APPENDIX I

Hydrology and Hydraulics Technical Report

DRAFT
Hydrology and Hydraulics Technical Report for the Municipal Waterways Maintenance Plan
PTS #616992

Prepared for:

The City of SAN DIEGO

Transportation & Storm Water Department

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ACRONYMS AND ABBREVIATIONS

Acronyms/ Abbreviations	Definition
BMP	Best Management Practice
cfs	cubic feet per second
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
fps	feet per second
FIS	Flood Insurance Study
GIS	geographic information systems
H&H	hydrology and hydraulics
HEC-RAS	Hydrologic Engineering Center–River Analysis System
IHHA	Individual Hydrologic and Hydraulic Assessment
in/hr	inches per hour
min	minutes
MMP	Master Storm Water System Maintenance Program
MS4	Municipal Separate Storm Sewer System
MWMP	Municipal Waterways Maintenance Plan
NOAA	National Oceanic and Atmospheric Administration
N/A	not applicable
SanGIS	San Diego Regional Geographic Information System
SDDDM	City of San Diego Drainage Design Manual
TSW	City of San Diego Transportation & Storm Water Department
USACE	United States Army Corps of Engineers

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GLOSSARY

Aggradation	The deposition of sediment in a stream, with the effect of filling and raising the level of a stream bed.
Channel	An open graded or lined channel which is wider than 8 feet across the bottom per City of San Diego Council Policy No. 800-4. Channels and ditches are analyzed using the same methodology and for the purpose of general discussion throughout this report they are referred to as channels.
Channel Bank	Refers to the side walls of a stream or channel. Bank material refers to the substrate (e.g., sand, silt, clay, rock, bedrock, concrete) that makes up the side walls of channels or streams.
Channel Bed	Refers to the bottom of a stream or channel. Bed material refers to substrate (e.g., sand, silt, clay, rock, bedrock, concrete) composition that forms the bottom of channels.
Culvert	A hydraulically short conduit that is typically used to convey surface water beneath a highway or railroad embankment, or other type of obstruction.
Desilting Basin	A basin designed to temporarily detail sediment-laden runoff and allow sediment to settle out before runoff is discharged.
Detention Basin	To temporarily store peak storm runoff and release it in a controlled manner to reduce, eliminate flooding, or other adverse downstream effects.
Ditch	An open graded or lined ditch which is 8 feet or less across the bottom per City of San Diego Council Policy No. 800-4. Channels and ditches are analyzed using the same methodology and for the purpose of general discussion throughout this report they are referred to as channels.
Domain of Analysis	The longitudinal extents of the channel or ditch outside the extents of the facility group or facility segment that was evaluated for potential impacts caused by maintenance.
Erosion	The action of flowing water that removes soil, rock, or dissolved material from one location in a stream system, transporting it to another location. (Definition of erosion is limited to the focus of this report).
Facility	Facility refers to drainage infrastructure including channels, ditches, basins, inlets, outlets, headwalls, etc.

Facility Group	Drainage facilities that are located in the same drainage and proximity are associated to the same group. Each facility group consists of one or more facility segments.
Facility Segment	Drainage facilities are divided into segments primarily based on a change in channel substrate (earthen versus concrete-lined), Coastal Zone boundary, and/or a four-lane or larger roadway.
Geographic Information System	A computer program that captures, stores, checks, and displays data related to positions on the Earth's surface.
Hydraulics	For the purpose of this report, hydraulics is defined as the quantification of runoff flow rate that a channel can accommodate given the current condition of the evaluated channel.
Hydrology	For the purpose of this report, hydrology is defined as the quantification of runoff flow rate resulting from selected storm events.
Level of Service	The conveyance capacity from the hydraulic analysis can be compared with the hydrologic peak flows for different recurrence intervals to assign the level of service for the channel segment.
MS4	The storm water conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, built/constructed channels, or storm drains) that is owned or operated by the City.
Nomograph	A diagram designed to approximately graph mathematical functions.
Normal Depth	The depth of flow in a channel or culvert when the slope of the water surface and channel bottom is the same and the water depth remains constant.
Peak Flow	The maximum flow anticipated to result from a particular storm event.
Return Period	Also referred to as recurrence interval: see storm frequency.
Sedimentation	The process of settling or being deposited as a sediment (see aggradation).
Shear Stress	The amount of force applied by the flow of water on channel bed and bank material.
Storm Frequency	Based on statistical analysis, the storm frequency is the estimated time interval between events of a similar size or intensity (e.g., 100-year storm event). This can also be expressed as a probability of a storm event being equaled or exceeded in an area in any given year (e.g., 1% chance for the 100-year storm event). This is an alternate way to express return period.

Subcritical Flow	Occurs when the actual water depth is greater than critical depth, and is dominated by gravitational forces and behaves in a slow or stable way.
Substrate	A substance or layer that underlies something or on which some process occurs.
Supercritical Flow	Occurs when the actual water depth is less than critical depth, and is dominated by inertial forces and behaves as rapid or unstable flow.
Watershed	A watershed, or drainage basin, is an area of land that conveys precipitation and runoff toward a common body of water, such as a creek or stream, which then flows into a larger body of water, such as a river, lake, or estuary, prior to discharging to the ocean. Within a watershed, water flows from high (e.g., mountains or hills) to low (e.g., lakes and streams) elevations.

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EXECUTIVE SUMMARY

Under City of San Diego (City) Charter Section 26.1 and Council Policy 800-04 (City of San Diego 2012), the City is responsible for maintaining adequate drainage facilities to remove storm water runoff in an efficient, economic, environmental, and aesthetically acceptable manner to protect property and life. The City generally accepts responsibility for maintenance of public drainage facilities that are designed and constructed to City standards and located within a public street or drainage easement dedicated to the City. Although City Council Policy 700-44 (City of San Diego 1984) establishes the responsibility to protect private properties from flood damage to be with the property owners themselves, the City's Transportation & Storm Water Department is responsible for evaluating and conducting maintenance and repair of the public municipal storm water conveyance system throughout much of the City. The *City of San Diego Municipal Waterways Maintenance Plan* (MWMP) outlines specific activities, methods, and procedures that will guide ongoing maintenance and repair of facilities. This *Hydrology and Hydraulics Technical Report* summarizes the engineering technical analysis performed to identify maintenance activities proposed under the MWMP.

The results of this analysis will guide the proposed scope of storm water system maintenance activities and identify potential Capital Improvement Project(s) that can be implemented to reduce flood risk, improve capacity, and reduce erosion in municipal waterways. Within the MWMP, this analysis is also used to present the benefits of flood risk reduction maintenance within the context of strategies to avoid, minimize, or mitigate potential effects to biological, water quality, cultural, and environmental resources within the City.

Fifty-nine facility groups were selected for potential inclusion in the MWMP. To assess the potential to reduce flood risk and local, adverse hydraulic impacts (e.g., erosive velocities) from removing sediment and vegetation, a hydrology and hydraulics (H&H) analysis was prepared for each facility group and summarized in this *Hydrology and Hydraulics Technical Report*. The purpose of the H&H analyses was to assess whether proposed maintenance could reduce flood risk to surrounding properties or cause adverse hydraulic conditions within the proposed maintenance area, including areas upstream or downstream (within the domain of analysis). The technical analysis is based on Federal Emergency Management Agency and City data and information; guidance in the City of San Diego Drainage Design Manual, dated January 2017 (City of San Diego 2017); the Southern California Coastal Water Research Project's *Hydromodification Screening Tools* (SCCWRP 2010); and other applicable technical information.

The MWMP facility groups were subdivided into multiple segments primarily based on channel substrate (i.e., a substance or layer that underlies something). The segments were then sorted into one of three categories to determine the level of hydraulic analysis necessary to evaluate impacts.

Category 1 facilities include concrete-lined channel segments that are lined in the bed, banks, and controlled outlet/storage detention basins. Category 2 facilities include engineered channel segments (not concrete lined) for which recorded as-built drawings were available and used to evaluate channel design capacity. Category 3 facilities include earthen channels without available as-built drawings and no previous engineering-based channel design or capacity information.

Varying levels of H&H analysis were applied to Category 1, 2, and 3 segments to provide a comparison of channel capacity, velocity, and resistance to erosive sheer stress information to evaluate pre- and post-maintenance flood and erosion risks. For all segments, hydrologic peak flows for the 2-, 5-, 10-, 25-, 50-, and 100-year frequency storm events were estimated using one of four methods as discussed in Section 3.1.1. Hydraulic analysis, using models such as the U.S. Army Corps of Engineers' Hydrologic Engineering Center–River Analysis System (HEC-RAS), was conducted to estimate the capacity and level of service of the segment, as well as the velocity of water during the various frequency storm events. The calculated velocity, combined with channel substrate conditions, helped determine the potential for erosion within the channels, as well as within upstream and downstream reaches, within the domain of analysis.

TERMS OF REFERENCE AND LIMITATIONS

This report summarizes the engineering analysis performed to evaluate the extent of maintenance necessary for each of the 59 facility groups included in the MWMP. This work was performed by multiple firms, including D-Max Engineering Inc.; Dudek; Environmental Science Associates; Geosyntec Consultants; Rick Engineering Company; and URS Corporation, an AECOM Company. They are collectively referred to as the "consultant team" for the City. The analysis for each facility group was directed by qualified and registered professional engineers within each firm.

Recommendations from this report may be modified when factoring in other environmental constraints, such as biological and cultural resources, which may exclude or limit the maintenance recommended in this report. Additional analysis is recommended to evaluate potential increases in the level of service that could be achieved by capital improvements to address restrictions identified in this report.

The professional opinions and recommendations expressed in this report are made in accordance with generally accepted standards of practice. The City and consultant team provides no warranty, expressed or implied, with respect to the use of any information or methods disclosed in this report. Furthermore, the City and consultant team assumes no liability with respect to the use of any information, advice, or methods disclosed in this report.

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1 INTRODUCTION

1.1 BACKGROUND

Under City of San Diego (City) Charter Section 26.1 and Council Policy 800-04 (City of San Diego 2012), the City is responsible for maintaining adequate drainage facilities to remove storm water runoff in an efficient, economic, environmental, and aesthetically acceptable manner to protect property and life. The City generally accepts responsibility for maintenance of public drainage facilities that are designed and constructed to City standards and located within a public street or drainage easement dedicated to the City. Although City Council Policy 700-44 (City of San Diego 1984) establishes the responsibility to protect private properties from flood damage to be with the property owners themselves, the City's Transportation & Storm Water Department (TSW) is responsible for evaluating and conducting maintenance and repair of the public municipal storm water conveyance system throughout much of the City.

The City maintained drainage facilities in accordance with the Master Storm Water System Maintenance Program (MMP), which is proposed to be replaced by the *City of San Diego Municipal Waterways Maintenance Plan* (MWMP). The MWMP was prepared to outline specific activities, methods, and procedures that will guide ongoing storm water system maintenance and repair of facilities. The MWMP provides a comprehensive approach to identify and regulate maintenance activities, primarily within open storm water facilities (i.e., those facilities located above ground and not within closed systems, such as pipes). This *Hydrology and Hydraulics Technical Report* was prepared to summarize the engineering technical analysis performed to identify maintenance activities for facilities in the MWMP.

1.2 SCOPE OF WORK

The objectives of the MWMP require the ability of TSW to be responsive to newly identified flood risks while also streamlining approvals for routine preventive maintenance that reduces flood risks. To accomplish this, the MWMP identifies the following:

1. A range of plan-wide activities that may occur throughout the storm water system where flood risks may arise and that would be conducted in accordance with a regulatory framework identified under the MWMP and associated permits.
2. A list of Facility Maintenance Plans (FMPs) that provide specific details and requirements for the majority of facilities that are likely to require routine maintenance and repair.

Together, these two components provide operational flexibility while also providing specific, detailed analysis for the majority of anticipated maintenance and repair activities to streamline the review and approval process.

This technical report was drafted based on a facility evaluation list of 59 channel/ditch and basin facility groups that were selected as the most likely locations where FMPs would be required (Tables 1-1 and 1-2). Of those facility groups, the MWMP proposes FMPs for 56 channel/ditch and basin facility groups. The MWMP also proposes FMPs for 10 structural facility groups, but these are not addressed in this technical report. The conditions affecting the structural facility group capacity and maintenance recommendations were assessed based on visual inspection and a hydrology and hydraulics (H&H) analysis was not required. The structure FMPs provide facility-specific H&H recommendations. This technical report provides analysis of all 59 channel/ditch and basin facility groups evaluated, which then can be used as the basis for a project-level analysis for the 56 proposed facility group FMPs. The conclusions of this project-level analysis may be also used to analyze additional similar or related activities identified for a program-level analysis in the MWMP program area; however, such program-level analysis is not included in this technical report. However, information for the 16 channel/ditch facility segments where no FMPs are proposed is included in Appendix A to support potential future preparation and approvals of future FMPs.

To assess the potential to reduce flood risks and local, adverse hydraulic impacts (e.g., erosive velocities) by removing sediment and vegetation, H&H analyses were prepared for each facility group in the MWMP area and are summarized in this report. Some facilities may be located within Special Flood Hazard Areas, which includes floodways identified in the Federal Emergency Management Agency (FEMA) Flood Insurance Study and associated Flood Insurance Rate Maps. The potential maintenance in Special Flood Hazard Areas would maintain the hydraulic function of these areas and would not involve permanent substantial structures or alterations to the channelization of any Special Flood Hazard Area in a manner than would reduce the current flood carrying capacity. Due to the findings of the MWMP analysis, this report may not prescribe maintenance activities for all facility groups in the six watershed management areas within the City's jurisdiction.

1.3 PURPOSE

The purpose of the H&H analyses was to answer the following technical questions:

- Will proposed maintenance activities reduce flood risk to surrounding properties?
- Is there a potential for maintenance to cause adverse hydraulic conditions within the proposed maintenance area or upstream or downstream (within the domain of analysis) of the proposed maintenance area?

This technical report uses the City of San Diego Drainage Design Manual (SDDDM), FEMA data, and guidance from the Southern California Coastal Water Research Project's *Hydromodification Screening Tools* (SCCWRP 2010) to assess the H&H conditions. In addition, the H&H analysis provides information that allows for environmental impact analysis of MWMP implementation activities.

Table 1-1
Channel Facility Summary

Facility Group Name	Watershed	No. of Segments	Segment Names (Segment Numbers)
Green Valley Creek – Pomerado	San Dieguito	2	Pomerado 1 (1-04-030) Pomerado 2 (1-04-033)
Los Peñasquitos Canyon Creek - Sorrento	Los Peñasquitos	1	Sorrento Valley 1 (2-01-000)
Los Peñasquitos Lagoon – Industrial	Los Peñasquitos	2	Industrial 1 (2-01-120) Industrial 2 (2-01-122)
Los Peñasquitos Lagoon – Tripp	Los Peñasquitos	1	Tripp 1 (2-01-130)
Los Peñasquitos Canyon Creek – Black Mountain	Los Peñasquitos	2	Black Mountain 1 (2-01-200) Black Mountain 2 (2-01-210)
Soledad Canyon Creek - Sorrento	Los Peñasquitos	4	Roselle 1 (2-03-000) Roselle 2 (2-03-002) SorValRd 1 (2-03-004) SorValRd 2 (2-03-006)
Carroll Canyon Creek - Carroll	Los Peñasquitos	1	Carroll Canyon 1 (2-03-012)
Soledad Canyon Creek – Flintkote	Los Peñasquitos	1	Flintkote 1 (2-03-100)
Soledad Canyon Creek – Dunhill	Los Peñasquitos	1	Dunhill 1 (2-03-150)
Chicarita Creek – Via San Marco	Los Peñasquitos	1	Via San Marco 1 (2-05-140)
Torrey Pines - Torrey	Mission Bay	1	Torrey Pines 1 (3-00-120)
Mission Bay – MBHS	Mission Bay	2	PB-Olney 1 (3-02-101) MBHS 1 (3-02-103)
Mission Bay – Mission Bay Drive	Mission Bay	1	Mission Bay Drive 1 (3-02-130)
Miramar – Engineer	Mission Bay	1	Engineer 1 (3-03-901)
Tecolote Creek - Chateau	Mission Bay	1	Chateau 1 (3-04-055) Chateau 2 (3-04-250)

Table 1-1
Channel Facility Summary

Facility Group Name	Watershed	No. of Segments	Segment Names (Segment Numbers)
Tecolote Creek – Morena	Mission Bay	1	Morena 1 (3-04-101)
Tecolote Creek – Genesee	Mission Bay	1	Genesee 1 (3-04-160)
San Diego River – Nimitz	San Diego River	3	Nimitz 1 (4-01-103) Nimitz 2 (4-01-105) Nimitz 3 (4-01-107)
San Diego River – Valeta	San Diego River	1	Valeta 1 (4-01-120)
San Diego River – Camino del Rio	San Diego River	2	Camino del Arroyo 1 (4-03-101) Camino del Rio 1 (4-03-103)
Murphy Canyon Creek - Stadium	San Diego River	4	Stadium 1 (4-04-000) Stadium 2 (4-04-002) Murphy Canyon 1 (4-04-006) Murphy Canyon 2 (4-04-008)
Alvarado Canyon Creek – Mission Gorge	San Diego River	4	Mission Gorge 1 (4-07-002) Mission Gorge 2 (4-07-004) Mission Gorge 3 (4-07-009) Mission Gorge 4 (4-07-011)
Alvarado Canyon Creek – Alvarado	San Diego River	3	Alvarado 1 (4-07-021) Alvarado 2 (4-07-023) Alvarado 3 (4-07-250)
Murray Reservoir – Cowles Mountain	San Diego River	2	Cowles Mountain 1 (4-07-901) Cowles Mountain 2 (4-07-911)
Norfolk Canyon Creek - Fairmount	San Diego River	6	Fairmount 1 (4-08-008) Fairmount 2 (4-08-011) Fairmount 3 (4-08-014) Fairmount 4 (4-08-017) Baja 1 (4-08-105) Aldine 1 (4-08-150)

Table 1-1
Channel Facility Summary

Facility Group Name	Watershed	No. of Segments	Segment Names (Segment Numbers)
Washington Canyon Creek - Washington	Pueblo San Diego	2	Washington 1 (5-02-151) Washington 2 (5-02-153)
Mission Hills Canyon Creek - Titus	Pueblo San Diego	1	Titus 1 (5-02-162)
Powerhouse Canyon Creek - Pershing	Pueblo San Diego	2	Pershing 1 (5-03-011) Pershing 2 (5-03-100)
San Diego Bay – 28th St	Pueblo San Diego	1	28th St 1 (5-03-901)
Chollas Creek – National	Pueblo San Diego	2	National 1 (5-04-004) National 2 (5-04-006)
Chollas Creek – Rolando	Pueblo San Diego	3	Cartagena 1 (5-04-044) Rolando 1 (5-04-046) Rolando 2 (5-04-048)
Chollas Creek– Martin	Pueblo San Diego	1	Martin 1 (5-04-101)
Chollas Creek– J St	Pueblo San Diego	1	J St 1 (5-04-163)
Auburn Creek – Home	Pueblo San Diego	5	Home 1 (5-04-220) Home 2 (5-04-224) Home 3 (5-04-227) Home 4 (5-04-229) Home 5 (5-04-231)
Auburn Creek – Wightman	Pueblo San Diego	2	Wightman 1 (5-04-239) Wightman 2 (5-04-241)
Auburn Creek – Oakcrest	Pueblo San Diego	1	Oakcrest 1 (5-04-245)
Chollas Creek– Megan	Pueblo San Diego	2	Megan 1 (5-04-260) Megan 2 (5-04-262)
Chollas Creek – 54th St	Pueblo San Diego	1	54th St 1 (5-04-280)
South Chollas Creek – Southcrest	Pueblo San Diego	2	Alpha 1 (5-05-006) Ocean View 1 (5-05-008)
South Chollas Creek – Euclid	Pueblo San Diego	2	Euclid 1 (5-05-019) Euclid 2 (5-05-021)
South Chollas Creek – Federal	Pueblo San Diego	2	Federal 1 (5-05-035) Federal 2 (5-05-037)
South Chollas Creek Encanto Branch – Castana	Pueblo San Diego	1	Castana 1 (5-05-205)
South Chollas Creek Encanto Branch – Imperial	Pueblo San Diego	2	Imperial 1 (5-05-304) Imperial 2 (5-05-306)
South Chollas Creek Encanto Branch – Jamacha	Pueblo San Diego	5	Jamacha 1 (5-05-603) Jamacha 2 (5-05-606)

