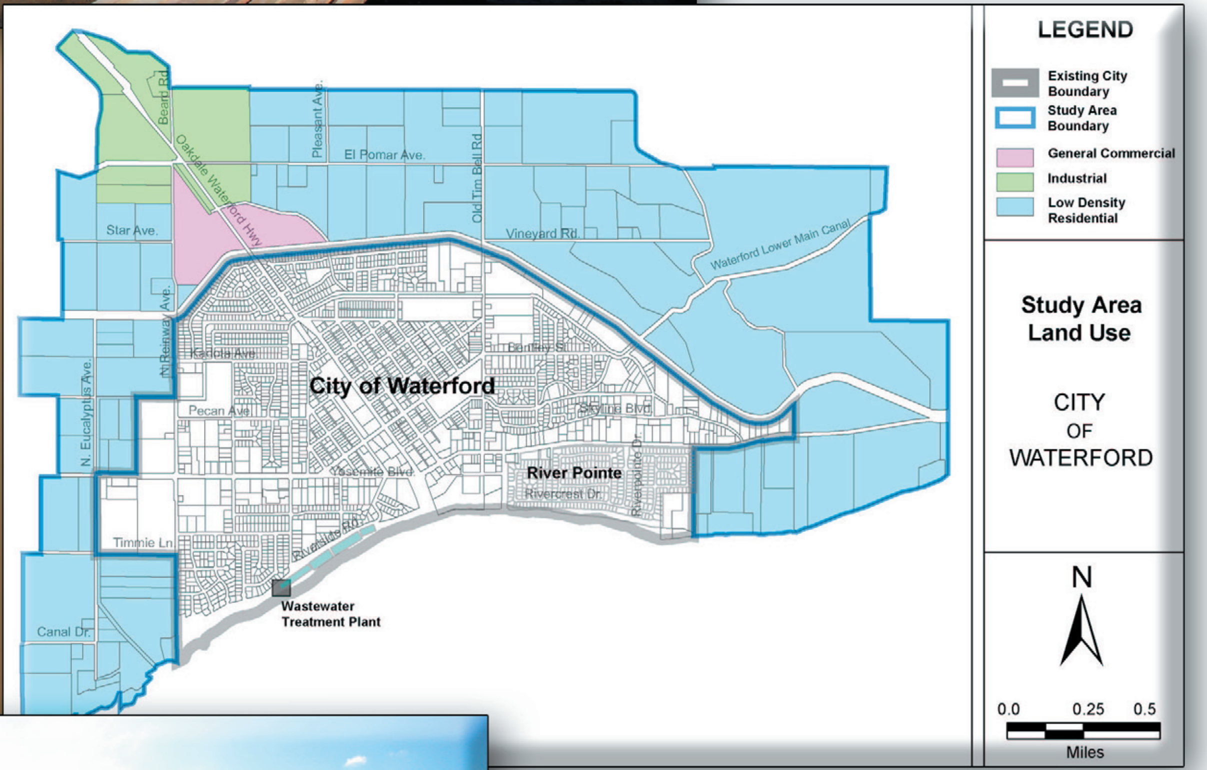
City of Waterford
Incorporated 1969



Sewer System Master Plan

FINAL

February 2006

RMC
Water and Environment

RMC
Water and Environment

Los Angeles
Sacramento
San Francisco
San Jose
Walnut Creek

February 17, 2006

City of Waterford
Mr. Tony Marshall, P.E.
Consulting City Engineer
322 Sun West Place
Manteca, CA 95337

Subject: Final Sewer System Master Plan

Dear Mr. Marshall:

RMC is pleased to submit this final version of the Sewer System Master Plan for the City of Waterford. This Plan documents the following:

- Land use analyses, wastewater flow projections, and the development of a hydraulic model for the City's proposed annexation area;
- A Master Plan for the future sewer collection system network for buildout expansion of the City within the study area boundary; and,
- A Capital Improvement Program (CIP) for sewer improvements needed to serve this area

We greatly appreciate the support and guidance that we have received from the City throughout this process.

If you have any questions, please don't hesitate to contact us at (916) 273-1500.

Sincerely,
RMC Water and Environment

Glenn Hermanson, P.E.
Project Manager

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Innovative Solutions for Water and the Environment

City of Waterford
Sewer System Master Plan

Final Report

Prepared by:
RMC
Water and Environment

February 17, 2006

Table of Contents

List of Tables

List of Figures

Appendices

Acknowledgements

This Sewer System Master Plan represents a collaborative effort between RMC and the City of Waterford. We would like to thank the following key personnel from the City whose invaluable knowledge, experience, and contributions were instrumental in the preparation of this Master Plan.

Tony Marshall – Consulting City Engineer, City of Waterford

Robert Borchard – Consulting City Planner, City of Waterford

List of Abbreviations

ADWF	average dry weather flow
BSPS	Baker Street Pump Station
BWF	base wastewater flow
CAD	computer aided design
CCI	construction cost index
cfs	cubic feet per second
CIP	capital improvement project
City	City of Waterford
DU	dwelling unit
ENR	engineering news record
ft	feet
fps	feet per second
FY	fiscal year
gal	gallon
GIS	geographic information system
gpad	gallons per acre per day
gpcd	gallons per capita per day
gpd	gallons per day
gpd/DU	gallons per day per dwelling unit
gpm	gallons per minute
GWI	groundwater infiltration
HDD	horizontal directional drilling
in	inch
I/I	infiltration and inflow
LF	linear feet
MG	million gallons
mgd	million gallons per day
MID	Modesto Irrigation District
NA	not applicable
PDWF	peak dry weather flow
PF	peaking factor
PS	pump station
PWWF	peak wet weather flow
RDI/I	rainfall dependent infiltration and inflow
sqft	square feet
WWTP	wastewater treatment plant

Chapter 1 Introduction

This report presents the results of a study to develop a master plan for sanitary sewers for proposed areas of annexation to the City of Waterford (City). The report was prepared by RMC Water and Environment (RMC) under a contract with the City dated March 20, 2005.

1.1 Background and Purpose

The City is proposing to annex approximately 1,610 acres of agricultural land surrounding the existing City boundary as shown in **Figure 1**. To help plan for the development of the annexation area, the City contracted with RMC to develop the following planning documents:

- Water Distribution Master Plan
- Sewer System Master Plan
- Storm Drainage Master Plan
- Urban Water Management Plan
- Wastewater Treatment Plant Master Plan

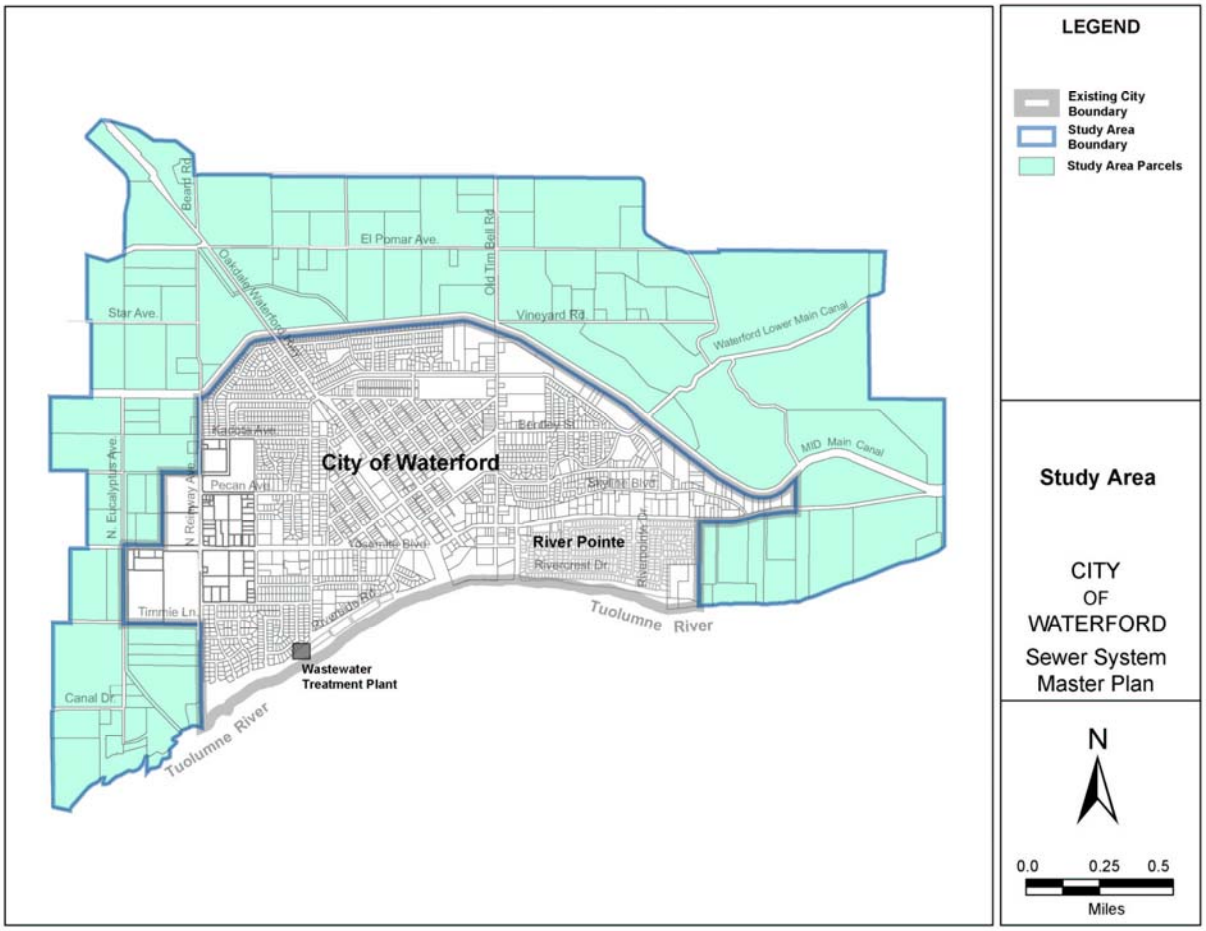
This Sewer System Master Plan provides information required for the City's planning and financial efforts, and defines the sanitary sewer system improvements necessary to accommodate the City's future land use development plans. The scope of this Master Plan includes the following major tasks:

1. Create a computerized hydraulic model of the future sewer system in the expansion area using H2OMap Sewer Professional, Suite 7.0;
2. Create a master plan for the future sewer collection system network for buildout expansion of the City within the study area boundary; and,
3. Develop a Capital Improvement Program (CIP) for sewer improvements needed to serve this area.

1.2 Study Area

The City of Waterford is located in the eastern portion of Stanislaus County, approximately 13 miles east of Modesto and 11 miles northeast of Turlock. The City is bordered on the south by the Tuolumne River, on the north by the Modesto Irrigation District (MID) Modesto Main Canal, on the west by Eucalyptus Avenue, and on the east by a parcel boundary south of MID Lateral Connection No. 8. The study area for this Master Plan comprises approximately 1,610 acres of agricultural land surrounding the City's existing boundary to the north, east, and west. The study area forms a semicircular arc around the existing City, and is bounded by the Tuolumne River on the south. Terrain in the western half of the study area is very flat, with the exception of the southwestern corner of the study area that straddles the cliff north of the Tuolumne River. Terrain in the eastern half of the study area is more varied, rising from 160 feet above sea level to around 200 feet above sea level in the eastern and northeastern sections of the study area. **Figure 1** presents the geographical limits of the study area.

Figure 1: Study Area

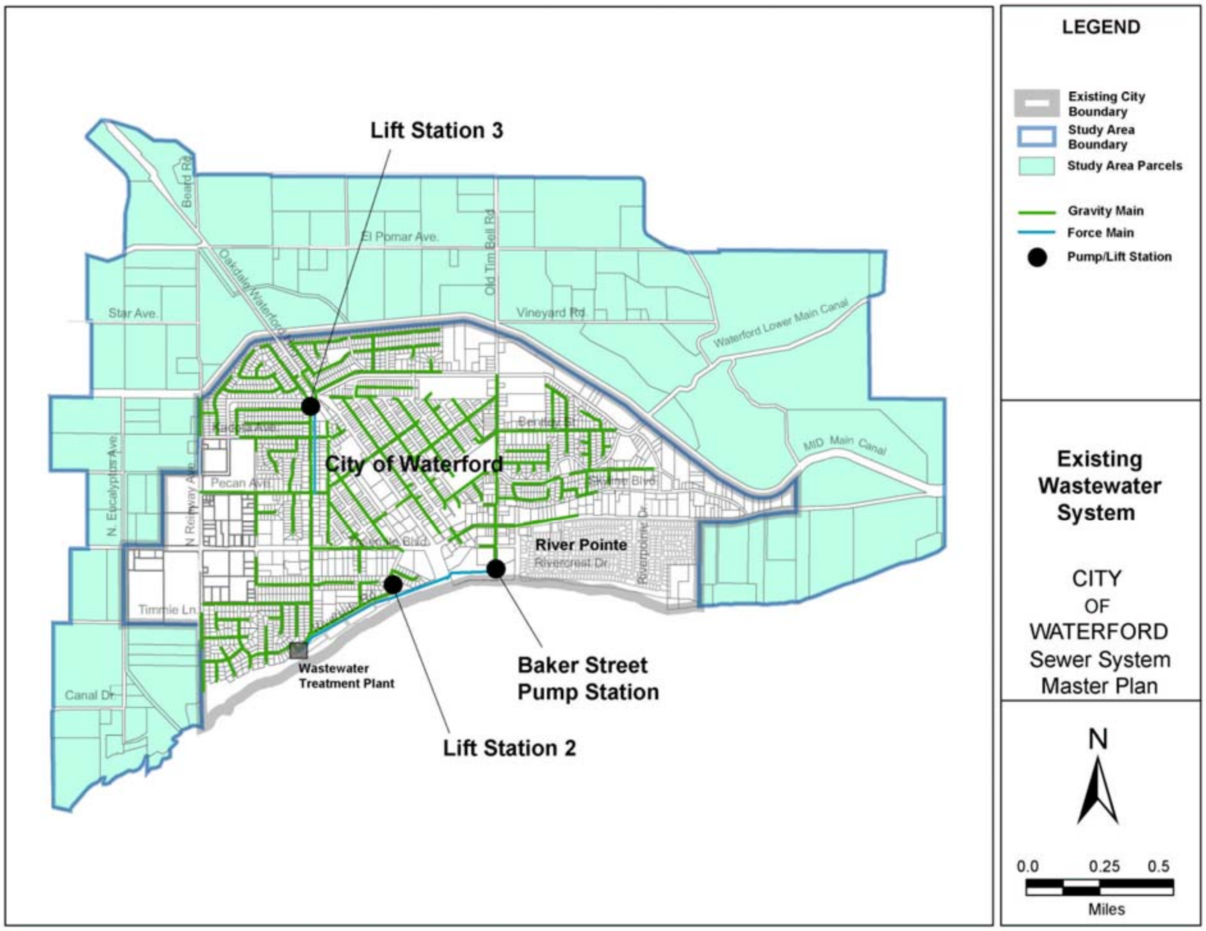


1.3 Existing Sewer System and Wastewater Facilities

The City of Waterford currently owns and operates a wastewater collection system comprised of gravity sewers, force mains, and three lift (pump) stations as shown in **Figure 2**. All of the City's wastewater is currently conveyed to and treated at a single wastewater treatment plant (WWTP), which lies just south of Riverside Drive, on a bluff above the northern bank of the Tuolumne River.

The Baker Street Pump Station (BSPS), the City's largest pump station, is located at the southern terminus of Baker Street, just west of North Appling Road and east of Hickman Road. Wastewater flows from all parcels east of the downtown area enter BSPS and are conveyed to the WWTP via an 8-inch force main. Wastewater from the remainder of the City is conveyed to the WWTP via two gravity mains. Lift stations 2 and 3 lift wastewater flows at the eastern terminus of Riverside Road and just south of the MID Canal on North Western Avenue, respectively, into gravity sewers that continue to the WWTP headworks.

Figure 2: Existing Wastewater System



Chapter 2 Service Area and Land Use Plans

This section provides a summary of the City's proposed annexation area (study area), buildout land use estimates, and the corresponding land use databases that were created for the development of this Master Plan.

2.1 Description of Proposed Annexation Areas

The City's proposed annexation area consists primarily of agricultural lands surrounding the City's existing boundary. The proposed annexation area's boundary, service area boundaries, land use maps, and databases were developed by incorporating the following information:

- GIS Parcel Map – Downloaded from the Stanislaus County GIS Library[1]
- Annexation Area Map – Hard copy provided by MCR Engineering, Inc.
- River Pointe Development files – AutoCAD files provided by TKC Engineering
- Land Use Map – Hard copy provided by MCR Engineering, Inc.

A GIS (Geographic Information System) land use database was developed for each parcel by assigning the land use category from the paper map provided by MCR Engineering to the downloaded GIS parcel map. The proposed land uses associated with the proposed annexation area are discussed and quantified below.

2.2 Proposed Land Uses

Table 2-1 presents a summary of the proposed buildout land use categories, their associated densities, and gross acreage developed as part of the land use evaluation task for this Master Plan.

Table 2-1: Proposed Land Uses

Land Use Category	Residential Density (DU/acre)	Gross Acreage [a]	Percentage of Area
Low Density Residential	4.5	1,316	81%
Industrial	n/a	126	8%
General Commercial	n/a	48	3%
	Subtotal	**1,490**	**92%**
Major roads and canals	n/a	129	8%
	TOTAL	**1,619**	**100%**

a. Gross acreage includes future roadways, medians, and sidewalks. Net acreage information is not available since the study area has not been subdivided into individual parcels and roadways. On average, net acreage is approximately 80 to 90 percent of the gross acreage.

As shown in **Table 2-1**, and illustrated in **Figure 3**, the majority of existing vacant land is planned for future low density residential development. At this time, the location and number of schools and parks

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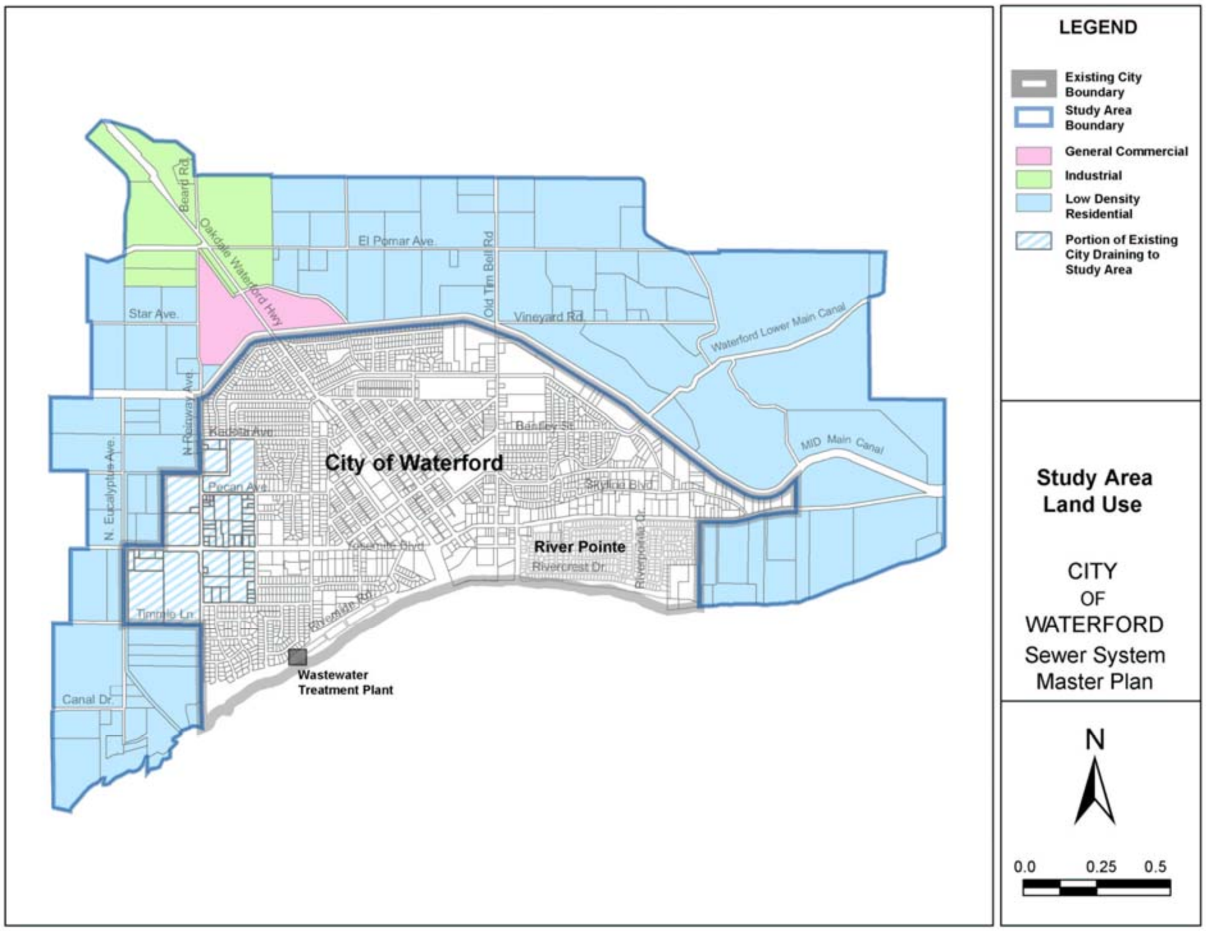
[1] http://regional.stangis.org/

have not been identified. Schools, parks, an artificial lake, and stormwater detention basins will be located within the low density residential area.

Figure 3: Study Area Land Use



Chapter 3 Analysis Methodology

3.1 Wastewater Flows

Presented below are summaries of the components of modeled wastewater flows, flow generation factors used to develop flow projections, and the projected values for peak buildout wastewater flows in the study area.

3.1.1 Wastewater Flow Components

The wastewater flows developed for this Master Plan are composed of several components, termed base wastewater flow (BWF), groundwater infiltration (GWI), and rainfall-dependent infiltration and inflow (RDI/I). The latter two components are referred to jointly as infiltration/inflow (I/I). **Figure 4** provides a graphical representation of the wastewater flow components.

