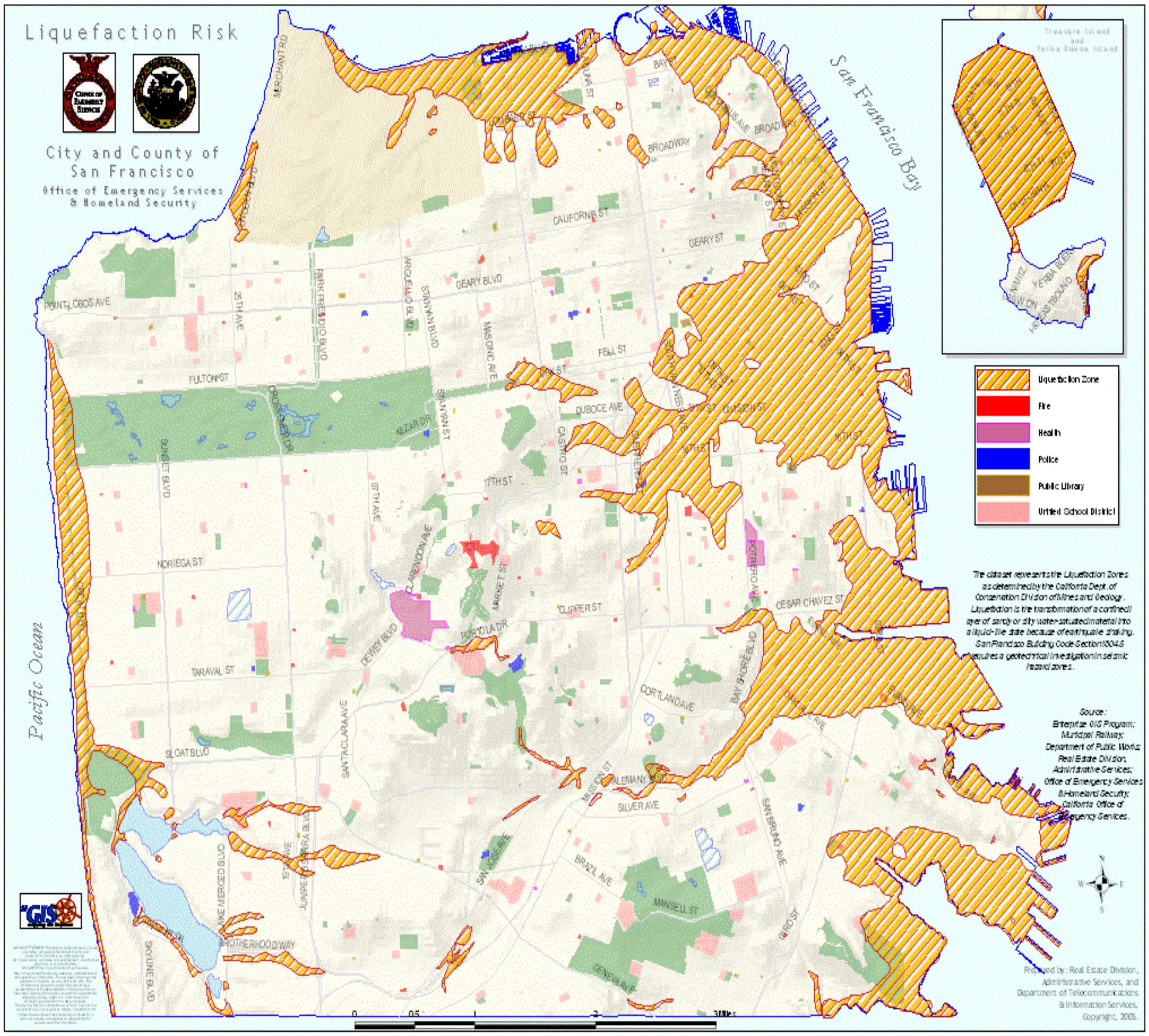

Figure 4 Liquefaction Zones

3.3.5 Downstream Control

In addition to flow and maximum allowable HGL, the third key parameter needed for sewer design is downstream control hydraulic grade. From a practical sewer design perspective, a designer must determine the HGL boundary condition at the most downstream end of the sewer system. The maximum HGL at the downstream end influences the HGL upstream and is a component of upstream hydraulic calculations. For San Francisco, the most downstream point of the collection system is at the weirs located at overflow structures. For example, the Islais Creek Transport/Storage Facilities built in the late 1990s under the Clean Water Program have been constructed to discharge when the HGL reaches an elevation of –3.0 City Datum. Therefore the downstream control hydraulic grade will be the hydraulic grade elevation required for flow to discharge across the weirs.