Table 1-1
Channel Facility Summary

Facility Group Name	Watershed	No. of Segments	Segment Names (Segment Numbers)
			Jamacha 3 (5-05-610) Lobrico 1 (5-05-702) Cadman 1 (5-05-802)
Paleta Creek – Cottonwood	Pueblo San Diego	2	Cottonwood 1 (5-06-005) Cottonwood 2 (5-06-008)
Paleta Creek – Solola	Pueblo San Diego	3	Solola 1 (5-06-020) Solola 2 (5-06-023) Cervantes 1 (5-06-025)
Sweetwater River – Parkside	Sweetwater	1	Parkside 1 (5-11-003)
Nestor Creek - Nestor	Otay	6	Cedar 1 (5-22-008) Cedar 2 (5-22-010) Dahlia 1 (5-22-013) Cerissa 1 (5-22-016) Grove 1 (5-22-023) 30th St 1 (5-22-028)
Nestor Creek – Outer	Otay	2	Outer 1 (5-22-110) Outer 2 (5-22-112)
Tijuana River - Pilot & Smugglers	Tijuana River	2	Pilot Channel 1 (6-01-020) Smuggler's Gulch 1 (6-01-100)
Tijuana River – Tocayo	Tijuana River	2	Tocayo 1 (6-02-115) Tocayo 2 (6-02-118)
Tijuana River – Smythe	Tijuana River	5	Via Encantadores 1 (6-03-135) Via Encantadores 2 (6-03-138) Via Encantadores 3 (6-03-143) Smythe 1 (6-03-147) Via de la Bandola 1 (6-03-150)
Tijuana River – La Media	Tijuana River	1	La Media 1 (6-06-011)

MBHS = Mission Bay High School; PB = Pacific Beach

Table 1-2
Basin Facility Summary

Facility Group	Watershed	Number of Segments	Segment Names (Segment Numbers)
Green Valley Creek – Paseo del Verano	San Dieguito	1	Paseo del Verano 1 (1-04-200)
Los Peñasquitos Canyon Creek – 5-805 Basin	Los Peñasquitos	1	5-805 Fwys 1 (2-01-900)
Alta La Jolla – Vickie	Los Peñasquitos	1	Vickie 1 (3-00-150)
Maple Canyon Creek - Maple	Pueblo San Diego	1	Maple 1 (5-02-140)
Spring Canyon Creek - Cactus	Tijuana	2	Cactus 1 (6-04-251) Cactus 2 (6-04-253)
Tijuana River – Siempre Viva	Tijuana	1	Siempre Viva 1 (6-05-110)

1.4 REPORT ORGANIZATION

This report is organized as follows:

- Chapter 1 provides the background and purpose.
- Chapter 2 provides an overview of H&H concepts and the City's storm water system.
- Chapter 3 summarizes the technical methodology used for the H&H analyses of channel facilities.
- Chapter 4 summarizes the technical methodology used for the H&H analyses of basin facilities.
- Chapter 5 summarizes the results of the H&H analysis performed for each facility group.
- Chapter 6 describes the post-maintenance erosion control measures.
- Chapter 7 describes the use of H&H analysis results to support environmental impacts analysis for the MWMP.
- Chapter 8 presents a glossary of terms used in this report.
- Chapter 9 presents the references used in this report.
- Appendix A provides the H&H fact sheets that summarize the results from the H&H analysis for each facility group.

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2 INTRODUCTION TO BASIC HYDROLOGY AND HYDRAULICS CONCEPTS AND CITY PROCESSES

This chapter introduces the overall concepts that apply to how maintenance of the City's storm water system is considered by this report. This includes an introduction to the hydrologic cycle, how this cycle applies to the City's storm water system, and discussion of system maintenance required to function safely and as intended.

2.1 HYDROLOGIC CYCLE

Understanding the operation and maintenance considerations for the City's storm water system begins with an understanding of the hydrologic cycle. The hydrologic cycle is the movement of water on, above, and below the Earth's surface. The continuous physical processes that form the hydrologic cycle are illustrated in Figure 2-1 and can originate at any one of the following processes: evaporation, condensation, precipitation (e.g., rainfall), interception, infiltration, evapotranspiration, runoff, and storage.

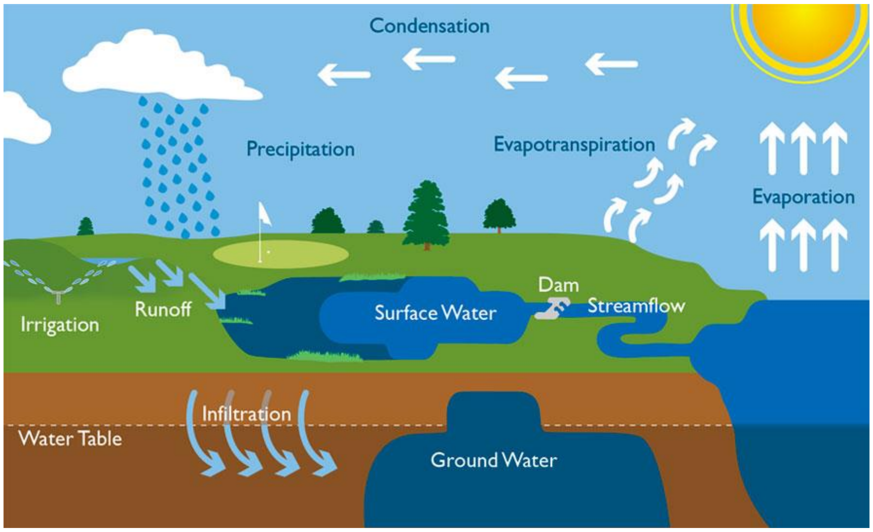

Figure 2-1. Schematic of a Hydrologic Cycle[1]

A common starting point in the cycle is to consider water that evaporates from land surfaces, water bodies, and the oceans and becomes water vapor, which is carried over the Earth by atmospheric circulation. Water vapor is then condensed and precipitated (rain or snow) over the land and oceans.

[1] Reprinted from *Best Management Practices for New York State Golf Courses*, n.d. Retrieved October 2018 from http://nysgolfbmp.cals.cornell.edu/hydrologic-cycle/.

On land, precipitation can be intercepted by vegetation, infiltrate into the ground and flow through soil as subsurface flow, or flow over the ground surface (i.e., runoff).

Focusing on the precipitation that becomes runoff, surface channels—natural or constructed—collect and convey the runoff via the effect of gravity from the high point of a drainage basin (i.e., watershed) to lower elevations. Most runoff in San Diego watersheds ultimately ends up in the Pacific Ocean. Runoff may consist of precipitation that falls directly on streams, surface water that flows over land and through channels, or subsurface water that discharges laterally into a stream. Streamflow is the total runoff confined in stream channels.

2.2 CITY STORM WATER SYSTEM

Precipitation that results in runoff (i.e., storm water runoff) within the watersheds that are coincident with the City of San Diego (upland areas and direct precipitation over the City) is collected within and conveyed by the City storm water system. The City's storm water system's primary function is to safely convey the runoff to protect life and property from potential flooding. This system is effectively a drainage system that includes, but is not limited to, a network of underground storm drain pipes, culverts, outlet/inlet structures (e.g., headwalls), detention basins, ditches, and channels (as defined by City Council Policy 800-04). Since the City's storm water system is separate from the sanitary sewer system, the drainage system is referred to, in a regulatory context, as a Municipal Separate Storm Sewer System (MS4). Groundwater and surface water within the San Diego region are regulated by the San Diego Regional Water Quality Control Board, which maintains and enforces the Regional MS4 Permit. The permit regulates storm water discharges from the City's MS4 to receiving water bodies within the six watershed management areas that encompass the City of San Diego, which are as follows: San Dieguito, Los Peñasquitos, Mission Bay, San Diego River, San Diego Bay, and Tijuana River.

2.3 OPERATION AND MAINTENANCE

The City is responsible for safely operating, maintaining, and repairing the storm water system. Determining the necessity of maintenance activities is based on a multitude of considerations, which are described in detail in Section 2 of the MWMP. It is important to assess maintenance in the context of the natural processes that occur within open channels because of conveyed runoff. Processes such as aggradation (sedimentation), degradation (erosion), and vegetation growth in the channel can impact channel conveyance capacity, which in turn can impact flooding risks.

Aggradation is the process by which the supply of sediment is greater than the amount a channel can transport under a given flowrate. Under this condition, sediment deposits in the channel and accumulates over time. When the climate is dry, channels may deposit more sediment, leading to a decrease in capacity and potentially clogging the channel. Degradation occurs when flowing water removes the channel substrate (i.e., surface on which organisms grow) due to high velocities and transports it downstream. Erosion can damage the channel or adjacent infrastructure. Vegetation growth can also impact channel capacity and generally decreases capacity because vegetation increases flow resistance in the channel. In addition, vegetation growth may damage the channel lining (e.g., roots causing cracking in concrete-lined channels).

Horizontal and vertical adjustments to channel alignments due to aggradation or degradation can be limited by constructed infrastructure. For example, drainage crossings beneath roadways (i.e., culverts) limit vertical adjustment and adjacent development (e.g., roads, sidewalks, parking lots, buildings) limits lateral movement of natural channels. Maintenance activities that address these natural processes include vegetation management, sediment/debris removal, drain structure/structural clearing, and invasive plant species management. Maintenance activities may also include repair activities, such as concrete repair/replacement and bank re-stabilization. The maintenance recommendations in this report are based solely on the H&H analysis presented in this report for each facility group. These H&H maintenance recommendations may be modified in the MWMP when factoring in other environmental constraints, such as biological and cultural resources, which may exclude or limit the maintenance recommended in this report. The specific maintenance recommendations for each facility group and/or segment are provided in Appendix A.

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3 TECHNICAL METHODOLOGY FOR CHANNEL ANALYSIS

This chapter summarizes the technical methods used for the H&H analyses of channel facilities as follows:

- Section 3.1 describes the methods used to quantify the hydrologic flows anticipated in response to precipitation.
- Sections 3.2 describes the methods used to quantify the hydraulic capacity of the channel facilities.
- Section 3.3 describes the process by which channels were analyzed to compare the anticipated flows to the facility capacity to assess if maintenance was necessary

3.1 HYDROLOGICAL ANALYSES

The volume and rate of runoff produced from a watershed for a given storm event (i.e., hydrologic response to precipitation) depends on the drainage area, types of land use, and rainfall intensity measured over time at a specific location. Therefore, for the purposes of this report, hydrologic analyses refer to quantifying the flow resulting from precipitation that is collected and conveyed by the City's storm water system.

The drainage area directly impacts the quantity of flow, and various land use areas within the watershed directly affect the volume of runoff. When measuring runoff, each land use type is assigned a runoff coefficient, which represents the relationship between the amount of runoff and the amount of precipitation. The coefficients range from 0 to 1; lower values represent land use with higher permeability (e.g., parks or open space), and higher values represent land use with lower permeability (e.g., roadways or buildings). The volume of runoff produced from a watershed increases when there are more impermeable surfaces, since water does not have as much opportunity to infiltrate surfaces. The rainfall intensity at a specific location also affects the volume of runoff at a specific location. Rainfall intensity is a historic average of the amount of precipitation that falls over a specified period. The National Oceanic and Atmospheric Administration (NOAA) prepares rainfall intensity values, which are based on years of historical data. The return period for a certain storm event is based on the probability that the given event will be equaled or exceeded in any given year.

A range of hydrologic peak flows, including events for the 2-, 5-, 10-, 25-, 50-, and 100-year frequency storm events, were estimated for the 59 facility groups (119 facility segments) and are summarized in Table 5-1 in Section 5 of this report, and also reported for each facility group in the fact sheets located in Appendix A.

3.1.1 TYPES OF ANALYSIS

The following types of analyses were used to estimate the hydrologic peak flows for the facilities in this report:

1. FEMA Flood Insurance Studies (FIS) from 2012 and 2016
2. Existing Studies, including Drainage Channel Field Assessment Reports (City of San Diego 2016a) and Individual Hydrologic and Hydraulic Assessment (IHHAs) reports prepared for the MMP
3. The Rational Method
4. The Unit Area Method

Where available, previous studies were reviewed to compile peak flows for FIS, Drainage Channel Field Assessment Reports, and IHHAs. Alternatively, a method to approximate peak flows based on other published peak flows (6-Hour Approximation Method) was combined with the Rational Method for areas less than 1 square mile (i.e., 640 acres), or the Unit Area Method, for areas greater than 1 square mile, to model channel segments where peak flows were not available from previous studies. See Section 3.1.2.3 of the SDDDM for a detailed explanation of each method and how it is applied.

The following sections describe each type of peak flow analysis or source of peak flow information in greater detail.

3.1.1.1 FEMA Flood Insurance Studies

A FEMA FIS is a compilation and presentation of flood risk data for specific watercourses, lakes, and coastal flood hazard areas within a community. When a flood study is completed for the National Flood Insurance Program, the information and maps are assembled into an FIS. The FIS report contains detailed flood elevation data in flood profiles and data tables. As stated in Chapter 1, the potential maintenance in Special Flood Hazard Areas would maintain the hydraulic function of these areas and would not involve substantial structures or alterations to the channelization of any Special Flood Hazard Area in a manner than would reduce the current flood carrying capacity. More information about FIS can be found on the FEMA website (https://www.fema.gov/flood-insurance-study) and FIS for a particular location can be found at the FEMA Map Service Center website (https://msc.fema.gov/portal). The FIS specifically list peak flows for 10-, 50-, and 100-year frequency storm events. To obtain 2-, 5- and 25-year peak flows for the segments, a power regression analysis plotted on logarithmic paper (i.e., two-dimensional graph paper) was employed. The analysis uses observed variables to predict the behaviors of other variables. In this analysis, the coefficient of determination (i.e., the portion of difference in the predicted variables that was explained by all the observed variables) was higher than 0.95 in all regression estimates, confirming the goodness of fit.

Figure 3-1 is an example of the peak flow rates published in FIS for a location. It presents peak discharges at the location for the 10%, 2%, 1%, and 0.2% annual chance of the discharges associated with a storm event being equal or exceeded. These four percentages correspond to the peak discharges of the 10-, 50-, 100-, and 500-year frequency storm events. As an example of estimating the additional, non-published peak flow rates (i.e., the 2-, 5-, and 25- year peak flows) using a regression analysis, the highlighted entries in Figure 3-2 were plotted using Microsoft Excel. A power trend line was fit to the data to estimate the 2-, 5-, and 25-year event peak flows, as shown in Figure 3-2.

		Peak Discharges (cubic feet per second)			
Flooding Source and Location	**Drainage Area (sq. miles)**	**10% Annual-Chance**	**2% Annual-Chance**	**1% Annual-Chance**	**0.2% Annual-Chance**
At Atchison, Topeka & Santa Fe Railway	17.8	1,500	4,500	6,700	18,700
At Interstate Highway 805	15.0	1,300	3,800	5,600	15,700
At Carroll Canyon Road	12.0	1,000	3,000	4,500	12,500
Coleman Creek					
Approximately 1,800 Feet Downstream of Highway 78	8.1	--	--	8,750	--
Coyote Creek					
At Apex of Alluvial Fan	132.0	5,200	16,000	24,000	35,200
Culp-Tubb Canyon					
At Apex of Alluvial Fan	13.0	2,400	6,000	8,500	12,500
Dear Springs Creek					
At Mouth	1.8	--	--	1,550	--
Descanso Creek					
At Mouth	5.6	1,300	3,800	6,000	10,400
Dry Canyon					

-- Data Not Available

Figure 3-1. Example FEMA Flood Insurance Studies Data (FEMA 2016)

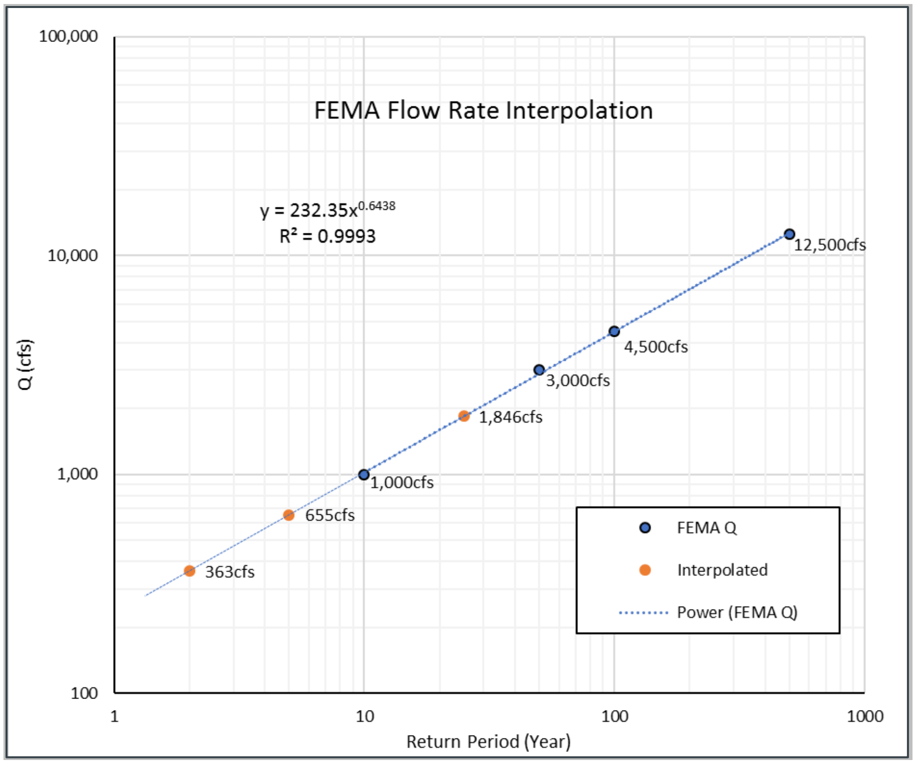

Figure 3-2. Example Power Regression Analysis

3.1.1.2 Existing Studies

Facility segments with IHHA reports previously prepared as part of the MMP were reviewed and summarized for this report. The peak flows in these reports were estimated using one of two methods: a modified Rational Method using the Civil Computer-Aided Design and Drafting Civil Design Hydrology Program Package or existing available hydrologic studies.

3.1.1.3 Rational Method and 6-Hour Approximation Method

The procedures for estimating peak flows using the Rational Method/Modified Rational Method were performed as outlined in the SDDDM for the 100-year frequency storm event. The 2-, 5-, 10-, 25-, and 50-year frequency storm event flow rates were then approximated by taking the ratio of the storm event of interest (i.e., 2-, 5-, 10-, 25-, or 50-year) 6-hour precipitation value and the 100-year storm event 6-hour precipitation value (P_{100}), and then multiplying the 100-year storm event peak flow (Q_{100}) by the ratio to estimate the flow rate for the storm event of interest.