Base Wastewater Flow

Base wastewater flow represents the sanitary and process flow contributed by the users connected to the collection system. BWF rates vary based on type of land use (e.g., residential, commercial, industrial), the hour of the day, and the day of the week. Average BWF rates are often expressed in units of gallons per day per acre (gpad), gallons per day per capita (gpcd), or gallons per day per dwelling unit (gpd/DU) and vary with the type of land use. Diurnal patterns (hourly flows over the course of a day), which may differ between weekdays and weekends, also vary based on type of land use. For the purposes of this Master Plan, which reflects the results from a steady-state hydraulic model of the study area's collection system, diurnal patterns were not specifically addressed; rather, the peak diurnal flow is represented as a peaking factor of the average flow.

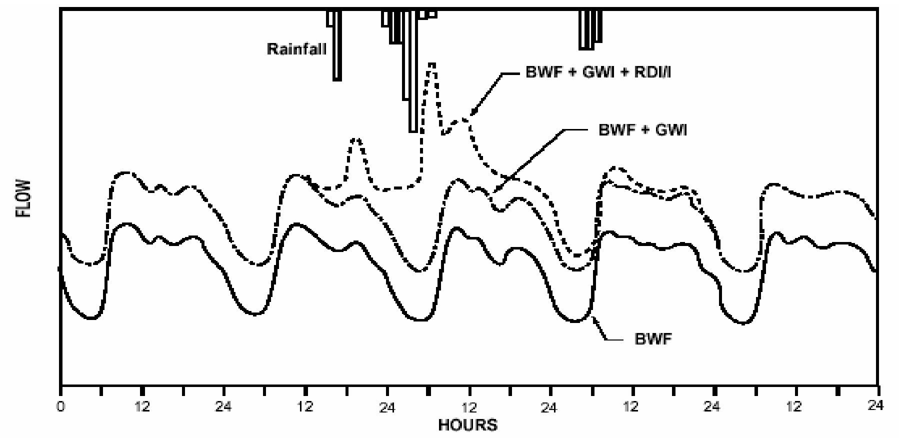
Groundwater Infiltration

Groundwater infiltration is extraneous water that enters the sewer system through defective joints and cracks in sewer mains, manhole walls, and service laterals located below the groundwater table. Since groundwater levels can vary based on the time of year and amount of rainfall that occurs during the wet weather season, GWI rates typically vary on a seasonal basis, being lowest in the summer and early fall and highest in late winter and spring. GWI is generally represented as a constant flow rate, since GWI generally does not vary significantly over the course of a typical day.

Rainfall Dependent Infiltration/Inflow

RDI/I is the wet weather portion of sewer flow that may enter the sewer system through pipe and manhole defects during and after a storm, as well as through direct surface drainage connections or manhole lids. Depending on the condition of the sewer system and the size and intensity of the storm event, RDI/I can cause significantly higher peak flows than those that normally occur on non-rainfall days. RDI/I represents the difference between the total flow during and immediately following a storm event and the non-rainfall "base flow" (BWF plus GWI) that is estimated to have occurred during the storm period. For a steady-state flow analysis, the peak RDI/I flow rate is the parameter of interest.

Figure 4: Wastewater Flow Components



3.1.2 Flow Generation Factors

For the purposes of this Master Plan, BWF was combined with dry weather GWI to form a single component, termed average dry weather flow (ADWF). Unit ADWF factors (in gpd/acre or gpd/person) were combined with buildout land use information (acreage and population density) to calculate the ADWF input for each parcel in the land use database (see Chapter 2). The calculated unit ADWF factors are summarized in **Table 3-1**.

Residential Sewage Generation Factor

Proposed residential areal ADWF factors were developed using the following formula:

ADWF Factor (gpad) = [Residential Density]*[Population Density]*[90 gpcd]

where residential density was assumed to be 4.5[2] dwelling units per acre and population density was assumed to be 3.5 persons per dwelling unit. The proposed per capita sewage generation factor of 90 gpcd is based on the flow generation factor for future residential land used in the City of Winters, and has been assumed to similarly represent the future characteristics of residential areas in this Master Plan's study area.

Non-Residential Sewage Generation Factors

Non-residential flows were also generated based on an areal method for the two proposed non-residential land use categories. Areal flow generation factors of 2,000 gpad and 2,500 gpad for industrial and general commercial land uses, respectively, are based on representative planning flow generation factors for the City of Winters. The proposed ADWF unit flow factors are also listed in **Table 3-1**.

Sewer system facilities must be sized to convey the peak flows in the system. Since the study area's proposed future collection system was modeled as a steady-state system, a conservative master plan criterion was used that assumed the peak I/I flow would coincide with the peak dry-weather flow (PDWF). The PDWF is calculated by applying a peaking factor (PF) to the ADWF. Therefore, the design flow or peak wet weather flow (PWWF) for any segment of the collection system was calculated using the following formula:

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[2] In order to correct for streets, medians, and sidewalks, a net acreage correction factor of approximately 86% was applied to the residential density (i.e., 4.5 x 0.857 = 3.857).

Design Flow = **PWWF** = **PDWF + I/I**
where **PDWF** = **ADWF x PF**
PF = **3**
I/I = **600 gpad**

Because the City does not have any current flow monitoring data, a peaking factor of 3 was assumed. Similarly, a conservative areal I/I generation factor of 600 gpad was assumed.

3.1.3 Projected Wastewater Flows

Table 3-1 presents the estimated ADWF and PWWF for the study area.

Table 3-1: Study Area Wastewater Flow Projections

Land Use Category	Gross Acreage	Unit Flow Factor		Buildout ADWF (mgd)	Buildout PWWF (mgd)
Low Density Residential	1,316	1,215	gpad	1.60	5.59
Industrial	126	2,000	gpad	0.25	0.83
General Commercial	48	2,500	gpad	0.12	0.39
			TOTAL	**1.97**	**6.81**[a]

a. Does not include approximately 1.07 mgd of non-study area wastewater flows (i.e., from schools, residential areas, homes currently on septic tanks, flows from River Pointe, etc.) from adjacent areas of the existing City system that in the future may be conveyed through the new sewers recommended in this Master Plan. Refer to Section 4.1 for more information.

3.2 Sewer System Configuration

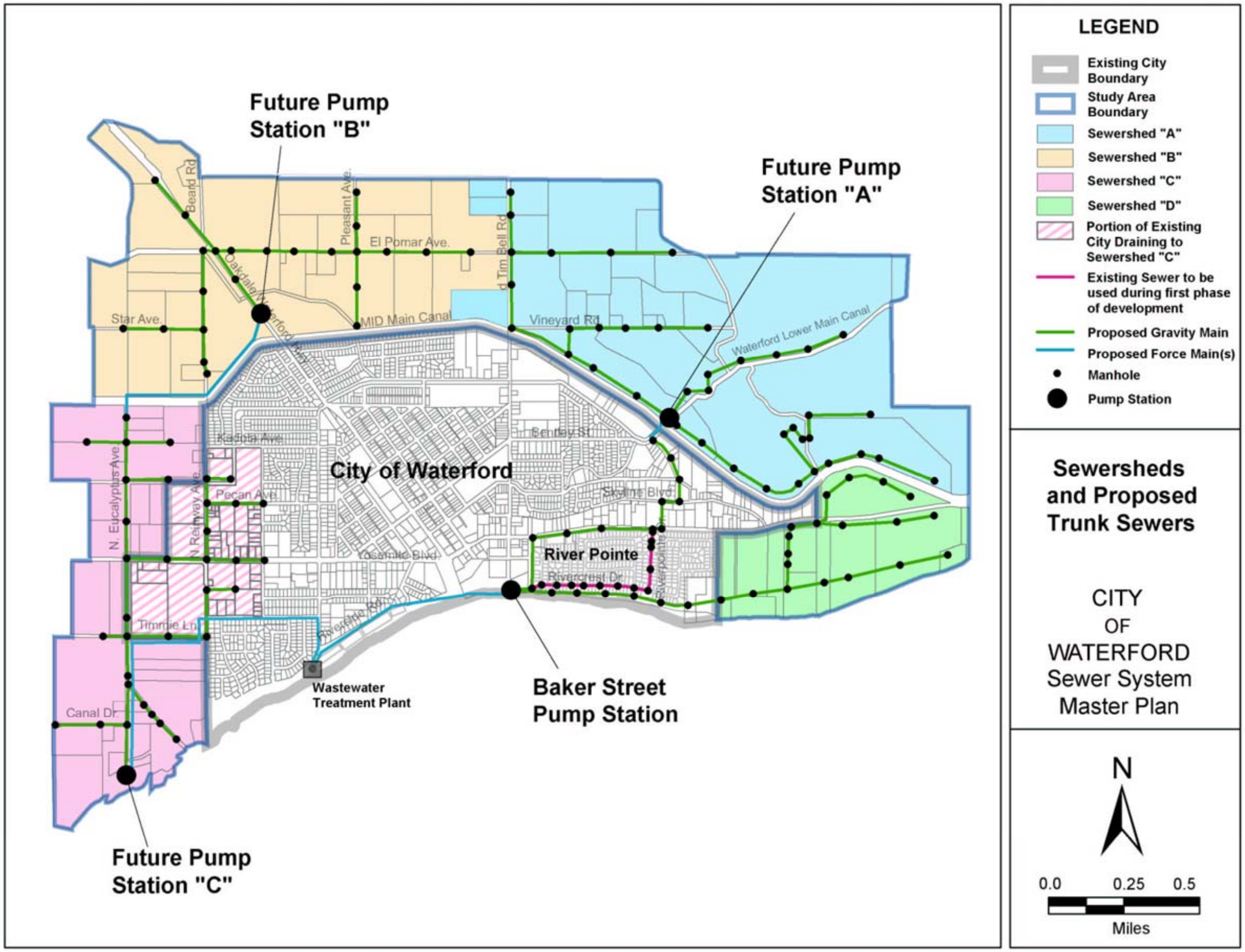
This section presents a summary of the methodologies used to develop sewersheds for the study area and the corresponding sewer alignments. **Figure 5** presents the proposed sewersheds and alignments of trunk sewers for the study area. The methodologies and design criteria used to develop the sewersheds and sewer alignments shown in Figure 5 are discussed in the following sections.

3.2.1 Sewershed Definition

For the purposes of this Master Plan, a sewershed is defined as a geographic and/or hydrologic region, or basin, in which all wastewater flows are conveyed to a single point, or outlet, before being conveyed elsewhere. Typically, a sewershed comprises a series of collector sewers and lift stations upstream of a major regional trunk sewer or pump station. The wastewater flows leaving one or more sewersheds are typically conveyed to a larger trunk sewer or to the wastewater treatment plant itself.

Topography typically governs the size and shape of the sewersheds in a given collection system. The study area for this Master Plan is comprised of two distinct topographical regions: 1) very flat (typical slope is less than 0.15 %), and 2) moderately sloped (slopes vary between 1.5 and 3 percent). Sewersheds in areas that are very flat are generally governed by sewer depth, as sewers following a minimum design slope tend to quickly become prohibitively deep in areas with little or no topography. In areas with moderate slopes, sewer depth becomes less constrictive and sewersheds are typically defined by prominent geographical features, such as canals and natural waterways. The proposed sewersheds for the study area are shown in **Figure 5** and discussed in the following section.

Figure 5: Sewersheds and Proposed Trunk Sewers



3.2.2 Methodology for Developing Proposed Sewer Alignments

Sewer Design Criteria

In addition to providing the basis of the master planning performed for the 2005 Sewer System Master Plan, the material presented in this section can be used as a basis for the City's design standards. The following criteria are discussed below:

- Manning's *'n'* factor
- Minimum Pipe Size
- Maximum Allowable Flow Depth
- Minimum Velocity/Slope
- Maximum Velocity
- Maximum Collector Sewer Depth
- Minimum Pipe Depth
- Design Requirements at Increases in Pipe Size
- Headloss in Manholes
- Hydraulic Design Criteria for Force Mains
- Inverted Siphons

A summary of the recommended design criteria is presented in **Table 3-2**.

Table 3-2: Recommended Master Plan Design Criteria

CRITERIA	RECOMMENDED VALUE
Manning's *'n'*	0.013 for all materials
Minimum Gravity Sewer Pipe Size	8 inches
Maximum Allowable Flow Depth (d/D)	Under peak design flow conditions: ▪ d/D = 0.7 for 8- and 10-inch pipe and 12-inch pipe with service connections ▪ d/D = 1.0 for 12-inch (without service connections) and larger pipe.
Minimum Velocity/Slope	▪ Criteria 1: Minimum design slope selected to provide a minimum velocity of 2 fps for sewers between 8- and 18-inch and a minimum velocity of 3 fps for sewers 39-inch and larger. For sewers between 21- and 36-inch, the minimum slope allows the velocity to transition from 2 fps to 3 fps. Velocities calculated with Manning's '*n*' =0.013 and full pipe conditions. ▪ Criteria 2: Minimum velocity of 2 fps at peak dry weather flow at buildout.
Maximum Velocity	10 fps
Maximum Collector Sewer Depth	8- and 10-inch pipe and 12-inch pipe with service connections have a maximum depth of 16 feet.
Minimum Pipe Depth	▪ Provide a minimum depth to pipe invert of 7 feet for all gravity sewers including the sewers at the periphery of the system. ▪ At least 4 feet of separation between the flow line of creeks and the crown of the sewer at creek crossings.
Increases in Pipe Size	▪ Match crowns when increasing in pipe size. ▪ Set branch sewer elevations 0.1 ft. above the main sewer elevation when the branch sewer is the same size as the main sewer.
Headloss in Manholes	Deflection manholes with deflections greater than 20 degrees are assigned a 0.1-foot drop. Deflections greater than 90 degrees are not allowed.
Force Mains	▪ Maximum velocity: 8 fps during PWWF at buildout. ▪ Minimum velocity: 3.5 fps with one pump running (force mains with 20% slope or less); additional analysis required (force mains with greater than 20% slope) ▪ 100% non-corrodible pipe material (i.e., HDPE or PVD with no metallic fittings or thrust restraint devices). ▪ Pipe friction will be calculated using the Hazen-Williams formula with a roughness coefficient C = 100 for all pipe sizes and materials.
Inverted Siphons	▪ Avoid inverted siphons whenever possible. ▪ Downflow and upflow legs of the siphon have a maximum slope of 15 percent. ▪ Upstream invert elevation will be calculated by adding 12 inches plus the pipe friction to the downstream invert elevation. ▪ Pipe friction will be calculated using the Hazen-Williams formula with a roughness coefficient C = 100. ▪ Minimum velocity of 3 fps at ADWF during early years of operation ▪ Minimum velocity of 4 fps at PDWF during early years of operation. ▪ Minimum pipe diameter of 8 inches and minimum of two barrels. ▪ The downstream manhole must be located in an easily accessed location and safely accessed (busy street locations are not allowed).

Manning's 'n' Factor

Manning's 'n' roughness coefficient is the friction factor utilized in the Manning's Equation for gravity flow to describe the roughness of a particular pipe material or condition. There has been much debate over the idea that the 'n' value of a pipe can change over time as the pipe ages and a slime layer grows on the pipe wall. One side of the debate claims that the roughness or 'n' value of this slime layer is the same whether the slime layer grows on a concrete wall, a vitrified clay wall, or a plastic wall. The other side of this debate proposes that a different 'n' value should be used for different pipe materials, generally ranging from 0.008 for plastic pipe to 0.016 for unlined concrete pipe (Jeppson, 1976) with vitrified clay pipe between the two values.

A Manning's 'n' design value of 0.013, the most widely accepted value in the industry, provides some degree of conservatism if, in fact, there is a significant benefit to the smoother plastic pipe and PVC-lined (T-lock) pipe walls. For Waterford, it is recommended that an 'n' value of 0.013 be used for all pipe materials.

Minimum Pipe Diameter

Although there are some agencies that allow new 6-inch sewers (and many agencies, including Waterford, that have substantial amounts of existing 6-inch pipe), a minimum sanitary sewer pipe size of 8-inches is generally accepted as the industry standard and is the current proposed Waterford design criteria. Therefore, except for service lines (laterals), the minimum acceptable gravity pipe diameter for all newly constructed pipelines in this Master Plan shall be 8-inches.

Maximum Allowable Flow Depth

Depending on the pipe size, three different criteria concerning the depth of flow are being used by major sewer agencies in California.

For smaller pipes, usually up to 10 or 12 inches in diameter, the depth of flow to pipe diameter (d/D) ratio of 0.7 or 0.75 is used for the design at peak flow. This lower (d/D) ratio is more conservative and is used to prevent flow blockages in smaller pipes due to debris and avoid potential backup into connected service laterals.

Larger pipes (12 or 15 inches and larger) are generally designed to flow full at peak design flow conditions. A pipe designed for full or 100 percent capacity has a d/D ratio of 1.0.

In order to save costs, some agencies allow surcharging of large diameter gravity flow sewers under peak flows associated with infrequent (long return period) storm events. The main disadvantage of this approach is that once surcharging is allowed, its extent is hard to control and may result in flooding of basements and other low lying areas, and low flow velocities that may cause solids to settle out in the pipe. Also, gravity sewers are not designed for pressure flows, and flows under surcharged conditions may result in some exfiltration of sewage.

For the Waterford Sewer System Master Plan, it is recommended that the maximum depth of flow at peak design conditions in any collector (10-inch diameter or less) shall be 0.7 of the pipe diameter. Sewers 12 inches in diameter and larger may be designed to flow full unless direct service connections are planned, in which case the 0.7 diameter maximum depth shall govern.

Minimum Velocity/Slope

For municipal wastewater and its associated grit and solids content, 2 fps is commonly used as the minimum design velocity at full or half full pipe flow conditions. When the sewers are less than half full, velocities will drop below 2 fps, and some deposition of solids will occur. Re-suspension of solids occurs when the depth of sewage is greater than half full, and the velocity increases above 2 fps until a maximum velocity is reached at approximately 94 percent of full pipe depth. From 94 percent depth to full pipe, the velocity decreases back to 2 fps.

Table 3-3 lists the full pipe velocity criteria used by various cities and agencies. The criteria were found in the respective standards or design manuals.

Table 3-3: Comparison of Minimum Velocity Criteria of Various Agencies

Agency	Minimum Velocity (fps)	Condition
Central Contra Costa Sanitary District	2 [a]	At half pipe and full pipe conditions.
City of Los Angeles	3 [b]	At peak dry weather flow that exists at the time the pipe is placed into service.
Washington Suburban Sanitary Commission	2.5 [c]	At half pipe and full pipe conditions.
City of Dallas	2	At half pipe and full pipe conditions.
City of Phoenix	2	At half pipe and full pipe conditions.
Clark County Sanitation District (NV)	2 [c]	At half pipe and full pipe conditions.
Sacramento County	2 to 3 [d]	At half pipe and full pipe conditions.

a. Minimum velocity in small sewers (8”, 10” and 12”) is required to be higher.
b. Minimum velocity in upstream terminal reach is allowed to be lower.
c. Minimum velocity in upstream terminal reach is required to be higher.
d. Minimum velocity is 2 fps for 8 to 18-inch, 3 fps for 39-inch plus, and varies from 2 fps to 3 fps between 21- and 36-inch.

Once minimum velocities and Manning’s ‘n’ are selected, minimum pipe slopes can be specified. **Table 3-4** presents the minimum pipe slopes for various agencies for pipe sizes ranging from 8 to 36 inches. County Sanitation District 1 of Sacramento County (CSD-1) has over 2500 miles of mainline sewers and based on observed conditions in their various trunk sewers, they recently steepened their minimum required slopes for sewers greater that 18-inch. CSD-1 now requires that minimum velocities for sewers from 21- to 36-inches in diameter transition from 2 fps to 3 fps and sewers 39-inches and greater have a minimum velocity of 3 fps at full pipe flow. While this change in slope is minor, the decrease in maintenance requirements is noticeable.

Based on historical work order data and blockage reports, CSD-1 has also determined that the terminal sewer reaches (sewers in cul-de-sacs for example) require more maintenance than downstream sewers because of lower flows. Although they have not yet modified their standards, they are considering steepening their required minimum slope for terminal sewer reaches. As shown in **Table 3-4**, various leading sanitation agencies currently require steeper terminal reaches. Until this requirement is more common in Northern California, RMC is not proposing this requirement for Waterford.

Table 3-4: Minimum Pipe Slopes for Various Agencies

Pipe Size (in.)	Central Contra Costa Sanitary District	City of Los Angeles	Washington Suburban Sanitary Commission	City of Dallas	City of Phoenix	Clark County Sanitation District	Sacramento County (CSD-1)	Waterford's Draft Design Standards
8	0.0077	0.0087 0.0044 [a] 0.0060 [b]	0.0050 0.0100 [c]	0.0033	0.0033	0.0033 0.0060 [c]	0.0035	0.0035
10	0.0057	0.0065	0.0040	0.0025	0.0024	0.0025	0.0025	0.0025
12	0.0022	0.0051	0.0030	0.0020	0.0019	0.0020	0.0020	0.0020
15	0.0015	0.0038	0.0019	0.0015	0.0014	0.0015	0.0015	0.0015
18	0.0012	0.0030	0.0015	0.0011	0.0011	0.0012	0.0012	0.0012
21	0.00095	0.00239	0.00120	0.00090	0.00092	0.00092	0.0012	0.0012
24	0.00080	0.00200	0.00100	0.00080	0.00077	0.00077	0.0011	0.0011
27	0.00070	0.00171	0.00102	0.00060	0.00066	0.00066	0.0010	0.0010
30	0.00060	0.00149	0.00089	0.00055	0.00057	0.00057	0.0010	0.0010
33	0.00055	0.00131	0.00078	0.00050	0.00050	0.00050	0.0010	0.0010
36	0.00050	0.00117	0.00070	0.00045	0.00045	0.00045	0.0010	0.0010

a. Minimum slope in upper reaches of system with few connections.
b. Minimum slope in upstream terminal reach.
c. Minimum slope in upstream terminal reach.
d. Agencies using 2 fps criteria: Sacramento County, Dallas, Phoenix, Clark County Sanitation District.
e. Agencies using 2.5 fps: Washington Suburban Sanitary Commission
f. Agencies using 3 fps: Los Angeles.
g. Agencies using Manning's 'n' coefficient =0.013: Sacramento County, CCCSD, WSSC, Dallas, Phoenix, CCSD.
h. Agencies using Manning's 'n' coefficient =0.014: Los Angeles.