Section XIV of the 1982 SFDPW *Subdivision Regulations* publication (See Table 1), *Required Capacity of Storm and Combined Sewers*, contains a subsection, *Hydraulic Considerations*, which states on page 38: "*The tidal elevation to be used in hydraulic computations, where applicable, shall be -3.5 City Datum.*" The combined sewerage system weirs need to be sufficiently high to protect against all tides equal to, or higher than, the design tide. If any tide elevation is expected to be higher than a weir, the weir should be equipped with tide gates or some other form of check valve. A weir that is equipped with a tide gate will require a higher hydraulic grade elevation for discharge than one without a tide gate. Therefore, the downstream hydraulic grade control elevation is higher for weirs equipped with tide gates. This downstream hydraulic grade control may be even higher during the times when the weirs are discharging against an extreme high tide which is exerting backwater pressure against the tide gates.

Tide gates Elevations of the controlling weir elevations throughout the city are presented in Table 2.

Table 2 Controlling Weir Elevations of San Francisco Combined Sewerage System
2030 Sewer System Master Plan
City and County of San Francisco

General Location Of Controlling Weir	Weir Crest Elevation *(feet above/below City Datum)*
Marina	-4.00
North Point	-3.51
Jackson	-3.90
Howard	-3.00
Channel	-3.50
Mariposa	-3.10
20th St	-3.00
Islais Creek	-3.00
Sunnydale	-2.60
Yosemite – Griffith	-2.50
Yosemite - Fitch	-2.70
Yosemite - Bancroft	-3.00
Sunset	6.00
Lake Merced	6.50

A related issue is the expectation that sea level will rise in the future in association with global climate change. This expectation is documented in the Sewer System Master Plan Document PMC07, *Climate Change – Sea Level Rise*[4]. The City may need to consider reconfiguring the combination of overflow weir elevations and tide gates to implement stronger protection against additional sea level rise. The reconfiguration may not be consistent throughout the city. Tide levels in the bay are slightly higher in the south. For example, tide levels in Hunters Point/Sunnydale cove are approximately 1 foot higher than in the North Point and Marina districts.

3.3.6 Backflow Prevention

A final consideration in sewer design is the local (lateral) connections to the sewer. Combined sewage must be prevented from flowing in reverse through the lateral connecting sewers and causing sewage backups into buildings and residences.

Section XIII of the 1982 SFDPW *Subdivision Regulations* publication (See Table 1), *Recommended Standards of Design for Sewer Systems*, contains a subsection *Sewers, Depth and Cover*, which states on page 32: "*Back flow preventors should be installed in all properties below street grade."* An SFDPW General Information Sheet on side sewer installation cites the following: "*It should be noted that Section 409A of the Plumbing Code requires that all drainage piping serving fixtures within a building that are located below the elevation of the curb shall be protected from backflow by an approved type of backwater valve or device*."

In relation to the subsidence issue described the above Official Grade Section, there may be a conflict if the property is located in a zone of subsidence. There could be an instance where the local piping is not below the street or curb but still needs backflow protection. In this case, the developer or builder may follow the regulations explicitly and not install a backflow prevention device when a larger picture hydraulic analysis would show that it is needed.

Jurisdictional problems can also affect implementation of backflow prevention measures. Plumbing within property lines is under the jurisdiction of the Plumbing Inspection Division of the Bureau of Building Inspection. SFDPW is only able to influence and regulate the sewers up to the local sewer trap facility.