The method described above is represented in the following equation:

$$Q_{unknown\ storm\ event} = \frac{P_{unknown\ storm\ event}}{P_{100}} * Q_{100}$$ Equation 3-1

Where:

$Q_{unknown\ storm\ event}$ = peak flow, in cubic feet per second (cfs) of storm event to be approximated (i.e., 2-, 5-, 10-, 25-, or 50-year storm events)

$P_{unknown\ storm\ event}$ = 6-hour precipitation (inches) of storm event to be approximated (i.e., 2-, 5-, 10-, 25-, or 50-year storm events)

Q_{100} = peak flow, in cubic feet per second (cfs) for the 100-year storm event

P_{100} = 6-hour precipitation (inches) for the 100-year storm event

Geographic information system (GIS) software was then used to outline the drainage area in relation to the outlet of each channel segment. Figure 3-3 shows an example of a flow accumulation and drainage line as generated in GIS.

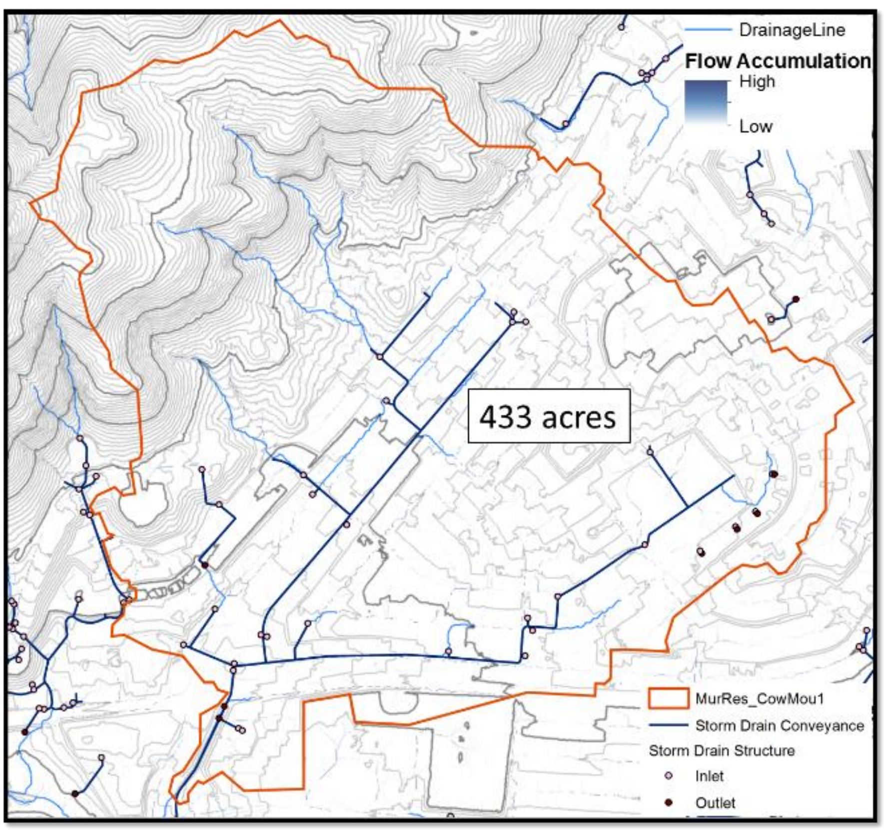

Figure 3-3. Example GIS Drainage Delineation

Peak flows for drainage areas delineated in GIS less than 1 square mile (i.e., 640 acres) were calculated using the Rational Method to estimate runoff. The Rational Method formula estimates the peak rate of runoff at any location in a watershed as a function of the drainage area (A), runoff coefficient (C), and rainfall intensity (i) for a duration equal to the time of concentration (Tc), which is the time required for water to flow from the most remote point of the basin to the location being analyzed. The Rational Method formula is expressed in Equation 3-2.

$$Q = C * i * A$$ Equation 3-2

Where:

Q = peak flow, in cubic feet per second (cfs)

C = runoff coefficient, unitless

i = rainfall intensity, in inches per hour (in/hr)

A = area, in acres (ac)

The runoff coefficient (C) was determined using the land use shapefile from SanGIS, the online, public Regional Data Warehouse for San Diego GIS data. Each land use was assigned a C factor based on the SDDDM guidelines, and then the factors were area-weighted, meaning varying weight (or influence) was assigned based on the composition of land type for a specific area, to determine a composite C for the drainage area using Equation 3-3.

$$C = \frac{\sum_{i=1}^{n} C_i * A_i}{A}$$ Equation 3-3

Where:

C_i = C factor for land use “I”

A_i = area of land use “i,” in acres (ac)

n = total number of land uses

A = total drainage area, in acres (ac)

Figure 3-4 shows an example of the weighted C factor for a modeled area.

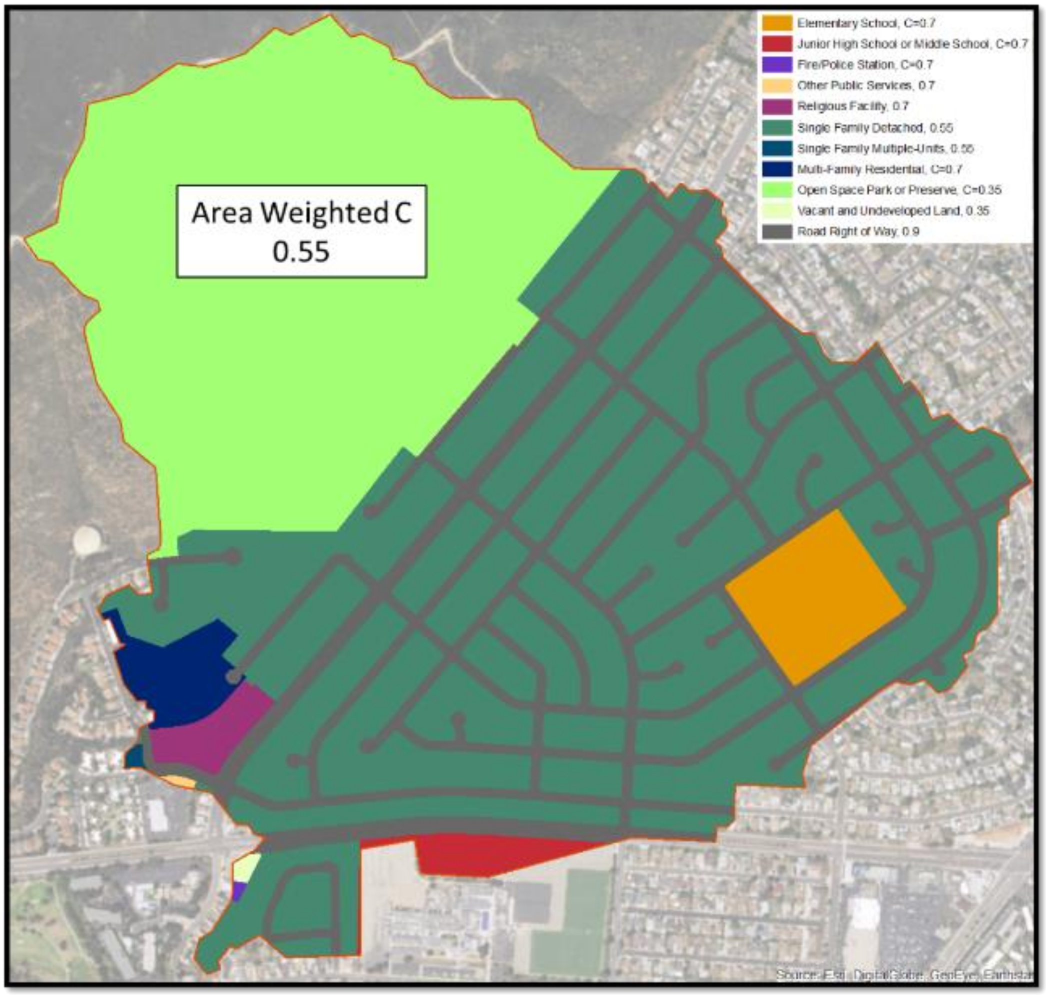

Figure 3-4. Example Rational Method C Factor

The rainfall intensity (i) was determined using nomographs provided in the SDDDM. These nomographs, which are diagrams designed to approximately graph mathematical functions, relate rainfall intensity to time of concentration (T_c). T_c was calculated using Equation 3-4.

$$T_c = T_i + T_t \qquad \text{Equation 3-4}$$

Where:

T_c = time of concentration, in hours (hr)

T_i = inlet time, in hours (hr), or the time required for the storm water to flow to the first inlet in the system; it is the sum of time in overland flow across lots and in the street gutter.

T_t = travel time, in hours (hr), or the time required for the storm water to flow in the storm drain from the most upstream inlet to the point in question.

Travel times were calculated using the length of the longest flow path and the velocity of the flow to account for flow from the most hydraulically remote location in the drainage area. Figure 3-5 shows an example of the lengths of the longest channel flow paths for a natural, storm drain and channel system, which were determined using GIS tools. The flow path length in this example results in a calculated time of concentration of 23.6 minutes.

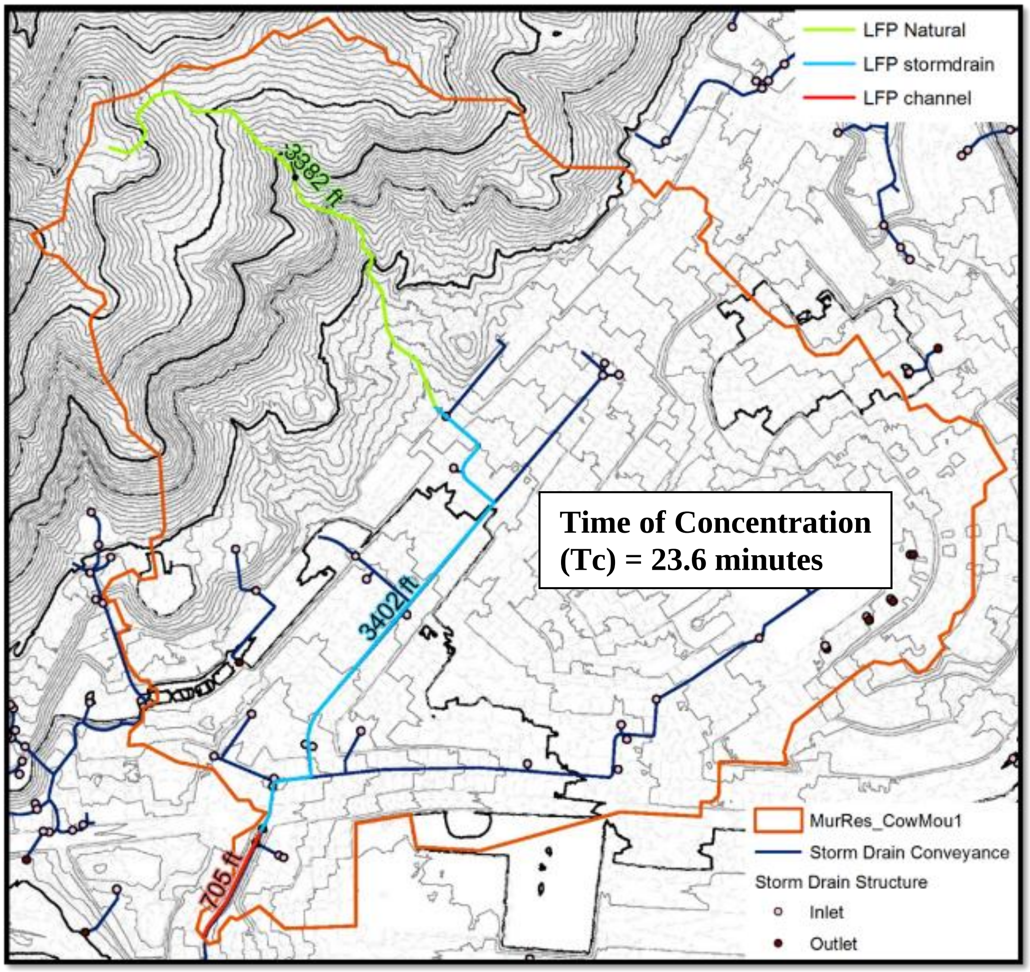

Figure 3-5. Example Longest Flow

The longest flow path for the inlet travel time portion is over natural landscape, so the following equation (Equation 3-5) from the SDDDM was used.

$$T_i = T_c = \left(\frac{11.9 * L^3}{\Delta E}\right)^{0.385} + 0.167\ hours \quad \text{Equation 3-5}$$

Where:

T_c = time of concentration, in hours (hr)

L = watercourse distance, in miles (mi)

ΔE = change in elevation along effective slope line, in feet (ft)

The storm drain and open channel travel times were estimated using Equation 3-6.

$$T_t = \frac{L}{V * 60}$$ Equation 3-6

Where:

T_t = travel time, in hours (hr)

L = length of conveyance system, in feet (ft)

V = velocity, in feet per second (fps)

Open channel flow velocity was estimated using Equation 3-7.

$$V = \frac{1.49}{n} * R^{\frac{2}{3}} * S^{\frac{1}{2}}$$ Equation 3-7

Where:

V = velocity, in feet per second (fps)

n = Manning's roughness coefficient, dimensionless (0.015 for concrete channel and 0.013 for reinforced concrete pipe), unitless

R = hydraulic/wetted radius, in feet (ft)

S = longitudinal slope of channel, in foot per foot (ft/ft)

To determine the rainfall intensity, T_c was plotted on the rainfall intensity nomograph from the SDDDM. Plotting the Total T_c for the modeled area, using 23.6 minutes as an example, on the nomograph results in a rainfall intensity of approximately 2.3 inches/hour. This number is derived by finding where a straight line from 23.6 minutes on the bottom axis intersects the 100-year storm event curve (step 1) and then tracing a straight line from that intersection point to the Intensity axis on the left side of the figure (step 2) to determine the estimated rainfall intensity (2.3 in/hr in this example). Finally, the rainfall intensity is multiplied by the elevation factor (step 3) according to the elevation of the drainage area. These steps to estimate an example rainfall intensity are shown in Figure 3-6.

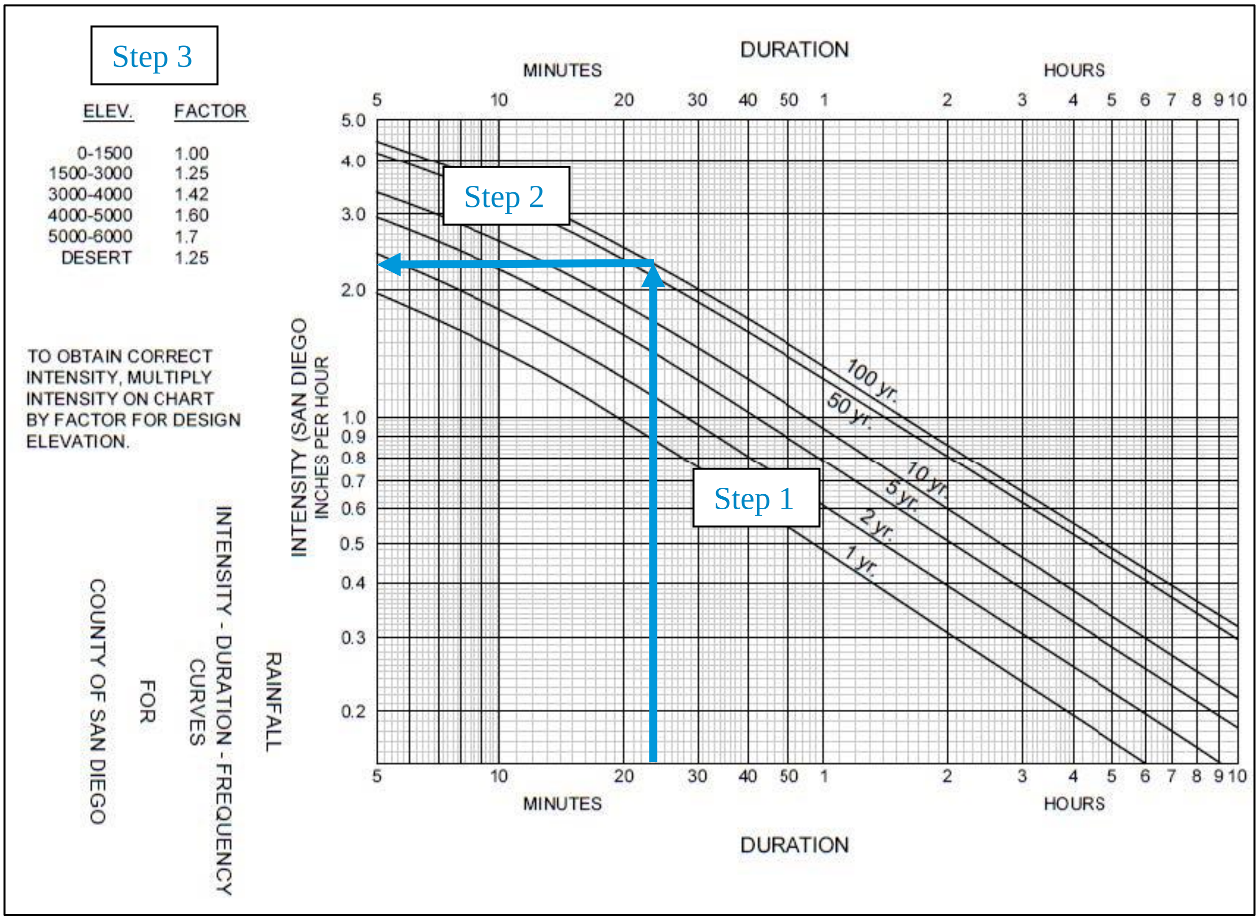

Figure 3-6. Example Rainfall Intensity Determination

The 100-year rainfall intensity was then used to calculate the Q_{100} using the Rational Method equation. Q_{100} is used to scale the additional storm events (e.g., 2-, 5-year storm event) using 6-hour precipitation values (see Table 3-1) as obtained from the NOAA Precipitation Frequency Data Server (hdsc.nws.noaa.gov).

Table 3-1
Rational Method and 6-Hour Precipitation Frequency Data

Storm Event	6-hour Precipitation (P) (in)	Runoff Coefficient (C)	Intensity (I) (inches per hour)	Area (A) (acres)	Equation	Peak Flow Rate (Q) (cfs)
100-year	2.63	0.55	2.4	433	$Q_{100} = C * i * A$	572
50-year	2.36	Not Applicable			$Q_{50} = \frac{P_{50}}{P_{100}} * Q_{100}$	513
25-year	2.09				$Q_{25} = \frac{P_{25}}{P_{100}} * Q_{100}$	455
10-year	1.74				$Q_{10} = \frac{P_{10}}{P_{100}} * Q_{100}$	378
5-year	1.48				$Q_{5} = \frac{P_{5}}{P_{100}} * Q_{100}$	322
2-year	1.15				$Q_{2} = \frac{P_{2}}{P_{100}} * Q_{100}$	250

cfs = cubic feet per second; hr = hour; in = inch

3.1.1.4 Unit Area and 6-Hour Approximation Methods

In the Unit Area Method, for segments with a drainage area greater than 1 square mile, Q_{100} was estimated based on the size of the watershed tributary related to the segment and the unit 100-year peak discharge. These assumptions are shown in Table 3-2.

Table 3-2
Unit Area Method Assumptions

100-Year Peak Discharge (Q_{100}) Estimation Based on Watershed Size			
Watershed Area (square miles)	≥1 and <2	≥2 and <4	≥4
cfs per acre	2	1.5	1

cfs = cubic feet per second

The 2-, 5-, 10-, 25-, and 50-year storm event peak discharges were then approximated by multiplying the ratio of the given storm event 6-hour precipitation value and the 100-year storm event 6-hour precipitation value by Q_{100}. An example calculation is provided below for a hypothetical drainage area.