Recommendations for Minimum Slopes and Velocities

Two criteria are recommended to determine the design minimum slopes for sewers in Waterford. The first criteria requires the minimum design slopes to provide a minimum velocity of 2 fps for sewers between 8 and 18 inches in diameter and a minimum velocity of 3 fps for sewers 39 inches and larger. For sewers between 21 and 36 inches, the minimum slope allows the velocity to transition from 2 fps to 3 fps. The velocities are calculated with Manning's 'n' =0.013 and full pipe conditions. The second criterion requires the design slope to provide a minimum velocity of 2 fps at peak dry weather flow at buildout. These criteria will minimize the possibility of inexperienced designers trying to meet depth requirements by oversizing the sewers and flattening the slope.

Maximum Velocity

The maximum velocity used by various agencies generally ranges from 8 to 15 fps. This Master Plan recommends a maximum velocity of 10 fps for gravity sewers, except in the following location:

- **Project 2**: A 470 foot segment of pipe between Skyline Boulevard and Yosemite Boulevard will see velocities near 11 fps during PWWF. The parcel through which the pipe passes is currently under development, thus facilitating the acquisition of an easement. Because the feasibility of Project 2 hinges on the location of this pipe, few velocity-reducing adjustments to the alignment were possible.

Maximum Collector Sewer Depth

The City currently lacks standards that address the maximum depth of sewer services or collector sewers. CSD-1 limits the maximum depth of sewer services to 16 feet, which then limits the depth of collector sewers to 16 feet since sewer service lines connect to collector sewers. This restriction exists because the CSD-1 Maintenance and Operations group has the capability to make repairs to service lines and collector sewers to a depth of 16-feet with their own excavation and shoring equipment. Excavations deeper than 16-feet require the M&O group to hire an outside contractor to perform the necessary repairs. Since most sewer repairs occur on service lines and collector sewers, it was logical for CSD-1 to limit collector sewers to a maximum depth of 16-feet. Following similar logic, we recommend that the maximum depth for service sewers and collector sewers in Waterford be limited to 16 feet.

For trunk sewers (sewer 15-inch and larger and 12-inch sewers without service sewer connections), we recommend that the maximum depth be evaluated on a case-by-case basis. In general, a maximum cover of 20 feet can be used.

Minimum Pipe Depth

When discussing the depth of a pipeline, two terms are used: depth and cover. Sometimes these terms are used interchangeably, but for the purposes of this Master Plan, the following definitions will be used:

- Depth: Distance from ground surface to invert of pipe.
- Cover: Distance from ground surface to crown (top) of pipe.

The deeper a gravity sewer is located, the more flexibility there is with respect to alignment and connection point selection for future upstream connections. If a gravity sewer is too shallow, future upstream development using gravity connections may be restricted, and a lift station may be required. For this reason, it is important to plan sewers at proper depths during the master planning process. For this Master Plan, it is recommended that a minimum depth of 7 feet be used for planning future sewers, including the sewers at the periphery of the system. The following procedure will be followed to confirm that this minimum depth criterion is met:

- Delineate trunk shed boundary.
- Using existing features such as roads and property lines, create plan view of sewer system skeleton within the trunk shed.
- Calculate design flows.
- Using design flows, calculate pipe sizes and slopes.
- Connect far corners of parcel to trunk sewer skeleton using distances measured parallel to the parcel boundary and minimum slopes (this represents a collector sewer serving the future development at the periphery of the parcel.) Check minimum depth at far corners as well as at all other locations in the parcel.

Due to topographic features such as canals, creeks, etc., there may be locations where the minimum depth criteria cannot be met. This will be considered acceptable as long the following two conditions are satisfied:

- The length of the reach of pipe at less than minimum depth is relatively short (less than about 50 feet).
- There is at least 4 feet of separation between the flow line of the creek or canal and the crown of the sewer. The flow line elevations will be based on either field survey data or flow line information from Modesto Irrigation District. USGS topographic maps are not accurate enough to determine flow line elevations of canals/creeks for this purpose.

During the final design phase, details such as concrete encasement, pipe material, flotation caps, creek restoration details, hydroseed mixes, manhole setback distances, and trench plugs will be determined based on the depth of sewer, diameter of sewer, length of crossing, and permit requirements.

Design Requirements at Increases in Pipe Size

As design wastewater flowrates increase from upstream to downstream, it is necessary to increase the size of the sewer pipe. Pipe size increases are only allowed at manholes. There are several methods that may be used to determine the relative vertical alignment of the upstream and downstream pipes at changes in pipe size:

- Match the elevation of the energy grade lines of the two pipes at the design flowrate.
- Match the crown elevations.
- Match the 2/3 diameter points.
- Match the 0.7 diameter points.
- Match the 5/6 diameter points.

Method 1 is the most rigorous and is usually only used during final design. Methods 3, 4, and 5 are quick approximations of Method 1. Method 2 is the most conservative and easiest to apply at the planning stage. Therefore for this Master Plan, method 2, matching crown elevations at pipe size increases, is recommended.

There may be locations in the collection system where two pipes of the same size connect together but the design flow in the branch pipe is significantly lower than that in the mainline pipe. At these locations, if the crown elevations are matched, the higher flow level in the main sewer will cause a backwater condition in the branch sewer. For this Master Plan, it is recommended that the branch sewer elevation be set 0.1 foot above the main sewer elevation when the branch sewer is the same size as the main sewer.

Headloss in Manholes

There are various approaches used to account for the headloss generated by manholes:

- Every manhole (straight or deflection) is assigned a 0.1-foot drop.
- Deflection manholes are assigned a minimum of 0.1-foot drop.
- Calculation is made for each headloss component, including headloss due to change of direction, change of slope, and sidewall friction within the manhole, for pipelines with velocities greater than 3 fps.

Method 1 can be excessive except in areas with an abundance of available fall. Method 3 is too rigorous for a planning level analysis. For this Master Plan, Method 2 is recommended with these added clarifications: Deflection manholes with changes in direction greater than 20 degrees will be assigned a 0.1-foot drop. Deflections greater than 90 degrees are not allowed.

Hydraulic Design Criteria for Force Mains

Pump stations and force mains should be avoided in sewage collection systems as much as possible but may become necessary to keep the collection system from becoming excessively deep. The hydraulic criteria for selecting the diameter of force mains are presented below.

Various agencies use different design criteria for minimum and maximum velocities in force mains. **Table 3-5** presents typical criteria from several agencies:

Table 3-5: Comparison of Force Main Velocity Criteria of Various Agencies

Agency	Force Main Velocity
Washington Suburban Sanitation District	▪ Maximum: 6 fps ▪ Minimum: 2 fps to keep solids in suspension, ▪ 3 to 3.5 fps to resuspend solids
City of Dallas	3 to 5 fps
City of Phoenix	3.5 to 6 fps

The maximum velocity in a force main is usually determined by balancing a number of factors including cost of the pipeline; cost of power usage (higher velocity results in higher headloss); and cost of pumps, motors, electrical equipment, and surge protection facilities. Given that the design flow rate for sewer force mains (PWWF at buildout) occurs infrequently, it is cost effective to set the maximum velocity at a high velocity since the daily peak flow rate is typically much lower. (For a typical water pump station, the daily flow rate is closer to the design flow rate, which tends to lower the cost effective maximum velocity for water transmission pipelines compared to sewage force mains.) For this Master Plan, a maximum force main velocity of 8 fps at PWWF is recommended.

Force mains connected to major pump stations (e.g., Baker Street Pump Station) flow constantly, whereas small pump stations pump intermittently, and the solids in the force mains can settle out during low flow periods as the wet well fills. This is especially true during the early startup years of a pump station before its upstream catchment area fully develops. To resuspend the solids that may settle out in the force main, a minimum velocity of 3.5 fps with one pump running is recommended for use in the Master Plan.

Most force mains are relatively flat and the 3.5 fps recommendation is applicable. A small number of pump stations pump uphill through force mains that are constructed on steep slopes. This adverse slope requires a higher sewage velocity to transport solids. Therefore, if a force main is steeper than 20 percent, additional analysis is required to determine the acceptable minimum velocity.

Dual Force Mains

To obtain the required velocities for both initial and ultimate design flow conditions, dual force mains may be needed. Dual force mains also have the ability to allow for future inspection and rehabilitation of the pipes, which generally cannot be adequately inspected or repaired without being taken off line and dewatered for up to 24 hours at a time

In most cases, dual force mains can be built in two stages, since initial flows are generally significantly lower than design flows at buildout. However, building dual force mains in two stages may not be prudent in locations where available space may not be available in the future or in locations where one-time construction is strongly preferred to minimize impacts to the environment (e.g., wetlands), costly mobilization (e.g., highway and river crossings), or disturbance to the public.

Based on discussions with the City, the use of dual force mains is not deemed necessary at this time, and it has been assumed that all pump stations will have a single force main. Each force main will be sized to carry the peak design flow at a maximum velocity of 8 fps.

If dual force mains are constructed in the future, however, each force main must have sufficient capacity to carry the peak dry weather flow at buildout so that one force main can be dewatered and undergo inspection or rehabilitation. Since force main inspections and rehabilitation events are relatively rare, the maximum velocity criteria can be relaxed and increased to 10 fps for peak dry weather flows through a single pipe.

Headloss

The Hazen-Williams formula will be used for calculating the friction headloss of force mains. The Hazen-Williams roughness coefficient, C, varies with pipe material, velocity, size, and age. For this Master Plan, a roughness coefficient of C = 100 is proposed to be used for all pipe sizes and materials.

Inverted Siphons

The term siphon as used in wastewater practice refers to an inverted siphon or depressed sewer which dips below the hydraulic grade line to avoid obstructions and stands full of sewage even with no flow. Its purpose is to carry sewage under an obstruction and to regain as much elevation as possible after passing the obstruction. Inverted siphons should be avoided unless clearly necessary to cross under major obstructions such as rivers or large creeks, major utility pipelines, highways, etc., and other alternatives are significantly more expensive. Alternatives to inverted siphons include deeper gravity sewers and/or pump stations, a well as “D”-shaped or box sewers. There are currently no inverted siphons in the City of Waterford’s sewer system, and it is generally the City’s preference to construct deeper sewers and/or pump stations to clear deep obstructions.

The approach used in this Master Plan will be to avoid inverted siphons whenever possible. If it becomes necessary to use an inverted siphon, the following approach will be used:

- The length of the downflow and upflow legs of the siphon will based on a maximum slope of 15 percent to allow floatables to be conveyed downward and solids to be conveyed upward. [source: City of Los Angeles Sewer Design Manual Figure F272]
- The upstream invert elevation will be calculated by adding 12 inches plus the pipe friction to the downstream invert elevation. (The 12-inch factor is a conservative factor used at the planning phase; during the design phase, detailed hydraulic calculations would be performed.)
- The pipe friction will be calculated using the Hazen-Williams formula with a ‘C’ coefficient of 100.
- The pipe barrel diameter will be determined based on the following three criteria [source: City of Los Angeles Sewer Design Manual]:
- – Minimum velocity of 3 fps at ADWF during early years of operation.
- – Minimum velocity of 4 fps at PDWF during early years of operation.
- – Minimum 8-inch pipe diameter.
- Two barrels will be assumed for each siphon.

Development of Sewer System Layout

In general, development of the future sewer collection system layout was governed by the methodologies and criteria presented above. In cases where those methodologies and design criteria could not practically be met, or conflicted with one another, other design and constructability considerations (see Section 4.1) were evaluated. In areas with little to no topography, for instance, maximum depth criteria were exceeded in some cases in the interest of avoided costs for multiple lift stations. In areas with very steep slopes, namely the hillier areas nearer the Tuolumne River, maximum slope and/or velocity criteria were exceeded in some cases in the interest of avoided costs for additional pump stations and excessive force mains. In general, it has been the City’s preference to avoid the construction of pump stations where possible, and to utilize gravity sewers to the extent practicable.

The topographic data used during the development of the sewer system was obtained from the following sources:

- **AutoCAD files** – City of Waterford
- **2-Foot Contour Intervals** – City of Waterford

Overall development of the proposed alignments was intended to reflect the following major considerations, which serve as synopses of the methodologies and criteria discussed above:

- The alignment should respect, to the degree practicable, the barriers presented by parcel boundaries, existing roads, and canals.
- Regional topography and minimum slope/maximum depth considerations should allow the most remote future connections to be served by the proposed trunk sewer.
- Construction, operation, and maintenance costs associated with the proposed alignment should be manageable.

3.3 Hydraulic Model

The following sections describe the hydraulic model computer software that was used for this study, and discuss the model simulations used to analyze the proposed future collection system for the study area.

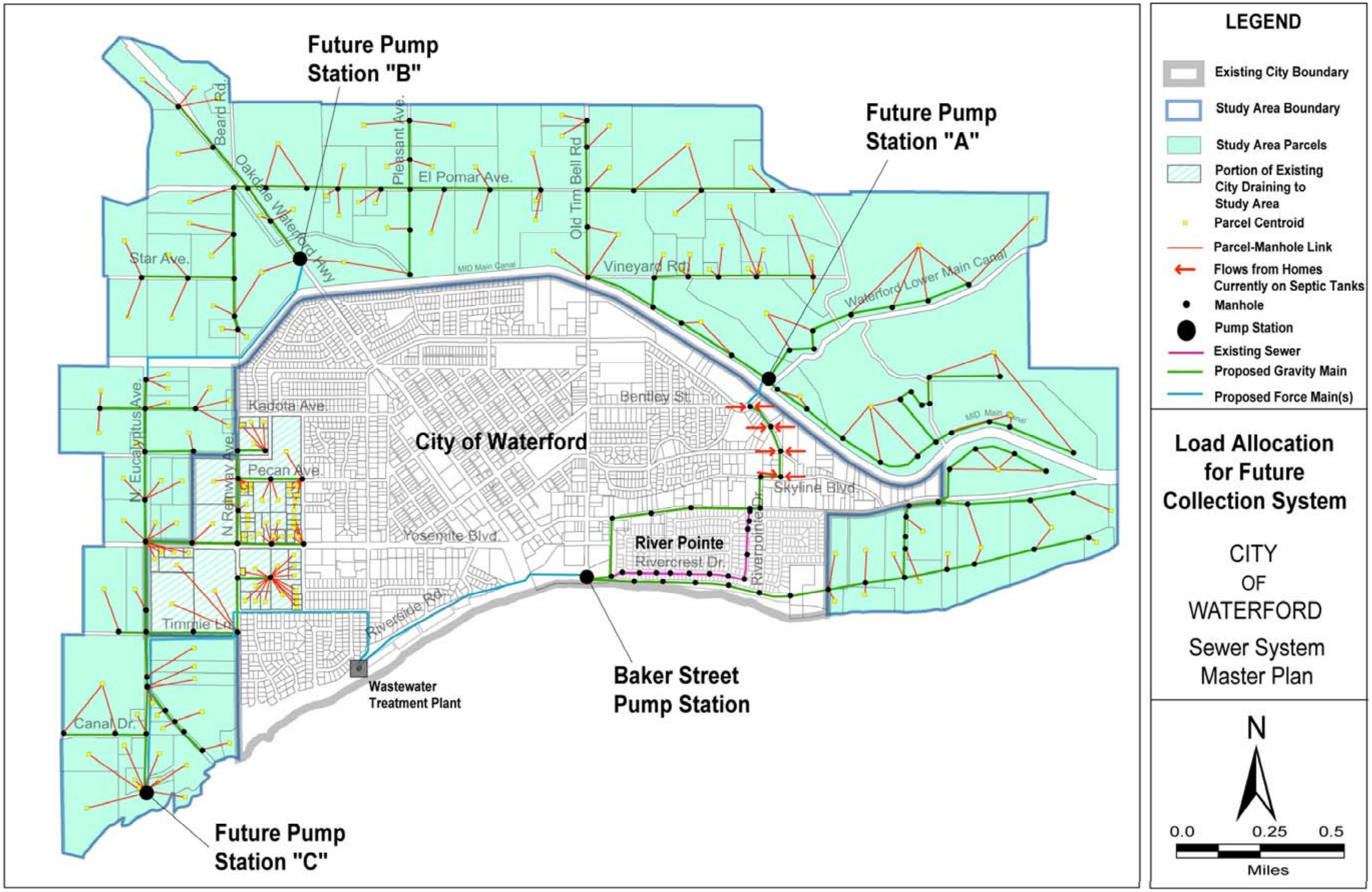
3.3.1 Software

A steady-state, or static, hydraulic model of the study area's trunk sewer collection system was developed as part of this Sewer System Master Plan using H2OMap Sewer Professional Suite 7.0. The model of the proposed collection system includes only those sewers considered to be the trunk sewer network, as well as certain key sewers within the City's existing boundaries (i.e., River Pointe). Collection sewers that will serve individual streets and convey flows to the trunk sewer network were not considered in laying out the modeled trunk system. All manholes and sewers were named using a numeric identifier. 11" by 17" maps showing the identification numbers of all manholes, sewers, and parcels are included in Appendix A.

3.3.2 Allocation of Model Loads

The parcel-manhole links shown in **Figure 6** represent the locations where projected flows from study area parcels were loaded into the modeled collection system network. Certain larger parcels were loaded to more than one manhole, with each link representing an equal percentage of the total projected flows from a given parcel. The intent of this methodology was to distribute wastewater flows as realistically as possible.

Figure 6: Load Allocations for Proposed Future Collection System



3.3.3 Model Simulations

There are two types of hydraulic models used to simulate a sewer collection system: 1) a steady state/static simulation; and 2) an extended period/dynamic simulation. An extended period/dynamic model employs a continuous simulation of the changes in system flow rates, and is typically used to analyze the operational performance of the system over a 24-hour or longer period. Extended period/dynamic modeling requires more extensive data input than a steady-state model, including various 24-hour diurnal curves for various land use categories within the sewer collection system and a representation of time-varying I/I response to rainfall. Simulations from a steady state model represent a snapshot of the system performance at a given point in time under specific sewage generation conditions (typically a peak flow condition), and are typically used for sizing of sewers and pump stations. Hence, for the purposes of this Master Plan, a steady-state hydraulic model has been used in system analyses to size sewers and pump stations. A single model scenario for peak wet weather flows was created for this purpose.

3.3.4 Cost Criteria

Table 3-6 presents the cost criteria used to develop cost estimates for the recommended sewer collection system projects for the study area. It should be noted that the estimated capital costs presented in Table 4-1 are considered conceptual planning level costs, and have an expected accuracy of -30% to +50%.

Sanitary Sewer and Pump Station Costs

Sanitary sewer installation costs vary according to many factors including pipe type, diameter, depth, material, soil and groundwater conditions, complexity of construction, and need for traffic control and surface restoration. The costs used in this Master Plan for installation of sewer pipes includes mobilization, traffic control, trenching, dewatering, pipe installation and lateral connections, manholes, and pavement replacement. These baseline construction costs are based on recent Northern California bids and cost estimates for similar projects.

Costs for HDD projects (Projects 1 and 13) are based on actual construction bid data from across the country. For this Master Plan, $500/ft was used for HDD projects, including two 24-inch diameter drills of approximately 500 feet each.

Pump station costs were estimated based on costs curve data presented in Figure 29-3 of *Pumping Station Design* by Robert Sanks. The Sanks cost curve, considered to be the industry standard, was developed using historical construction costs of submersible wastewater pumping stations.

Construction Contingency and Project Implementation Multiplier

A construction contingency and project implementation multiplier of 1.625[3] was applied to each potential improvement project's estimated baseline construction cost. This allowance is assumed to include:

- Potential construction issues unforeseen at the planning level
- Administration costs
- Environmental assessments and permits
- Planning and engineering design
- Construction administration and management
- Legal fees

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[3] The 1.625 multiplier is based on a 30% construction cost contingency plus a 25% engineering and administration factor to calculate the capital cost. Hence, for budgeting purposes, it is assumed that the contingency and project implementation multiplier is 1.625 (1.00 x 1.25 x 1.30 = 1.625).

Table 3-6: Cost Criteria for Recommended Projects

Facility Type	Size (in)		Unit Cost ($/LF)	
			Existing Street	Not in Existing Street
Gravity Mains	8		$85	$60
	10		$95	$70
	12		$115	$90
	15		$135	$110
	18		$145	$120
	21		$160	$135
	24		$180	$150
Horizontal Directional Drilling	24[a]		$500	
Force Mains	10		$75	$50
	12		$77	$52
	14		$80	$55
Pump Stations [b]	Future PS C	*4.07 mgd*	$650,000	
	Future PS A	*2.47 mgd*	$500,000	
	Future PS B	*2.39 mgd*	$500,000	
	BSPS Expansion	*3.81 mgd*	$600,000	

a. For force main canal crossings, it has been assumed that 24-inch HDD construction methods will be used. For example, for a 14-inch force main, a 24-inch directional drill will be made, and the force main can be pulled through.

b. Unit costs for pump stations were derived from the Sanks curve in *Pumping Station Design.*

Chapter 4 Recommended Projects

The recommended projects for the proposed future sewer collection system were developed based on the methodologies and criteria presented in the previous sections, and considered study area topography; input from the City; plans for the River Pointe development; and available plans for the more recently proposed Grupe development. This section provides an overview of some specific design and constructability considerations that were used in developing the recommended projects, which are shown in **Figure 7**.

4.1 Design and Constructability Considerations

4.1.1 River Pointe Development

The River Pointe development, representing the last major infill project within the City of Waterford's existing boundaries, has influenced several of the proposed collection system projects for the City's study area. Based on discussions with City staff, it was determined to be both feasible and desirable to 1) construct a new sewer through a portion of the existing City (Project 2), and 2) to temporarily tie the sewer in Project 2 into a recently constructed sewer that conveys flows from River Pointe towards the Baker Street Pump Station. Because capacity in the existing River Pointe sewer is limited, an additional project (Project 6) was developed to convey increasing future study area flows during subsequent phases of development. See Section 4.3 for a discussion of the timing of Project 6.