3.4 Recommendations for Sewer Design Governance

Currently, a comprehensive document governing sewer design does not exist. The 1982 SFDPW *Subdivision Regulations* publication has been widely cited above. However, these regulations only officially apply to subdivisions, of which there are few in the City and County of San Francisco. Furthermore, many of the drivers for sewer design cited above are not related to subdivisions. Currently, BOE engineers have the flexibility to subjectively adhere to guidelines and criteria for design and analysis. While this subjectivity provides some flexibility, it is not ideal in terms of consistency. Furthermore, there is little guidance that can be provided to developers or consulting engineers who represent developers. Based on this lack of a clear governing document, the DDMP team recommends the City establish a document that provides guidance and design criteria for sewer design. The governing document would list and describe tenets associated with each of the issues discussed in

Sections 3.3.a-f. The existence of this document would also provide the option for SFDPW to prescribe criteria to developers or consulting engineers to adhere to as part of development and redevelopment analysis and designs. Specific recommendations are provided below.

Dry-weather flow. Dry-weather flow has the potential to influence the sewer system in quantity and quality. Combined sewer design criteria policy should prescribe an assessment to determine the proportion of total peak flow and volume attributable to dry-weather flow. If the basis for the design is a change in land use to one with greater residential, commercial, industrial, or institutional density, then the sewer design flow shall comprise the diurnal and seasonal dry-weather flow (including groundwater or shallow subsurface flow) added to the wet –weather rainfall runoff design flow.

Design Rainfall. The City should publish clear guidance on design rainfall events to be used for sewer design and should standardize on the storm that has a 20% probability of occurrence in any given year or 5-year storm. This standard design event should be adopted as the level to which the City will protect against flooding (up to a design HGL level) for all customers and in all sewered (combined or separate) areas. This design rainfall should also provide a range of durations. For example, a 30- to 120-minute duration, 5-year design rainfall may be used for catchbasin and small tributary sewer design, whereas a longer three- to 24-hour duration design rainfall may be used for main and trunk sewer design. The 5-year design rainfall and clear guidance on the appropriate duration to use for design should be clearly stated and published and easily accessible (posted on City web sites) by all parties involved in sewer and drainage facility design. The City should also publish clear guidance on objectives for managing design rainfall events that exceed the 5-year recurrence, up to, and including the 100-year event.

As a backup for clear guidance on design rainfall, the City should develop a tool to facilitate quick rainfall frequency analysis calculations. The tool would be a simple spreadsheet or database macro routine and would be maintained by a small cadre of BOE personnel who have a strong knowledge of rainfall frequency analysis and the network of rain gauges in the City. This tool would be used exclusively by the City to maintain an up to date frequency analysis as new data are obtained, to analyze spatial effects of rainfall, and to use as a basis or rational to instruct designers to deviate from normal procedures and use a modified design rainfall in certain areas of the City or for certain projects if BOE personnel feel this is warranted.

The objective of hydrologic probability analysis is to define hydrologic occurrences or events (related to rainfall, surface runoff, streamflow, etc.) with a probability of being equaled or exceeded in any year. As it relates to rainfall, the straightforward procedure to determine storm probabilistic recurrence interval is to rank a historical record of rainfall events and to then apply a standard frequency distribution. While this is a straightforward procedure, there are some aspects in defining the period of record “events” that should be considered carefully. They are listed and generally described as follows:

Interevent Period. In order to establish rainfall events from a period of record dataset, an interevent period must be defined. The interevent period is some duration of no rainfall or rainfall below some minimum threshold (e.g., 0.01 inch) that separates rainfall events.

Spatial Distribution of Rainfall Record. The data set used for the frequency analysis should be spatially pertinent to the location to which the design rainfall event will be applied. A design rainfall calculated from rainfall data taken from the west side of the city may differ significantly from the calculation based on rainfall from the east side of the city.

Length of Rainfall Record. Due to global warming, sea level rise, urban heat effects, and other natural or anthropogenic activity, the rainfall record over the recent past may be statistically different from the older portions of a rainfall record.

