2 TECHNICAL APPROACH

2.1 Modeling Process Approach

This Master Plan of Drainage model was prepared using XP-SWMM (Storm Water Management Model), a software package approved by the County of Los Angeles Department of Public Works (County of Los Angeles DPW). XP-SWMM is an improved version of the U.S. EPA's SWMM. It is a hydrologic and hydraulic modeling tool used to develop comprehensive storm, sewer, and flood scenarios. The use of this model provided a holistic approach to analyzing the storm drain system of the City of Rancho Palos Verdes. Both the hydrology and hydraulic analysis were prepared within the same model. The data input for XP-SWMM was imported from ArcGIS, a tool used to create, compile, and analyze data using various types of geographic information.

The modeling process approach used for this MPD is shown in Figure 2-1 and consisted of the following steps:

1. The City's existing storm drain database was obtained. The database includes location, material, size, invert (downstream and upstream) elevations, and length of the pipes; and location, type and invert elevations of the structures.
2. The existing storm drain database data was reviewed and organized.
3. Field visits were conducted to survey accessible storm drain catch basins and manholes using the ArcGIS field application to collect information needed for the analysis.
4. Unique IDs were assigned to each storm drain pipe and structure.
5. Each drainage area was divided into subwatersheds to determine the tributary area contributing flow to a node (storm drain inlet or subwatershed outlet).
6. The conveyance flow path and the longest flow path were delineated for each subwatershed (Figure 2-2).
7. The County of Los Angeles data [including land use, soil types and the rainfall depth (50-year 24-hour rainfall isohyets)] were imported into the ArcGIS model builder (developed by Michael Baker for this MPD).
8. Unique sources of data from each subwatershed were overlayed geographically to create a hybrid layer combining all the required parameters (soil type, percent impervious, rainfall depth, tributary area, conveyance length and slope).
9. The ArcGIS data was imported into XP-SWMM in the following sequence:
    a. Storm drain structures
    b. Storm drain pipes
    c. Open channels
    d. Subwatershed parameters (soil type, percent impervious, rainfall depth, tributary area, conveyance length and slope)
10. Hydrology and hydraulics calculations were performed using XP-SWMM.
11. Results included:
    a. Peak flow rate and runoff hydrograph for each subwatershed
    b. Velocity and hydraulic grade line (HGL) for each storm drain pipe

Hydrology and hydraulic modeling guidelines and procedures are further discussed in the next sections.