4.1.2 Future Grupe Development

Although area-specific development plans have not been produced for the majority of the study area, a Grupe development in the northeast section of the study area is currently in the planning phase of development. Consequently, this proposed development has influenced the development of several recommended collection system projects. Specifically, some of the proposed sewers in Projects 3, 4, 5 and 9 reflect the preliminary layouts provided by Grupe for parcel subdivisions, streets, and an artificial lake. Additionally, since it has been logically assumed that the proposed Grupe development will be the first portion of the study area to come online, the recommended phasing of the collection system projects is centered both chronologically and numerically on this section of the study area.

4.1.3 Existing City Parcels near Reinway Ave. and Pecan Ave.

At the direction of City staff, portions of the proposed collection system in the southwest portion of the study area have been developed with the ability to convey additional flows from within the existing City limits. The area of concern is shown in **Figure 3** and includes Waterford High School and Moon Elementary School (with approximately 600 and 750 students, respectively), and approximately 70 acres of single-family residential parcels in the area bounded by Reinway Avenue, Kadota Avenue, Pasadena Avenue, and Washington Road. This request led to the recommendation of two additional collection system projects (Projects 16 and 17) within existing City boundaries. Project 14, which includes larger diameter sewers flowing to Future Pump Station C, has been developed with sufficient depth and capacity to intercept and convey approximately 0.62 mgd from the existing City parcels described above.

4.1.4 Existing City Parcels near Skyline Blvd. and Bentley St.

In addition to the parcels mentioned above, approximately 50 single family residential parcels in the vicinity of Project 2 are expected to be connected to the recommended sewers in that area. These homes currently use septic tanks, but will be connected to the City's collection system in the future. Using the same wastewater flow generation factors as for the City's study area, approximately 0.19 mgd (PWWF) is projected to be generated by these parcels. Sufficient capacity for these parcels has been reserved in Projects 2, 6, and 7.

Figure 5 shows where the flows from the existing City parcels discussed in the two paragraphs above are expected to enter the recommended future collection system.

4.2 Project Descriptions and Costs

A total of 17 projects, which include the trunk sewer system only (i.e., small collector sewers are not included), have been developed and recommended for the future sewer collection system in the study area. **Figure 7** presents the 17 recommended projects. **Figure 8** gives the diameters for all pipes in the recommended sewer system. Descriptions, costs, and phasing of the recommended projects, as well as any associated implementation issues, are presented in the subsequent sections. The proposed projects include four combined pump station and force main projects and thirteen gravity sewer projects. Individual project descriptions, including pipe diameters, pipe lengths, pump station parameters, and estimated costs, are presented in **Table 4-1**. Additionally, hydraulic profiles for several key projects are presented in **Figure 9 through Figure 13**.

Figure 7: Recommended Projects

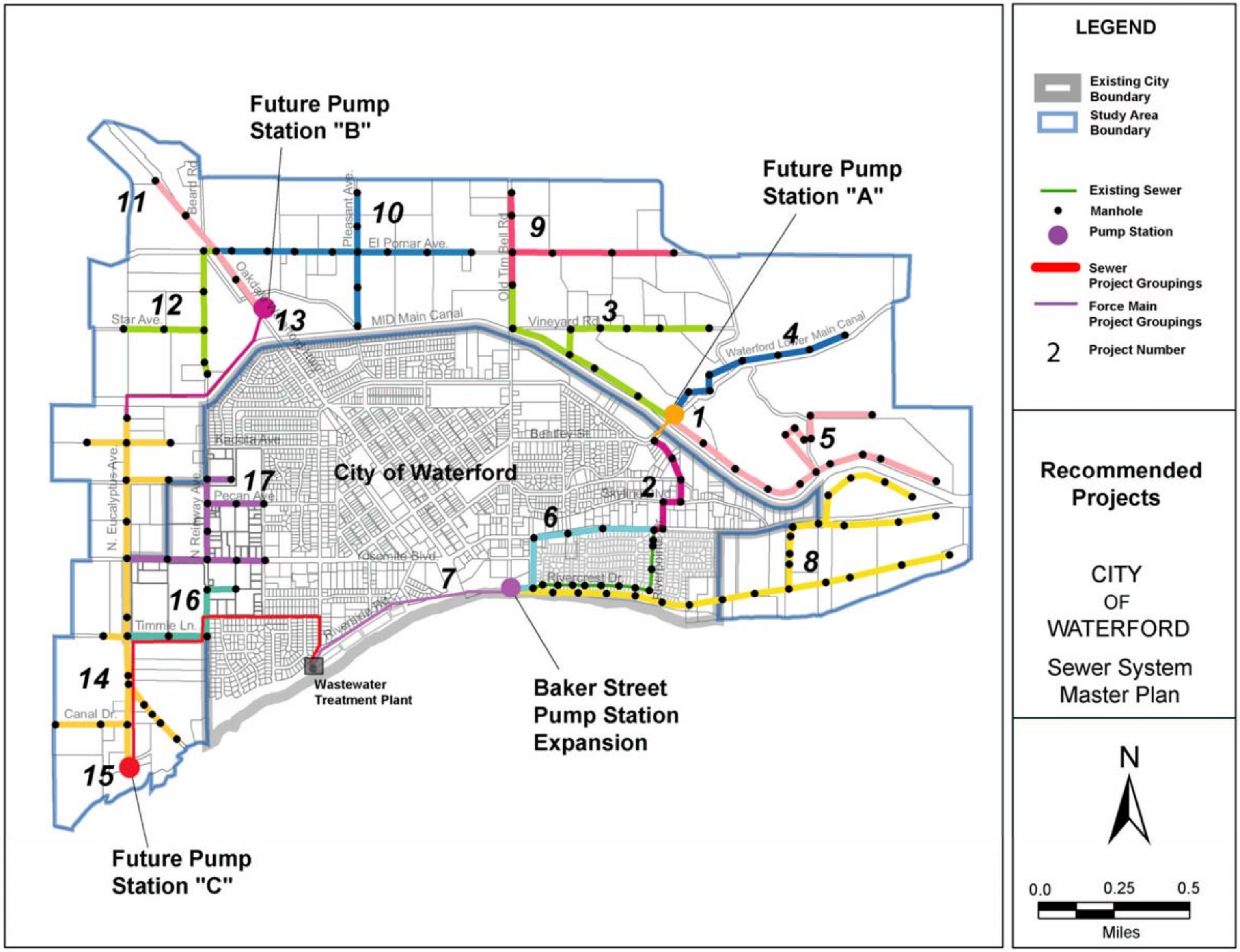


Figure 8: Pipe Diameters for Recommended Sewer System

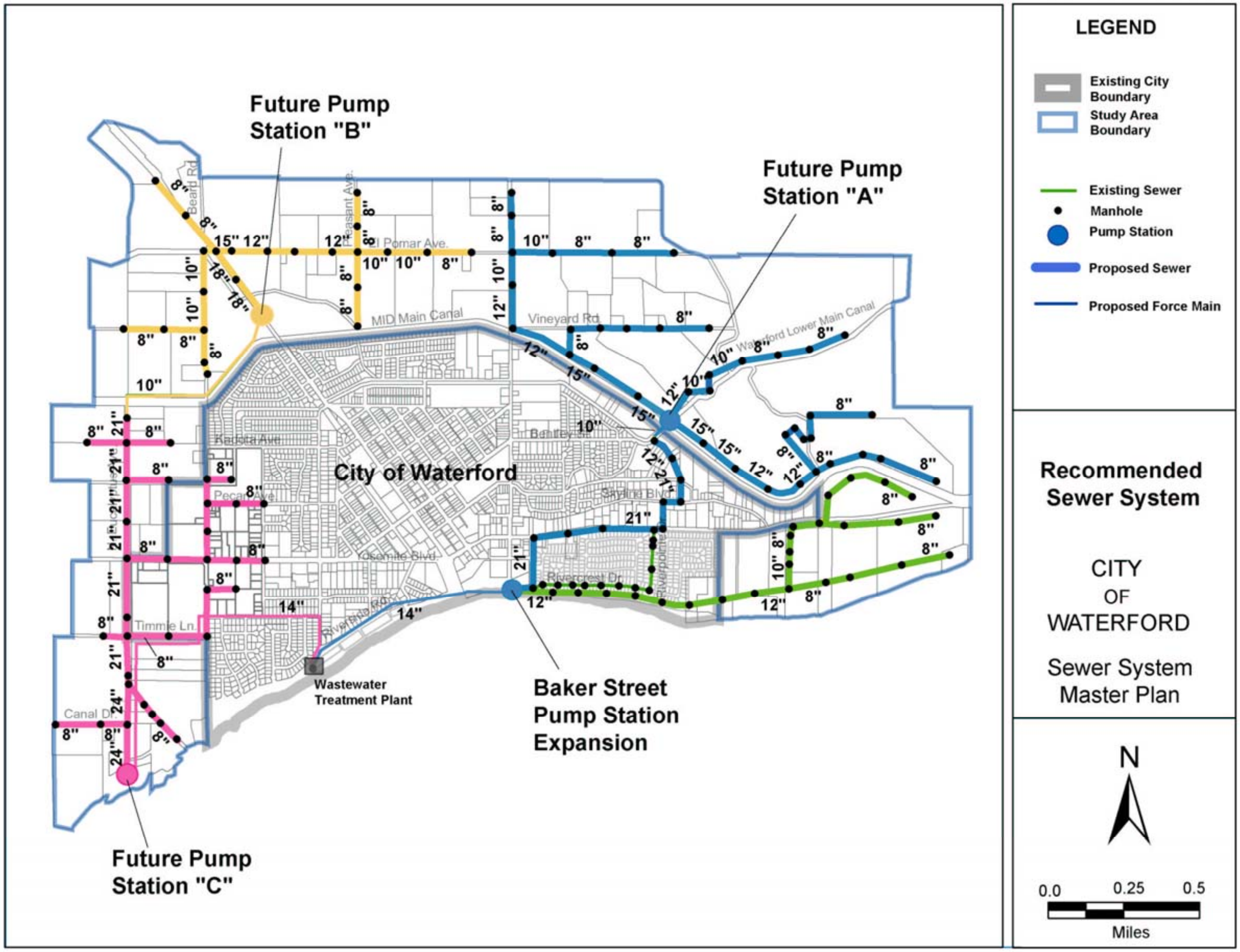


Table 4-1: Recommended Projects and Estimated Costs

Project No.	Description	Diameter (in)	Length (ft)	Design Flow at Downstream Segment (mgd)	Pump Station Firm Capacity [a] (mgd)	Estimated Construction Cost [b]	Estimated Capital Cost [c]
1	**Future Pump Station A**						
	Future Pump Station A	---	---	---	*2.47 mgd*	$500,000	***$1,211,000***
	Single Force Main to Skyline-Bentley Sewer	10	490	*2.47*	---	$245,000	
					Subtotal	***$745,000***	
2	**Skyline-Bentley Sewer**						
	PS A Force Main discharge to Bentley St. north of Welch St.	12	450	*2.49*	---	$51,750	***$529,000***
	Bentley St. to Yosemite Blvd. and Riverpointe Dr.	21	1,710	*2.64*	---	$273,600	
					Subtotal	***$325,350***	
3	**Vineyard Road Sewers**						
	Vineyard Rd. to MID Canal east of Old Tim Bell Rd.	8	2,830	*0.20*	---	$240,550	***$1,101,000***
	Old Tim Bell Rd. to junction with 8-in sewer at MID Canal	12	1,840	*0.68*	---	$211,600	
	Junction at MID Canal to Future Pump Station A	15	2,050	*1.01*	---	$225,500	
					Subtotal	***$677,650***	
4	**Waterford Lower Main Canal Sewers**						
	Along WLMC to just west of Lateral Number Eight	8	1,830	*0.35*	---	$109,800	***$402,000***
	East of Lateral Number Nine to just northeast of MID Canal	10	1,260	*0.53*	---	$88,200	
	Northeast of MID Canal to Future Pump Station A	12	550	*0.60*	---	$49,500	
					Subtotal	***$247,500***	
5	**Eastern Area Sewers**						
	Sewers north and east of junction of MID Canal and Lateral Number Eight	8	5,080	*0.62*	---	$304,800	***$989,000***
	Just west of Lateral Number Eight to MID Canal north of Bentley Street	12	1,640	*0.75*	---	$147,600	
	MID Canal to Future Pump Station A	15	1,420	*0.85*	---	$156,200	
					Subtotal	***$608,600***	
6	**Yosemite Boulevard Sewers**						
	Skyline Blvd. and Bentley St. to Baker Street PS	21	3,290	*2.64*	---	$526,400	***$855,000***
					Subtotal	***$526,400***	
7	**Baker Street Pump Station Expansion**						
	Baker Street Pump Station Expansion	---	---	---	*3.81mgd* [d]	$600,000	***$1,468,000***
	Single Force Main to WWTP [d]	14	3,790	*3.81*	---	$303,200	
					Subtotal	***$903,200***	

(continued on next page)

Table 4-1 Continued

Project No.	Description	Diameter (in)	Length (ft)	Design Flow at Downstream Segment (mgd)	Pump Station Firm Capacity [a] (mgd)	Estimated Construction Cost [b]	Estimated Capital Cost [c]
8	**Southeastern Area Sewers**						
	Northern branch to midway between northern and southern branches	8	5,190	*0.30*	---	$311,400	***$1,554,000***
	Southern branch to junction with northern branch	8	2,820	*0.19*	---	$169,200	
	Northern branch to junction with southern branch	10	611	*0.52*	---	$42,770	
	Junction of northern and southern branches to Baker St. PS	12	4,810	*0.71*	---	$432,900	
					Subtotal	***$956,270***	
9	**Old Tim Bell Road Sewers**						
	El Pomar Ave. to just east of Old Tim Bell Rd; Old Tim Bell Rd. to El Pomar Ave.	8	3,120	*0.29; 0.09*	---	$265,200	***$625,000***
	El Pomar Ave. east of Old Tim Bell Rd. to just north of Vineyard Rd.	10	1,260	*0.52*	---	$119,700	
					Subtotal	***$384,900***	
10	**El Pomar Avenue Sewers**						
	Sewers on Pleasant Ave; El Pomar Ave. east of Pleasant Ave.	8	3,760	*0.37; 0.22*	---	$319,600	***$1,165,000***
	East of Pleasant Ave. on El Pomar Ave. to Pleasant Ave.	10	1,200	*0.42*	---	$114,000	
	El Pomar Ave. and Pleasant Ave. to just east of Oakdale Waterford Hwy.	12	2,170	*1.01*	---	$249,550	
	El Pomar Ave. to Oakdale Waterford Highway	15	250	*1.12*	---	$33,750	
					Subtotal	***$716,900***	
11	**Oakdale Waterford Highway Sewers**						
	Oakdale Waterford Hwy to El Pomar Ave.	8	1,610	*0.36*	---	$136,850	***$526,000***
	El Pomar Ave. and Oakdale Waterford Hwy to Future Pump Station B	18	1,290	*2.35*	---	$187,050	
					Subtotal	***$323,900***	
12	**Star Avenue Sewers**						
	Star Ave. to N. Reinway Avenue; N. Reinway Ave. to just south of El Pomar Ave.	8	2,160	*0.26; 0.19*	---	$183,600	***$542,000***
	N. Reinway Ave. to Oakdale Waterford Highway	10	1,580	*0.56*	---	$150,100	
					Subtotal	***$333,700***	
13	**Future Pump Station B**						
	Future Pump Station B	---	---		*2.39 mgd*	$500,000	***$1,575,000***
	Single Force Main to Western Trunk Sewers	10	3,480	*2.39*	---	$469,250	
					Subtotal	***$969,250***	

(continued on next page)

Table 4-1 Continued

Project No.	Description	Diameter (in)	Length (ft)	Design Flow at Downstream Segment (mgd)	Pump Station Firm Capacity [a] (mgd)	Estimated Construction Cost [b]	Estimated Capital Cost [c]
14	**Eucalyptus Avenue Sewers**						
	All east-west sewers intersecting north-south Eucalyptus trunk sewer;	8	5,110	*varies*	---	$306,600	***$2,418,000***
	Eucalyptus Ave. from PS B Force Main discharge to just south of Timmie Ln.	21	4,460	*3.37*	---	$713,600	
	South of Timmie Lane to Future PS C	24	1,460	*4.00*	---	$467,500	
					Subtotal	***$1,487,700***	
15	**Future Pump Station C**						
	Future Pump Station C	---	---	---	*4.07 mgd*	$650,000	***$1,887,000***
	Single Force Main to WWTP	14	6,720	*4.07*	---	$511,350	
					Subtotal	***$1,161,350***	
16	**Timmie Lane Sewers**						
	East of N. Reinway Avenue to Eucalyptus Avenue Sewer	8	2,670	*0.14*	---	$226,950	***$369,000***
					Subtotal	***$226,950***	
17	**North Reinway Avenue Sewers**						
	All sewers east of N. Eucalyptus Ave.	8	5,850	*0.26*	---	$497,250	***$808,000***
					Subtotal	***$497,250***	
18						**Master Plan Implementation and Management [e]**	***$901,000***
						TOTAL	***$18,925,000***

a. Firm capacity is the pump station capacity with the largest pump not operating.
b. Baseline Construction Costs were calculated based on the unit costs presented in Table 3-6.
c. Estimated Capital Cost = (Baseline Construction Cost) x (1.625). See page 3-16.
d. The firm capacity presented for BSPS represents study area flows and the future flows from homes currently on septic tanks; the figure shown does not include flows from parcels currently draining to BSPS. A more detailed analysis of the existing capacity of BSPS should be evaluated prior to the implementation of Project 7.
e. See description below.

The length for these projects totals approximately 4.2 miles for force mains and approximately 14.3 miles for future gravity sewers. Project 18, or Master Plan Implementation and Management, is assumed to be 5% of the total estimated capital cost for Projects 1 through 17. A small portion of the cost includes additional engineering analyses for certain recommended projects. The total estimated capital cost for all projects, including Project 18, is approximately $18.9 million.

4.2.1 Profiles of Interest

Figure 9: Profile for Projects 2 and 6

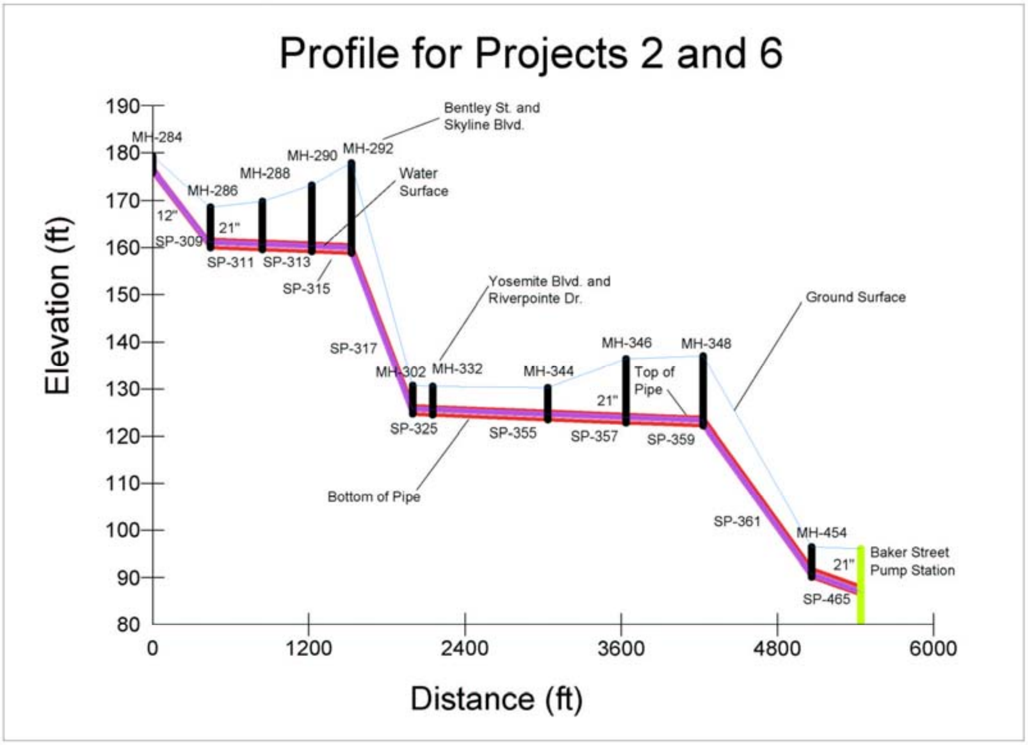


Figure 10: Profile for Projects 3 and 9

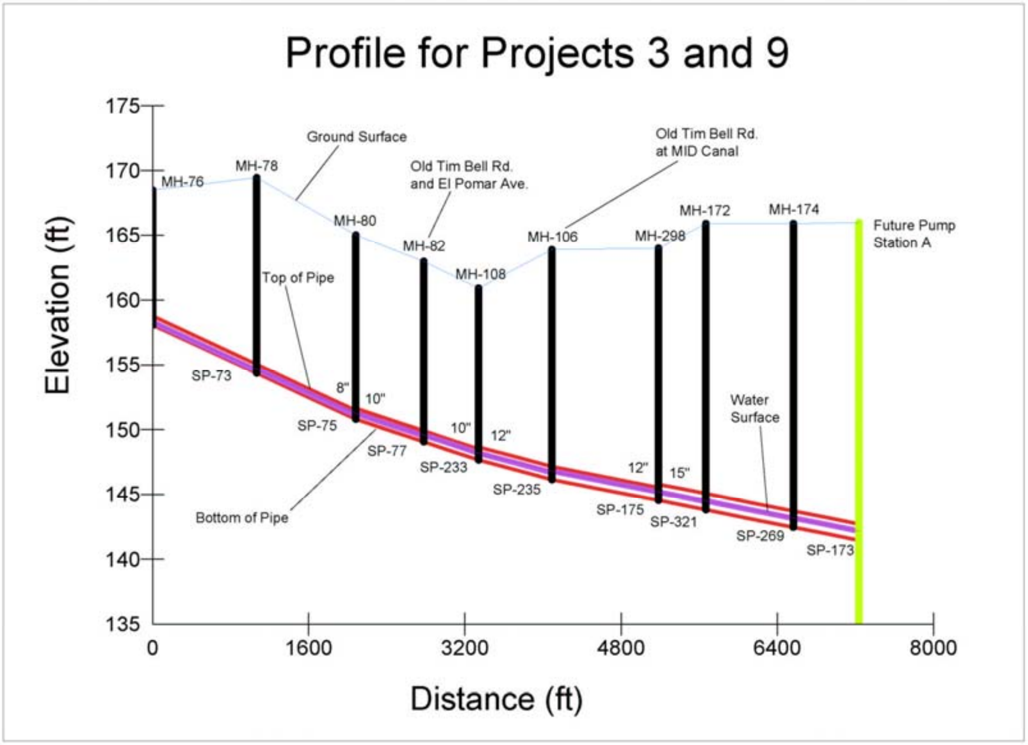
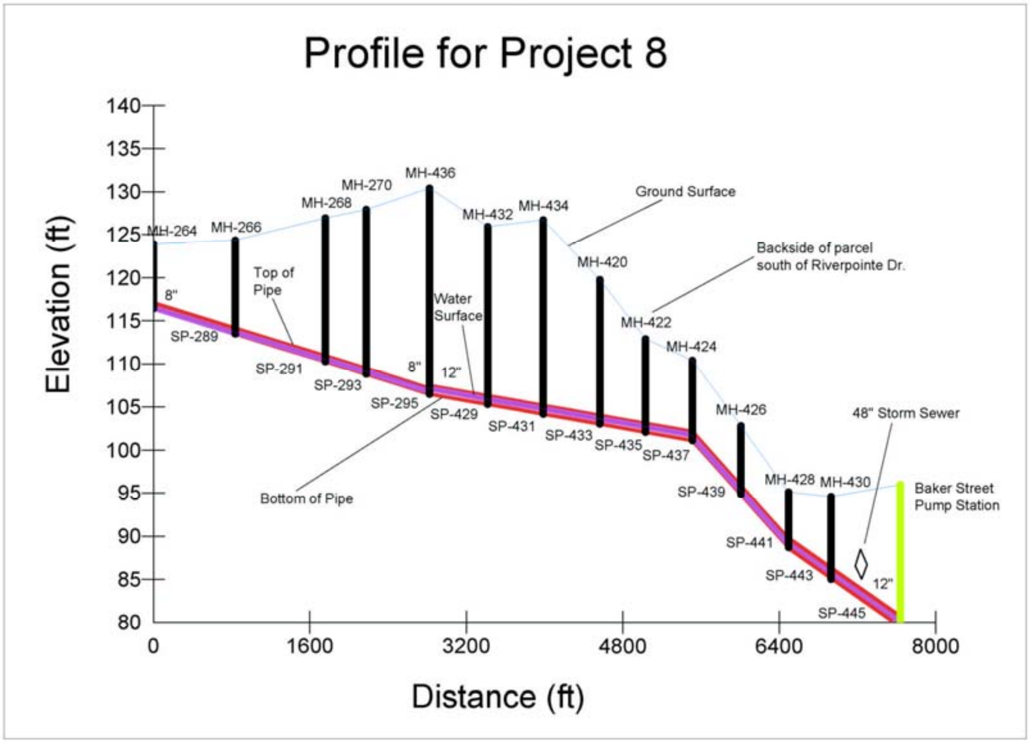