The working tool proposed here would draw from a database repository of all of the verified and official rainfall records in the city. The user would specify a value for the following parameters in order to determine the most appropriate calculation for the intended use of the design event:

1. Design Event Duration (1-, 3-, 12-, 24-hour, etc.) – What duration of rainfall the design event is to represent.
2. Interevent Period – What period of non-rainfall separates “events” for the frequency analysis.
3. Threshold Rainfall – What threshold of rainfall will be ignored in the calculation of interevent period. For example, if a 24-hour interevent period is selected, the user may specify that any rainfall measurement less than 0.01 inch of rainfall is treated the same as 0 relative to the intervent period (such that the interevent period doesn’t reset in the calculation).
4. Spatial Record of Rainfall – Which of the rainfall gauges is to be used for the calculation.
5. Length of Record of Rainfall – For a specific rainfall record at a gauge, which portions of the record should be used in the calculations. For example, the full historical record could be used or some more recent subset such as the last 50 or 30 years.

Design HGL. The design HGL of a sewer at every point along its length should relate to the lowest elevation of potential flow egress. Prior to design of the sewer, the design engineer should determine the points of potential egress along the entire reach of sewer to be designed, including manholes, catchbasin inlets, and lateral connections. For lateral connections, the point of egress should be considered to be the invert of the trap u-joint. The sewer should be designed such that the HGL is a minimum of 2 feet below each point of potential egress. The only exception would be for cases when the 2-feet-below-egress elevation is below the elevation of the crown of the pipe being designed. A safety factor would be added to these criteria to allow for unanticipated hydraulic losses in the system (which might cause higher HGLs for the same design flows) and to account for future sea level rise. This safety factor should be related to a time frame over which the City can meet this HGL responsibility with current funding levels. If the above stated criteria cannot be achieved, as may be the case in some low-lying areas, the only recourse would be to implement a system of pumping.

This design HGL elevation would be adopted as the City's *official hydraulic grade (OHG)*. An implementation program could consist of a number of measures including:

1. Develop and document the City's OHG and, as necessary, adopt code changes that make conformance to the OHG an integral part of sewer design.
2. Inform property owners who appear to be at or below OHG and advise them of their responsibility to implement appropriate plumbing and drainage relative to OHG.
3. Develop a program of grants/low-no interest loans for existing property owners to "floodproof" their property including simple steps such as backflow preventors and sump pumps for low areas (e.g., alleyways between buildings) and modify entrances to allow for improvement of street grade. Property owners would be responsible for the maintenance of any implemented facilities or devices.
4. For extreme situations of property in low-lying areas, provide loans/grants to property owners to raise their buildings in conjunction with raising the roadway to at or above OHG.
5. Coordinate OHG standards to standards that regulate the installation and maintenance of backflow prevention devices.
6. Institute a system to provide incentive to property owners to disconnect roof drains and possibly sump pumps from the combined sewer system and have them direct their discharge into bioswales and/or the local roadway. This would contribute to meeting the design OHG levels. Disconnection activity would have to be done with City guidance and oversight to ensure that consequent surface ponding and flooding is manageable.

Official Grade. Official grade should be officially stated to be unrelated to sewer design. Sewers should be designed according to design HGL criteria as stated above and not according to official grade. Where feasible, the City will inform those whom it may concern that certain property is below the City's official grade and prone to flooding. Should the design HGL stated above be impossible to achieve based on severe subsidence, the design engineer should consider other measures such as storage chambers to mitigate flooding flow and volume.

Downstream Control. Downstream control should be determined based on the design condition HGL at the most downstream point of the sewer being designed. At the most downstream point of the combined sewer system, this would be at the elevation of the overflow weirs. The City's current InfoWorks hydrodynamic model should be used to determine the specific downstream control if the model is not also being used in the design. The downstream control elevation at an overflow weir will be the head required to move the design flow over the weir and through the tide gate. Policies associated with downstream control need to account for predictions of sea level rise.

Backflow Prevention. Currently, backflow prevention is required by the Plumbing and Health Codes. In addition, the design engineer, concurrent with the design HGL analysis, should review all lateral connections along a reach of sewer being designed and ensure that backflow prevention is implemented. In essence, any property susceptible to backflow should have a backflow prevention device installed and maintained.

The terminology regulating backflow protection for planning and code implementation purposes should reference the local adjacent sewer hydraulic grade and not grade elevation topographic data sets such as the City's *Official Grade Map*. Statements such as "below the elevation of the curb" should be foregone and replaced with ones such as "below the elevation of the hydraulic grade in the connecting local sewer main." This would require the hydraulic grade elevations be readily available for the pertinent design event.