The drainage area for this example was 3.6 square miles (2,302 acres); therefore, the Unit Area Method was used to estimate peak flow rates because the area is greater than 1 square mile. Based on the assumptions in Table 3-3, 1.5 cfs/acre was used to estimate Q_{100}. Q_{100} was then used to scale the additional storm events using 6-hour precipitation values (see Table 3-3) as obtained from the NOAA Precipitation Frequency Data Server (hdsc.nws.noaa.gov).

Table 3-3
Unit Area Method and 6-Hour Assumption Method

Storm Event	6-Hour Precipitation (P) (in)	Equation	Peak Flow (Q) (cfs)
100-year	2.3	$Q_{100} = 2302 * 1.5$	3,453
50-year	2.1	$Q_{50} = \frac{P_{50}}{P_{100}} * Q_{100}$	3,153
25-year	1.8	$Q_{25} = \frac{P_{25}}{P_{100}} * Q_{100}$	2,702
10-year	1.5	$Q_{10} = \frac{P_{10}}{P_{100}} * Q_{100}$	2,252
5-year	1.3	$Q_{5} = \frac{P_{5}}{P_{100}} * Q_{100}$	1,952
2-year	0.9	$Q_{2} = \frac{P_{2}}{P_{100}} * Q_{100}$	1,351

cfs = cubic feet per second; in = inches

3.2 HYDRAULIC ANALYSES

Channel characteristics directly impact flow capacity and velocity. Therefore, for the purposes of this report, hydraulic analyses refer to quantifying the capacity of the facilities that comprise the City's storm water system. Assuming a channel has uniform flow, capacity for a given channel cross-section can be determined using Manning's equation for open channel flow. Manning's equation, as indicated in Section 3.2.1 of the SDDDM, computes basic differences in flow velocities and water surface elevations by measuring hydraulic roughness, which is the amount of resistance water experiences when passing over land and channel features. The type of channel substrate and the type and density of present vegetation determines which Manning's roughness coefficient is selected. Channel capacity decreases as vegetation increases, and the roughness coefficient value increases. The cross-sectional area of the channel directly impacts the capacity, as does the channel depth. The channel slope also has a proportional relationship to the channel capacity.

In addition to flow rate quantification, the hydraulic analyses also estimate the velocity of water during 2-, 5-, 10-, 25-, 50-, and 100-year frequency storm events. This velocity, combined with channel substrate conditions, helps determine the potential for erosion within the channels, as well as within the upstream and downstream reaches included in this analysis. The hydraulic analysis methods described in the following sections are based on the SDDDM and guidance from the *Hydromodification Screening Tools* (SCCWRP 2010).

3.2.1 TYPE OF ANALYSIS

The conveyance capacity (i.e., flow the channel can convey before flooding) and velocities within the channel segment were estimated using the U.S. Army Corps of Engineers' (USACE) Hydrologic Engineering Center–River Analysis System (HEC-RAS) model. Based on the characteristics of the channel segments one of the following three types of analysis were used to estimate the hydraulic capacity:

1. Existing Studies
2. Simple HEC-RAS
3. Detailed HEC-RAS

3.2.1.1 Existing Studies

Facility segments with IHHA reports previously prepared as part of the MMP were reviewed and summarized for this report. The hydraulics analysis methodology used in the IHHA reports are similar to the detailed HEC-RAS methodology described in this report.

3.2.1.2 HEC-RAS

HEC-RAS can perform one-dimensional hydraulic calculations for natural and engineered channels using the energy equation and the momentum equation. These equations determine the depth, velocity, and width of flow. For the MWMP, HEC-RAS modeling was performed using a sub-critical (i.e., slow or stable) or mixed (sub-critical and super-critical; i.e., slow and stable to fast and unstable) flow regime. More information regarding the HEC-RAS model can be found in the associated user manual available on the USACE website (http://www.hec.usace.army.mil/software/hec-ras/documentation.aspx).

Major HEC-RAS model inputs and parameters utilized in the MWMP hydraulic analysis, including channel geometry, hydraulic roughness, and boundary conditions that are applicable to both simple and detailed HEC-RAS models, are described below.

Geometric Input

Topographic data for the HEC-RAS program were extracted using the HEC-GeoRAS toolbox for ArcGIS. HEC-GeoRAS tools were used to create GIS stream elements, including the centerline, bank stations, flow paths, and channel cross-sections, based on the City's 2014 Digital Elevation Model (DEM), a high-resolution elevation model developed by NOAA to support tsunami forecasting and warning efforts. The results from HEC-GeoRAS were then imported into HEC-RAS where manual modifications to cross-sectional data were performed to accurately reflect DEM data (e.g., cross-sections underneath bridges). This manual entry was based on as-built information and field verification.

Hydraulic Roughness Input

Manning's roughness coefficients were selected in accordance with the SDDDM. The hydrology and hydraulic fact sheets in Appendix A summarize the assumptions used to assign hydraulic roughness input for each segment.

Boundary Conditions

Boundary conditions were necessary for the program to compute water surface elevations. The following assumptions were used for boundary conditions:

- When this information is available from previous reports/models (e.g., FEMA FIS), known water surface elevations were used.
- When the information is not available from previous reports/models, the steady flow boundary conditions of the hydraulic models were defined by calculating the normal depth of the channel at the downstream and upstream ends. In case of sub-critical flow, a downstream boundary condition was needed for the analysis, since the flow downstream was controlled. For supercritical flow, normal depth calculations at the upstream end were used. To determine the downstream boundary conditions for channels with a culvert downstream, the domain of analysis was extended to include open channel flow at the downstream of the culvert with the ability of forming a normal depth.

The following sections provide more detail on how the two types of HEC-RAS models, simple or detailed, were developed. Section 3.3 further describes the assessment methodology implemented for each facility segment.

3.2.1.3 Simple HEC-RAS

Simple HEC-RAS models were developed for facility groups that were engineered segments with as-built drawings or concrete-lined (bed and bank) segments where geometry was relatively easy to characterize and input into the model. For simple HEC-RAS models, model inputs for channel geometry were necessary at the start of the segment, end of the segment and the following locations for the hydraulic structures (e.g., culvert, pedestrian bridge) within the segment:

- Upstream of a hydraulic structure;
- Midpoint of a hydraulic structure; and
- Downstream of a hydraulic structure.

These locations are depicted in Figure 3-7.

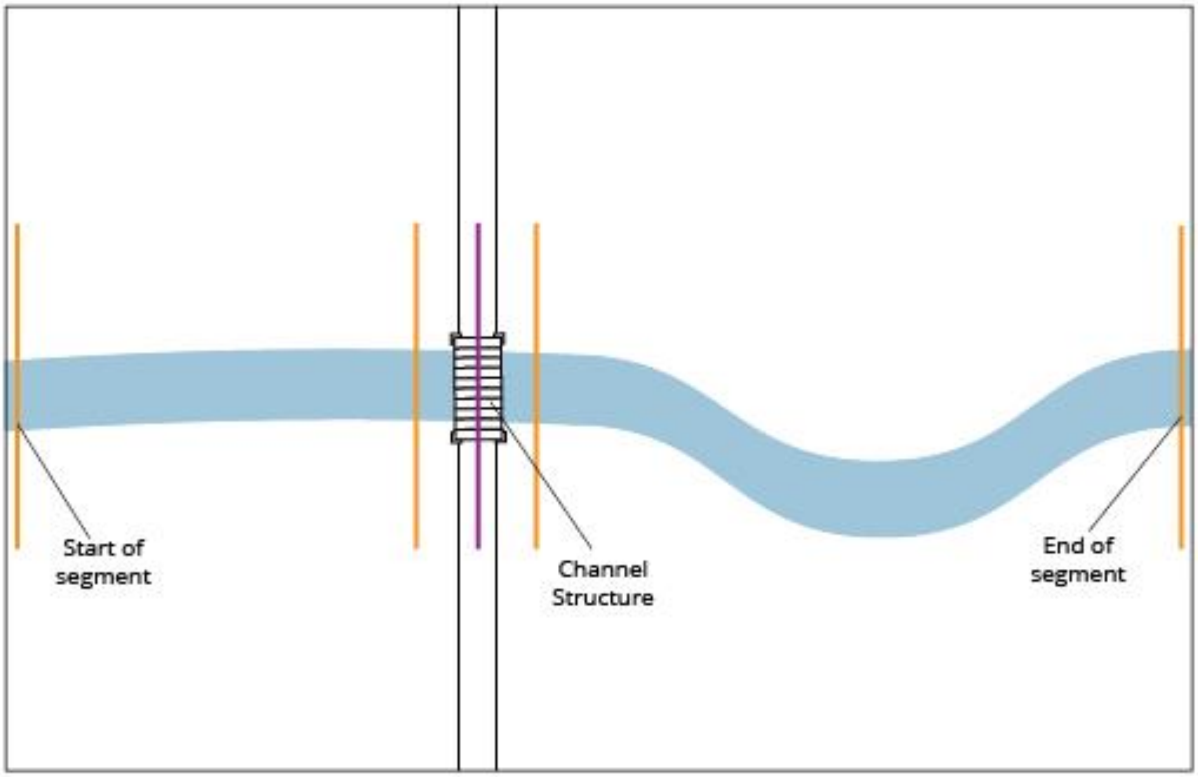

Figure 3-7. Simple Model Cross-Section Input

3.2.1.4 Detailed HEC-RAS

Detailed HEC-RAS models were developed for facility groups that did not have as-built drawings (excluding concrete-lined segments); i.e., natural water courses that had more complex geometry inputs into the model. As a result, detailed HEC-RAS models included additional cross-sections. In addition to the HEC-RAS cross-section locations used for simple HEC-RAS analysis, the detailed HEC-RAS analysis included three cross-sections, at each major bend as follows:

- At the beginning of the curvature
- At the midpoint of the curve
- At the end of the curvature

These locations are depicted in Figure 3-8.

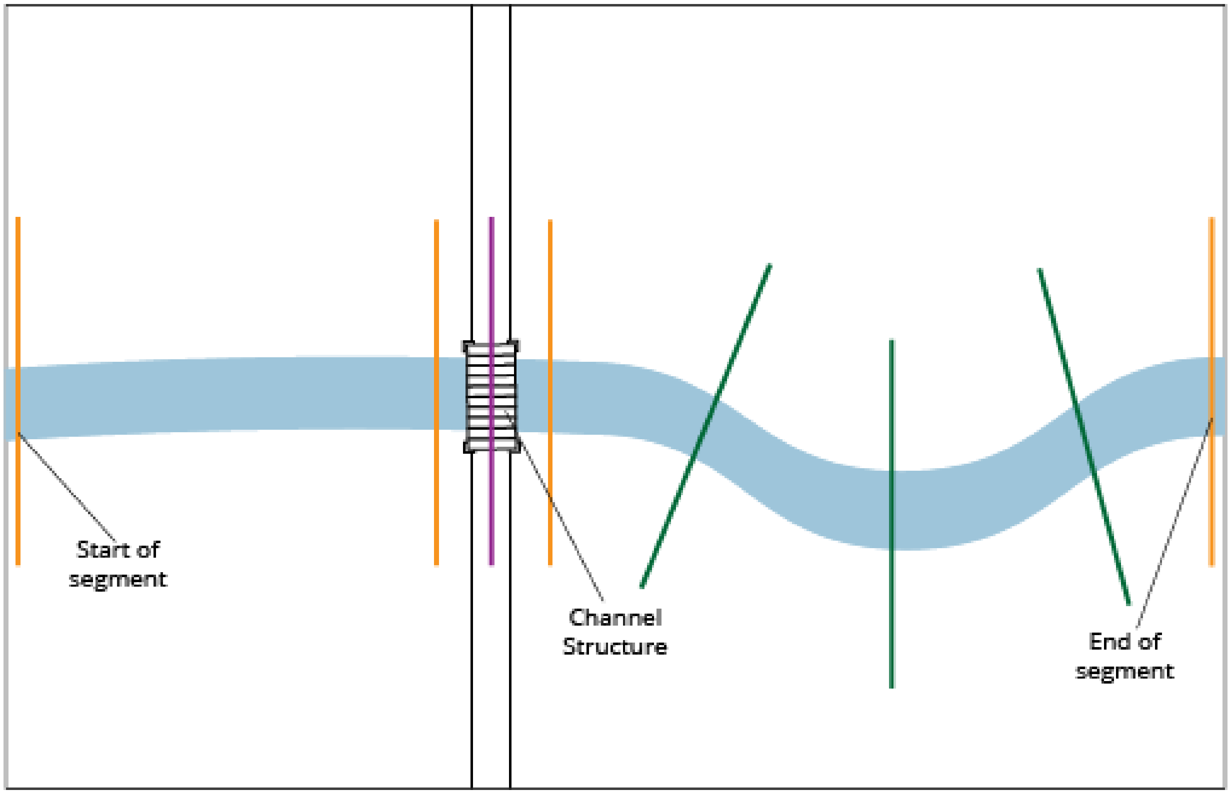

Figure 3-8. Detailed Model Cross-Section Input

Detailed HEC-RAS models also considered an extended domain of analysis. The domain of analysis is the longitudinal extents of the channel or ditch that is analyzed outside the extents of the facility group or facility segment. This is necessary to account for increased velocities and conveyance capacity that result from performing recommended maintenance, and that may spread downstream (and sometimes upstream) from the segment that receives maintenance. To evaluate the effects of increased velocities and conveyance capacity, the HEC-RAS models were extended upstream and downstream of the segment. The total length that was evaluated is defined as the domain of analysis.

Determining the domain of analysis includes the following: assessing the incremental flow accumulations downstream of the segment, identifying hard points downstream, and quantifying downstream tributary influences. The downstream and upstream extents of analysis are defined as follows:

- **Downstream**, extends the domain until it reaches the closest of the following:
    - At least one reach downstream of the first grade-control point (but preferably the second downstream grade-control location)
    - A tidal backwater/lentic water body

- An equal order tributary (Strahler 1952)
- A two-fold increase in drainage area

Or, it demonstrates sufficient flow attenuation through existing hydrologic modeling.

- **Upstream**, extends the domain to whichever of the following comes first:
  - A distance upstream equal to 20 channel widths
  - To grade control point in good condition

The proposed extents for the domain of analysis are consistent with the current state of science as published in the Southern California Coastal Water Research Project's *Final Hydromodification Management Plan* (SCCWRP 2011) and the City's Storm Water Standards Manual (City of San Diego 2018).

3.3 ASSESSMENT METHODOLOGY

To effectively evaluate the hydraulic impacts for the MWMP in a cost-efficient manner, the 59 MWMP-identified facility groups were divided into segments, and then sorted into categories as illustrated in Figure 3-9. The following parameters were established to evaluate the hydraulic impacts of proposed maintenance on the facilities:

1. A facility group was divided into multiple segments primarily when a change in substrate (i.e., channel lining) was observed within its extent (i.e., the full length of the facility group). The 59 facility groups were divided into 119 segments.
2. Each segment was sorted into one of three categories based on the channel lining and availability of as-built drawings, which were used to determine the level of hydraulic analysis necessary to evaluate the impacts.

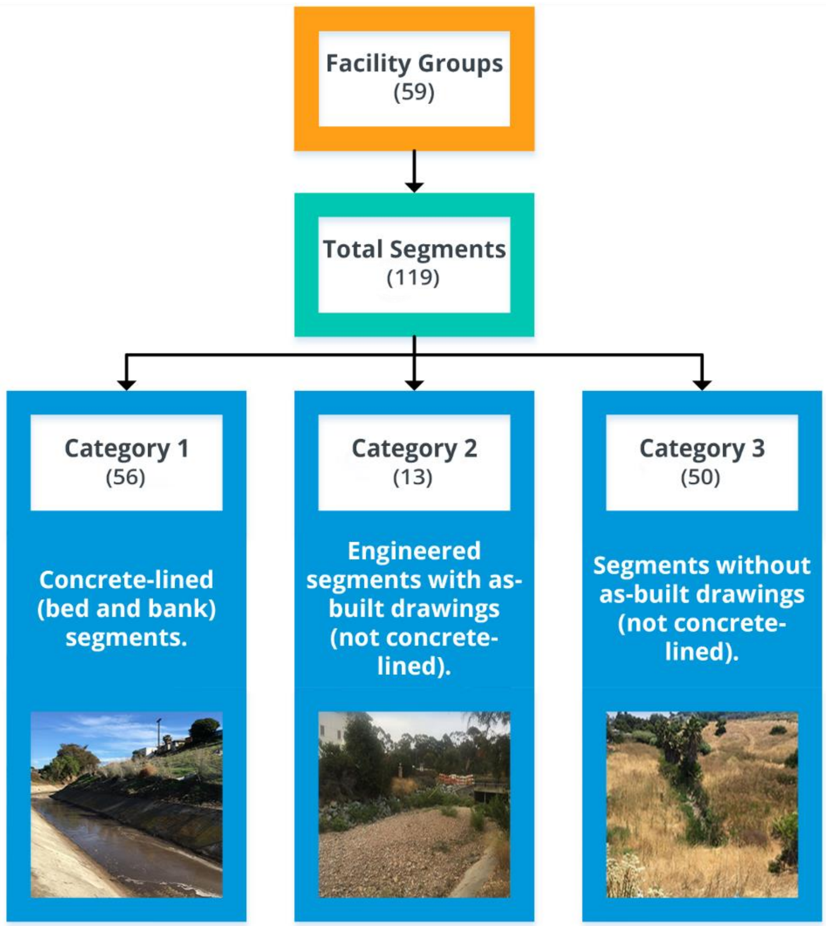

Figure 3-9. Facility Group Categorization

Categories were defined according to how much information was available for each facility group and the material of construction. Table 3-4 defines the three categories identified in the channel assessment.

Table 3-4
Descriptions and Analyses for the Categories Identified in the Channel Assessment

Category	Description	HEC-RAS Analysis
Category 1: Concrete-lined (bed and bank) segments	Channel segments that are lined in the bed and the banks with concrete, that exhibit greater resistance to erosion, and can convey flows at higher velocities.	Simple
Category 2: Engineered segments with as-built drawings (excluding concrete-lined (bed and bank) segments)	Channel segments that are typically lined with vegetation, riprap, or a manufactured liner. For this technical analysis, this category includes segments with available as-built drawings. Engineered channels are typically designed to safely convey the designed storm event without flooding or erosion.	Simple
Category 3: Segments without as-built drawings (excluding concrete-lined (bed and bank) segments)	Channel segments that are watercourses formed by nature and typically exist in a state of equilibrium, having the ability to adjust their bed or banks in response to changes in amount of flow and sediment. May also include engineered channels lined with vegetation, riprap or manufactured liner without available as-built drawings. Natural or earthen channel segments exhibit less resistance to erosion and convey flows at lower velocities compared to concrete-lined segments.	Detailed

HEC-RAS = Hydrologic Engineering Center–River Analysis System

Depending on the category, different H&H analyses were used to appropriately evaluate the facility groups. The properties identified for each category of channels determined the proposed operations and maintenance activities, including vegetation management, necessary to properly maintain those channels. The following sections describe the types of H&H analyses used and the process by which each category of segments was analyzed.

3.3.1 CHANNEL CATEGORY ANALYSIS

This section describes the process by which each category of segments was analyzed using the H&H approaches indicated in Sections 3.1 and 3.2. These category-specific analyses determined if the proposed maintenance activities would reduce flood risk to surrounding properties and if those activities could cause adverse hydraulic conditions within the proposed maintenance areas or upstream or downstream (within the domain of the analysis) of the proposed maintenance areas. The results of the analyses were expressed in terms of level of service, which is a measure of the conveyance capacity from the hydraulic analysis relative to the hydrologic peak flows from the hydrologic analysis for different recurrence intervals. For facility segments with IHHA reports, the previous analysis was used and summarized.