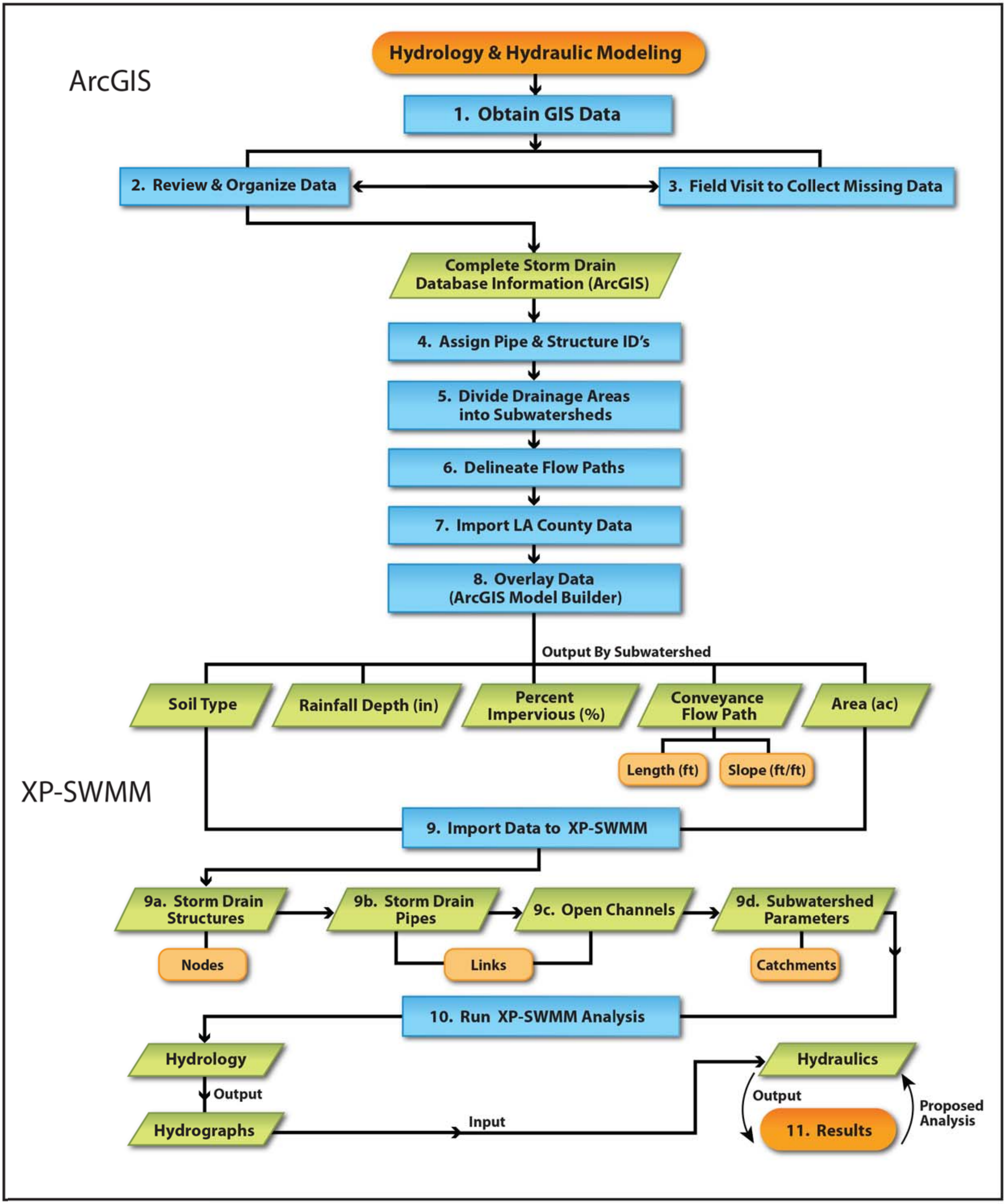

Figure 2-1: Modeling Process Approach

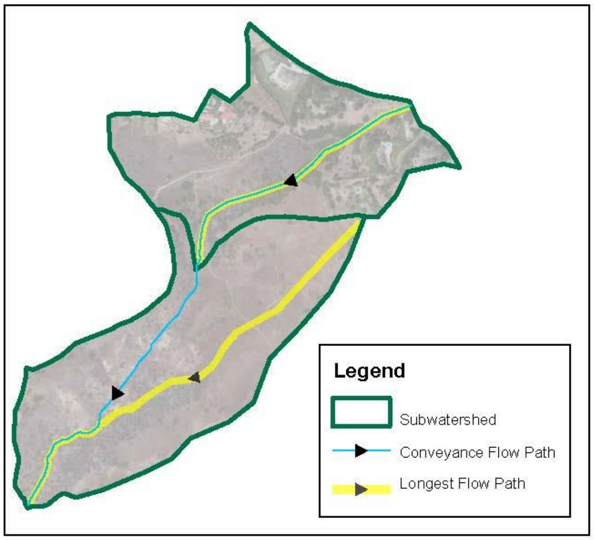

Figure 2-2: Subwatershed Flow Paths

2.2 Storm Drain System Identification Number

The storm drain pipe ID and the storm drain structure ID protocols were created using the type of structure or conveyance and the unique object ID that is automatically given to each line and point in ArcGIS. For example, MH4486 stands for the manhole with object ID 4486, and SD00219 stands for the storm drain pipe with object ID 219. The unique IDs given to the open channels and street conveyances were created using the corresponding abbreviation and the XP-SWMM link number given when the lines were imported. Abbreviations used for the unique IDs include:

Storm drain structure IDs:

- CB: Catch Basin
- MH: Manhole
- PC: Private Outlet
- OS: Outlet Structure
- JS: Junction Structure
- IS: Inlet Structure
- TS: Transition Structure
- GB: Grade Break
- MC: Material Change
- PL: Plug