Figure 11: Profile for Project 8



As shown in Figure 11, the proposed 12-inch sewer travels below an existing 48-inch storm sewer just before entering the Baker Street Pump Station. The vertical alignment of Project 8 is lower than the existing sewer connecting to the BSPS. For this reason, the new wet well of the BSPS expansion will be deeper than the existing wet well. Additional analysis during the design of Projects 6, 7 and 8 may generate a less expensive alternative.

Figure 12: Profile for Projects 10 and 11

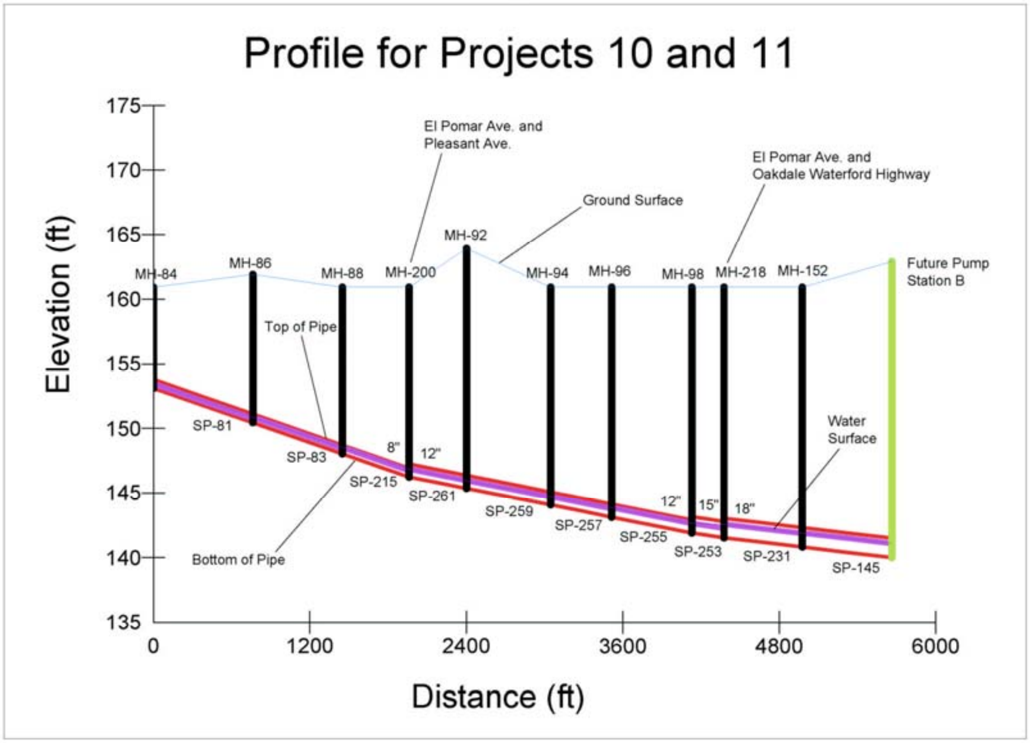
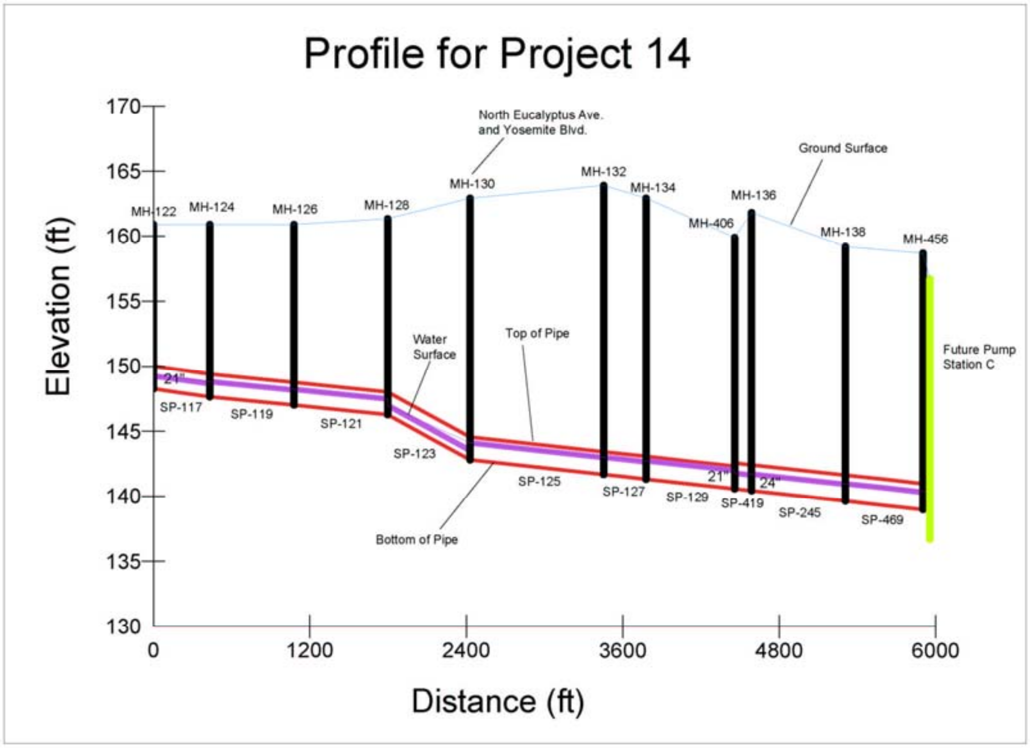


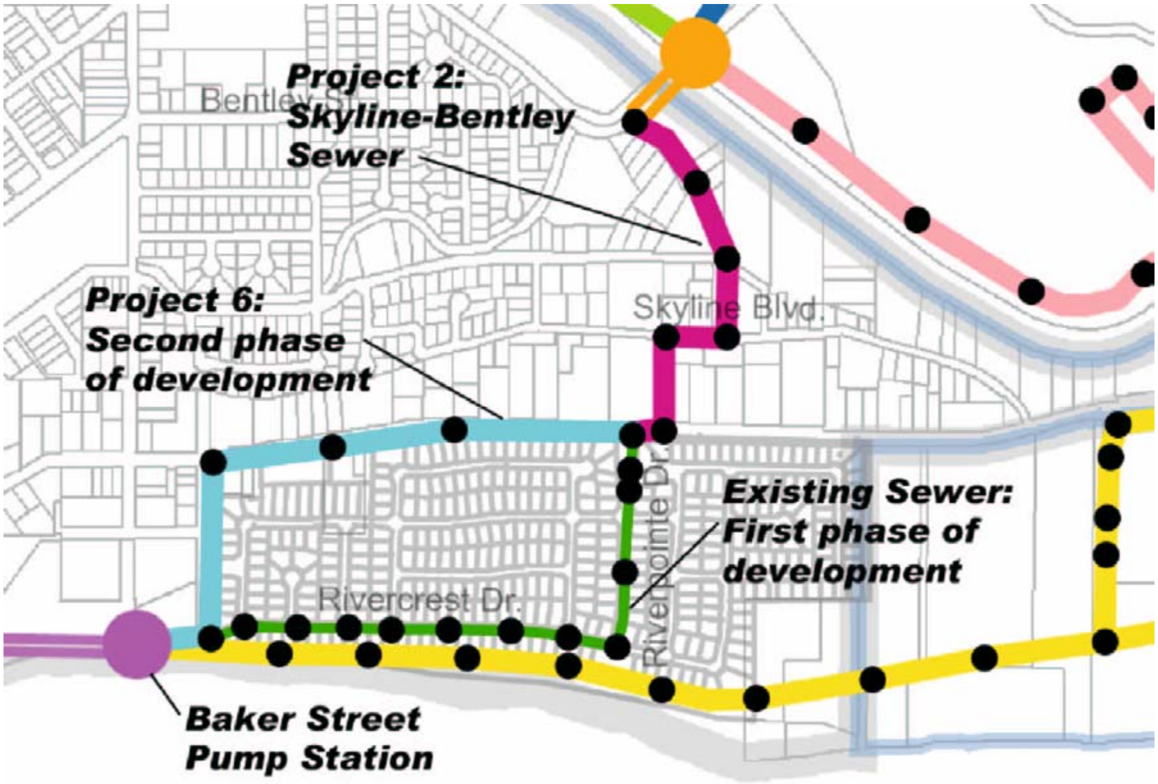
Figure 13: Profile for Project 14



4.3 Proposed Phasing

Proposed phasing for the recommended collection system projects corresponds to the numbering scheme presented in Table 4-1 and Figure 7, and reflects the anticipated sequence of upcoming development events. It is recommended that Project 1 (the construction of Future Pump Station A), for example, be implemented prior to Project 2 (the construction of the Skyline-Bentley Sewer that will convey flows from Future Pump Station A). The phasing of Projects 3, 4, 5, 6, 7 and 9 are somewhat flexible, depending on the timing of future study area developments in Sewershed A. Because the existing sewers in River Pointe have limited capacity, flows from Sewershed A can only be routed through River Pointe for a relatively short time. Based on the available capacity in the River Pointe sewers, it has been determined that only about 150 homes from the study area can be routed through River Pointe. Project 6, which will eventually intercept flows from Sewershed A, must be timed such that it will be constructed before more than 150 homes are constructed in Sewershed A. **Figure 14** illustrates the phasing of Project 6 in greater detail.

Figure 14: Phasing of Project 6



In general, the phasing proposed for Projects 1 to 9 is more firm than the phasing of Projects 10 to 17. This generalization reflects the assumption that the Grupe development will enter the construction phase prior to the rest of the study area, and that appropriate conveyance capabilities will be required in this area first. Depending on the timing of developments in the western half of the study area, phasing of Projects 10 to 17 may need to be revised.

4.4 Implementation Issues

A variety of issues may affect the implementation of the future collection system improvement projects presented in this Master Plan. These issues may include changes in road alignments, permitting issues for canal crossings, changes in the location or permitted capacity of the City's wastewater treatment facilities, refinement of study area land uses (including school and park parcels), and future developer plans, among others. The proposed collection system layout in this Master Plan is intended to offer a conceptual solution to the City's future needs; more rigorous analyses will be required, including the analysis of existing and future road alignments, geotechnical analyses of proposed pipeline alignments, and environmental permitting analyses, before design and construction phases can begin.

4.5 Additional Recommendations

4.5.1 H2OMap Sewer System Hydraulic Model

The H2OMap Sewer model developed for this Master Plan provides the City with a valuable tool for analyzing the capacity of the sewer system at a planning level. The model can also be used to test the impact of development proposals. The model should be updated periodically to reflect changes in the sewer system (new sewer construction and any development) and revised flow information.

4.5.2 Sewer System Management Plan (SSMP)

Historically, Waterford has had relatively few sewer overflows. Sewer overflows can be caused by many factors, including root clogs, grease clogs, broken pipes, wet weather infiltration, pump station mechanical failure, vandalism, illegal disposal of wastes, and power failures. State and federal regulators feel that to protect public health, regulations need to be imposed on sanitary sewer systems. Because of the broad range of factors that cause overflows, the proposed regulations will also be broad and will regulate aspects of capacity, management, operations, and maintenance, or CMOM for short. California is currently adopting the majority of the proposed federal CMOM regulations with the keystone of the state's regulations being a requirement for sanitary sewer system owners to develop a Sanitary Sewer System Management Plan. Waterford should continue to track potential SSMP regulations and proactively meet the requirements.

4.5.3 Sewer Cleaning Program

Periodic cleaning of sewers is necessary to prevent stoppages, and can be performed either hydraulically or mechanically. Hydraulic cleaning usually consists of cleaning a sewer with water under pressure that produces high water velocities. Mechanical cleaning methods usually consist of using equipment that scrapes, cuts, pulls or pushes material out of a pipe. It is recommended that the City develop a sewer cleaning program to maintain optimum performance of its collection system.

4.5.4 Manhole and Pipe ID Program

It is recommended that the City develop a system to track scheduled and performed maintenance. As part of this effort, it is recommended that the City assign each manhole and pipe an identification (ID) number to ensure efficient tracking of each maintenance activity.

References

1. Brown and Caldwell, River Pointe CAD files, August 2004.
2. DJH Engineering, "Wastewater Treatment Master Plan," February 2005.
3. City of Waterford, Existing Collection System Map, 2005.
4. DeLorme, Waterford Annexation Area 3-D Topoquad, 2002.
5. MCR Engineering, City of Waterford Proposed Sphere of Influence Map, January 2005.
6. MCR Engineering, Waterford Land Use Map.
7. MCR Engineering, Waterford Annexation Area Map.
8. Stanislaus County, Waterford GIS Parcel Map.
9. TFP Engineers, Wastewater Treatment Facility Improvement Drawings, September 1994.
10. The Grupe Company, River Pointe CAD files, May 2005.
11. TKC Engineering, River Pointe CAD files.
12. Tri State Photogrammetry, Waterford Study Area Ortho Photos.