One approach for regulating buildings and property below official grade or local hydraulic grade is for the City to develop a funding mechanism to provide both grants and low- or no-interest loans to property owners to improve their property to protect from high hydraulic grade. This could include:

1. Providing grants/loans to raise buildings at sub-standard elevation.
2. Improving ingress/egress/access for property at significant sub-standard elevation, especially ahead of plans to modify or improve the adjacent roadway surface.
3. Providing grants to install backflow prevention devices, sump pumps, etc. in areas of subsidence (this would manage situations where the property owner was not aware nor responsible for the problems caused by subsidence, but is now responsible and subject to problems including combined sewage intrusion or diminished capacity to send building wastewater to the sewer during storm events).
4. Providing low-cost loans for other property improvements that contribute to floodproofing buildings in problem areas including improvements to protect from the effects of future sea level rise.

4.0 SURFACE FLOW MANAGEMENT

As previously stated, the San Francisco sewer system serves to drain a combination of stormwater, groundwater infiltration, and sanitary sewage from its inception points throughout the city to discharge points either in the San Francisco Bay or the Pacific Ocean. The major component of flow in the system is stormwater runoff. The previous section addressed design aspects of the sewer conveyance facilities, the system of pipes, manholes, and storage facilities that move and temporarily store water as it moves from the ingress locations to treatment and discharge locations. This section addresses the system of surface drainage that moves rainfall once it hits land across the surface of buildings, streets, parking areas, vegetation, streets, parks, yards, and other land surfaces until it reaches a catchbasin or other inlet to the sewer conveyance system. The fail-safe principles for surface flow management should be to minimize negative impacts of flooding and contamination to the maximum extent practicable.

Under larger magnitude storm conditions, the distinction between surface drainage and in-sewer conveyance becomes less precise as the surface drainage facilities and below-ground sewerage facilities begin to reach their design capacities. Flooding and ponding on the surface may be attributable to either or both surface drainage and catchbasin/sewerage inadequacies as well as from backflow from a strained combined sewer system.

The responsibility for managing surface flow in the City of San Francisco is not clearly within the jurisdiction of any single agency. The SFDPW is responsible for the management of the public right-of-way as well as the design and maintenance of roadways. Because streets and public right-of-way are often integral aspects of surface flow management, the SFDPW, by default, is often involved in surface flow issues. SFDPW takes on a role of helping to coordinate all aspects of urban flood management, but does not hold any official responsibility. Prior to 1997, management of both the sewerage system and the street/roadway system was clearly under the purview of SFDPW. In 1997, responsibility of the sewerage system was transferred to the SFPUC's jurisdiction.

Major historical surface flow issues can generally be related to one or more of the following issues:

1. Development or re-development did not adhere to the City's Official Grade requirements.
2. Subsidence has occurred rendering properties more susceptible to flooding.
3. Development or re-development within historic drainage-ways or former creek beds without adequate accommodation to manage flows through the development.
4. Increased imperviousness.
5. Increased storm intensities.

4.1 Summary of Existing Surface Flow Management Policies, Procedures, and Guidelines

4.1.1 Surface Flow and Street Drainage

Surface flow and street drainage are influenced by surface conditions, topography, and configuration. Section XII of the a 1982 SFDPW *Subdivision Regulations* (See Table 1) publication, *Recommended Design of Streets, Blocks and Lots*, contains a subsection, *Streets*, which states on page 26: "*Street and drainage channel cross-sections shall be designed to provide a transport channel for overland or surface flow in excess of the 5-years storm capacity of the sewer system. The channel capacity shall be the difference between the sewer capacity and the quantity of runoff generated by a 100-year storm as defined by the U.S. Weather Bureau or by City furnished data, applied over the tributary area involved*."

Many streets in San Francisco have been designed and/or modified to accommodate smooth flow of rail traffic (MUNI surface light rail and cable cars), elongated buses, and transit tunnel vents and stations. This accommodation can be in conflict with or complicate surface drainage. In some instances, the roadway crowns at intersections are at elevations that promote drainage out of the street right-of-way and onto adjacent private property.