Flow conveyance IDs:

- SD: Storm drain pipe
- OC: Open channel (includes both hardened and natural soft bottom conveyances)
- ST: Street

2.3 Hydrology Methodology

The procedures outlined in the 2006 County of Los Angeles Hydrology Manual and the Modified Rational Method (MODRAT) were used to compute subwatershed runoff rates. The MODRAT is a hydrologic model based on the Rational Method and developed by the County of Los Angeles Department of Public Works (DPW). This hydrologic model uses a time of concentration and a design storm to create runoff hydrographs from a subwatershed of any size over a specific period.

The existing City of Rancho Palos Verdes Master Drainage Study (AKM, 2004) divided the city into four major drainage areas. Michael Baker reviewed the drainage areas with the City and decided to further subdivide these with the City limits to restrain the XP-SWMM model size and improve computational time. Ten new drainage areas were delineated for this study. Michael Baker updated the boundaries based on field investigations and aerial images, and the 2006 topographic map obtained from the City. The drainage area divisions were prepared considering the cities bordering RPV and the receiving water. Some of the area tributary to these drainage areas originates outside the City boundary.

XP-SWMM includes a MODRAT module approved by the County of Los Angeles DPW. This module was used to complete the hydrology analysis for this MPD and comprises steps 5 through 8 of the modeling process approach outlined in Section 2.1 and consisted of the following steps:

1. Subwatersheds were delineated for each drainage area using the 2006 topographic contour elevations and following the County of Los Angeles Hydrology Manual criteria, which requires subwatersheds of around 40 acres for open space areas. For developed areas, the criteria requires subwatersheds tributary to a storm drain to be delineated using the “model inlet node” (catch basin, manhole, inlet, or junction structure) and the area contributing flow.
2. The conveyance flow path and the longest flow path were delineated for each subwatershed. The length and slope were calculated using the ArcGIS Model Builder.
3. The land uses (Exhibit A), soil types and rainfall depth (Exhibit B) were obtained from the County of Los Angeles DPW database. For each subwatershed, the predominant soil type, weighted area-average rainfall depth, and percent impervious were computed using the ArcGIS Model Builder.
4. The ArcGIS Model Builder produced new shapefiles including sets of data for each subwatershed.
5. Each shapefile was imported into XP-SWMM.
6. Different scenarios were created and run for the 10-, 25- and 50-year storm events. The rainfall depth for the 10- and 25- year storm events was calculated by multiplying the 50-year 24-hour rainfall depth by the reduction factors provided by the County of Los Angeles Hydrology Manual: 0.714 for the 10-year storm and 0.878 for the 25-year storm.
7. The results provided time of concentration and runoff hydrographs for each subwatershed. The time of concentration is the time it takes for precipitation in the most remote hydrological part of the watershed to reach the outlet. The time of concentration is used as the rainfall duration to calculate the total flow at the subwatershed outlet.
8. Each runoff hydrograph was associated with either
    a. a storm drain structure for a subwatershed tributary to a storm drain; or
    b. a node for open space areas.

Hydrology results summary tables are included for each drainage area. Each summary table provides:

- hydrology ID (created by XP-SWMM to run the MODRAT);
- storm drain structure ID (generated by Michael Baker, see section 2.2);
- subarea (acres); and
- 10-, 25- and 50-year peak flow rates (cfs) for each subwatershed.

2.4 Hydraulic Analysis

2.4.1 Existing Condition Analysis

A hydraulic analysis of the existing storm drain system was prepared using the results of the updated hydrology analysis. The existing condition hydraulic analysis was prepared to identify the deficient storm drain systems. Table 2-1, 2-2 and 2-3 summarize the existing City pipe inventory and Exhibit C shows the storm drain lines for which data is missing. This analysis was prepared using the XP-SWMM program for the entire drainage system. The analysis comprises steps 9 through 11 of the modeling process approach outlined in Section 2.1 and consisted of the following steps:

1. Required input data was imported into the XP-SWMM model from ArcGIS:
    a. Storm drain catch basins, manholes, grade breaks, transitions, junctions, inlet and outlet structures were input as nodes.
    b. Downstream and upstream invert elevations and the diameter or height and roughness coefficients for every storm drain pipe were input as links.
    c. Open channels were input as links.
2. The ground elevations at each node were generated using the 2006 topographic contour elevations obtained from the City.
3. XP-SWMM used the hydrographs for the 10-, 25-, and 50-year storm events at each “model inlet node” (catch basin, manhole, inlet, or junction structure) to calculate HGL for each storm drain pipe and each open channel.
4. The results provided maximum flow, maximum velocity and HGL profiles for each storm event and each storm drain.
5. The results were analyzed for system deficiencies, and preliminary alternatives to remove hydraulic deficiencies were prepared (see Sections 2.4.4, 2.4.5 and 2.4.6.).

Table 2-1: City Pipe Inventory

Diameter (inch)	Material	Total Pipe Segments	Total Length (ft)
-	RCB	20	890
4	PVC	1	11
6	PVC	3	28
8	ACP	1	143
8	PVC	5	71
8	RCP	2	44
10	ACP	4	310
12	ACP	19	528
12	ADS N-12	3	610

Table 2-1: City Pipe Inventory			
Diameter (inch)	**Material**	**Total Pipe Segments**	**Total Length (ft)**
12	CMP	19	703
12	CON	20	2630
12	CSPP	1	28
12	HDPE	1	189
12	PVC	28	1527
12	RCP	18	389
12	VCP	7	1215
15	CMP	2	218
15	CON	9	461
15	PVC	1	27
15	RCP	22	704
18	ACP	2	37
18	CMP	179	11608
18	CON	6	322
18	HDPE	48	4106
18	PVC	3	44
18	RCP	836	39635
21	CMP	4	327
21	RCP	103	8790
24	CMP	103	7846
24	CSPP	3	431
24	RCP	558	45799
27	RCP	115	10851
30	ADS N-12	10	642
30	CMP	54	6311
30	HDPE	1	159
30	RCP	397	30547
33	RCP	65	7986
36	CMP	60	7521
36	HDPE	3	474
36	RCP	361	33195
39	RCP	65	7999
42	CMP	26	1660
42	RCP	148	16699
45	CMP	1	39
45	RCP	46	5873
48	CMP	12	1975
48	RCP	134	14442
51	RCP	13	1656
54	CMP	8	1309
54	RCP	52	5483
54	STL	7	4089
57	RCP	4	754
60	CMP	4	394
60	RCP	30	3039
63	RCP	10	1279
66	RCP	13	1020
66	STL	9	2198
69	RCP	5	1063

Table 2-1: City Pipe Inventory			
Diameter (inch)	Material	Total Pipe Segments	Total Length (ft)
72	CMP	2	551
72	RCP	13	1319
75	RCP	7	915
78	RCP	17	1549
78	STL	1	36
84	CSPP	3	519
84	RCP	4	202
87	RCP	6	1140
90	RCP	6	560
96	RCP	2	156
120	CMP	7	846
UNKNOWN		139	11415
TOTALS		**3,891**	**317,536**

Table 2-2: Summary by Diameter		
Diameter (inch)	Total Length (ft)	% of Total
RCB	890	0.3%
4	11	0.0%
6	28	0.0%
8	258	0.1%
10	310	0.1%
12	7819	2.6%
15	1410	0.5%
18	55752	18.2%
21	9117	3.0%
24	54076	17.7%
27	10851	3.5%
30	37659	12.3%
33	7986	2.6%
36	41190	13.5%
39	7999	2.6%
42	18359	6.0%
45	5912	1.9%
48	16417	5.4%
51	1656	0.5%
54	10881	3.6%
57	754	0.2%
60	3433	1.1%
63	1279	0.4%
66	3218	1.1%
69	1063	0.3%
72	1870	0.6%
75	915	0.3%
78	1585	0.5%
84	721	0.2%
87	1140	0.4%
90	560	0.2%

Table 2-2: Summary by Diameter		
Diameter (inch)	**Total Length (ft)**	**% of Total**
96	156	0.1%
120	846	0.3%
TOTAL	**306,121**	**100.0%**