Appendix A - Model Data

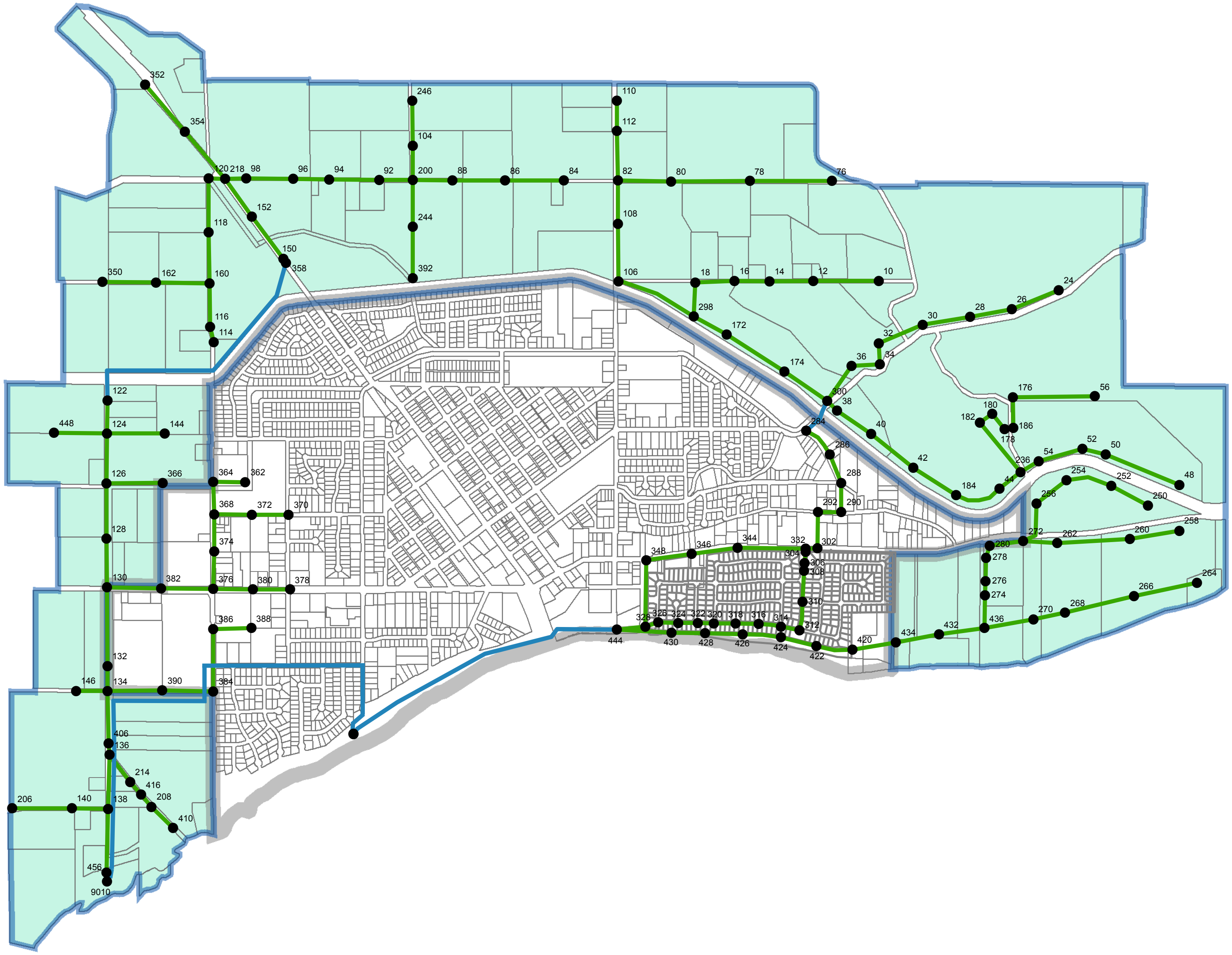


FIGURE A-1

Manhole ID Map

CITY
OF
WATERFORD

Sewer System
Master Plan

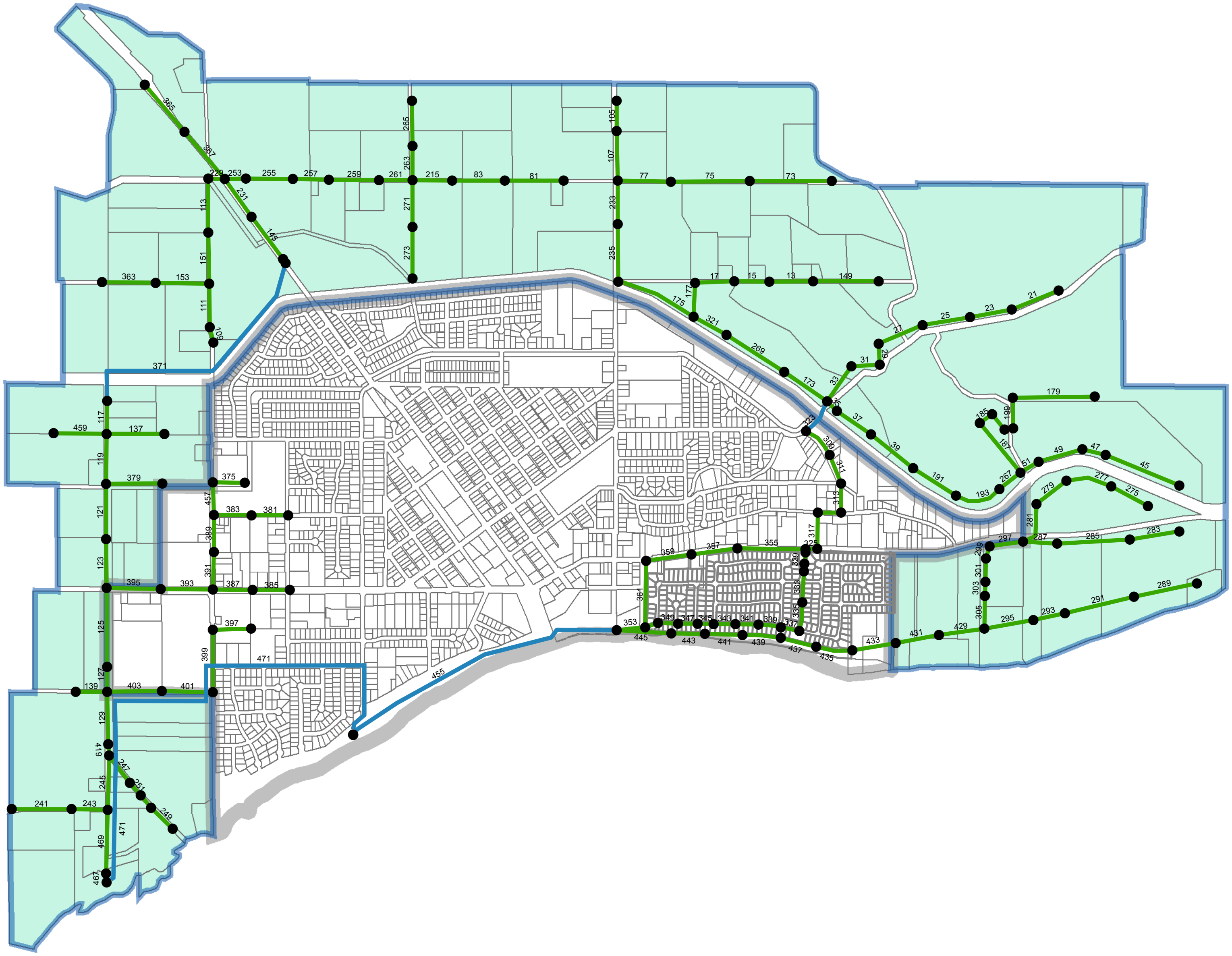


FIGURE A-2

Pipe ID Map

CITY
OF
WATERFORD

Sewer System
Master Plan

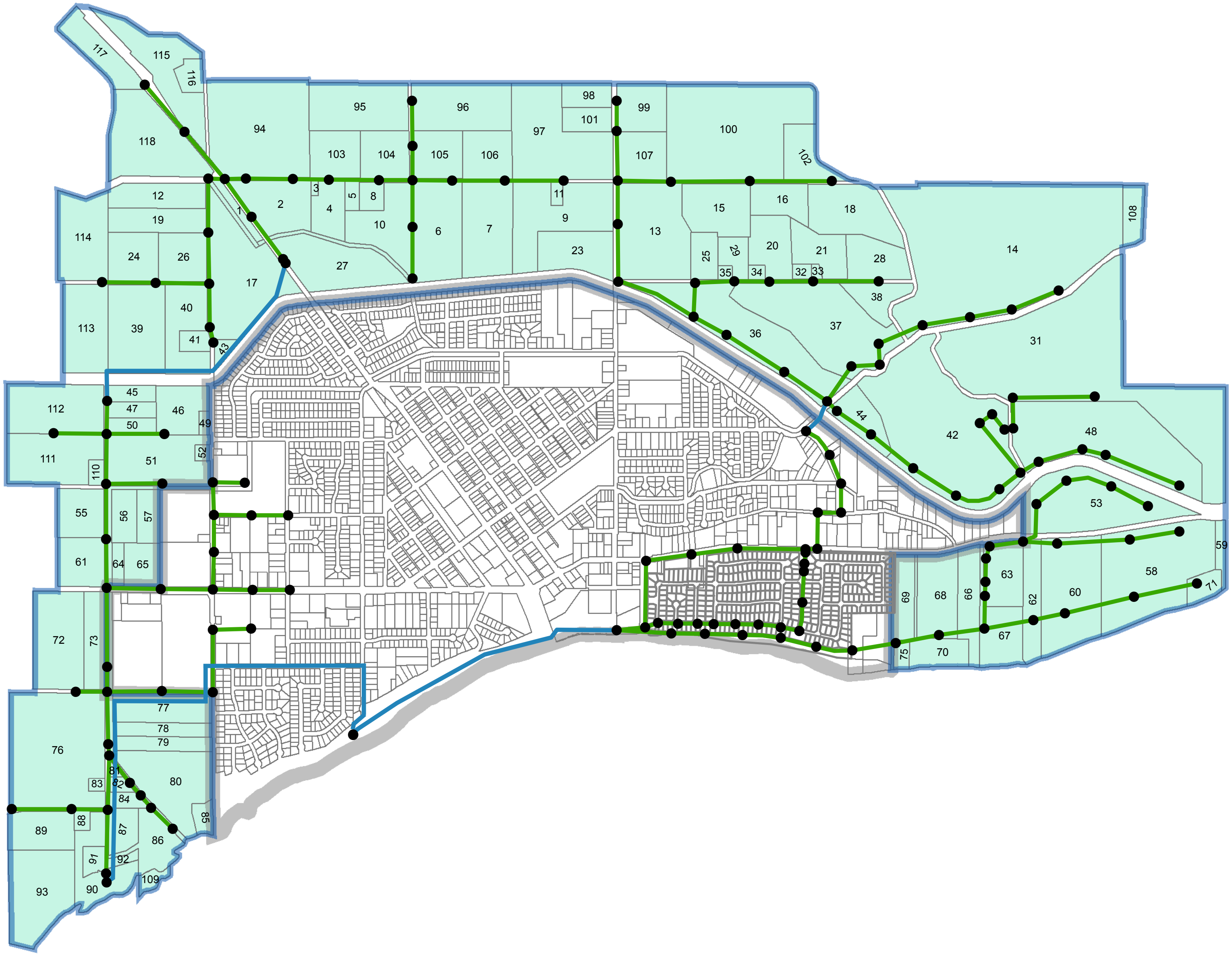


FIGURE A-3

Parcel ID Map

CITY
OF
WATERFORD

Sewer System
Master Plan

Table A-1: Study Area Manholes

Manhole ID	Diameter (ft)	Manhole Rim Elevation (ft)	Load 1[a] (gpm)	Load 2[b] (gpm)
10	4.0	175.83	94.9	---
12	4.0	180.92	53.2	---
14	4.0	173.92	31.4	---
16	4.0	167.61	14.9	---
18	4.0	163.45	14.7	---
24	4.0	192.93	88.9	---
26	4.0	194.00	74.9	---
28	4.0	186.44	74.9	---
30	4.0	188.91	74.9	---
32	4.0	174.89	51.1	---
34	4.0	177.27	---	---
36	4.0	167.92	51.1	---
38	4.0	167.00	11.9	---
40	4.0	167.92	11.9	---
42	4.0	168.80	45.2	---
44	4.0	170.50	45.2	---
48	4.0	171.23	87.3	---
50	4.0	171.53	42.5	---
52	4.0	171.50	42.5	---
54	4.0	171.00	42.5	---
56	4.0	181.93	87.3	---
76	4.0	168.50	25.6	---
78	4.0	169.47	110.6	---
80	4.0	165.03	71.6	---
82	4.0	162.99	27.7	---
84	4.0	160.92	150.9	---
86	4.0	161.92	81.8	---
88	4.0	160.92	57.0	---
92	4.0	163.92	12.8	---
94	4.0	160.92	49.0	---
96	4.0	160.92	86.2	---
98	4.0	160.92	86.2	---
104	4.0	160.92	54.2	---
106	4.0	163.91	74.5	---
108	4.0	160.92	38.6	---
110	4.0	164.92	27.6	---
112	4.0	161.92	27.1	---
114	4.0	162.92	12.2	---
116	4.0	162.92	117.4	---
118	4.0	160.92	69.2	---
120	4.0	159.72	42.3	---
122	4.0	160.92	18.3	---
124	4.0	160.92	9.2	---
126	4.0	160.92	4.5	---
128	4.0	161.36	55.6	---
130	4.0	162.92	50.0	16.0
132	4.0	163.92	23.2	---
134	4.0	162.92	---	---
136	4.0	161.84	33.4	---
138	4.0	159.20	2.4	---
140	4.0	160.92	61.7	---
144	4.0	160.92	32.7	---
146	4.0	160.92	57.2	---
150	4.0	162.92	133.9	---
152	4.0	160.92	70.0	---
160	4.0	163.92	---	---
162	4.0	160.92	86.2	---
172	4.0	165.92	45.6	---
174	4.0	165.92	45.6	---
176	4.0	188.71	87.3	---
178	4.0	189.73	---	---
180	4.0	183.92	---	---
182	4.0	180.60	45.2	---
184	4.0	169.50	45.2	---
186	4.0	186.49	---	---
200	4.0	160.92	---	---
206	4.0	160.45	61.7	---
208	4.0	159.92	---	---
214	4.0	161.64	3.5	---
218	4.0	160.92	---	---
236	4.0	171.00	---	---
244	4.0	160.92	40.5	---
246	4.0	160.39	109.0	---
250	4.0	163.92	21.2	---
252	4.0	163.92	21.2	---
254	4.0	163.92	21.2	---
256	4.0	164.28	21.2	---
258	4.0	164.33	6.9	---
260	4.0	175.69	54.2	---
262	4.0	178.92	38.0	---
264	4.0	123.90	10.4	---
266	4.0	124.36	54.2	---
268	4.0	126.92	38.0	---

Manhole ID	Diameter (ft)	Manhole Rim Elevation (ft)	Load 1[a] (gpm)	Load 2[b] (gpm)
270	4.0	127.92	25.2	---
272	4.0	174.92	---	---
274	4.0	128.27	32.0	---
276	4.0	136.44	---	---
278	4.0	137.92	29.4	---
280	4.0	159.92	---	---
284	4.0	179.31	---	25.9
286	4.0	168.64	---	25.9
288	4.0	169.85	---	25.9
290	4.0	173.30	---	25.9
292	4.0	177.87	---	25.9
298	4.0	164.00	---	---
300	4.0	166.00	---	---
302	4.0	130.71	---	---
304	4.0	130.47	---	315.0
306	4.0	122.70	---	---
308	4.0	124.60	---	---
310	4.0	117.20	---	---
312	4.0	113.40	---	---
314	4.0	111.90	---	---
316	4.0	107.40	---	---
318	4.0	102.30	---	---
320	4.0	97.70	---	---
322	4.0	95.50	---	---
324	4.0	95.50	---	---
326	4.0	97.10	---	---
328	4.0	95.00	---	---
332	4.0	130.54	---	---
344	4.0	130.22	---	---
346	4.0	136.37	---	---
348	4.0	136.99	---	---
350	4.0	158.92	96.1	---
352	4.0	161.00	142.5	---
354	4.0	158.92	110.7	---
358	4.0	163.00	---	---
362	4.0	163.06	17.1	---
364	4.0	171.60	---	---
366	4.0	162.00	57.6	---
368	4.0	164.41	---	42.9
370	4.0	165.21	---	44.0
372	4.0	163.73	---	15.0
374	4.0	164.44	---	7.7
376	4.0	162.30	---	28.0
378	4.0	164.96	---	7.0
380	4.0	168.05	---	15.0
382	4.0	163.00	---	---
384	4.0	163.90	---	46.3
386	4.0	165.21	---	---
388	4.0	165.09	---	56.5
390	4.0	163.00	---	---
392	4.0	163.76	53.5	---
406	4.0	159.91	32.2	---
410	4.0	162.74	7.0	---
416	4.0	160.92	65.0	---
420	4.0	119.80	---	---
422	4.0	112.90	---	---
424	4.0	110.40	---	---
426	4.0	102.80	---	---
428	4.0	95.10	---	---
430	4.0	94.60	---	---
432	4.0	125.92	61.1	---
434	4.0	126.70	28.7	---
436	4.0	130.38	26.8	---
442	4.0	105.00	---	---
444	4.0	96.00	---	---
446	4.0	103.95	---	---
448	4.0	160.92	107.1	---
454	4.0	96.44	---	---
456	4.0	158.70	187.0	---
458	4.0	200.00	---	---

a. Load 1 refers to study area flows

b. Load 2 refers to non-study area flows

Table A-2: Study Area Pipes

Pipe ID	Type	Upstream Invert (ft)	Downstream Invert (ft)	Length (ft)	Diameter (in)	Slope	Coefficient
13	Gravity	150.907	148.918	568	8	0.0035	0.013
15	Gravity	148.918	147.325	455	8	0.0035	0.013
17	Gravity	147.325	145.544	509	8	0.0035	0.013
21	Gravity	169.130	166.830	657	8	0.0035	0.013
23	Gravity	166.830	164.901	551	8	0.0035	0.013
25	Gravity	164.901	162.719	623	8	0.0035	0.013
27	Gravity	162.719	161.170	620	10	0.0025	0.013
29	Gravity	161.170	160.483	275	10	0.0025	0.013
31	Gravity	160.483	159.561	369	10	0.0025	0.013
33	Gravity	159.561	158.464	548	12	0.0020	0.013
35	Gravity	147.740	147.464	184	15	0.0015	0.013
37	Gravity	148.537	147.740	531	15	0.0015	0.013
39	Gravity	149.587	148.537	700	15	0.0015	0.013
45	Gravity	160.618	156.991	1,036	8	0.0035	0.013
47	Gravity	156.991	155.890	315	8	0.0035	0.013
49	Gravity	155.890	153.833	588	8	0.0035	0.013
51	Gravity	153.833	152.867	276	8	0.0035	0.013
73	Gravity	158.097	154.370	1,065	8	0.0035	0.013
75	Gravity	154.370	150.808	1,018	8	0.0035	0.013
77	Gravity	150.808	149.069	696	10	0.0025	0.013
81	Gravity	152.424	149.754	763	8	0.0035	0.013
83	Gravity	149.754	148.039	687	10	0.0025	0.013
105	Gravity	152.701	151.317	395	8	0.0035	0.013
107	Gravity	151.317	149.069	642	8	0.0035	0.013
109	Gravity	152.438	151.717	206	8	0.0035	0.013
111	Gravity	151.717	149.744	564	8	0.0035	0.013
113	Gravity	143.831	142.074	703	10	0.0025	0.013
117	Gravity	148.262	147.664	432	21	0.0014	0.013
119	Gravity	147.664	147.020	646	21	0.0010	0.013
121	Gravity	147.020	146.279	719	21	0.0010	0.013
123	Gravity	146.279	142.813	633	21	0.0055	0.013
125	Gravity	142.813	141.685	1,024	21	0.0011	0.013
127	Gravity	141.685	141.331	324	21	0.0011	0.013
129	Gravity	141.331	140.584	680	21	0.0011	0.013
137	Gravity	150.293	147.664	751	8	0.0035	0.013
139	Gravity	147.491	145.953	412	8	0.0037	0.013
145	Gravity	140.822	140.000	685	18	0.0012	0.013
149	Gravity	153.884	150.907	850	8	0.0035	0.013
151	Gravity	146.144	143.831	661	10	0.0035	0.013
153	Gravity	148.572	146.144	694	8	0.0035	0.013
173	Gravity	141.910	140.903	672	15	0.0015	0.013
175	Gravity	146.162	143.982	1,090	12	0.0020	0.013
177	Gravity	145.544	143.982	446	8	0.0035	0.013
179	Gravity	173.391	169.670	1,063	8	0.0035	0.013
183	Gravity	167.858	166.961	256	8	0.0035	0.013
185	Gravity	166.961	166.277	195	8	0.0035	0.013
187	Gravity	166.277	163.360	833	8	0.0035	0.013
191	Gravity	150.919	149.587	666	12	0.0020	0.013
193	Gravity	152.171	150.919	626	12	0.0020	0.013
199	Gravity	169.670	168.285	396	8	0.0035	0.013
201	Gravity	168.285	167.858	122	8	0.0035	0.013
215	Gravity	148.039	146.248	512	10	0.0035	0.013
229	Gravity	142.074	141.543	212	10	0.0025	0.013
231	Gravity	141.543	140.822	601	18	0.0012	0.013
233	Gravity	149.069	147.668	560	10	0.0025	0.013
235	Gravity	147.668	146.162	753	12	0.0020	0.013
241	Gravity	147.296	144.585	775	8	0.0035	0.013
243	Gravity	144.585	142.954	466	8	0.0035	0.013
245	Gravity	140.433	139.642	719	24	0.0011	0.013
247	Gravity	144.788	143.143	470	8	0.0035	0.013
249	Gravity	147.658	146.281	393	8	0.0035	0.013
251	Gravity	145.549	144.788	218	8	0.0035	0.013
253	Gravity	141.914	141.543	247	15	0.0015	0.013
255	Gravity	143.142	141.914	614	12	0.0020	0.013
257	Gravity	144.078	143.142	468	12	0.0020	0.013
259	Gravity	145.369	144.078	645	12	0.0020	0.013
261	Gravity	146.248	145.369	439	12	0.0020	0.013
263	Gravity	147.811	146.248	447	8	0.0035	0.013
265	Gravity	149.860	147.811	585	8	0.0035	0.013
267	Gravity	152.867	152.171	348	12	0.0020	0.013
269	Gravity	143.252	141.910	895	15	0.0015	0.013
271	Gravity	148.379	146.248	609	8	0.0035	0.013
273	Gravity	150.710	148.379	666	8	0.0035	0.013
275	Gravity	157.955	156.071	538	8	0.0035	0.013
277	Gravity	156.071	153.950	606	8	0.0035	0.013
279	Gravity	153.950	152.221	494	8	0.0035	0.013
281	Gravity	152.221	150.139	595	8	0.0035	0.013
283	Gravity	157.270	154.980	654	8	0.0035	0.013
285	Gravity	154.980	151.690	940	8	0.0035	0.013
287	Gravity	151.690	150.139	443	8	0.0035	0.013
289	Gravity	116.418	113.484	838	8	0.0035	0.013
291	Gravity	113.484	110.266	919	8	0.0035	0.013
293	Gravity	110.266	108.802	418	8	0.0035	0.013
295	Gravity	108.802	106.500	649	8	0.0035	0.013

Pipe ID	Type	Upstream Invert (ft)	Downstream Invert (ft)	Length (ft)	Diameter (in)	Slope	Coefficient
297	Gravity	150.139	148.591	442	8	0.0035	0.013
299	Gravity	148.591	128.000	172	8	0.1198	0.013
301	Gravity	128.000	122.029	298	8	0.0200	0.013
303	Gravity	122.029	121.396	181	10	0.0035	0.013
305	Gravity	121.396	106.500	430	10	0.0346	0.013
309	Gravity	176.000	160.000	445	12	0.0360	0.013
311	Gravity	160.000	159.561	399	21	0.0011	0.013
313	Gravity	159.561	159.143	381	21	0.0011	0.013
315	Gravity	159.143	158.810	303	21	0.0011	0.013
317	Gravity	158.810	124.614	472	21	0.0725	0.013
321	Gravity	143.982	143.252	487	15	0.0015	0.013
323	Force Main	168.000	176.000	489	10	-0.0163	100
325	Gravity	124.614	124.430	154	21	0.0012	0.013
327	Gravity	124.430	121.410	46	12	0.0653	0.013
329	Gravity	121.410	115.050	144	12	0.0441	0.013
331	Gravity	115.050	113.190	103	12	0.0181	0.013
333	Gravity	113.190	105.960	402	12	0.0180	0.013
335	Gravity	105.960	104.540	371	12	0.0038	0.013
337	Gravity	104.440	102.880	247	12	0.0063	0.013
339	Gravity	102.880	98.190	284	12	0.0165	0.013
341	Gravity	98.190	93.440	304	12	0.0156	0.013
343	Gravity	93.440	89.870	282	12	0.0127	0.013
345	Gravity	89.870	89.380	210	12	0.0023	0.013
347	Gravity	89.380	88.880	253	12	0.0020	0.013
349	Gravity	88.880	88.380	261	12	0.0019	0.013
351	Gravity	88.280	87.310	173	12	0.0056	0.013
353	Gravity	87.210	86.390	369	12	0.0022	0.013
355	Gravity	124.414	123.441	885	21	0.0011	0.013
357	Gravity	123.441	122.780	601	21	0.0011	0.013
359	Gravity	122.780	122.127	593	21	0.0011	0.013
361	Gravity	122.127	90.143	834	21	0.0383	0.013
363	Gravity	151.008	148.572	696	8	0.0035	0.013
365	Gravity	148.765	145.970	799	8	0.0035	0.013
367	Gravity	145.970	143.143	808	8	0.0035	0.013
371	Force Main	140.000	153.000	3,481	10	-0.0037	100
375	Gravity	154.203	152.511	416	8	0.0041	0.013
379	Gravity	149.574	147.020	730	8	0.0035	0.013
381	Gravity	154.438	152.777	475	8	0.0035	0.013
383	Gravity	152.777	151.055	492	8	0.0035	0.013
385	Gravity	156.116	154.424	483	8	0.0035	0.013
387	Gravity	154.424	152.642	509	8	0.0035	0.013
389	Gravity	151.055	149.364	483	8	0.0035	0.013
391	Gravity	149.364	147.642	492	8	0.0035	0.013
393	Gravity	147.642	145.256	682	8	0.0035	0.013
395	Gravity	145.256	142.813	698	8	0.0035	0.013
397	Gravity	153.590	151.868	492	8	0.0035	0.013
399	Gravity	151.868	149.029	811	8	0.0035	0.013
401	Gravity	149.029	146.703	665	8	0.0035	0.013
403	Gravity	146.703	144.221	709	8	0.0035	0.013
405	Gravity	140.000	139.000	52	18	0.0194	0.013
419	Gravity	140.584	140.433	131	24	0.0012	0.013
421	Gravity	146.281	145.549	209	8	0.0035	0.013
429	Gravity	106.500	105.314	593	12	0.0020	0.013
431	Gravity	105.314	104.175	570	12	0.0020	0.013
433	Gravity	104.175	103.024	575	12	0.0020	0.013
435	Gravity	103.024	102.085	470	12	0.0020	0.013
437	Gravity	102.085	101.127	479	12	0.0020	0.013
439	Gravity	101.127	94.846	496	12	0.0127	0.013
441	Gravity	94.846	88.679	487	12	0.0127	0.013
443	Gravity	88.679	87.809	435	12	0.0020	0.013
445	Gravity	87.809	79.000	710	12	0.0124	0.013
455	Force Main	88.000	101.850	3,792	12	-0.0037	100
457	Gravity	152.511	151.055	416	8	0.0035	0.013
459	Gravity	150.058	147.664	685	8	0.0035	0.013
465	Gravity	90.143	86.390	375	21	0.0100	0.013
467	Gravity	138.986	138.966	18	24	0.0011	0.013
469	Gravity	139.642	138.986	596	24	0.0011	0.013
471	Force Main	151.700	101.850	6,716	14	0.0074	100