Presently, SFDPW staff who design roadways do not typically consider using streets for open-channel conveyance when the flow in the sewer system exceeds the City's adopted 5-Year Design Storm. SFDPW roadway designers typically consider the roadway only as a means to maintain the loads and effects from surface vehicles, bicyclists, and pedestrians. The roadway designer's current responsibility with respect to overland flow is to ensure that it is directed to the nearest catchbasin.

4.1.2 Federal Emergency Management Agency Flood Zone Delineation

The Federal Emergency Management Agency (FEMA) is currently conducting a flood zone remapping study for lands contiguous to the San Francisco Bay. Currently, the City anticipates participating in the National Flood Insurance Program (NFIP). The City Attorney's plan is for the City to adopt a limited flood plain ordinance in order to meet NFIP requirements and enable the City to join the program. Joining the NFIP will enable citizens to purchase federally subsidized flood insurance but may influence, limit, and/or hinder development. The results of this study could influence the local regulation of sewer design and drainage in these areas.

The role of "floodplain manager" for this program has been assigned by the City to the City Administrator's office. The floodplain manager will be authorized under the ordinance to develop floodplain maps showing flood plains using "best available data." The floodplain manager will also be responsible for assuring that the City's systems adequately reflect policies and procedures to enforce the flood plain ordinance including proper review and limits on building permits for buildings within the flood plain.

4.1.3 Separate Stormwater Areas

Approximately 10% of the city of San Francisco is served by separate sanitary sewer systems. Stormwater in these areas is managed either with separate stormwater infrastructure that drains stormwater to receiving water outfalls, on-site stormwater management facilities that capture and manage stormwater on site, or a site configuration that drains stormwater directly to the bay or ocean (post water-quality treatment if required).

The United States Environmental Protection Agency (EPA) began regulating smaller communities in 1999 under what is known as the National Pollutant Discharge Elimination System (NPDES) Phase II stormwater regulations. This followed the 1987 Amendment to the 1972 Clean Water Act known as Phase I for larger municipalities. Because such a small area of San Francisco is relevant to separate stormwater guidelines, the city is subject to Phase II guidelines rather than Phase I. The California State Water Resources Control Board administers the Phase II regulations through a General Permit. Separate stormwater areas in San Francisco are required to develop stormwater management plans (SWMPs) subject to conditions of the General Permit. Both the Port of San Francisco and the SFPUC administer SWMPs approved by the State. The SWMPs specify measures for post-construction stormwater management for new development and redevelopment.

The SFPUC and the Port of San Francisco have partnered to create *Stormwater Design Guidelines* for San Francisco's development community, designers, engineers, and the general public. The guidelines are intended to help applicants implement post-construction stormwater controls that meet the requirements of the NPDES Phase II program.

4.1.4 Low Impact Development

Low Impact Development (LID) encompasses multiple stormwater best management practices (BMP) that minimize the impact of development on natural hydrologic conditions by managing runoff close to its source. Stormwater runoff is managed through decentralized techniques that incorporate sheet flow dispersion, infiltration, and native vegetation. The City is currently involved with identifying opportunities to implement LID throughout the city to improve the overall performance of the city's wastewater and stormwater systems. The goals of the LID measures identified for each basin include reducing combined sewer overflows (CSOs), reducing flooding, reducing capacity requirements of the collection system and treatment plants, improving stormwater and receiving water quality, reducing potable water demand, enhancing habitats and community spaces, and recharging groundwater.

The City is moving toward a process that will involve identifying and screening candidate LID measures for any project as well as evaluate the costs and benefits of the measures. Screening could involve a combination of some of the following example criteria: space availability, stormwater volume, construction conflicts, environmental impacts, risk, policy conflicts, constructability, safety, soil type and depth, groundwater regime, etc.