Table 2-3: Summary by Material		
Material	**Total Length (ft)**	**% of Total**
RCB	890	0.3%
ACP	1018	0.3%
ADS N-12	1252	0.4%
CMP	41308	13.5%
CON	3413	1.1%
CSPP	978	0.3%
HDPE	4928	1.6%
PVC	1708	0.6%
RCP	243088	79.4%
STL	6323	2.1%
VCP	1215	0.4%
TOTAL	**306,121**	**% of Total**

2.4.2 Typical Assumptions

The following assumptions were used for the existing hydraulic models:

- For storm drain systems in which diameters were known but invert elevations were missing, a 3-foot cover was assumed to the top of the pipe using the 2006 topographic mapping.
- For storm drain systems in which diameters were unknown, an 18- or 24-inch storm drain size was assumed. If the pipe was connected to a system with known data, the diameter was assumed to be the same size as the (up or downstream) known system.
- For cases in which the adjacent upstream and downstream storm drain pipe invert elevations were known, the slope was calculated and used for the portion of the storm drain system where data was unavailable.
- For the natural open channels, a typical trapezoidal section was used. Typical cross sections were estimated using the topography and measuring the channel bottom width and sides slopes at different stations along the channel.
- For the natural open channels, the upstream and downstream invert elevations were taken from the topographic contour elevations. The top of bank elevations were calculated by adding the height of the channel to the upstream and/or downstream invert elevation.
- For street conveyance, a trapezoidal cross section was used, in which the width was the width of the street, the depth was 8 inches, and the side slopes were 1:1. The street conveyance was used to connect systems that outlet to streets to downstream facilities. These cross sections were not used for street flooded width calculations.

2.4.3 Hydrology Design Criteria

The hydrology design criteria used to identify deficient systems and for the recommended improvements analysis for the City's drainage system follows the County of Los Angeles DPW Hydraulic Design Manual guidelines. The 10-year storm event was used for storm drain systems that discharge outside of city jurisdiction storm drain facilities, and the 50-year storm event was used for storm drain systems that discharge into natural water courses or that outlet into sump areas.

2.4.4 Deficiency Identification

The purpose of preparing XP-SWMM models for the existing condition (drainage system) was to determine existing system deficiencies and recommended improvements. The XP-SWMM results identified the magnitude of overflow and locations of flooded storm drain structures. This information was used to map existing flooded storm drain structures for each drainage area. Then for each flooded storm drain structure, the downstream storm drain system was located. Two types of storm drain systems were identified within the City:

1. Type I: Storm drain systems not located under a street (comprised of storm drain pipes that collect runoff water and drain under private property, cross under a street, or that directly discharge into canyons).
2. Type II: Storm drain systems located under a street.

For each type of storm drain system, a different approach was used to identify deficient systems:

1. Type I storm drain systems were considered deficient if the upstream storm drain structure flooded in the existing condition.
2. Type II storm drain systems were considered deficient if, after completing the street capacity analysis (Section 2.4.5), the upstream storm drain structure flooded.

2.4.5 Street Capacity Analysis

The street capacity analysis was completed only for street segments with underground facilities classified as type II storm drains and when the upstream storm drain structure flooded in the existing condition. This analysis was completed using the following procedure in XP-SWMM:

1. The street section was added as a link parallel to the existing storm drain pipe.
2. The street cross section was determined by measuring the street width and using either a 6-inch or an 8-inch curb with or without a crown, depending on the case.
3. The model was run and the results were analyzed to identify if the storm drain structure flooded or not.
4. If the storm drain structure did not flood, the system was considered appropriate. Otherwise, a deficiency removal analysis of the storm drain pipe was completed.

2.4.6 Deficiency Removal and Recommended Improvements

The deficiency removal and recommended improvements analysis was prepared using the criteria and assumptions from previous sections for deficient systems. This analysis is a preliminary design study, and each recommended improvement project will require an engineering design study. The improvements to the existing storm drain system included:

a. Upsizing storm drain facilities; or
b. Adjusting invert elevations to increase the slope of pipe segments and the hydraulic conveyance capacity.