The baseline condition (i.e., the state of the facility before any maintenance is conducted) and the recommended maintenance condition were modeled for each segment. Depending on the category, the ultimate vegetation condition scenario was also modeled. These conditions were defined as follows:

- Baseline Condition - For this report, the baseline condition of each facility was defined as the condition observed during the site visit of the facility group. If the facility had been recently maintained, the baseline condition was defined as the pre-maintained condition, and previous site visit photographs and estimated Manning's coefficients were used.
- Recommended Maintenance Condition - For this report, the recommended maintenance for concrete-lined and engineered segments includes restoring to the as-built condition, and for natural or earthen channels, the recommended maintenance was selected to achieve the 100-year level of service. In some instances, the level of recommended maintenance was regulated (e.g., recommending vegetation trimming in lieu of total removal of vegetation) in conditions where the analysis showed potential for erosive conditions and/or to protect sensitive resources.
- Ultimate Vegetated Condition - For this report, the ultimate vegetated condition is defined as full growth of vegetation and accumulation of sediment within the segment.

The results of the channel maintenance analyses are presented in Chapter 5 and are also documented for each facility group within individual H&H fact sheets located in Appendix A, which summarize the hydraulic results (e.g., velocities, conveyance capacity) for each segment.

3.3.1.1 Category 1 Analyses

Category 1 includes segments that are concrete lined in both the bed (i.e., channel bottom) and banks (i.e., the sides of the channel that confine the flow). These facilities have the lowest likelihood for erosion because of the hardened substrate within concrete-lined channel segments.

Maintenance of Category 1 segments proposes to return the segments to the originally constructed flowline, restore capacity, and in certain storm scenarios, reduce the potential for flooding. Upstream and downstream impacts following maintenance were not explicitly evaluated since maintenance activities in concrete-lined segments were limited to restoring, but not increasing, the originally designed capacity.

The step-wise process for analyzing Category 1 segments is presented in Figure 3-10 followed by a narrative description of each step.

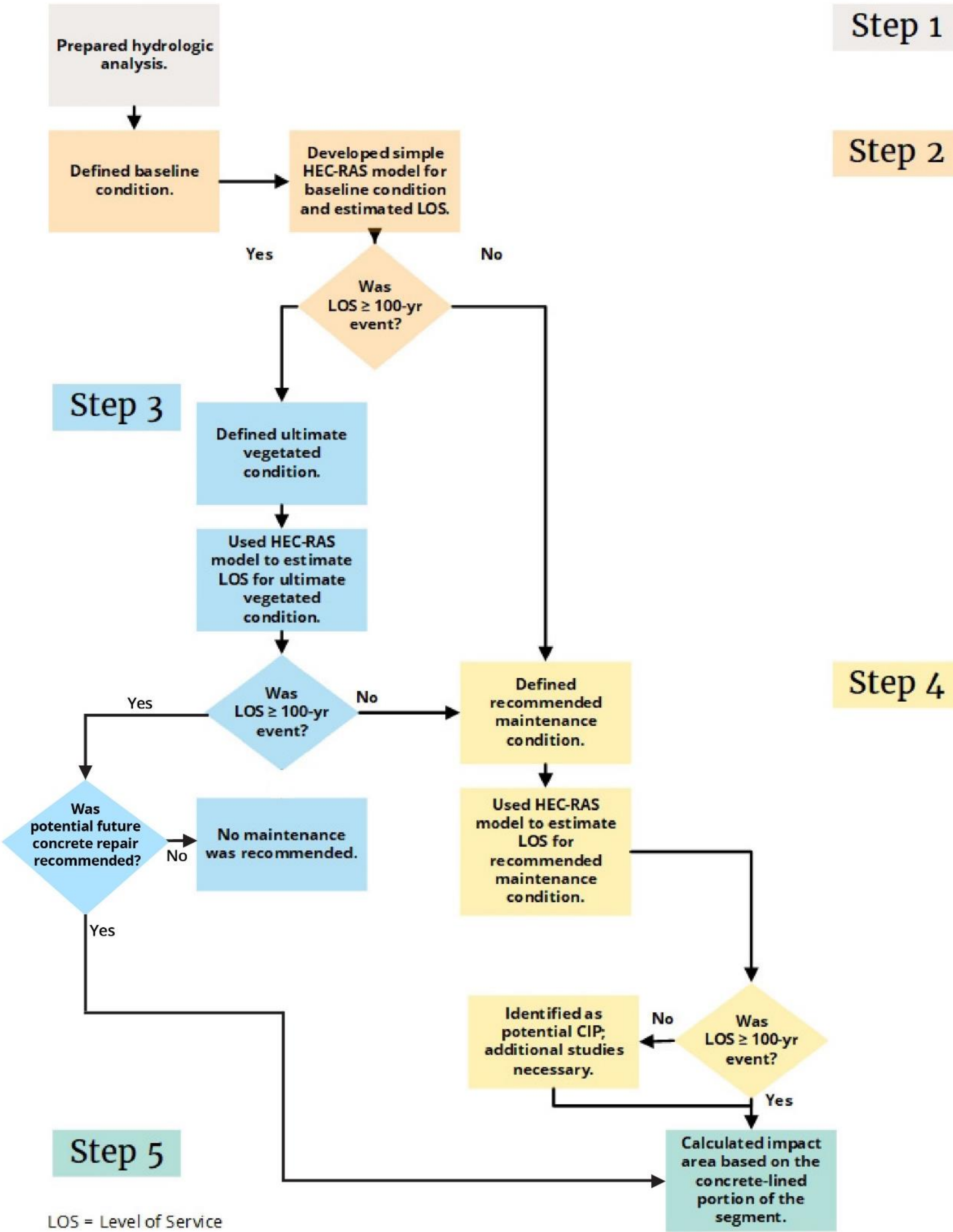

Figure 3-10. Step-Wise Process for Analyzing Category 1 Segments

The following steps were implemented for each Category 1 segment; results for each Category 1 segment are summarized in Appendix A:

- **Step 1**: The hydrology analysis, described in Section 3.1, was prepared for each segment and used in the hydraulics analysis.
- **Step 2**: Simple HEC-RAS model described in Section 3.2 was developed for hydraulic analysis of the baseline condition to estimate the level of service.
    - The current condition of the segment was assumed to be the baseline condition unless there was a record of maintenance performed for the segment, in which case, the baseline condition was assumed to be the pre-maintenance condition of the segment.
    - If the level of service for the baseline condition was greater than or equal to the 100-year event, the analysis proceeded to Step 3.
    - If the level of service for the baseline condition was less than the 100-year event, the analysis proceeded to Step 4.
- **Step 3**: Using the HEC-RAS model from Step 2, the level of service was estimated for the ultimate vegetated condition.
    - For the purposes of this analysis, ultimate vegetated condition was defined as full growth of vegetation and accumulation of sediment within the segment.
    - If the level of service for the ultimate vegetated condition was greater than or equal to the 100-year event and potential future concrete repair was not recommended, no maintenance was recommended for the segment.
    - If the level of service for the ultimate vegetated condition was less than the 100-year event, the analysis proceeded to Step 4.
- **Step 4**: Using the HEC-RAS model from Step 2, the level of service was estimated for the recommended maintenance condition.
    - For this analysis, the recommended maintenance condition for concrete-lined segments was defined as removing all sediment and vegetation within the concrete lining portion.
    - If the level of service for the recommended maintenance condition was less than the 100-year event, the segment was identified as needing potential capital improvements. Additional analysis is recommended to evaluate potential increases in the level of service that could be achieved by capital improvements.
- **Step 5**: The impact area was calculated based on the concrete-lined portion of the segment.

If a Category 1 segment was adjacent to a Category 3 segment, then the Category 1 segment was analyzed as part of the detailed HEC-RAS model developed for the Category 3 segment. The level of analysis was also adjusted for resource sensitive facilities to better evaluate impacts.

3.1.1.2 Category 2 Analyses

Category 2 includes engineered channel segments (not concrete lined) where as-built drawings were available. As-built drawings provide information on the original design dimensions, and suggested hydraulic analysis was considered to minimize the risk of erosion in upstream and downstream conditions.

Maintenance of Category 2 segments proposes to return the segments to the original as-built condition, restore capacity, and in certain storm scenarios, reduce the potential for flooding. Upstream and downstream impacts following maintenance were not explicitly evaluated, since the maintenance activities were limited to restoring, but not increasing, the designed capacity.

The step-wise process for analyzing Category 2 segments is presented in Figure 3-11, followed by a narrative description of each step.

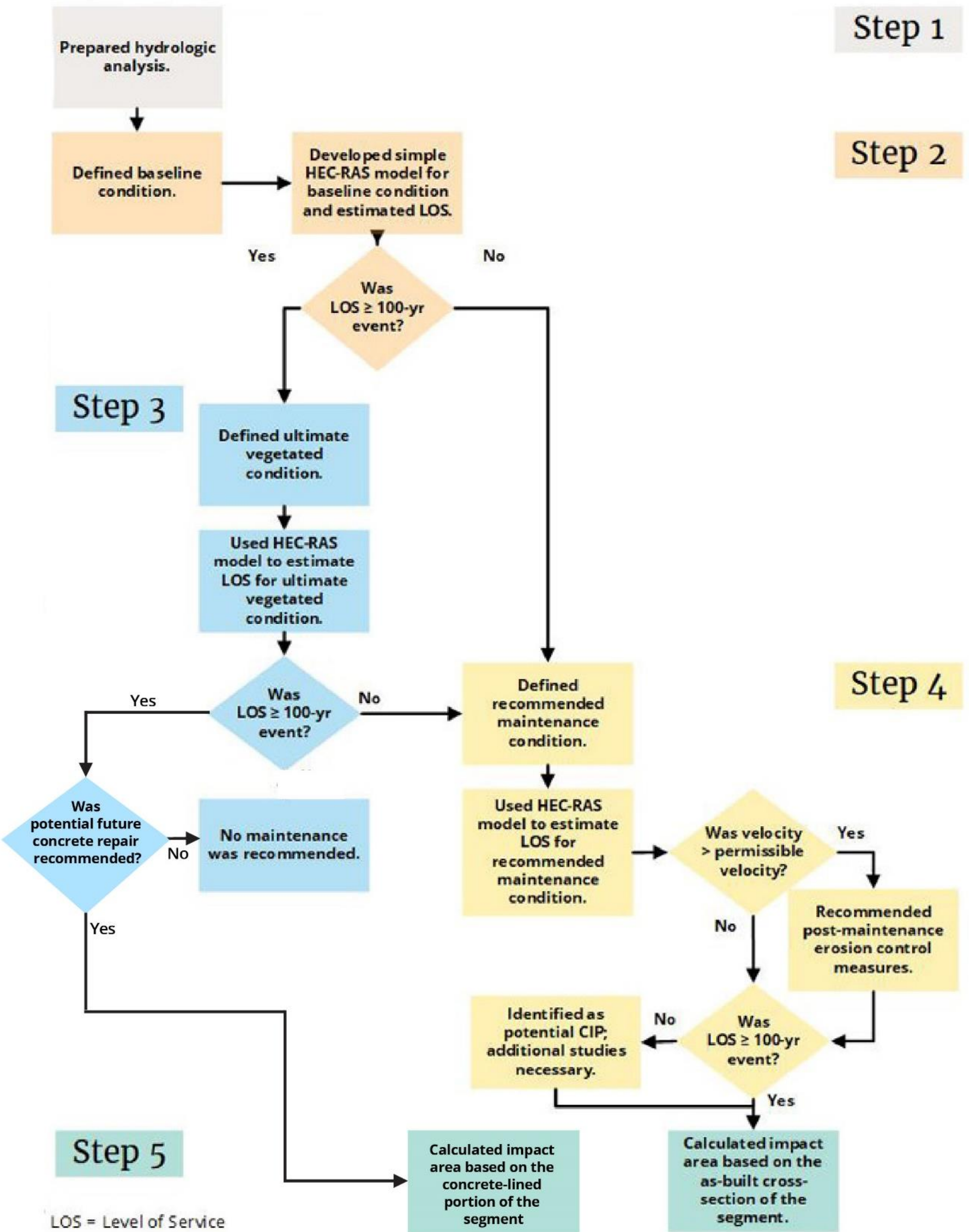

Figure 3-11. Step-Wise Process for Analyzing Category 2 Segments

The following steps were implemented for each Category 2 segment; results for each Category 2 segment are summarized in Appendix A:

- **Step 1**: The hydrology analysis, described in Section 3.1, was prepared for each segment and used in the hydraulics analysis.
- **Step 2**: Simple HEC-RAS model described in Section 3.2 was developed for hydraulic analysis of the baseline condition to estimate the level of service.
    - The current condition of the segment was assumed to be the baseline condition unless there was a record of maintenance performed for the segment, in which case the baseline condition was assumed to be the pre-maintenance condition of the segment.
    - If the level of service for the baseline condition was greater than or equal to the 100-year event, the analysis proceeded to Step 3.
    - If the level of service for the baseline condition was less than the 100-year event, the analysis proceeded to Step 4.
- **Step 3**: Using the HEC-RAS model from Step 2, the level of service was estimated for the ultimate vegetated condition.
    - For this analysis, ultimate vegetated condition was defined as full growth of vegetation and accumulation of sediment within the segment.
    - If the level of service for the ultimate vegetated condition was greater than or equal to the 100-year event and potential future concrete repair was not recommended, no maintenance was recommended for the segment.
    - If the level of service for the ultimate vegetated condition was less than the 100-year event, the analysis proceeded to Step 4.
- **Step 4**: Using the HEC-RAS model from Step 2, the level of service was estimated for the recommended maintenance condition.
    - The recommended maintenance condition includes restoring to the as-built condition. In some instances, the level of recommended maintenance was regulated (e.g., recommending vegetation trimming in lieu of total removal of vegetation) in conditions where the analysis showed potential for erosive conditions if maintenance was performed to restore to the as-built condition.
    - If the level of service for the recommended maintenance condition was less than the 100-year event, then the segment was identified as needing potential capital improvements. Additional analysis is recommended to evaluate potential increases in the level of service that could be achieved via capital improvements.

  - The velocities in the recommended maintenance condition at the level of service were compared with the recommended permissible velocities in the SDDDM which states the following:
    - If the velocities in the recommended maintenance condition are greater than the recommended permissible velocities, then post-maintenance erosion control measures are recommended for the segment.
    - If the velocities in the recommended maintenance condition are less than the recommended permissible velocities, then no post-maintenance erosion control measures are recommended for the segment.
- **Step 5**: The impact area was calculated based on the as-built cross-section of the segment or the concrete-lined portion of the segment.

It is important to note, that if a Category 2 segment was adjacent to a Category 3 segment, then the Category 2 segment was analyzed as part of the detailed HEC-RAS model developed for the Category 3 segment. The level of analysis was also adjusted for resource-sensitive facilities to better evaluate impacts.

3.1.1.3 Category 3 Analyses

Category 3 includes natural earthen channels without available as-built drawings. In these cases, no previous engineering information exists for channel capacity or design. Detailed HEC-RAS models were developed for these channels to determine capacity, velocity, and resistance to erosive shear stress (i.e., the force of flowing water against the channel).

The upstream and downstream extents of the channel segment (refer to domain of analysis in Section 3.2.1.3) were also evaluated for erosion/sedimentation, since the recommended maintenance activities may increase the conveyance capacity. The level of recommended maintenance was regulated (e.g., vegetation trimming in lieu of total removal of vegetation) so that the channel segment and upstream or downstream domain does not erode because of maintenance to achieve the desired level of service.

The step-wise process for analyzing Category 3 segments is presented in Figure 3-12, followed by a narrative description of each step.

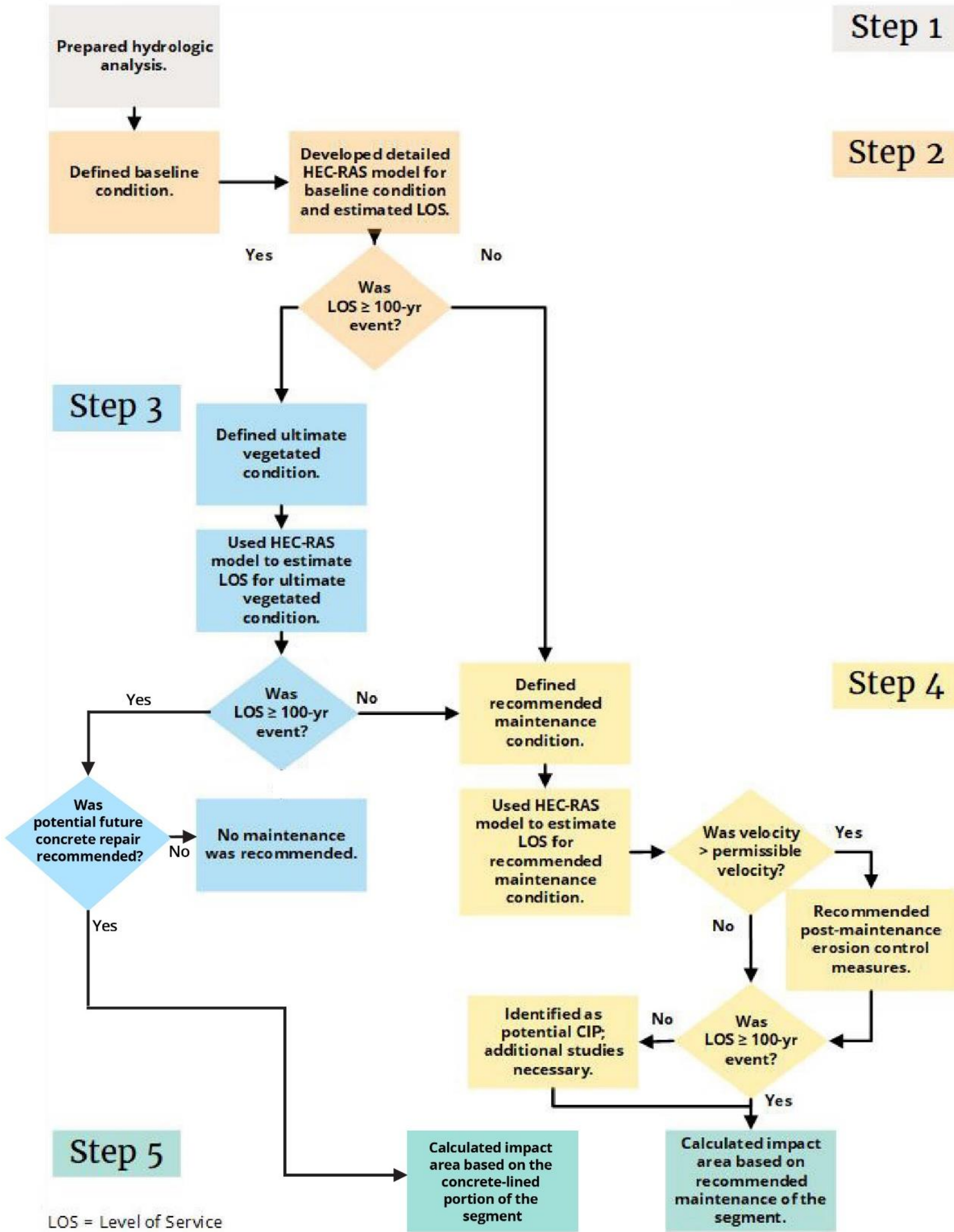

Figure 3-12. Step-Wise Process for Analyzing Category 3 Segments

The following steps were implemented for each Category 3 segment; results for each channel segment are summarized in Appendix A:

- **Step 1**: The hydrology analysis, described in Section 3.1, was prepared for each segment and used in the hydraulics analysis.
- **Step 2**: Detailed HEC-RAS model described in Section 3.2 was developed for hydraulic analysis of the baseline condition to estimate the level of service. The HEC-RAS models were extended upstream and downstream to include the domain of analysis (refer to Section 3.2.1.3).
  - The current condition of the segment was assumed to be the baseline condition unless there was a record of maintenance performed for the segment, in which case the baseline condition was assumed to be the pre-maintenance condition of the segment.
  - If the level of service for the baseline condition was greater than or equal to 100-year event, the analysis proceeded to Step 3.
  - If the level of service for the baseline condition was less than 100-year event, the analysis proceed to Step 4.
- **Step 3**: Using the HEC-RAS model from Step 2, the level of service was estimated for the ultimate vegetated condition.
  - Ultimate vegetated condition is full growth of vegetation and accumulation of sediment within the segment.
  - If the level of service for the ultimate vegetated condition was greater than or equal to 100-year event and potential future concrete repair was not recommended, no maintenance was recommended for the segment.
  - If the level of service for the ultimate vegetated condition was less than 100-year event, then the analysis proceeded to Step 4.
- **Step 4**: Using the HEC-RAS model from Step 2, the level of service was estimated for the recommended maintenance condition.
  - The recommended maintenance condition was selected to achieve the 100-year level of service. In some instances, the level of recommended maintenance was regulated (e.g., recommending vegetation trimming in lieu of total removal of vegetation) in conditions where the analysis showed potential for erosive conditions within the segment and/or upstream/downstream domain.
    - Also, on a case by case basis, no maintenance was recommended for facility segments with a less than 100-year level of service based on factors such as increasing erosive

conditions, FEMA floodplain limits established outside the facility banks, or no discernable improvement to flood protection goals post-maintenance.