After removing infeasible projects through screening, viable projects would be analyzed in greater detail to assess costs and benefits. Hydraulic and hydrologic modeling would be used to analyze the benefits to collection system performance, such as reduced flooding, reduced combined sewer discharges (CSDs), and reduced system capacity requirements. Additional benefits of implementing LID measures — such as reduced potable water demand, water and air quality improvements, enhanced habitats and community spaces, and recharged groundwater — would be factored into the analysis. The lifecycle costs of the LID projects would be estimated and compared to the total project benefits in order to evaluate the projects and prioritize them for implementation.

LID may be more appropriately discussed as a general policy that applies to combined sewer management and not solely under “surface flow” management. For example, successful implementation of LID in a catchment may enable a combined sewage piping network to provide service for a 9-year recurrence storm rather than a 5-year storm without LID. The challenge is to ensure that the LID is maintained and managed, just as the piping network is such that the benefit does not degrade over time. Until such time as LID techniques and methods have been implemented, tested, and affirmed, they should not be used to augment the level of service provided by the piping system — only to provide an enhanced level of protection/service over and above that required and provided by the piping system.

4.2 Recommendations for Surface Flow Management Governance

Street Design Criteria. A policy for design of streets to accommodate stormwater and overland flow must be clearly devised and articulated in the SFDPW street/roadway design criteria. These criteria would specify conveyance and/or storage performance up to and including the 100-year design event that has a 1% chance of occurring in any given year. Overland flow for a given extreme rainfall event in San Francisco can vary widely across the City based on drainage area characteristics, flow paths and patterns, topography (slopes), width and roughness of streets, and obstructions. As a result, it may be most appropriate to characterize risk by flood hazard indices rather than extreme rainfall recurrence interval.

A typical flood hazard measure is the product of depth and velocity of flow. Figure 5 presents the concept of using depth times velocity to define flood hazard to humans.

Overland flow along streets and right-of-ways will be characterized by depth and velocity. For a certain magnitude of flow there may be different combinations of depth and velocity according to the characteristics of the conveyance channel. For example, for the same flow rate, velocities will be greater, and depths lower, along a steep street compared to mildly sloped street with all other characteristics (width, roughness) equal. A depth times velocity indice establishes that deeper floodwaters and those moving with high velocity pose the most risk to human safety. The area below the dashed line in Figure 5 would be considered flood event depth x velocity product values that do not pose a high risk to humans.

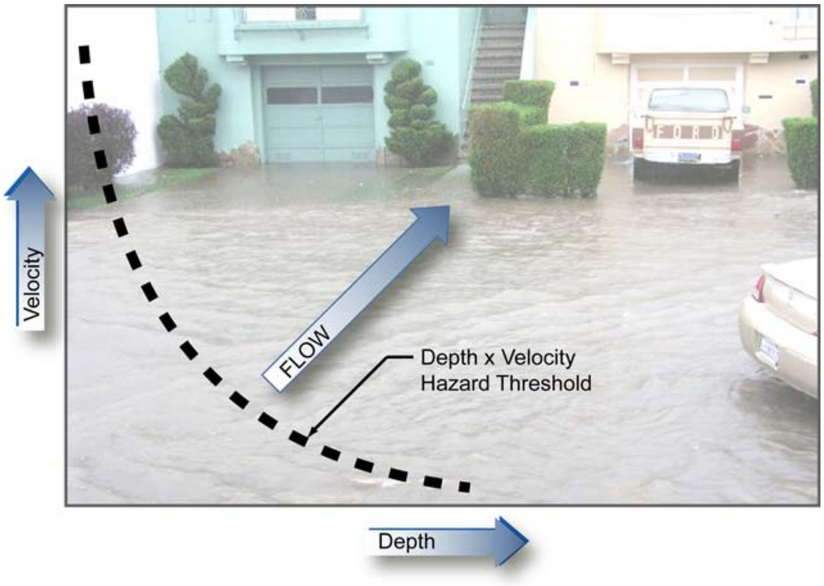

Figure 5 Depth/Velocity Hazard Threshold for Flooding

In many places the hazard threshold has been established as depth x velocity must be less than 1.0. In the UK, certain jurisdictions have customized this basic equation to include a debris factor(5):

Flood Hazard Rating (HR) = Depth x (Velocity + 0.5) + Debris Factor

where Debris Factor is assigned from 0 to 1.0 depending on the probability that debris will lead to a significantly greater hazard. The HR result can be sub-classified into human risk to some, most, or all.