Table A-3: Study Area Parcels

Parcel ID	APN	Area (sq. ft)	Area (acres)	Land Use	Sewershed	Manhole ID(s)	ADWF (gpm/acre)	ADWF (gpm)	GWI (gpm)	PWWF (gpm)
1	080-016-017	92,800	2.130	Industrial	C	152	1.389	2.959	0.888	9.765
2	080-016-001	572,201	13.136	Industrial	C	152	1.389	18.246	5.473	60.211
3	080-016-025	17,925	0.412	Low Density Residential	C	94	0.844	0.347	0.171	1.213
4	080-016-026	299,971	6.886	Low Density Residential	C	94	0.844	5.812	2.869	20.306
5	080-016-003	71,830	1.649	Low Density Residential	C	92	0.844	1.392	0.687	4.862
6	080-016-005	848,893	19.488	Low Density Residential	C	88	0.844	16.448	8.120	57.463
7	080-016-006	805,174	18.484	Low Density Residential	C	86	0.844	15.601	7.702	54.504
8	080-016-023	117,830	2.705	Low Density Residential	C	92	0.844	2.283	1.127	7.976
9	080-016-027	955,010	21.924	Low Density Residential	C	84	0.844	18.504	9.135	64.647
10	080-016-024	598,438	13.738	Low Density Residential	C	244	0.844	11.595	5.724	40.510
11	080-016-028	44,966	1.032	Low Density Residential	C	84	0.844	0.871	0.430	3.044
12	080-002-006	401,624	9.220	Industrial	C	120	1.389	12.807	3.842	42.261
13	080-022-023	1,141,413	26.203	Low Density Residential	B	106, 108	0.844	22.116	10.918	77.265
14	080-015-002	4,427,046	101.631	Low Density Residential	B	24, 26, 28, 30	0.844	85.777	42.346	299.676
15	080-022-024	576,841	13.242	Low Density Residential	B	78	0.844	11.177	5.518	39.048
16	080-022-003	324,054	7.439	Low Density Residential	B	12	0.844	6.279	3.100	21.936
17	080-016-017	1,246,107	28.607	Commercial	C	116, 150	1.736	49.661	11.919	160.903
18	080-022-004	716,009	16.437	Low Density Residential	B	10	0.844	13.873	6.849	48.468
19	080-002-007	402,943	9.250	Industrial	C	118	1.389	12.849	3.854	42.400
20	080-022-025	421,854	9.684	Low Density Residential	B	14	0.844	8.174	4.035	28.556
21	080-022-019	390,091	8.955	Low Density Residential	B	12	0.844	7.558	3.731	26.406
23	080-016-008	529,731	12.161	Low Density Residential	B	106	0.844	10.264	5.067	35.859
24	080-002-009	418,377	9.605	Low Density Residential	C	162	0.844	8.106	4.002	28.321
25	080-022-022	216,555	4.971	Low Density Residential	B	18	0.844	4.196	2.071	14.659
26	080-002-008	396,607	9.105	Low Density Residential	C	118	0.844	7.684	3.794	26.847
27	080-016-011	828,210	19.013	Commercial	C	150, 392	1.736	33.007	7.922	106.942
28	080-022-013	412,388	9.467	Low Density Residential	B	10	0.844	7.990	3.945	27.915
29	080-022-007	185,810	4.266	Low Density Residential	B	16	0.844	3.600	1.777	12.578
31	080-015-034	3,870,398	88.852	Low Density Residential	B	48, 56, 176	0.844	74.991	37.022	261.995
32	080-022-015	47,920	1.100	Low Density Residential	B	12	0.844	0.928	0.458	3.244
33	080-022-021	24,096	0.553	Low Density Residential	B	12	0.844	0.467	0.230	1.631
34	080-022-006	41,873	0.961	Low Density Residential	B	14	0.844	0.811	0.401	2.834
35	080-022-008	33,941	0.779	Low Density Residential	B	16	0.844	0.658	0.325	2.298
36	080-022-018	1,346,274	30.906	Low Density Residential	B	172, 174	0.844	26.085	12.878	91.132
37	080-022-017	1,509,291	34.649	Low Density Residential	B	32, 36	0.844	29.243	14.437	102.167
38	080-022-011	273,616	6.281	Low Density Residential	B	10	0.844	5.301	2.617	18.522
39	080-002-022	855,249	19.634	Low Density Residential	C	162	0.844	16.571	8.181	57.894
40	080-002-021	546,242	12.540	Low Density Residential	C	116	0.844	10.584	5.225	36.976
41	080-002-018	106,043	2.434	Low Density Residential	C	114	0.844	2.055	1.014	7.178
42	080-015-035	2,671,908	61.339	Low Density Residential	B	182, 44, 184, 42	0.844	51.770	25.558	180.867
43	080-058-001	74,049	1.700	Low Density Residential	C	114	0.844	1.435	0.708	5.013
44	080-015-001	351,422	8.068	Low Density Residential	B	38, 40	0.844	6.809	3.361	23.788
45	080-003-045	135,469	3.110	Low Density Residential	D	122	0.844	2.625	1.296	9.170
46	080-003-052	400,879	9.203	Low Density Residential	D	144	0.844	7.767	3.835	27.136
47	080-003-055	134,405	3.086	Low Density Residential	D	122	0.844	2.604	1.286	9.098
48	080-015-035	1,885,459	43.284	Low Density Residential	B	50, 52, 54	0.844	36.532	18.035	127.631
49	080-003-053	42,298	0.971	Low Density Residential	D	144	0.844	0.820	0.405	2.863
50	080-003-054	136,401	3.131	Low Density Residential	D	124	0.844	2.643	1.305	9.233
51	080-003-050	850,637	19.528	Low Density Residential	D	366	0.844	16.482	8.137	57.581
52	080-003-049	40,140	0.921	Low Density Residential	D	144	0.844	0.778	0.384	2.717
53	080-015-012	1,253,199	28.769	Low Density Residential	A	250, 252, 254, 256	0.844	24.281	11.987	84.832
55	080-003-017	386,151	8.865	Low Density Residential	D	128	0.844	7.482	3.694	26.139
56	080-003-034	225,638	5.180	Low Density Residential	D	128	0.844	4.372	2.158	15.274
57	080-003-012	210,199	4.826	Low Density Residential	D	128	0.844	4.073	2.011	14.229
58	080-015-025	1,600,523	36.743	Low Density Residential	A	260, 266	0.844	31.011	15.310	108.343
59	080-015-016	101,927	2.340	Low Density Residential	A	258	0.844	1.975	0.975	6.900
60	080-015-014	1,122,532	25.770	Low Density Residential	A	262, 268	0.844	21.750	10.737	75.987
61	080-003-016	389,898	8.951	Low Density Residential	D	130	0.844	7.554	3.730	26.393
62	080-015-013	372,678	8.556	Low Density Residential	A	270	0.844	7.221	3.565	25.227
63	080-034-012	434,408	9.973	Low Density Residential	A	278	0.844	8.417	4.155	29.406
64	080-003-015	86,013	1.975	Low Density Residential	D	130	0.844	1.667	0.823	5.822
65	080-003-040	265,184	6.088	Low Density Residential	D	130	0.844	5.138	2.537	17.951
66	080-034-016	395,855	9.088	Low Density Residential	A	436	0.844	7.670	3.786	26.796
67	080-034-011	472,915	10.857	Low Density Residential	A	274	0.844	9.163	4.524	32.013
68	080-034-015	584,333	13.414	Low Density Residential	A	432	0.844	11.322	5.589	39.555
69	080-034-002	348,562	8.002	Low Density Residential	A	434	0.844	6.754	3.334	23.595
70	080-034-019	317,869	7.297	Low Density Residential	A	432	0.844	6.159	3.041	21.517
71	080-015-024	153,009	3.513	Low Density Residential	A	264	0.844	2.965	1.464	10.358
72	080-007-059	844,871	19.396	Low Density Residential	D	146	0.844	16.370	8.081	57.191
73	080-007-060	342,585	7.865	Low Density Residential	D	132	0.844	6.638	3.277	23.190
75	080-034-018	75,420	1.731	Low Density Residential	A	434	0.844	1.461	0.721	5.105
76	080-007-022	1,823,479	41.861	Low Density Residential	D	140, 206	0.844	35.331	17.442	123.435
77	080-007-016	475,152	10.908	Low Density Residential	D	406	0.844	9.206	4.545	32.164
78	080-007-017	237,588	5.454	Low Density Residential	D	136	0.844	4.603	2.273	16.083
79	080-007-018	237,596	5.454	Low Density Residential	D	136	0.844	4.604	2.273	16.083
80	080-007-068	879,543	20.192	Low Density Residential	D	416	0.844	17.042	8.413	59.538
81	080-007-043	17,934	0.412	Low Density Residential	D	136	0.844	0.347	0.172	1.214
82	080-007-042	49,977	1.147	Low Density Residential	D	214	0.844	0.968	0.478	3.383
83	080-007-021	35,581	0.817	Low Density Residential	D	138	0.844	0.689	0.340	2.409
84	080-007-032	86,813	1.993	Low Density Residential	D	416	0.844	1.682	0.830	5.877
85	080-007-067	102,811	2.360	Low Density Residential	D	410	0.844	1.992	0.983	6.959
86	080-008-039	366,352	8.410	Low Density Residential	D	456	0.844	7.098	3.504	24.799
87	080-008-021	213,699	4.906	Low Density Residential	D	456	0.844	4.141	2.044	14.466
88	080-008-007	52,424	1.203	Low Density Residential	D	456	0.844	1.016	0.501	3.549
89	080-008-032	435,392	9.995	Low Density Residential	D	456	0.844	8.436	4.165	29.473
90	080-008-044	492,487	11.306	Low Density Residential	D	456	0.844	9.542	4.711	33.337
91	080-008-042	102,192	2.346	Low Density Residential	D	456	0.844	1.980	0.978	6.918
92	080-008-040	50,910	1.169	Low Density Residential	D	456	0.844	0.986	0.487	3.446
93	080-008-033	924,409	21.222	Low Density Residential	D	456	0.844	17.911	8.842	62.575
94	015-009-003	1,639,123	37.629	Industrial	C	96, 98	1.389	52.267	15.679	172.479
95	015-009-004	802,750	18.429	Low Density Residential	C	246	0.844	15.554	7.679	54.340
96	015-010-001	807,500	18.538	Low Density Residential	C	246	0.844	15.646	7.724	54.661
97	015-010-002	1,229,730	28.231	Low Density Residential	C	84	0.844	23.827	11.763	83.243
98	015-010-007	205,827	4.725	Low Density Residential	B	110	0.844	3.988	1.969	13.933
99	015-013-042	400,189	9.187	Low Density Residential	B	112	0.844	7.754	3.828	27.090
100	015-013-044	2,115,059	48.555	Low Density Residential	B	78, 80	0.844	40.980	20.231	143.173
101	015-010-006	201,653	4.629	Low Density Residential	B	110	0.844	3.907	1.929	13.650
102	015-013-045	378,399	8.687	Low Density Residential	B	76	0.844	7.332	3.620	25.615
103	015-009-005	405,755	9.315	Low Density Residential	C	94	0.844	7.862	3.881	27.466
104	015-009-006	395,908	9.089	Low Density Residential	C	104	0.844	7.671	3.787	26.800
105	015-010-005	405,499	9.309	Low Density Residential	C	104	0.844	7.857	3.879	27.449
106	015-010-004	404,184	9.279	Low Density Residential	C	86	0.844	7.831	3.866	27.360
107	015-013-043	409,635	9.404	Low Density Residential	B	82	0.844	7.937	3.918	27.729
108	---[a]	206,289	4.736	Low Density Residential	B	24	0.844	3.997	1.973	13.964
109	---[a]	82,144	1.886	Low Density Residential	D	456	0.844	1.592	0.786	5.560
110	---[a]	66,180	1.519	Low Density Residential	D	126	0.844	1.282	0.633	4.480
111	---[a]	767,974	17.630	Low Density Residential	D	448	0.844	14.880	7.346	51.986
112	---[a]	814,892	18.707	Low Density Residential	D	448	0.844	15.789	7.795	55.162
113	---[a]	681,114	15.636	Low Density Residential	C	350	0.844	13.197	6.515	46.106
114	---[a]	738,035	16.943	Low Density Residential	C	350	0.844	14.300	7.060	49.959
115	---[a]	794,306	18.235	Industrial	C	352	1.389	25.328	7.598	83.582
116	---[a]	137,340	3.153	Industrial	C	352	1.389	4.379	1.314	14.452
117	---[a]	422,379	9.696	Industrial	C	352	1.389	13.468	4.040	44.445
118	---[a]	1,052,153	24.154	Industrial	C	354	1.389	33.550	10.064	110.714

a. APN numbers were not provided for these parcels

Table A-4: Model Output - Manholes

ID	Rim Elevation (ft)	Base Flow (gpm)	Grade (ft)	Status	Hydraulic Jump	Unfilled Depth (ft)
10	175.83	94.9	154.132	Not Full	No	21.693
104	160.92	54.2	148.147	Not Full	No	12.777
106	163.91	74.5	146.699	Not Full	No	17.209
108	160.92	38.6	148.143	Not Full	No	12.781
110	164.92	27.6	152.833	Not Full	No	12.091
112	161.92	27.1	151.504	Not Full	No	10.42
114	162.92	12.2	152.527	Not Full	No	10.397
116	162.92	117.4	152.011	Not Full	No	10.913
118	160.92	69.2	144.381	Not Full	No	16.543
12	180.92	53.2	151.225	Not Full	No	29.699
120	159.72	42.3	142.669	Not Full	No	17.052
122	160.92	18.3	149.273	Not Full	No	11.651
124	160.92	9.2	148.862	Not Full	No	12.062
126	160.92	4.5	148.232	Not Full	No	12.692
128	161.36	55.6	147.015	Not Full	No	14.348
130	162.92	66.0	144.142	Not Full	Yes	18.782
132	163.92	23.2	143.406	Not Full	No	20.518
134	162.92	0.0	143.091	Not Full	No	19.833
136	161.84	33.4	141.718	Not Full	No	20.12
138	159.20	2.4	140.972	Not Full	No	18.232
14	173.92	31.4	149.274	Not Full	No	24.65
140	160.92	61.7	144.872	Not Full	No	16.052
144	160.92	32.7	150.437	Not Full	No	10.487
146	160.92	57.2	147.678	Not Full	No	13.246
150	162.92	133.9	140.514	Not Full	No	22.41
152	160.92	70.0	141.971	Not Full	No	18.953
16	167.61	14.9	147.698	Not Full	No	19.909
160	163.92	0.0	146.578	Not Full	No	17.346
162	160.92	86.2	148.931	Not Full	No	11.993
172	165.92	45.6	143.939	Not Full	No	21.985
174	165.92	45.6	142.626	Not Full	No	23.298
176	188.71	87.3	170.02	Not Full	No	18.692
178	189.73	0.0	168.208	Not Full	No	21.521
18	163.45	14.7	145.935	Not Full	No	17.513
180	183.92	0.0	167.311	Not Full	No	16.606
182	180.60	45.2	166.681	Not Full	No	13.921
184	169.50	45.2	151.555	Not Full	No	17.945
186	186.49	0.0	168.635	Not Full	No	17.852
200	160.92	0.0	146.902	Not Full	No	14.022
206	160.45	61.7	147.494	Not Full	No	12.955
208	159.92	0.0	146.349	Not Full	No	13.575
214	161.64	3.5	145.008	Not Full	No	16.627
218	160.92	0.0	142.645	Not Full	No	18.279
236	171.00	0.0	153.428	Not Full	No	17.572
24	192.93	88.9	169.37	Not Full	No	23.556
244	160.92	40.5	148.626	Not Full	No	12.298
246	160.39	109.0	150.127	Not Full	No	10.266
250	163.92	21.2	158.071	Not Full	No	5.853
252	163.92	21.2	156.235	Not Full	No	7.689
254	163.92	21.2	154.151	Not Full	No	9.773
256	164.28	21.2	152.455	Not Full	No	11.826
258	164.33	6.9	157.337	Not Full	No	6.994
26	194.00	74.9	167.167	Not Full	No	26.828
260	175.69	54.2	155.177	Not Full	No	20.517
262	178.92	38.0	151.944	Not Full	No	26.98
264	123.90	10.4	116.5	Not Full	No	7.399
266	124.36	54.2	113.687	Not Full	No	10.67
268	126.92	38.0	110.525	Not Full	No	16.399
270	127.92	25.2	109.093	Not Full	No	18.831
272	174.92	0.0	150.5	Not Full	No	24.424
274	128.27	32.0	121.602	Not Full	No	6.67
276	136.44	0.0	122.378	Not Full	Yes	14.064
278	137.92	29.4	128.24	Not Full	No	9.684
28	186.44	74.9	165.329	Not Full	No	21.115
280	159.92	0.0	148.732	Not Full	No	11.192
284	179.31	25.9	176.542	Not Full	No	2.769
286	168.64	25.9	161.126	Not Full	Yes	7.514
288	169.85	25.9	160.7	Not Full	No	9.145
290	173.30	25.9	160.293	Not Full	No	13.003
292	177.87	25.9	159.176	Not Full	No	18.697
298	164.00	0.0	144.64	Not Full	No	19.36
30	188.91	74.9	163.201	Not Full	No	25.708
302	130.71	0.0	125.741	Not Full	Yes	4.965
304	130.47	315.0	121.617	Not Full	No	8.853
306	122.70	0.0	115.308	Not Full	No	7.392
308	124.60	0.0	113.449	Not Full	No	11.151
310	117.20	0.0	106.347	Not Full	Yes	10.853
312	113.40	0.0	104.779	Not Full	No	8.621
314	111.90	0.0	103.144	Not Full	No	8.756
316	107.40	0.0	98.458	Not Full	No	8.942
318	102.30	0.0	93.723	Not Full	No	8.577
32	174.89	51.1	161.703	Not Full	No	13.184
320	97.70	0.0	90.314	Not Full	Yes	7.386

ID	Rim Elevation (ft)	Base Flow (gpm)	Grade (ft)	Status	Hydraulic Jump	Unfilled Depth (ft)
322	95.50	0.0	89.845	Not Full	No	5.655
324	95.50	0.0	89.349	Not Full	No	6.151
326	97.10	0.0	88.63	Not Full	No	8.47
328	95.00	0.0	87.66	Not Full	No	7.34
332	130.54	0.0	125.576	Not Full	No	4.963
34	177.27	0.0	161.016	Not Full	No	16.255
344	130.22	0.0	124.603	Not Full	No	5.618
346	136.37	0.0	123.942	Not Full	No	12.428
348	136.99	0.0	122.557	Not Full	No	14.433
350	158.92	96.1	151.258	Not Full	No	7.666
352	161.00	142.5	149.076	Not Full	No	11.924
354	158.92	110.7	146.416	Not Full	No	12.508
36	167.92	51.1	160.108	Not Full	No	7.816
362	163.06	17.1	154.304	Not Full	No	8.751
364	171.60	0.0	152.615	Not Full	No	18.987
366	162.00	57.6	149.765	Not Full	No	12.235
368	164.41	42.9	151.336	Not Full	No	13.069
370	165.21	44.0	154.605	Not Full	No	10.606
372	163.73	15.0	152.97	Not Full	No	10.761
374	164.44	7.7	149.655	Not Full	No	14.787
376	162.30	28.0	147.994	Not Full	No	14.309
378	164.96	7.0	156.184	Not Full	No	8.775
38	167.00	11.9	148.386	Not Full	No	18.614
380	168.05	15.0	154.542	Not Full	No	13.511
382	163.00	0.0	145.609	Not Full	No	17.391
384	163.90	46.3	149.288	Not Full	No	14.615
386	165.21	0.0	152.057	Not Full	No	13.152
388	165.09	56.5	153.779	Not Full	No	11.308
390	163.00	0.0	146.962	Not Full	No	16.038
392	163.76	53.5	150.894	Not Full	No	12.861
40	167.92	11.9	149.174	Not Full	No	18.75
406	159.91	32.2	141.811	Not Full	No	18.097
410	162.74	7.0	147.726	Not Full	No	15.011
416	160.92	65.0	145.763	Not Full	No	15.161
42	168.80	45.2	150.217	Not Full	No	18.583
420	119.80	0.0	103.631	Not Full	No	16.169
422	112.90	0.0	102.691	Not Full	No	10.209
424	110.40	0.0	101.483	Not Full	No	8.917
426	102.80	0.0	95.202	Not Full	No	7.598
428	95.10	0.0	89.285	Not Full	Yes	5.815
430	94.60	0.0	88.167	Not Full	No	6.433
432	125.92	61.1	105.897	Not Full	No	20.027
434	126.70	28.7	104.782	Not Full	No	21.918
436	130.38	26.8	107.034	Not Full	Yes	23.349
44	170.50	45.2	152.77	Not Full	No	17.73
446	103.95	0.0	103.949	Full	No	0
448	160.92	107.1	150.323	Not Full	No	10.601
454	96.44	0.0	90.75	Not Full	No	5.688
456	158.70	187.0	140.394	Not Full	No	18.31
48	171.23	87.3	160.855	Not Full	No	10.374
50	171.53	42.5	157.286	Not Full	No	14.24
52	171.50	42.5	156.238	Not Full	No	15.262
54	171.00	42.5	154.231	Not Full	No	16.769
56	181.93	87.3	173.628	Not Full	No	8.3
76	168.50	25.6	158.225	Not Full	No	10.275
78	169.47	110.6	154.673	Not Full	No	14.794
80	165.03	71.6	151.186	Not Full	No	13.839
82	162.99	27.7	149.529	Not Full	No	13.458
84	160.92	150.9	152.745	Not Full	No	8.179
86	161.92	81.8	150.157	Not Full	No	11.767
88	160.92	57.0	148.454	Not Full	No	12.47
92	163.92	12.8	146.034	Not Full	No	17.89
94	160.92	49.0	144.785	Not Full	No	16.139
96	160.92	86.2	143.935	Not Full	No	16.989
98	160.92	86.2	142.679	Not Full	No	18.245