- If the level of service for the recommended maintenance condition was less than the 100-year event, then the segment was identified as needing potential facility capital improvements in Appendix A. Additional analysis is recommended to evaluate potential increases in the level of service that could be achieved via capital improvements.
- The velocities in the recommended maintenance condition at the level of service were compared with the recommended permissible velocities in the SDDDM:
  - If the velocities in the recommended maintenance condition are greater than the recommended permissible velocities, then post-maintenance erosion control measures are recommended for the segment in Appendix A.
  - If the velocities in the recommended maintenance condition are less than the recommended permissible velocities, then no post-maintenance erosion control measures are recommended for the segment in Appendix A.

- **Step 5:** The impact area was calculated based on recommended maintenance of the segment or the concrete-lined portion of the segment.

4 TECHNICAL METHODOLOGY FOR BASINS

The City's storm water system includes basins to manage storm water runoff. The basins are generally designed to collect storm water and slowly release it at a controlled rate to provide flood risk reduction benefits and/or provide water quality treatment. Two types of basins are analyzed in this study:

- **Desilting Basin**: A basin designed to temporarily detain sediment-laden runoff and allow sediment to settle out before runoff is discharged.
- **Detention Basin**: A basin designed to temporarily store peak storm runoff and release it in a controlled manner to reduce flooding, or other adverse downstream effects.

This chapter summarizes the technical questions evaluated for analyzing the basin facilities:

- Section 4.1 describes the approach used to determine if basins need to be maintained and how much maintenance is required.
- Section 4.2 describes the approach for establishing the frequency of maintenance.

4.1 MAINTENANCE

San Diego Region Model BMP Design Manual (San Diego Copermittees 2018) states that the normal expected maintenance for storm water detention basins is to remove accumulated materials such as sediment, trash or debris; maintain vegetation health; and maintain integrity of side slopes, inlets, energy dissipators, and outlets. Based on this requirement it was established that the basin facilities need to be maintained. Maintenance of basin facilities proposes to return the basins to the original as-built condition, restore capacity, and in certain storm scenarios, reduce the potential for flooding.

4.2 FREQUENCY OF MAINTENANCE

The frequency of the maintenance is dependent on the capacity of the basin facilities. The two key features of the basin that determine its capacity are the volume of the basin and the performance of the outlet structure. Basin capacity decreases as sediment accumulates within it and vegetation growth increases. The outlet structure's performance is impacted by the amount of sediment and/or vegetation that accumulates around it, clogging the holes in the outlet structure.

The frequency of the maintenance will be established based on inspection of the basin and outlet works as part of the annual prioritization process. The basin maintenance threshold is based on the percentage of storage volume occupied by sediment as measured by the sediment depth observed in the facility relative to an allowable sediment depth determined on a basin by basin basis. The allowable sediment depth was determined based on review of the as-built plans and other basin characteristics such as the height of the emergency spillway and/or outlet works above the bottom of the basin or the height of the sediment storage as designed. If the ratio of sediment depth to allowable sediment height exceeds these thresholds, maintenance is recommended to reestablish the as-built conditions of the facility. The maintenance thresholds are discussed below for the different basin types.

4.2.1 BASINS WITH MAINTENACE THRESHOLDS

In cases where the maintenance thresholds are documented in the as-built information, the determination of when maintenance needs to be performed will be based on that data and presented in the H&H fact sheet for the facility. In cases where the as-built maintenance threshold documentation is not available, the thresholds discussed in the following sections based on basin type will be applied.

4.2.2 PERMANENT DESILTING BASINS

The permanent desilting basins maintenance criteria developed for the MWMP is a blend of permanent detention basin requirements and temporary construction related desilting basin requirements since permanent desilting basins are not a common storm water best management practice. The long-term maintenance activities and frequencies for permanent desilting basins are very similar to permanent detention basins; however, the trigger for maintenance is similar to temporary desilting basins. Maintenance considerations for desilting basins in the MWMP are referenced from the California Stormwater Quality Association's *California Stormwater BMP Handbook – New Development and Redevelopment Fact Sheet TC-22 – Extended Detention Basin* (Fact Sheet TC-22) (CASQA 2003) and the *California Stormwater BMP Handbook – Construction Fact Sheet SE-2 – Sediment Basin* (CASQA 2011). The fact sheets indicate that vegetation removal constitutes the largest recurring maintenance activity necessary for basins, followed by removing sediment/debris and addressing slope erosion and standing water. Typical activities and frequencies include the following:

- Schedule annual inspection for standing water, slope stability, sediment accumulation, trash and debris, and presence of burrows.
- Remove accumulated trash and debris in the basin and around the riser pipe.
- Vegetation trimming or removal is generally recommended to be done at least annually and possibly more frequently if aesthetics is an important consideration.
- For a desilting basin without a forebay, sediment/debris removal (and bottom re-grade) is recommended when the accumulated sediment volume reaches 50% of the designated sediment storage volume.

- For a desilting basin with a forebay, sediment/debris removal (and bottom re-grade) is recommended when the accumulated sediment volume reaches 25% of the designated sediment storage volume.

4.2.3 DETENTION BASINS

Maintenance considerations for detention basins are referenced from Fact Sheet TC-22 (CASQA 2003). The fact sheet indicates that vegetation removal constitutes the largest recurring maintenance activity necessary for detention basins, followed by removing sediment/debris and addressing slope erosion and standing water in the bottom. Typical activities and frequencies include the following:

- Schedule annual inspection for standing water, slope stability, sediment accumulation, trash and debris, and presence of burrows.
- Remove accumulated trash and debris in the basin and around the riser pipe.
- Vegetation trimming or removal is generally recommended to be done at least annually, and possibly more frequently if aesthetics is an important consideration.
- Sediment/debris removal (and bottom re-grade) is recommended approximately every 10 years or when the accumulated sediment volume reaches 10% of the detention basin storage volume.

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5 RESULTS

The results from the H&H analysis are summarized in Table 5-1 (channels) and Table 5-2 (basins). Detailed results for each facility group are summarized in Appendix A.

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Table 5-1
Summary of Hydrology and Hydraulics Results for Channels

Facility Number	Facility Group Name	Segment Name	Category	Hydrology Analysis	Hydraulic Analysis	Baseline Condition Capacity (cfs)	Recommended Maintenance Capacity(cfs)	Baseline Condition Level of Service	Recommended Maintenance Level of Service
1-04-030	Green Valley Creek – Pomerado	Pomerado 1	1	FEMA Report	Simplified HEC-RAS	867	1,375	<10	<25
1-04-033	Green Valley Creek – Pomerado	Pomerado 2	1	FEMA Report	Simplified HEC-RAS	770	1,164	>5	>10
2-01-000	Los Peñasquitos Canyon Creek - Sorrento	Sorrento Valley 1	3	FEMA Report	Detailed HEC-RAS	2,200	N/A	5	N/A
2-01-120	Los Peñasquitos Lagoon – Industrial	Industrial 1	3	SDDDM	Detailed HEC-RAS	277	295	50	100
2-01-122	Los Peñasquitos Lagoon – Industrial	Industrial 2	1	SDDDM	Detailed HEC-RAS	142	142	<2	2
2-01-130	Los Peñasquitos Lagoon – Tripp	Tripp 1	1	SDDDM	Detailed HEC-RAS	267	267	2	2
2-01-200	Los Peñasquitos Canyon Creek – Black Mountain	Black Mountain 1	2	SDDDM	Simplified HEC-RAS	470	650	<5	<25
2-01-210	Los Peñasquitos Canyon Creek – Black Mountain	Black Mountain 2	3	SDDDM	Detailed HEC-RAS	1,000	1,295	>2	<10
2-03-000	Soledad Canyon Creek - Sorrento	Roselle 1	3	FEMA Report	Detailed HEC-RAS	1,500	1,500	10	10
2-03-002	Soledad Canyon Creek - Sorrento	Roselle 2	1	FEMA Report	Detailed HEC-RAS	1,500	1,900	10	>10
2-03-004	Soledad Canyon Creek - Sorrento	Sorrento Valley Road 1	3	FEMA Report	Detailed HEC-RAS	5,600	N/A	100	N/A
2-03-006	Soledad Canyon Creek - Sorrento	Sorrento Valley Road 2	3	FEMA Report	Detailed HEC-RAS	5,600	N/A	100	N/A
2-03-012	Carroll Canyon Creek - Carroll	Carroll Canyon 1	2	FEMA Report	Simplified HEC-RAS	400	900	>2	>5
2-03-100	Soledad Canyon Creek – Flintkote	Flintkote 1	1	Previous Study	Detailed HEC-RAS	60	80	<1	>2
2-03-150	Soledad Canyon Creek – Dunhill	Dunhill 1	3	SDDDM	Detailed HEC-RAS	120	125	<2	<2
2-05-140	Chicarita Creek – Via San Marco	Via San Marco 1	1	SDDDM	Simplified HEC-RAS	96	112	<2	<2
3-00-120	Torrey Pines - Torrey	Torrey Pines 1	3	SDDDM	Detailed HEC-RAS	60	77	<2	<5
3-02-101	Mission Bay – MBHS	PB-Olney 1	3	SDDDM	Detailed HEC-RAS	59	59	2	2

Table 5-1
Summary of Hydrology and Hydraulics Results for Channels

Facility Number	Facility Group Name	Segment Name	Category	Hydrology Analysis	Hydraulic Analysis	Baseline Condition Capacity (cfs)	Recommended Maintenance Capacity(cfs)	Baseline Condition Level of Service	Recommended Maintenance Level of Service
3-02-103	Mission Bay – MBHS	MBHS 1	1	SDDDM	Detailed HEC-RAS	10	43	<1	2
3-02-130	Mission Bay – Mission Bay Drive	Mission Bay Drive 1	2	Unit Area	Simplified HEC-RAS	208	208	>2	>2
3-03-901	Miramar – Engineer	Engineer 1	2	Unit Area	Detailed HEC-RAS	<10	25	<2	<2
3-04-055	Tecolote Creek - Chateau	Chateau 1	1	FEMA Report	Simplified HEC-RAS	334	334	>2	>2
3-04-250	Tecolote Creek - Chateau	Chateau 2	1	FEMA Report	Simplified HEC-RAS	196	435	<2	<50
3-04-101	Tecolote Creek – Morena	Morena 1	3	SDDDM	Detailed HEC-RAS	72	N/A	100	N/A
3-04-160	Tecolote Creek – Genesee	Genesee 1	3	SDDDM	Detailed HEC-RAS	1,050	1,120	>10	>10
4-01-103	San Diego River – Nimitz	Nimitz 1	3	SDDDM	Detailed HEC-RAS	120	290	<2	<10
4-01-105	San Diego River – Nimitz	Nimitz 2	1	SDDDM	Detailed HEC-RAS	15	80	<2	<2
4-01-107	San Diego River – Nimitz	Nimitz 3	3	SDDDM	Detailed HEC-RAS	227	290	2	5
4-01-120	San Diego River – Valeta	Valeta 1	1	SDDDM	Detailed HEC-RAS	55	215	<2	100
4-03-101	San Diego River – Camino del Rio	Camino del Arroyo 1	1	SDDDM	Simplified HEC-RAS	440	445	>10	>10
4-03-103	San Diego River – Camino del Rio	Camino del Rio 1	1	SDDDM	Simplified HEC-RAS	290	330	>10	>25
4-04-000	Murphy Canyon Creek - Stadium	Stadium 1	3	FEMA Report	Detailed HEC-RAS	<510	1,050	<2	5
4-04-002	Murphy Canyon Creek - Stadium	Stadium 2	1	FEMA Report	Detailed HEC-RAS	<510	2,700	<2	50
4-04-006	Murphy Canyon Creek - Stadium	Murphy Canyon 1	1	FEMA Report	Detailed HEC-RAS	1,100	N/A	10	N/A
4-04-008	Murphy Canyon Creek - Stadium	Murphy Canyon 2	3	FEMA Report	Detailed HEC-RAS	3,000	N/A	100	N/A
4-07-002	Alvarado Canyon Creek - Mission Gorge	Mission Gorge 1	1	FEMA Report	Detailed HEC-RAS	1,250	1,800	>2	<5

Table 5-1
Summary of Hydrology and Hydraulics Results for Channels

Facility Number	Facility Group Name	Segment Name	Category	Hydrology Analysis	Hydraulic Analysis	Baseline Condition Capacity (cfs)	Recommended Maintenance Capacity(cfs)	Baseline Condition Level of Service	Recommended Maintenance Level of Service
4-07-004	Alvarado Canyon Creek – Mission Gorge	Mission Gorge 2	1	FEMA Report	Detailed HEC-RAS	950	1,300	<2	>2
4-07-009	Alvarado Canyon Creek – Mission Gorge	Mission Gorge 3	2	FEMA Report	Simplified HEC-RAS	1,956	2165	<5	>5
4-07-011	Alvarado Canyon Creek – Mission Gorge	Mission Gorge 4	1	FEMA Report	Simplified HEC-RAS	2,540	2,837	<10	>10
4-07-021	Alvarado Canyon Creek – Alvarado	Alvarado 1	2	FEMA Report	Detailed HEC-RAS	1,700	<3,400	5	<50
4-07-023	Alvarado Canyon Creek – Alvarado	Alvarado 2	1	FEMA Report	Detailed HEC-RAS	3,900	N/A	100	N/A
4-07-250	Alvarado Canyon Creek – Alvarado	Alvarado 3	1	SDDDM	Simplified HEC-RAS	426	N/A	<25	N/A
4-07-901	Murray Reservoir – Cowles Mountain	Cowles Mountain 1	1	SDDDM	Simplified HEC-RAS	317	340	<2	<2
4-07-911	Murray Reservoir – Cowles Mountain	Cowles Mountain 2	1	SDDDM	Simplified HEC-RAS	142	202	<2	<2
4-08-008	Norfolk Canyon Creek - Fairmount	Fairmount 1	1	SDDDM	Detailed HEC-RAS	600	N/A	>10	N/A
4-08-011	Norfolk Canyon Creek - Fairmount	Fairmount 2	1	SDDDM	Detailed HEC-RAS	50	563	<2	<10
4-08-014	Norfolk Canyon Creek - Fairmount	Fairmount 3	3	SDDDM	Detailed HEC-RAS	670	670	<25	<25
4-08-017	Norfolk Canyon Creek - Fairmount	Fairmount 4	1	SDDDM	Detailed HEC-RAS	120	120	<10	<10
4-08-105	Norfolk Canyon Creek - Fairmount	Baja 1	1	Unit Area	Detailed HEC-RAS	250	250	<2	<2
4-08-150	Norfolk Canyon Creek - Fairmount	Aldine 1	3	SDDDM	Detailed HEC-RAS	105	N/A	<2	N/A
5-02-151	Washington Canyon Creek - Washington	Washington 1	3	SDDDM	Detailed HEC-RAS	162	162	<50	<50
5-02-153	Washington Canyon Creek - Washington	Washington 2	1	SDDDM	Detailed HEC-RAS	70	183	<2	100
5-02-162	Mission Hills Canyon Creek - Titus	Titus 1	3	SDDDM	Detailed HEC-RAS	17	88	<2	<25
5-03-011	Powerhouse Canyon Creek - Pershing	Pershing 1	1	FEMA Report	Simplified HEC-RAS	630	633	<10	<10

Table 5-1
Summary of Hydrology and Hydraulics Results for Channels

Facility Number	Facility Group Name	Segment Name	Category	Hydrology Analysis	Hydraulic Analysis	Baseline Condition Capacity (cfs)	Recommended Maintenance Capacity(cfs)	Baseline Condition Level of Service	Recommended Maintenance Level of Service
5-03-100	Powerhouse Canyon Creek - Pershing	Pershing 2	1	FEMA Report	Simplified HEC-RAS	1,350	1,350	100	100
5-03-901	San Diego Bay– 28th Street	28th St 1	3	SDDDM	Detailed HEC-RAS	50	50	<5	<5
5-04-004	Chollas Creek – National	National 1	2	FEMA Report	Detailed HEC-RAS	3,095	3,095	>10	>10
5-04-006	Chollas Creek – National	National 2	1	FEMA Report	Detailed HEC-RAS	2,000	4,350	5	>19
5-04-044	Chollas Creek – Rolando	Cartagena 1	1	Unit Area	Simplified HEC-RAS	1,132	1,826	<2	>5
5-04-046	Chollas Creek – Rolando	Rolando 1	1	As-Built Drawing	Simplified HEC-RAS	829	829	>10	>10
5-04-048	Chollas Creek – Rolando	Rolando 2	2	As-Built Drawing	Simplified HEC-RAS	235	235	<2	<2
5-04-101	Chollas Creek– Martin	Martin 1	3	SDDDM	Detailed HEC-RAS	228	228	<50	<50
5-04-163	Chollas Creek – J Street	J St 1	3	SDDDM	Detailed HEC-RAS	17	17	<5	<5
5-04-220	Auburn Creek – Home	Home 1	2	FEMA Report	Detailed HEC-RAS	957	1,028	>50	>50
5-04-224	Auburn Creek – Home	Home 2	3	FEMA Report	Detailed HEC-RAS	630	1,200	25	100
5-04-227	Auburn Creek – Home	Home 3	3	FEMA Report	Detailed HEC-RAS	950	950	50	50
5-04-229	Auburn Creek – Home	Home 4	3	FEMA Report	Detailed HEC-RAS	1,200	N/A	100	N/A
5-04-231	Auburn Creek – Home	Home 5	3	FEMA Report	Detailed HEC-RAS	630	630	25	25
5-04-239	Auburn Creek – Wightman	Wightman 1	3	FEMA Report	Detailed HEC-RAS	248	248	25	25
5-04-241	Auburn Creek – Wightman	Wightman 2	3	FEMA Report	Detailed HEC-RAS	160	160	10	10
5-04-245	Auburn Creek – Oakcrest	Oakcrest 1	3	FEMA Report	Detailed HEC-RAS	450	N/A	100	N/A
5-04-260	Chollas Creek– Megan	Megan 1	1	SDDDM	Detailed HEC-RAS	602	747	25	100