A depth velocity product hazard threshold should be defined for San Francisco and serve as a level of service benchmark. This would recognize that it is not feasible to categorically protect from flooding risk against storm events of large/extreme magnitude equally across the City. This method would equalize the protection against a basic risk threshold across all areas of the City.

Jurisdiction. The current ambiguity of jurisdictional responsibility for all aspects of surface flow management needs to be addressed. A single agency should be charged responsible for management of all stormwater that is in excess of what can be reasonably conveyed within the combined sewer system under 5-year storm design conditions. This would include surface flow along streets and right-of-way as well as publicly owned spaces such as parks, open lands, and off-street parking areas.

The candidates for jurisdiction are the SFPUC and SFDPW. The DDMP Team recommends SFPUC be assigned as the controlling and responsible agency for surface flow management. This is logical as the SFPUC currently owns the sewer system and is responsible for its management, operation, and maintenance. Furthermore, SFPUC currently derives funding from ratepayers for combined sewer maintenance; these funds can be used to also support surface flow management. Through its Planning Department, SFPUC should be responsible to identify risks associated with surface ponding and overland flow routing, identify practical and cost-effective solutions for specific areas of high risk, and be the lead coordinator to implement solutions that manage identified risk.

SFDPW should collaborate with SFPUC to ensure that surface/overland flow issues are adequately addressed in the design and maintenance of streets and rights-of-way to accommodate sound management of stormwater flows. SFDPW may need to provide some of the gas tax and other funding that currently support roadway design and maintenance to SFPUC to support surface flow management.

Mapping. A concerted programmatic effort should be instituted to map areas that are possibly at risk based on the inability of surface flows to adequately drain (on account of land below official grade, sub-optimal drainage performance of streets, or sump areas). These maps should then be used to inform property owners of risk associated with the geographical proximity of their property to flood-prone areas. Risk should be associated with depth of ponding as well as depth-velocity curves. A depth-velocity curve plots depth on one access and velocity on the other. A line is then drawn demarcating areas of unacceptable risk (for example, low-depth, high-velocity as well as high-depth low-velocity situations are both considered high risk).

LID. In association with the SFPUC’s current LID program, establish building requirements and roadway design standards for future developments and redevelopments to reduce stormwater impact through the use of City approved standard LID measures. A clearly stated goal should be to allow the surface flow management and sewerage system to continue to account for increased storm intensities over time by reducing the peak flows/volumes and detaining the runoff peaks though LID measures. Implementation of LID measures should proceed equally in combined and separately sewered areas of the city.

Funding. General funding or subsidized financing should be established to encourage current property owners to implement measures to promote infiltration, detention, or retention of rainfall on their property where appropriate. This can be justified as saving the City Capital Improvement expenditures in the future as storm intensities increase and sea level rises.

Catchbasin Clogging. For many storm events in the 1- to 5-year recurrence interval range, a significant number of flooding complaints are attributable to catchbasin clogging. The City currently maintains a program to minimize the potential for catchbasin clogging. This program should be evaluated to ensure that it is adequately funded and achieving the intended effectiveness. If it is found to be operating at a substandard level, the program should be re-invigorated and overseen by the City’s designated surface flow management agency.

5.0 REFERENCES

(1) C.E. Grunsky, Report upon a System of Sewerage for the City and County of San Francisco, 1899.

(2) Bureau of Engineering, Department of Public Works, City and County of San Francisco, Subdivision Regulations, January 6, 1982

(3) Metcalf & Eddy, Rainfall Analysis Technical Memorandum, SFPUC Wastewater Master Plan Scope C, Revised Draft Technical Memorandum PMC2A, July 17, 2006.

(4) Carollo Engineers and Gleick, Peter, Climate Change – Sea Level Rise, SFPUC Wastewater Master Plan Scope C, Draft Project Memorandum PMC07, July 14, 2006.

(5) HR Wallingford Flood Hazard Research Centre, Middlesex University, Risk & Policy Analysts, Ltd. Flood Risks to People, Phase 2, FD2321/TR2 Guidance Document UK Defra/Environment Agency, March 2006.