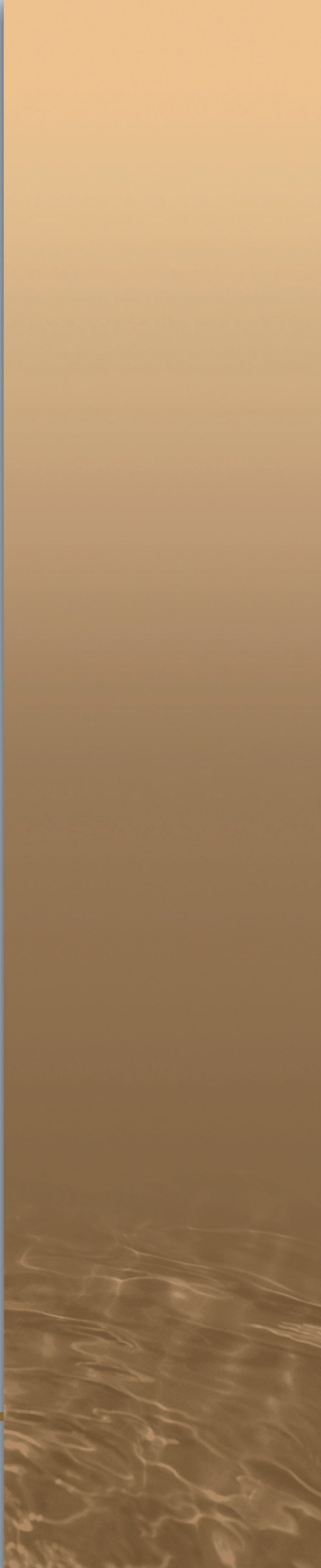
Table A-5: Model Output - Pipes

ID	From Manhole ID	To Manhole ID	Diameter (in)	Length (ft)	Slope	Total Flow (gpm)	Flow Type	Velocity (ft/s)	d/D	q/Q	Water Depth (ft)	Critical Depth (ft)	Froude Number	Full Flow (gpm)	Backwater Adjustment
105	110	112	8	395.276	0.004	27.6	Free Surface	1.26	0.198	0.086	0.132	0.112	0.728	322	Yes
107	112	82	8	642.477	0.004	54.7	Free Surface	1.53	0.279	0.170	0.186	0.159	0.739	322	Yes
109	114	116	8	205.956	0.004	12.2	Free Surface	0.99	0.133	0.038	0.089	0.074	0.704	322	Yes
111	116	160	8	563.648	0.004	129.6	Free Surface	1.94	0.441	0.403	0.294	0.249	0.723	322	No
113	118	120	10	702.712	0.003	381.1	Free Surface	2.22	0.660	0.773	0.550	0.408	0.563	493	Yes
117	122	124	21	432.014	0.001	1,679.90	Free Surface	2.60	0.578	0.633	1.011	0.705	0.502	2,653	Yes
119	124	126	21	645.695	0.001	1,828.90	Free Surface	2.32	0.685	0.812	1.198	0.737	0.394	2,252	Yes
121	126	128	21	718.673	0.001	1,891.00	Free Surface	2.37	0.692	0.826	1.212	0.750	0.398	2,290	No
123	128	130	21	632.537	0.005	1,946.60	Free Surface	4.52	0.420	0.369	0.736	0.762	1.068	5,278	Yes
125	130	132	21	1,024.17	0.001	2,189.26	Free Surface	2.49	0.760	0.925	1.330	0.810	0.383	2,366	Yes
127	132	134	21	324.231	0.001	2,212.46	Free Surface	2.48	0.770	0.939	1.347	0.814	0.377	2,357	Yes
129	134	406	21	679.569	0.001	2,372.42	Pressurized	2.20	1.000	1.003	1.750	0.843	0.293	2,364	No
13	12	14	8	568.379	0.004	148.1	Free Surface	2.01	0.477	0.460	0.318	0.266	0.714	322	Yes
137	144	124	8	751.455	0.003	32.7	Free Surface	1.32	0.215	0.102	0.144	0.122	0.732	322	Yes
139	146	134	8	412.1	0.004	57.2	Free Surface	1.59	0.281	0.172	0.187	0.163	0.764	332	No
145	152	150	18	685.146	0.001	1,527.70	Free Surface	2.35	0.766	0.933	1.148	0.703	0.387	1,638	No
149	10	12	8	850.34	0.004	94.9	Free Surface	1.79	0.372	0.295	0.248	0.212	0.735	322	Yes
15	14	16	8	455.253	0.004	179.5	Free Surface	2.11	0.534	0.558	0.356	0.295	0.696	322	Yes
151	160	118	10	660.969	0.003	311.9	Free Surface	2.42	0.521	0.535	0.434	0.367	0.727	583	Yes
153	162	160	8	693.582	0.004	182.3	Free Surface	2.12	0.539	0.567	0.359	0.297	0.694	322	Yes
17	16	18	8	508.836	0.004	194.4	Free Surface	2.15	0.561	0.604	0.374	0.307	0.687	322	Yes
173	174	9000	15	671.648	0.002	703.6	Free Surface	2.16	0.573	0.625	0.716	0.496	0.496	1,126	No
175	106	298	12	1,089.87	0.002	403.3	Free Surface	2.09	0.537	0.562	0.537	0.397	0.562	717	Yes
177	18	298	8	446.162	0.004	209.1	Free Surface	2.19	0.587	0.650	0.391	0.319	0.677	322	Yes
179	56	176	8	1,063.08	0.004	87.3	Free Surface	1.75	0.356	0.271	0.237	0.203	0.736	322	Yes
183	178	180	8	256.335	0.004	174.6	Free Surface	2.10	0.525	0.543	0.350	0.290	0.700	322	Yes
185	180	182	8	195.465	0.004	174.6	Free Surface	2.10	0.525	0.543	0.350	0.290	0.700	322	Yes
187	182	236	8	833.4	0.004	219.8	Free Surface	2.21	0.606	0.683	0.404	0.327	0.668	322	No
191	184	42	12	666.279	0.002	525	Free Surface	2.22	0.636	0.732	0.636	0.456	0.529	717	No
193	44	184	12	625.799	0.002	479.8	Free Surface	2.18	0.599	0.669	0.599	0.435	0.543	717	Yes
199	176	186	8	395.745	0.004	174.6	Free Surface	2.10	0.525	0.543	0.350	0.290	0.700	322	Yes
201	186	178	8	121.944	0.004	174.6	Free Surface	2.10	0.525	0.543	0.350	0.290	0.700	322	Yes
21	24	26	8	656.86	0.004	88.9	Free Surface	1.76	0.359	0.276	0.240	0.205	0.736	322	Yes
215	88	200	10	511.82	0.003	289.7	Free Surface	2.38	0.498	0.497	0.415	0.353	0.735	583	Yes
229	120	218	10	212.191	0.003	423.4	Free Surface	2.27	0.714	0.858	0.595	0.431	0.537	493	Yes
23	26	28	8	551.283	0.003	163.8	Free Surface	2.06	0.505	0.509	0.337	0.281	0.706	322	Yes
231	218	152	18	600.506	0.001	1,457.70	Free Surface	2.34	0.734	0.890	1.102	0.686	0.402	1,638	Yes
233	82	108	10	560.46	0.003	290.2	Free Surface	2.10	0.552	0.589	0.460	0.354	0.605	493	Yes
235	108	106	12	752.66	0.002	328.8	Free Surface	1.99	0.476	0.459	0.476	0.357	0.577	717	Yes
241	206	140	8	774.524	0.004	61.7	Free Surface	1.58	0.297	0.192	0.198	0.169	0.739	322	Yes
243	140	138	8	465.929	0.004	123.4	Free Surface	1.92	0.430	0.384	0.286	0.242	0.725	322	No
245	136	138	24	719.021	0.001	2,513.52	Free Surface	2.63	0.643	0.744	1.285	0.836	0.439	3,377	Yes
247	214	136	8	469.956	0.004	75.5	Free Surface	1.68	0.330	0.235	0.220	0.188	0.739	322	No
249	410	208	8	393.496	0.003	7	Free Surface	0.83	0.102	0.022	0.068	0.056	0.683	322	No
25	28	30	8	623.355	0.004	238.7	Free Surface	2.25	0.642	0.742	0.428	0.342	0.651	322	Yes
251	416	214	8	217.509	0.003	72	Free Surface	1.66	0.322	0.224	0.214	0.183	0.739	322	Yes
253	98	218	15	247.037	0.002	781.1	Free Surface	2.21	0.612	0.693	0.765	0.524	0.484	1,127	Yes
255	96	98	12	614.359	0.002	694.9	Free Surface	2.32	0.793	0.969	0.793	0.528	0.450	717	No
257	94	96	12	468.048	0.002	608.7	Free Surface	2.28	0.707	0.849	0.707	0.492	0.499	717	Yes
259	92	94	12	645.413	0.002	559.7	Free Surface	2.25	0.665	0.781	0.665	0.471	0.517	717	Yes
261	200	92	12	439.258	0.002	546.9	Free Surface	2.24	0.654	0.763	0.654	0.466	0.522	717	Yes
263	104	200	8	446.726	0.004	163.2	Free Surface	2.06	0.504	0.507	0.336	0.280	0.706	322	Yes
265	246	104	8	585.293	0.004	109	Free Surface	1.85	0.401	0.339	0.268	0.227	0.730	322	Yes
267	236	44	12	347.888	0.002	434.6	Free Surface	2.13	0.562	0.606	0.562	0.413	0.556	717	Yes
269	172	174	15	894.547	0.002	658	Free Surface	2.12	0.549	0.584	0.687	0.479	0.502	1,126	Yes
27	30	32	10	619.684	0.003	313.6	Free Surface	2.13	0.579	0.636	0.483	0.368	0.596	493	Yes
271	244	200	8	608.816	0.004	94	Free Surface	1.78	0.370	0.292	0.247	0.210	0.736	322	Yes
273	392	244	8	666.168	0.004	53.5	Free Surface	1.52	0.276	0.166	0.184	0.157	0.739	322	Yes
275	250	252	8	538.217	0.004	21.2	Free Surface	1.16	0.174	0.066	0.116	0.098	0.721	322	Yes
277	252	254	8	606.119	0.004	42.4	Free Surface	1.42	0.245	0.132	0.163	0.140	0.737	322	Yes
279	254	256	8	493.964	0.004	63.6	Free Surface	1.60	0.302	0.198	0.201	0.172	0.740	322	Yes
281	256	272	8	594.815	0.004	84.8	Free Surface	1.73	0.351	0.264	0.234	0.200	0.737	322	Yes
283	258	260	8	654.038	0.004	6.9	Free Surface	0.83	0.101	0.021	0.068	0.056	0.682	322	Yes
285	260	262	8	940.247	0.004	61.1	Free Surface	1.58	0.295	0.190	0.197	0.169	0.739	322	Yes
287	262	272	8	442.997	0.004	99.1	Free Surface	1.81	0.381	0.308	0.254	0.216	0.734	322	Yes
289	264	266	8	838.263	0.004	10.4	Free Surface	0.94	0.123	0.032	0.082	0.068	0.699	322	Yes
29	32	34	10	274.746	0.003	364.7	Free Surface	2.21	0.640	0.740	0.533	0.398	0.573	493	Yes
291	266	268	8	919.482	0.004	64.6	Free Surface	1.61	0.304	0.201	0.203	0.173	0.739	322	Yes
293	268	270	8	418.214	0.004	102.6	Free Surface	1.83	0.388	0.319	0.259	0.220	0.733	322	Yes
295	270	436	8	648.601	0.004	127.8	Free Surface	1.95	0.437	0.394	0.291	0.247	0.728	324	Yes
297	272	280	8	442.323	0.004	183.9	Free Surface	2.12	0.542	0.572	0.361	0.298	0.693	322	No
299	280	278	8	171.874	0.120	183.9	Free Surface	7.63	0.211	0.098	0.141	0.298	4.278	1,882	Yes
301	278	276	8	298.496	0.020	213.3	Free Surface	4.20	0.360	0.277	0.240	0.322	1.760	769	Yes
303	276	274	10	180.836	0.004	213.3	Free Surface	2.20	0.418	0.366	0.349	0.301	0.755	583	No
305	274	436	10	430.472	0.035	245.3	Free Surface	5.21	0.247	0.134	0.206	0.324	2.404	1,834	Yes
309	284	286	12	444.914	0.036	1,739.30	Free Surface	8.92	0.542	0.572	0.542	0.836	2.379	3,040	Yes
31	34	36	10	368.744	0.003	364.7	Free Surface	2.21	0.640	0.740	0.533	0.398	0.573	493	Yes
311	286	288	21	398.724	0.001	1,765.20	Free Surface	2.40	0.644	0.746	1.126	0.724	0.429	2,365	Yes
313	288	290	21	380.635	0.001	1,791.10	Free Surface	2.41	0.650	0.757	1.138	0.729	0.426	2,365	Yes
315	290	292	21	302.556	0.001	1,817.00	Free Surface	2.42	0.657	0.768	1.150	0.735	0.424	2,365	No
317	292	302	21	471.728	0.072	1,842.90	Free Surface	11.24	0.209	0.096	0.366	0.740	3.911	19,199	Yes
321	298	172	15	486.611	0.002	612.4	Free Surface	2.09	0.526	0.544	0.657	0.462	0.508	1,126	Yes
325	302	332	21	153.526	0.001	1,842.90	Free Surface	2.51	0.644	0.747	1.127	0.740	0.447	2,469	Yes
327	332	304	12	46.282	0.065	0	Pressurized	0.00	0.000	0.000	0.000	0.000	0.000	4,096	Yes
329	304	306	12	144.149	0.044	315	Free Surface	5.99	0.207	0.094	0.207	0.349	2.778	3,368	Yes
33	36	9000	12	548.396	0.002	415.8	Free Surface	2.11	0.547	0.580	0.547	0.404	0.559	717	No
331	306	308	12	102.533	0.018	315	Free Surface	4.37	0.258	0.146	0.258	0.349	1.798	2,159	Yes
333	308	310	12	402.193	0.018	315	Free Surface	4.35	0.259	0.147	0.259	0.349	1.788	2,150	Yes
335	310	312	12	370.594	0.004	315	Free Surface	2.50	0.387	0.317	0.387	0.349	0.820	992	No
337	312	314	12	246.875	0.006	315	Free Surface	2.99	0.339	0.247	0.339	0.349	1.060	1,275	No
339	314	316	12	284.249	0.017	315	Free Surface	4.22	0.264	0.153	0.264	0.349	1.715	2,059	Yes
341	316	318	12	303.665	0.016	315	Free Surface	4.14	0.268	0.157	0.268	0.349	1.670	2,005	Yes
343	318	320	12	282.173	0.013	315	Free Surface	3.84	0.283	0.175	0.283	0.349	1.503	1,803	Yes
345	320	322	12	209.594	0.002	315	Free Surface	2.09	0.444	0.406	0.444	0.349	0.631	775	Yes
347	322	324	12	252.581	0.002	315	Free Surface	1.96	0.465	0.442	0.465	0.349	0.577	713	Yes
349	324	326	12	260.682	0.002	315	Free Surface	1.94	0.469	0.449	0.469	0.349	0.567	702	No
35	38	9000	15	184.308	0.002	594	Free Surface	2.07	0.516	0.528	0.645	0.454	0.511	1,126	No
351	326	328	12	173.34	0.006	315	Free Surface	2.87	0.350	0.263	0.350	0.349	0.998	1,199	Yes
353	328	9006	12	369.499	0.002	315	Free Surface	2.05	0.450	0.417	0.450	0.349	0.614	755	No
355	332	344	21	885.098	0.001	1,842.90	Free Surface	2.42	0.664	0.779	1.162	0.740	0.421	2,365	No
357	344	346	21	600.754	0.001	1,842.90	Free Surface	2.42	0.664	0.779	1.162	0.740	0.421	2,365	No
359	346	348	21	593.139	0.001	1,842.90	Free Surface	2.42	0.664	0.779	1.162	0.740	0.421	2,365	No
361	348	454	21	834.011	0.038	1,842.90	Free Surface	8.97	0.245	0.132	0.429	0.740	2.865	13,964	Yes
363	350	162	8	695.897	0.004	96.1	Free Surface	1.79	0.375	0.299	0.250	0.213	0.735	322	Yes
365	352	354	8	798.702	0.003	142.5	Free Surface	1.99	0.466	0.443	0.311	0.261	0.717	322	Yes
367	354	218	8	807.611	0.004	253.2	Free Surface	2.27	0.669	0.787	0.446	0.353	0.637	322	No
37	40	38	15	530.734	0.002	582.1	Free Surface	2.06	0.510	0.517	0.637	0.450	0.512	1,126	Yes
375	362	364	8	416.108	0.004	17.1	Free Surface	1.15	0.151	0.049	0.101	0.088	0.769	347	Yes
379	366	126	8	729.826	0.003	57.6	Free Surface	1.55	0.287	0.179	0.191	0.164	0.739	322	Yes
381	370	372	8	474.626	0.004	44	Free Surface	1.44	0.250	0.137	0.167	0.142	0.738	322	Yes
383	372	368	8	491.961	0.004	59	Free Surface	1.56	0.290	0.183	0.193	0.166	0.740	322	Yes
385	378	380	8	483.256	0.004	7	Free Surface	0.83	0.102	0.022	0.068	0.056	0.683	322	Yes
387	380	376	8	509.217	0.004	22	Free Surface	1.17	0.177	0.068	0.118	0.100	0.722	322	No
389	368	374	8	483.256	0.004	118.96	Free Surface	1.90	0.421	0.370	0.281	0.238	0.727	322	Yes
39	42	40	15	700.243	0.002	570.2	Free Surface	2.05	0.504	0.506	0.630	0.445	0.513	1,126	Yes
391	374	376	8	491.961	0.004	126.66	Free Surface	1.93	0.436	0.394	0.291	0.246	0.724	322	Yes
393	376	382	8	681.79	0.004	176.66	Free Surface	2.10	0.529	0.549	0.353	0.292	0.698	322	Yes
395	382	130	8	698.106	0.003	176.66	Free Surface	2.10	0.529	0.549	0.353	0.292	0.698	322	Yes
397	388	386	8	491.96	0.004	56.5	Free Surface	1.55	0.284	0.176	0.189	0.162	0.739	322	No
399	386	384	8	811.179	0.004	56.5	Free Surface	1.55	0.284	0.176	0.189	0.162	0.739	322	Yes
401	384	390	8	664.532	0.004	102.76	Free Surface	1.83	0.389	0.319	0.259	0.220	0.732	322	Yes
403	390	134	8	709.17	0.004	102.76	Free Surface	1.83	0.389	0.319	0.259	0.220	0.732	322	No
405	150	9004	18	51.599	0.019	1,661.60	Free Surface	6.92	0.343	0.252	0.514	0.735	1.988	6,581	Yes
419	406	136	24	130.572	0.001	2,404.62	Free Surface	2.65	0.613	0.695	1.227	0.816	0.459	3,462	Yes
421	208	416	8	209.2	0.003	7	Free Surface	0.83	0.102	0.022	0.068	0.056	0.683	322	Yes
429	436	432	12	592.831	0.002	399.9	Free Surface	2.09	0.534	0.558	0.534	0.395	0.563	717	Yes
431	432	434	12	569.503	0.002	461	Free Surface	2.16	0.583	0.643	0.583	0.426	0.548	717	Yes
433	434	420	12	575.479	0.002	489.7	Free Surface	2.19	0.606	0.683	0.606	0.440	0.540	717	No
435	420	422	12	469.899	0.002	489.7	Free Surface	2.19	0.606	0.683	0.606	0.440	0.540	717	No
437	422	424	12	479.015	0.002	489.7	Free Surface	2.19	0.606	0.683	0.606	0.440	0.540	717	No
439	424	426	12	495.576	0.013	489.7	Free Surface	4.35	0.356	0.271	0.356	0.440	1.499	1,805	No
441	426	428	12	486.608	0.013	489.7	Free Surface	4.35	0.356	0.271	0.356	0.440	1.499	1,805	Yes
443	428	430	12	434.861	0.002	489.7	Free Surface	2.19	0.606	0.683	0.606	0.440	0.540	717	No
445	430	9006	12	709.546	0.012	489.7	Free Surface	4.32	0.358	0.274	0.358	0.440	1.483	1,786	Yes
45	48	50	8	1,036.13	0.004	87.3	Free Surface	1.75	0.356	0.271	0.237	0.203	0.736	322	Yes
453	446	442	42	6.425	0.000	5,473.92	Free Surface	1.49	0.793	0.969	2.775	1.060	0.155	5,649	No
457	364	368	8	416.367	0.003	17.1	Free Surface	1.09	0.157	0.053	0.104	0.088	0.714	322	Yes
459	448	124	8	684.821	0.003	107.1	Free Surface	1.85	0.397	0.333	0.265	0.225	0.731	322	Yes
465	454	9006	21	375.311	0.010	1,842.90	Free Surface	5.54	0.347	0.258	0.607	0.740	1.465	7,131	No
467	456	9010	24	18.483	0.001	2,826.32	Free Surface	2.66	0.704	0.844	1.408	0.888	0.413	3,349	No
469	138	456	24	596.411	0.001	2,639.32	Free Surface	2.65	0.665	0.782	1.330	0.857	0.431	3,376	Yes
47	50	52	8	314.56	0.004	129.8	Free Surface	1.94	0.442	0.403	0.295	0.249	0.723	322	Yes
49	52	54	8	587.918	0.004	172.3	Free Surface	2.09	0.521	0.536	0.347	0.288	0.700	322	Yes
51	54	236	8	275.927	0.004	214.8	Free Surface	2.20	0.598	0.668	0.398	0.324	0.672	322	Yes
73	76	78	8	1,064.87	0.004	25.6	Free Surface	1.23	0.191	0.080	0.127	0.108	0.727	322	Yes
75	78	80	8	1,017.78	0.004	136.2	Free Surface	1.97	0.454	0.423	0.303	0.255	0.720	322	Yes
77	80	82	10	695.748	0.003	207.8	Free Surface	1.93	0.453	0.422	0.378	0.297	0.631	493	Yes
81	84	86	8	762.797	0.004	150.9	Free Surface	2.02	0.481	0.469	0.321	0.269	0.713	322	Yes
83	86	88	10	686.894	0.002	232.7	Free Surface	1.99	0.483	0.472	0.403	0.315	0.625	493	Yes

Appendix B - CD of Model Input and Output and Report

CD Files and Content

File Name	Description
Final Results.HSW Final Results.DB Final Results.OUT	H2OMap Sewer Model, database, and analysis results for the City's study area collection system
Tables for Appendices.xls	Excel file presenting the manhole, sewer, and parcel data for the Final Results.HSW model



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Incorporated 1969

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