Table 5-1
Summary of Hydrology and Hydraulics Results for Channels

Facility Number	Facility Group Name	Segment Name	Category	Hydrology Analysis	Hydraulic Analysis	Baseline Condition Capacity (cfs)	Recommended Maintenance Capacity(cfs)	Baseline Condition Level of Service	Recommended Maintenance Level of Service
5-04-262	Chollas Creek– Megan	Megan 2	3	SDDDM	Detailed HEC-RAS	355	355	100	100
5-04-280	Chollas Creek – 54th St	54th St 1	1	SDDDM	Simplified HEC-RAS	40	93	<2	5
5-05-006	South Chollas Creek – Southcrest	Alpha 1	1, 2, & 3	FEMA Report	Detailed HEC-RAS	1,300	2,000	5	10
5-05-008	South Chollas Creek – Southcrest	Ocean View 1	1 & 2	FEMA Report	Detailed HEC-RAS	1,300	N/A	5	N/A
5-05-019	South Chollas Creek – Euclid	Euclid 1	3	FEMA Report	Detailed HEC-RAS	1,250	N/A	<5	N/A
5-05-021	South Chollas Creek – Euclid	Euclid 2	1	FEMA Report	Detailed HEC-RAS	225	N/A	<2	N/A
5-05-035	South Chollas Creek – Federal	Federal 1	3	FEMA Report	Detailed HEC-RAS	580	830	10	25
5-05-037	South Chollas Creek – Federal	Federal 2	1	FEMA Report	Detailed HEC-RAS	1,500	1,500	100	100
5-05-205	South Chollas Creek Encanto Branch - Castana	Castana 1	3	SDDDM	Detailed HEC-RAS	49	N/A	<50	N/A
5-05-304	South Chollas Creek Encanto Branch – Imperial	Imperial 1	3	FEMA Report	Detailed HEC-RAS	1,873	N/A	25	N/A
5-05-306	South Chollas Creek Encanto Branch – Imperial	Imperial 2	1	FEMA Report	Detailed HEC-RAS	3,400	N/A	100	N/A
5-05-603	South Chollas Creek Encanto Branch – Jamacha	Jamacha 1	3	SDDDM	Detailed HEC-RAS	244	440	<2	<2
5-05-606	South Chollas Creek Encanto Branch -–Jamacha	Jamacha 2	3	SDDDM	Detailed HEC-RAS	250	N/A	5	N/A
5-05-610	South Chollas Creek Encanto Branch – Jamacha	Jamacha 3	3	SDDDM	Detailed HEC-RAS	40	N/A	<2	N/A
5-05-702	South Chollas Creek Encanto Branch – Jamacha	Lobrico	3	SDDDM	Detailed HEC-RAS	15	N/A	<2	N/A
5-05-802	South Chollas Creek Encanto Branch – Jamacha	Cadman 1	3	SDDDM	Detailed HEC-RAS	125	N/A	<2	N/A
5-06-005	Paleta Creek – Cottonwood	Cottonwood 1	1	Unit Area	Simplified HEC-RAS	630	678	<2	<2
5-06-008	Paleta Creek – Cottonwood	Cottonwood 2	1	Unit Area	Simplified HEC-RAS	519	522	<2	<2

Table 5-1
Summary of Hydrology and Hydraulics Results for Channels

Facility Number	Facility Group Name	Segment Name	Category	Hydrology Analysis	Hydraulic Analysis	Baseline Condition Capacity (cfs)	Recommended Maintenance Capacity(cfs)	Baseline Condition Level of Service	Recommended Maintenance Level of Service
5-06-020	Paleta Creek – Solola	Solola 1	1	FEMA Report	Detailed HEC-RAS	470	470	100	100
5-06-023	Paleta Creek – Solola	Solola 2	1	FEMA Report	Detailed HEC-RAS	325	325	<50	<50
5-06-025	Paleta Creek – Solola	Cervantes 1	3	FEMA Report	Detailed HEC-RAS	470	N/A	100	N/A
5-11-003	Sweetwater River – Parkside	Parkside 1	1	Unit Area	Simplified HEC-RAS	735	735	>2	>2
5-22-008	Nestor Creek - Nestor	Cedar 1	3	FEMA Report	Detailed HEC-RAS	160	160	<2	<2
5-22-010	Nestor Creek - Nestor	Cedar 2	1	FEMA Report	Detailed HEC-RAS	980	1,093	<100	100
5-22-013	Nestor Creek - Nestor	Dahlia 1	1	FEMA Report	Detailed HEC-RAS	864	N/A	100	N/A
5-22-016	Nestor Creek - Nestor	Cerrissa 1	3	FEMA Report	Detailed HEC-RAS	340	420	>10	<25
5-22-023	Nestor Creek - Nestor	Grove 1	3	FEMA Report	Detailed HEC-RAS	456	456	100	100
5-22-028	Nestor Creek - Nestor	30th St 1	1	FEMA Report	Detailed HEC-RAS	140	165	<10	<10
5-22-110	Nestor Creek – Outer	Outer 1	3	SDDDM	Detailed HEC-RAS	53	80	<2	<2
5-22-112	Nestor Creek – Outer	Outer 2	1	SDDDM	Detailed HEC-RAS	4.7	5	2	>2
6-01-020	Tijuana River - Pilot & Smugglers	Pilot Channel 1	3	Previous Study	Detailed HEC-RAS	10	200	<2	<2
6-01-100	Tijuana River - Pilot & Smugglers	Smuggler's Gulch 1	3	Previous Study	Detailed HEC-RAS	653	900	2	>2
6-02-115	Tijuana River – Tocayo	Tocayo 1	3	Unit Area	Detailed HEC-RAS	220	N/A	<2	N/A
6-02-118	Tijuana River – Tocayo	Tocayo 2	1	Unit Area	Detailed HEC-RAS	180	220	<2	<2
6-03-135	Tijuana River – Smythe	Via Encantadoras 1	3	As-Built Drawing	Detailed HEC-RAS	1,182	1,314	50	100
6-03-138	Tijuana River – Smythe	Via Encantadoras 2	1	As-Built Drawing	Detailed HEC-RAS	1,182	1,314	50	100

Table 5-1
Summary of Hydrology and Hydraulics Results for Channels

Facility Number	Facility Group Name	Segment Name	Category	Hydrology Analysis	Hydraulic Analysis	Baseline Condition Capacity (cfs)	Recommended Maintenance Capacity(cfs)	Baseline Condition Level of Service	Recommended Maintenance Level of Service
6-03-143	Tijuana River – Smythe	Via Encantadoras 3	1	As-Built Drawing	Detailed HEC-RAS	610	610	2	2
6-03-147	Tijuana River – Smythe	Smythe 1	3	As-Built Drawing	Detailed HEC-RAS	<550	935	<2	25
6-03-150	Tijuana River – Smythe	Via de la Bandola 1	1	As-Built Drawing	Simplified HEC-RAS	295	295	<2	<2
6-06-011	Tijuana River – La Media	La Media 1	3	Unit Area	Detailed HEC-RAS	19	19	<2	<2

SDDDM = City of San Diego Drainage Design Manual; FEMA = Federal Emergency Management Agency; HEC-RAS = Hydrologic Engineering Center–River Analysis System; N/A = not applicable; MBHS = Mission Bay High School; PB = Pacific Beach

Table 5-2
Summary of H&H Results for Basins

Facility Number	Facility Group Name	Segment Name	Category	Basin Type/ Maintenance Threshold (Percent)	Baseline Sediment Depth (Feet)/ Allowable Sediment Depth (Feet) Ratio	Sediment Removal Recommended
1-04-200	Green Valley Creek - Paseo del Verano	Paseo del Verano 1	1	Desilting basin w/o forebay (50%)	2’/4’ (50%)	Yes
2-01-900	Los Peñasquitos Canyon Creek – 5-805 Basin	5-805 Fwys 1	1	Desilting basin/As-Built Recommendation	0’/6’ (0%)	Yes
3-00-150	Alta La Jolla - Vickie	Vickie 1	1	Detention basin/As-Built Recommendation	2.4’/2.4” (100%)	Yes
5-02-140	Maple Canyon Creek - Maple	Maple 1	3	Desilting basin w/o forebay (50%)	5’/5’ (100%)	Yes
6-04-251	Spring Canyon Creek - Cactus	Cactus 1	1	Detention Basin (10%)	0.5’/2.8 (18%)	Yes
6-04-253	Spring Canyon Creek - Cactus	Cactus 2	1	Detention Basin (10%)	2’/3.7’ (54%)	Yes
6-05-110	Tijuana River – Siempre Viva	Siempre Viva 1	3	Detention Basin (10%)	1.5’/1.4’ (>100%)	Yes

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6 POST-MAINTENANCE EROSION CONTROL MEASURES AND BANK REPAIR

The H&H analysis includes an assessment of the potential for maintenance activities to reduce flood risk and identifies potential adverse hydraulic impacts, such as potential erosive velocities. H&H analysis for 17 facility segments proposed for maintenance indicate an increase in predicted velocities that would increase the potential risk of erosion post-maintenance. In the post-maintenance condition for these facility segments, control measures are needed to reduce the risk of post-maintenance erosion. In some instances where analysis shows erosive velocities, the level of recommended maintenance has been limited (e.g., recommending vegetation trimming in lieu of total removal of vegetation) to balance flood risk reduction with the potential for erosion. Where erosive velocities are still predicted despite reduced/adjusted maintenance methods, a post-maintenance erosion control measure is recommended. These measures are typically aimed at reducing velocity within the facility to reduce erosion post-maintenance (i.e., no increase of erosion risk compared with pre-maintenance conditions). Post-maintenance erosion control measures for this assessment are mainly focused within earthen-bottom channel/ditch facilities, but the measures may be installed in the earthen-bottom or concrete-lined portions of the facility based on the specific hydraulic conditions of the channel/ditch. The H&H analysis also includes identification of areas where earthen bank repair activities are needed based on site observations. Determination of the appropriate methods of bank repair will be based on the recommendations of a site-specific geotechnical analysis following the current City guidelines for geotechnical reports, and may include measures described in this chapter.

A suite of post-maintenance erosion control measures were determined potentially suitable for one or more of the 17 facility segments. The 17 facility segments are representative of the drainage conditions analyzed that would require post-maintenance erosion controls as part of the MWMP. Selection, design, installation, monitoring, and adaptation/modifications of these post-maintenance erosion control measures will occur during the implementation of the MWMP. The following sections present the results of:

- a literature review of various erosion control measures,
- erosion control measure applicability for potential use within MWMP facilities,
- an assessment strategy used to evaluate potential erosion control measure alternatives for facility segments, and
- results of the site-specific assessment.

6.1 BACKGROUND

In many urban environments, channels and their associated floodplains have been constrained by surrounding development, and those changes may increase erosive forces, necessitating the addition of measures to protect public safety and reduce property loss. In general, many urban streams have been straightened and channelized, and the natural process of stream channel meandering and evolution have been disrupted. When scour and bank failure occur, the result can be property loss and infrastructure degradation, which in turn can impact public safety. A common practice is to address bank erosion through stabilizing activities that use hardened structures such as riprap or concrete placement on channel banks, or riparian vegetation to reduce erosion and channel degradation. A potential alternative or complimentary method is to use in-stream velocity-reducing structures that address the erosive flow velocities causing the failures.

In-stream velocity-reduction measures can reduce the velocity and/or shift the direction of flow away from sensitive areas or bank(s). Depending on the site characteristics and project goals, measures range from small-scale, temporary stabilization features to larger, more permanent structures. Materials can be natural or built, and include rock, wood, wire, cement, or proprietary products such as turf-reinforced mats. In general, the structures are placed perpendicular to flow or angled into the flow to interrupt and/or redirect the flow of water and flatten the channel hydraulic gradient, thus reducing flow velocity.

In-stream structures can be designed to achieve some or all of the following: reduce erosive potential, provide bank protection, redirect streamflow, provide grade control, or create scour pool habitat (Sotiropoulos and Diplas 2014). The channel conditions dictate which measures may be applicable, and the cost and constructability varies depending on the material and complexity of design. The level of service of these erosion control features is contingent upon their appropriate design, installation and both short- and long-term maintenance activities. In-stream structures have the potential for sedimentation and/or unintended scour, thus they require maintenance and adaptive management.

6.2 IDENTIFICATION OF SUITABLE POST-MAINTENANCE EROSION CONTROL MEASURES

To determine which post-maintenance erosion control measures would be suitable for MWMP facilities, a literature review of 15 potential measures was conducted to evaluate the effectiveness and practicability of the various measures. The measures reviewed ranged from simple measures like rock or wooden check dams to more complex engineered solutions like rock and wire gabions and engineered embedded rock structures (e.g., rock vanes and stream barbs).

Each measure was evaluated based on evaluation criteria listed below:

- Types of ditch or channels the structure would be appropriate for based on channel/ditch widths.
- Level of effort estimated to install and remove the structure.
- Expected maintenance level or the amount of inspection, maintenance and/or repair.
- Cost of the materials, labor, and/or inspections.
- Various benefits and limitations of using a structure (e.g., use of created/non-natural materials, long life span, simple design and/or construction).
- Durability of the structure in terms of temporary, semi-permanent or permanent.
- Lifespan of the structure in terms of short (less than 2 years), medium (2–5 years) and long (greater than 5 years).
- Results of a site-specific geotechnical assessment (bank repair only).

The review and evaluation of potential measures resulted in the selection of eight suitable measures. These measures were grouped into three categories, based on estimated functionality. Functionality criteria include grade control measures to disrupt flow, channel lining measures to preserve vulnerable areas and bank protection/repair measures to stabilize bank conditions. A brief measure description and the application for each potential measure is presented in Table 6-1 through Table 6-3.

Table 6-1
Channel Lining Post-Maintenance Erosion Control Measures Alternatives

Measure	Description	Application
Design Criteria: Channel lining measures shall be evaluated based on the maximum permissible velocity tables in Chapter 7 of the SDDDM. These tables indicate the highest velocity allowable for a lining or material type from unlined (soil) to concrete lined. In addition, for proprietary materials, the manufacturer's specifications shall be used in the evaluation process.		
Turf Reinforced Matting (TRM)	Erosion control blankets made of ultraviolet stabilized polymeric fibers, nettings, and/or wire mesh that create a three-dimensional matrix that allows for vegetation growth.	Biobased approach; relatively simple design with a long life span.
		TRM may require less maintenance than coir mats and may be implemented to protect bed and/or banks. TRM can be used with velocities up to 23 fps per manufacturer's specifications.
		TRM can be combined with other velocity reduction structures.
Coir Mat	Coconut fiber that is woven into a three-dimensional matrix that allows for vegetation growth. Proprietary products.	Biobased approach; relatively simple design and construction with a short to medium lifespan.
		Coir mats are a more temporary measure than TRM and can be implemented to protect bed and/or banks. Temporary coir mats can be used with velocities up to 8 fps and semi-permanent coir mats can be used with velocities up to 16 fps per manufacturer's specifications.
		Coir mats can be combined with other velocity reduction structures. Vegetation is limited to grasses unless the mat is cut to allow container plants.
Riprap	Rock structures that span the channel width.	Bioengineering approach; low maintenance and a long lifespan.
		Riprap can be implemented to protect bed and/or banks. Riprap can typically be used with velocities up to 18 fps depending on the rock size.
		Rock size will vary based on the expected channel velocities.

Table 6-1
Channel Lining Post-Maintenance Erosion Control Measures Alternatives

Measure	Description	Application
Design Criteria: Channel lining measures shall be evaluated based on the maximum permissible velocity tables in Chapter 7 of the SDDDM. These tables indicate the highest velocity allowable for a lining or material type from unlined (soil) to concrete lined. In addition, for proprietary materials, the manufacturer's specifications shall be used in the evaluation process.		
		In locations where large debris is a concern, the chain link or wire may be removed from the design to allow collected debris to reduce velocity through the structure.
One Rock Dam	A velocity reducing dam that is one rock tall (minimum rock weight is 20 pounds), and several rows long. The dam should not be taller than one third of the bankfull depth and rocks should be similar sized. This measure is intended to allow flood flows to carry smaller-sized material into the gaps of the One Rock Dam and gradually strengthen the structure.	Bioengineering approach; simple design and construction with a long lifespan.
		There is minimal soil/vegetation disturbance during construction and One Rock Dam area can be seeded prior to installation for vegetation establishment.
		Soilcrete burlap bags can be used to mix native soil with cement to mimic rocks if no local rocks are available.

Table 6-2
Grade Control Post-Maintenance Erosion Control Measures Alternatives

Design Criteria: Grade control measures shall be evaluated based on the effective slope of the channel. The effective slope of the channel should be designed to be less than the critical slope.		
Measure	**Description**	**Application**
Anchored Brush Wood Fence & Wooden Check Dam	Check dams made of posts and brush or wood that span the width of a ditch or channel.	Biobased approach; relatively simple design and construction with a medium lifespan.
		Brush Wood Fence is permeable, allowing sediment to pass through while providing velocity attenuation.
		In locations where large debris is a concern, the horizontal wood pieces/branches or wire may be removed from the design to allow collected debris to reduce velocity through the structure.
Chain Link Fence or Woven Wire Fence	Check dams made of metal posts and chain link or woven wire that span the width of a channel. The woven wire fence is constructed using wire, staples and posts either straight across the channel or in a crescent shape with its open end upstream.	Engineered approach; can be a complex design with a long lifespan.
		Chain Link or Woven Wire Fences are a hardened structure that may require less maintenance than a biobased design.
		In locations where large debris is a concern, the chain link or wire may be removed from the design to allow collected debris to reduce velocity through the structure.
One Rock Dam	A velocity reducing dam that is one rock tall (minimum rock weight is 20 pounds), and several rows long. The dam should not be taller than one third of the bankfull depth and rocks should be similar sized. This measure is intended to allow flood flows to carry smaller-sized material into the gaps of the One Rock Dam and gradually strengthen the structure.	Bioengineering approach; simple design and construction with a long lifespan.
		There is minimal soil/vegetation disturbance during construction and One Rock Dam area can be seeded prior to installation for vegetation establishment.
		Soilcrete burlap bags can be used to mix native soil with cement to mimic rocks if no local rocks are available.

Table 6-3
Bank Protection/Repair Post-Maintenance Erosion Control Measures Alternatives

Design Criteria: Bank protection/repair measures are evaluated based on the radius of the bends. If the radius of less than two times the 100-year flow top width or less than 100 feet, whichever is greater, protection measures should be implemented. When erosion protection is provided, channels are allowed to have minimum radius equivalent to 1.2 times the 100-year flow top width, but in no case shall the radius of curvature be less than 50 feet.		
Measure	**Description**	**Application**
Riprap	Rock structures that placed along channel bends and are typically larger and more permanent structures.	Bioengineering approach; low maintenance and a long lifespan.
		Riprap can be implemented to protect bed and/or banks. Riprap can typically be used with velocities up to 18 fps depending on the rock size.
		Rock size will vary based on the expected channel velocities.

Based on these recommendations, FMPs are included in MWMP Appendix A-4 to generically describe potential installation of the measures described in Table 6-1 through 6-3.

To evaluate the applicability and effectiveness of each of these measures for each facility segment, further analysis will need to be done using the design criteria in Chapter 7 of the SDDDM. The evaluation will begin by reviewing the channel characteristics, such as longitudinal slope, channel geometry, location of the velocity increase, and the channel lining, to narrow down the appropriate post-maintenance erosion control or bank repair measures. In some cases, a combination of measures may be used to reduce velocities. One of the first steps will be evaluating the channel lining options and the channel lining's maximum permissible velocity for its applicability to the channel conditions. If the velocity increase is determined to be based more on the longitudinal slope of the channel, then the grade control measures will be further evaluated. If the velocity issue is localized to a bend or bank repair is recommended, the bank protection/repair alternatives will be further analyzed. In locations where bank repair is recommended, the analysis will be based on a site-specific geotechnical evaluation of the conditions to determine the applicable measures.