When the ideal storm drain pipe size was larger than the downstream pipe size in areas with very steep terrain, the pipe size was increased for only the deficient portion of the storm drain system; otherwise the downstream system size was also increased until a larger pipe size was joint or to the outlet structure.

2.5 Cost Estimates

Total project costs were estimated for each project identified and are included for each drainage area (Chapter 3-12). The total project costs were calculated by estimating the project construction costs, engineering costs, and project administration. The estimation was completed for each system and compiled separately for each drainage area. New atlas maps were developed for this MPD and used as the basis for the cost analysis. The following steps were used to calculate the total project cost estimates:

1. The existing atlas map number for each storm drain pipe for which an improvement is recommended was identified.
2. Pipe sizes and total length of all storm drain pipes within each map that need improvement were compiled for each drainage area.
3. Construction cost data was identified for a range of storm drain pipes and reinforced concrete boxes (RCB). The costs were based on previous master plan studies prepared by Michael Baker and in cooperation with the City. All costs are in 2015 dollars. Storm drain unit costs are per linear foot and included costs for excavation, shoring, bedding, backfill, compaction, removal of excess material, and trench resurfacing. Pipe removal costs were based on the existing pipe diameter and are per linear foot. Table 2-4 shows the unit prices used for installation and removal of the various pipe sizes. The construction cost for each system was determined from the recommended facility size, the length of the improvements, and the identified unit cost.

Table 2-4: Pipe Unit Price

Proposed Pipe Size	Unit Price	
	Installation	Removal
18-inch	$161	$24
24-inch	$190	$28
30-inch	$207	$31
36-inch	$288	$43
42-inch	$316	$47
48-inch	$334	$50
54-inch	$345	$52
60-inch	$397	$60
78-inch	$518	$78
4- x 2-foot RCB	$1,500	$225.00
6- x 2-foot RCB	$2,500	$375.00

4. The removal unit prices for pipes with sizes not listed in Table 2-1 were calculated either by using an equivalent size or by rounding up to the next size unit price.
5. The total construction cost includes pipe installation and removal, manholes, catch basin and junction structures construction, utility relocation, traffic control Storm Water Pollution Prevention Plan (SWPPP), mobilization and miscellaneous items.
6. The engineering total project cost includes:
   a. Construction cost
   b. Engineering and Design = 0.08 x construction
   c. Surveying = 0.01 x construction
   d. Construction management = 0.06 x construction
   e. Subtotal project cost = total a through e
   f. Contingencies = 0.2 x Subtotal project cost
7. For each drainage area, total project cost estimates per recommended improvement map are shown in the cost estimate section. The recommended improvements maps for each drainage area are included immediately after the cost estimates section for each chapter.

Because construction will take place over a number of years, the total cost of master plan implementation will vary from the numbers provided in this study. The funding programs should be adjusted to future construction cost indexes for the design and/or construction of all recommended improvements. According to Engineering News Record as of February 2015 the construction cost index is 9961.75.

2.5.1 Total Cost Estimates

Tables 2-5 and 2-6 provide the total cost estimates for the recommended improvement projects proposed in this MPD for City owned and LA County owned storm drain systems respectively, for each drainage area. The prioritization scheme and the Capital Improvement Project (CIP) schedule are included in Chapter 13.

Table 2-5: Total Recommended Improvements Cost Estimates City Owned Pipes

Drainage Area	Total Project Cost
OSS	$1,313,000
OSE	$1,155,000
OSW	$ 1,217,000
OWW	-
LAS	$ 1,778,000
LAE	$ 2,756,000
LAN	-
PVN	$ 1,073,000
PVW	$ 1,030,000
RHE	$ 1,535,000
Total	**$11,857,000**

Table 2-6: Total Recommended Improvements Cost Estimates LA County Owned Pipes	
Drainage Area	**Total Project Cost**
OSS	-
OSE	$1,705,000
OSW	$281,000
OWW	$1,015,000
LAS	$103,000
LAE	$628,000
LAN	-
PVN	-
PVW	-
RHE	$2,025,000
Total	**$5,757,000**