6.3 SITE-SPECIFIC ASSESSMENT EVALUATION PROCEDURE FOR POST-MAINTENANCE EROSION CONTROL MEASURES

A process was created to narrow down the measures identified in Section 6.2 based on the site-specific details for each facility segment. The selection of a particular in-stream structure or combination of structures and erosion control takes into consideration site-specific channel and watershed characteristics, long-term site goals, and management priorities. If a segment has a previously designed and permitted post-maintenance erosion control measure, the designed and permitted measure will not be revised unless channel conditions change and warrant a re-evaluation of the facility segment. Previously designed but not permitted post-maintenance erosion control measures will undergo the evaluation process as described in this section.

Channel characteristics evaluated in the selection of a recommended measures included:

- Dimensions
- Slope
- Typical flows
- Expected effect on conveyance capacity
- Current conditions
- Potential erosion
- Long term site goals

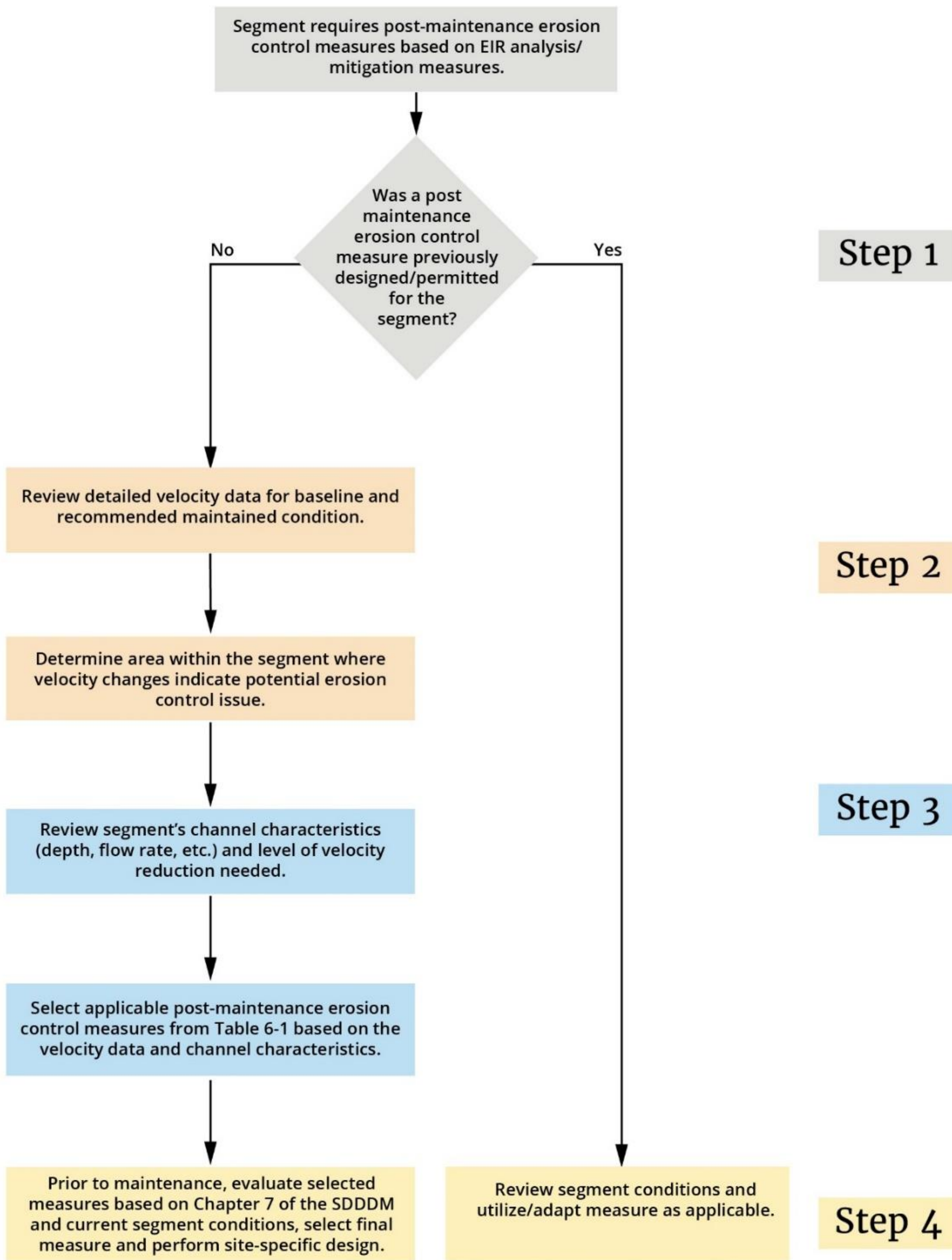

Figure 6-1. Step-Wise Process for Determining Segment Specific Post-Maintenance Erosion Control Measures Alternatives

The evaluation of site characteristics resulted in the identification of a minimum of two post-maintenance erosion control measures that are appropriate for a given channel. In general, given the favorability of biotechnical solutions, bio-based materials were considered a first priority in the assessment, followed by maintenance effort and cost. Figure 6-1 illustrates the methodology used in the evaluation process to determine the potential alternatives for each segment followed by a more detailed description of each step.

The following steps were implemented for each segment identified:

- **Step 1**: Determine if a post-maintenance erosion control measure was previously designed for the segment.
- **Step 2**: Review the recommended maintained condition hydraulic results for the segment.
    - Determine the location(s) where the velocity exceeds the acceptable velocity threshold based on the substrate type.
    - Determine the increase in velocity compared to the existing conditions hydraulic results.
- **Step 3**: Review the channel characteristics at the location(s) and applicability of the post-maintenance erosion control alternatives.
    - Review the velocity at the location and the amount of increase in the velocity that needs to be mitigated and select applicable alternatives.
    - Review the channel cross-section including bottom width (ditch, small channel, or large channel), steepness of the side slopes, channel depth, and flow depth to further narrow down the applicable alternatives. Channel characteristics such as velocity will determine the applicability of channel lining alternatives, and longitudinal slope will determine the effectiveness of grade control alternatives. If the potential erosion issue is limited to a small area or bank repair is recommended, bank protection/repair alternatives should be further evaluated.
    - A minimum of two measures were preliminarily selected to be analyzed prior to maintenance and final selection will be based on the segment conditions at that time.
- **Step 4**: Complete required regulatory alternatives analysis and site-specific design
    - Alternatives will be evaluated based on Chapter 7 of the SDDDM, with a focus on biotechnical solutions or using bio-based materials as well as durability (temporary, semi-permanent or permanent), and maintenance effort and cost.
    - Analysis will review the channel conditions prior to maintenance and evaluate alternative or a combination of alternatives to create most effective design.
    - The final measure will be selected, in consultation with the applicable regulatory agencies and a site-specific design will be developed to the satisfaction of the City Engineer.

- If a segment was previously designed/permitted, the post-maintenance erosion control measure will not be revised unless channel conditions change and warrant a re-evaluation of the facility segment.

After the permitted measure is installed, performance monitoring will be conducted annually by qualified personnel to confirm the measures remain in serviceable condition. Inspections include assessments of structural integrity and compliance with permit and site conditions. Additional inspection components may include appraisals of standing water; evidence of localized erosion; and/or sediment, trash, and/or debris accumulation to assess whether the measures are functional and meet intended purpose. If the measures are found to be failing or are found to be otherwise ineffective, the inspector will identify the need for corrective action. In the event that substantial erosion has occurred, erosion-impacted areas shall be identified for corrective action prior to the following rainy season. Monitoring, reporting, and repair work shall be approved and documented by TSW.

6.4 SITE–SPECIFIC ASSESSMENT RESULTS

This section discusses the MWMP facilities identified for the post-maintenance erosion control measures and discusses the results of the assessment based on the methods described in the previous section, up through Step 3. Step 4 will be completed prior to maintenance and will be based on the site-specific conditions at the time of maintenance.

6.4.1 IDENTIFICATION OF MWMP FACILITIES SUBJECT TO EROSIVE VELOCITIES

Part of the modeling effort for the MWMP included evaluation of the potential for erosion in the facility in the pre- and post-maintenance condition. The velocities throughout each segment were evaluated based on criteria in the SDDDM to determine if the velocities stayed within the permissible velocity range for the type of channel lining. The analysis identified 15 facility segments with potential for adverse hydraulic impacts within the following drainages and segments:

- Los Peñasquitos Canyon Creek (Black Mountain 1 and 2)
- Soledad Canyon Creek (Dunhill 1)
- Tecolote Creek (Genesee 1)
- Alvarado Canyon Creek (Mission Gorge 3, Alvarado 1)
- Norfolk Canyon Creek (Baja 1)
- Washington Canyon Creek (Washington 1)
- Chollas Creek (Martin 1, Rolando 2)

- Auburn Creek (Wightman 1 and 2, Home 1)
- South Chollas Creek (Alpha 1)
- South Chollas Creek Encanto Branch (Jamacha 1)

In addition, if a portion of a facility segment was not identified for maintenance but it may potentially be used for access, the segment was reviewed for potential erosion due to the access area. The analysis identified two facility segments with potential adverse hydraulic impact due to access areas within the following segments:

- Chollas Creek (Megan 2)
- South Chollas Creek Encanto Branch (Castana 1)

It should be noted that additional channels within the MWMP were evaluated and determined to have potential erosive flows in the pre-maintenance (i.e., existing) condition. In many of these areas maintenance is not recommended due to those erosive flows and/or a lack of flood risk reduction benefit. Post-maintenance erosion control measures could be implemented in these additional channels but would not be associated with maintenance. They would instead be considered as potential capital improvement projects, if warranted. Capital improvements are not proposed as part of the MWMP.

6.4.2 SUMMARY OF PROPOSED POST-MAINTENANCE EROSION CONTROL MEASURES

Using the methodology presented in Section 6.3, the facility segments were analyzed to determine the applicable post-maintenance erosion control measures to be analyzed prior to maintenance. Through the analysis, a minimum of two post-maintenance erosion control measures were identified for each segment with a focus on biotechnical solutions or using bio-based materials where feasible. For segments with a previously designed and permitted post-maintenance erosion control measure, the measure will not be revised unless channel conditions change and warrant a re-evaluation of the facility segment, in which case the methodology presented above will be used to evaluate the conditions at that time. Table 6-4 lists the potential alternatives for the facility segments where a post-maintenance erosion control measures has not been previously designed. These alternatives will be further analyzed at the time of maintenance to determine the type, number and location of the post-maintenance erosion control measures, following regulatory review. Table 6-5 lists the segments with post-maintenance erosion control measures previously designed and permitted.

Table 6-4
Post-Maintenance Erosion Control Measure Segment Specific Options

Facility Group Name	Segment Name (Facility Number)	Potential Alternatives
Los Peñasquitos Canyon Creek - Black Mountain	Black Mountain 1 (2-01-200)	● Riprap ● Chain-link or woven wire fence ● Anchored brushwood fence
Los Peñasquitos Canyon Creek - Black Mountain	Black Mountain 2 (2-01-210)	● Anchored brushwood fence) ● Chain-link or woven wire fence
Soledad Canyon Creek - Dunhill	Dunhill 1 (2-03-150)	● Coir mat (semi-permanent) ● One rock dam ● Riprap
Tecolote Creek - Genesee	Genesee 1 (3-04-160)	● Anchored brushwood fence ● Chain-link or woven wire fence ● Riprap
Alvarado Canyon Creek – Mission Gorge	Mission Gorge 3 (4-07-009)	● Coir mat (semi-permanent) ● One rock dam ● Riprap
Washington Canyon Creek	Washington 1 (5-02-151)	● Coir mat ● One rock dam ● Anchored brushwood fence
Chollas Creek - Rolando	Rolando 2 (5-04-048)	● Riprap ● Turf reinforcement mat ● One rock dam
Chollas Creek - Martin	Martin 1 (5-04-101)	● Coir mat (semi-permanent) ● Riprap ● Anchored brushwood fence
Auburn Creek - Home	Home 1 (5-04-220)	● Coir mat (semi-permanent) ● Riprap ● Anchored brushwood fence
Auburn Creek - Wightman	Wightman 1 (5-04-239)	● Coir mat (semi-permanent) ● One rock dam ● Riprap
Auburn Creek - Wightman	Wightman 2 (5-04-241)	● Coir mat (semi-permanent) ● One rock dam ● Riprap
Chollas Creek - Megan	Megan 2 (5-04-262)	● Coir mat (semi-permanent) ● Anchored brushwood fence
South Chollas Creek - Southcrest	Alpha (5-05-006)	● Anchored brushwood fence ● Chain-link or woven wire fence ● Riprap

Table 6-4
Post-Maintenance Erosion Control Measure Segment Specific Options

Facility Group Name	Segment Name (Facility Number)	Potential Alternatives
South Chollas Creek Encanto Branch - Castana	Castana (5-05-205)	● Coir mat (semi-permanent) ● Wooden check dam
South Chollas Creek Encanto Branch - Jamacha	Jamacha 1 (5-05-603)	● Anchored brushwood fence ● Coir mat (semi-permanent)

Table 6-5
Previously Designed and Permitted Post-Maintenance Erosion Control Measures

Facility Group Name	Segment Name (Facility Number)	Previously Designed & Permitted Alternative
Alvarado Canyon Creek - Alvarado	Alvarado 1 (4-07-021)	Chain link or woven wire fence
Norfolk Canyon Creek	Baja 1 (4-08-105)	Chain link or woven wire fence & Bollard debris structure

7 USE OF H&H ANALYSIS RESULTS

This section describes how results from the H&H analysis may be used to support environmental impact analysis associated with MWMP.

7.1 ENVIRONMENTAL IMPACTS ANALYSIS – HYDROLOGY

In general, potential significant impacts to hydrology may occur if facility maintenance activities would result in modification to existing drainage patterns, flow rates, or surface runoff such that downstream erosion, sedimentation, or increased flooding conditions result. Guidelines used to support hydrology environmental impact analysis include the City's *California Environmental Quality Act Significance Determination Thresholds* (City of San Diego 2016b) and Appendix G of California Environmental Quality Act Guidelines (14 CCR 15000 et seq.). The hydrology environmental impact analysis determines if implementation of the MWMP would result in potentially significant impacts, such as the following:

- Would the project result in a substantial increase in impervious surfaces and associated increased runoff?
- Would the project result in substantial alteration to on- and off-site drainage patterns due to changes in runoff flow rates or volumes?

The results of the facility-specific H&H analysis presented in this *Hydrology and Hydraulics Technical Report* and the fact sheets in Appendix A can be used to support the evaluation of potentially significant impacts related to flooding, groundwater, and erosion/sedimentation, resulting from facility maintenance activities in the environmental impact analysis. Information related to groundwater resources and the potential for MWMP maintenance activities to significantly impact groundwater recharge is in Section 2 of this *Hydrology and Hydraulics Technical Report*. The facility-specific fact sheets present a comparison of facility conveyance capacity and velocity to evaluate pre-maintenance and post-maintenance flood and erosion risk for each facility. Comparison of pre- and post-maintenance conveyance capacity can be used to evaluate whether potentially significant impacts related to flood risk may result from channel maintenance activities. Comparison of post-maintenance flow velocities with the recommended permissible velocities in the *SDDDM*, can be used to evaluate whether potentially significant impacts related to erosion risk may result from channel maintenance activities. If the H&H analysis indicated that velocities in the maintained condition were greater than the recommended permissible velocities, the fact sheets include recommendations for implementation of post-maintenance erosion control measures to bring flow velocities into an acceptable range to reduce potential impacts to less than significant.

For facility segments in which velocities in the recommended maintenance condition are greater than the pre-maintenance condition and greater than recommended permissible velocities, post-maintenance erosion control measures shall be implemented, including check dams or other similar velocity-reduction structures. The facilities identified to need potential post-maintenance erosion control measures are listed in Section 6.4.1 of this report. If additional facilities are identified with a greater than recommended permissible velocity due to maintenance, they will follow the same criteria outlined in this report.

Prior to the start of maintenance activities within these facilities, TSW shall prepare a site-specific maintenance plan prepared by a Professional Engineer that includes all information concerning the post-maintenance erosion-reduction goals and requirements, such as timing of installation, installation specifications, performance/assessment criteria, inspection schedule (by consultant or TSW staff), documentation of submittals, and reporting schedule. Post-maintenance erosion control measures assessment criteria include structural integrity and compliance with permit and site conditions. Additional criteria include appraisals of standing water, evidence of localized erosion, and/or sediment, trash and/or debris accumulation to assess whether the measures are functional and meet intended purpose. Post-maintenance erosion control measures shall be in conformance with the Facility Maintenance Plans for post-maintenance erosion control included as Appendix A-4 of the *Municipal Waterways Maintenance Plan*.

At a minimum, an evaluation process shall be completed following the rainy season (i.e., November through April) to verify that the erosion control measures are effective and in serviceable condition. The evaluation process shall be conducted by qualified personnel and use observations of channel properties to allow comparison of facility conditions to site-specific performance/assessment criteria, erosion and sedimentation indicators (i.e., scour, sediment deposition, or bank erosion), and vegetation assessments. In the event that substantial erosion has occurred, erosion-impacted areas shall be identified for corrective action prior to the following rainy season. Monitoring, reporting, and repair work shall be approved and documented by TSW. Post-maintenance erosion control measures shall be evaluated for a minimum of 12 months and up to 24 months to ensure reduction in erosion risk to, at a minimum, pre-maintenance conditions.

8 REFERENCES

Caltrans (California Department of Transportation). 2003. "Check Dams (SC-4)." Construction Site Best Management Practices Manual

CASQA (California Storm Water Quality Association). 2003. "Fact Sheet TC-22: Extended Detention Basin." In New Development and Redevelopment BMP Handbook. January 2003.

CASQA. 2011. "Construction Fact Sheet SE-2: Sediment Basin." In California Stormwater BMP Handbook. January 2011.

City of San Diego. 2016a. Summary of Findings for the Annual Drainage Channel Field Assessment and Maintenance Prioritization Project for the City of San Diego 2011 Master Storm Water System Maintenance Program (MMP).

City of San Diego. 2016b. *California Environmental Quality Act Significance Determination Thresholds*. July 2016.

City of San Diego. 2017. Drainage Design Manual. January 2017.

City of San Diego. 2018. Storm Water Standards Manual. October 2018. https://www.sandiego.gov/sites/default/files/storm_water_standards_manual_oct_2018.pdf.

County of San Diego. 2003. Hydrology Manual. Accessed April 17, 2018. https://www.sandiegocounty.gov/content/sdc/dpw/flood/hydrologymanual.html.

FEMA (Federal Emergency Management Agency). 2016. *FEMA Flood Insurance Study, San Diego County, California and Surrounding Areas*. Revised April 5, 2016.

NOAA (National Oceanic and Atmospheric Administration). 2017. Precipitation Frequency Data Server. Accessed November 2017. hdsc.nws.noaa.gov.

SCCWRP (Southern California Coastal Water Research Project). 2010. *Hydromodification Screening Tools: Field Manual for Assessing Channel Susceptibility*. SCCWRP Technical Report 606.

SCCWRP. 2011. *Final Hydromodification Management Plan*.

Sotiropoulos, F., and P. Diplas. 2014. National Cooperative Highway Research Program Report 795: Design Methods for In-Stream Flow Control Structures. Washington, D.C. Transportation Research Board. http://www.trb.org/Publications/ Blurbs/171759.aspx.

Strahler, A.N. 1952. "Hypsomic Analysis of Erosional Topography." *Geological Society of America Bulletin* 63:1117–1142.

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