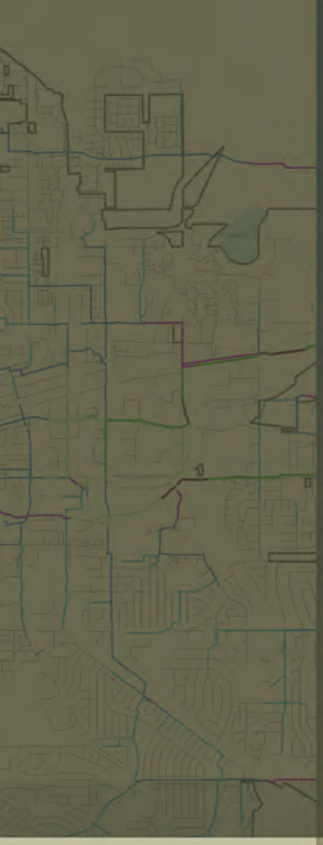

City of Boulder

Wastewater Collection System
MASTER PLAN

HDR

March 2009

Final Report

City of Boulder

Wastewater Collection System Master Plan

Prepared for

City of Boulder

March 2009

Prepared by

HDR Engineering

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Printed on Recycled and Recyclable Paper

Supporting Documents

The following technical memoranda were prepared throughout the course of the project. These memoranda provide additional technical information on the project assumptions, model development, systems analysis, alternative analysis, etc. Also included in the Appendix is additional supporting documentation regarding cost estimating and hydraulic model data.

Appendix A Documents:

TM 2.2 – Model Software Recommendations

TM 3.1 – Service Area and Planning Projections

TM 4.1 – Sanitary Sewer Maintenance Program Review

TM 4.2 – Review of Wastewater Collection Rehab and Repair Analysis and Budget

TM 5.1 – Model Development and Calibration

TM 6.1 – System Analysis and Results

TM 7.1 – System Improvement Plan

TM 7.2 – Recommended Improvement Factsheets

TM 12.1 – TVAP Collection System Analysis

TM 13.1 – RDII Storm Event Date Selection

TM 13.2 – RDII Storm Event Analysis

Appendix B Documents:

B.1 – Detailed Cost Estimates

B.2 – Model Input Data Tables, Results Tables and Output

B.3 – Model Network Mapping

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GLOSSARY OF TERMS

Average Dry Weather Flow (ADWF)	The yearly average daily wastewater flow comprised of population, employment and SIU contributions associated with non-rainfall periods. For this study, ADWF does include base infiltration associated with irrigation ditches and other groundwater influences. Generally used to represent the sanitary sewer system response to an average dry day of flow.
Collector Sewer	A sewer that collects flows from the local and local collector sewers and conveys that flow to the interceptor sewers. Typical collector sewer diameters range from 12 to 24”.
Densification	An area where land use density is zoned to increase or where otherwise indicated by development planning.
Diurnal Pattern	A repeating pattern of factors which represents hourly changes over a day. In the context of a hydraulic model, the diurnal pattern represents hourly changes in flow contribution due to normal residential, commercial, and industrial behaviors.
Dry Weather Flow	The portion of the wastewater flow that is comprised of population, employment and SIU contributions with base infiltration from irrigation ditches and streams. The flow does not include rainfall dependant infiltration and inflow.
Forcemain	A sewer that conveys pumped flow from a wet-well and pump station over a hydraulic obstacle where the flow cannot be conveyed by gravity such as a hill.
Hydraulic Model	A hydraulic network which attempts to best represent the actual collection system to evaluate and locate problems areas and to provide improvement recommendations for these areas. Hydraulic models mimic the actual operation of the system but do not match it exactly due to the many variables present between the system and model.
Infiltration	Water that enters the collection system through cracks in the manholes and pipes and leaking pipe joints in aging pipes. The source of the infiltration can come from a number of sources including groundwater, irrigation ditches, streams, and rainfall seeping through the ground.
Inflow	Water that enters the collection system mainly through manhole lids and other surface entrances. The primary source of the inflow is from rainfall drainage that flows over the manhole lids but can also come from fire hydrant flushes and other liquid spills.
Interceptor Sewer	A sewer that collects flows from the local, local collector and collector sewers and conveys that flow to the wastewater treatment plant. Typical interceptor sewer diameters are greater than 24”.
Local Collector Sewer	A sewer that collects flows from the local sewers and conveys that flow to the collector and interceptor sewers. Since this system has steeper slopes and therefore longer reaches of smaller diameter of pipe, this definition of local collectors has been used to represent these collection pipes that link the local sewers to the collector sewers. Typical local collector sewer diameters can range from 8 to 12”.
Local Sewer	A sewer that collects flows from homes and business service connections and conveys that flow to the local collector, collector and interceptor sewers. Typical local sewer diameters are less than 10”.

GLOSSARY OF TERMS

Model Calibration	Calibration is a process of changing model variables in the attempt to more closely match the model results to actual system operation. Due to the many variables present, exact calibration between the two is very difficult; instead an understanding of the level of model calibration obtainable is important while analyzing the system using the model.
Non-Sewered Area	An area where sewer service is not provided due to the land use (parks, open space, etc.) or right-of-ways where sanitary sewer flow loading is not assigned to.
Rainfall Dependant Inflow and Infiltration (RDII)	The fraction of rainfall that enters the sanitary sewer system due to precipitation. Generally used to represent the sanitary sewer system response to rainfall.
Return Frequency	The reciprocal of the annual probability of exceedance of a specific flow value (also known as recurrence interval). For example, a return frequency of 10-year indicates that in any given year, there is a 1-in-10 (10%) chance of that flow or precipitation value occurring.
Sanitary Flow	The portion of the wastewater flow that is comprised solely of population, employment and SIU contributions with no infiltration and inflow.
Sanitary Sewer	A sewer that conveys liquid and waterborne wastes from residences, commercial and industrial buildings, and institutions together with minor quantities of groundwater and stormwater that are not admitted intentionally into the system.
Sanitary Sewer Overflow (SSO)	An event when wastewater flow spills out from a manhole due to a backed up sewer. Causes can range from blocked pipes to an overloaded system due to heavy rainfall. Sanitary sewer overflows are considered disadvantageous and even hazardous since the wastewater flow that escapes can contaminate.
Service Line	A pipe that conveys wastewater flow from a customer to a point where it joins the public sewer system.
Sewer Basin	An area of the collection system where the majority of flow in the area drains into a single interceptor pipe which conveys the flow downstream into another sewer basin or to the wastewater treatment plant.
Sewershed	An area defined using boundaries such as streets, property lines, streams, and topography as well as engineering judgment which creates a collection of manholes of which loading can be assigned.
Significant Industrial User (SIU)	An industrial user which contributes a large quantity and/or poor quality of wastewater where pretreatment and monitoring of flow are required. Significant industrial users contribute non-domestic flow that is accounted for separately during system loading.
Siphon	A designed pipeline segment that flows under pressure to go under a hydraulic obstacle such as a stream.
Thiessen Polygon	In the context of sewer collection systems, a polygon shape which bisects areas between manholes of which the contributing flow from that polygon can be assigned to a particular manhole.

GLOSSARY OF TERMS

Traffic Analysis Zones (TAZ)	Publicly available spatially-oriented data that provides population and employment projections for estimating growth and increased sanitary flow contributions.
Unit Flow Factors	Sanitary flow factors that are based on contribution from a single unit such as a person. Typically, unit flow factors are expressed in gallons per day per person or employee.
Wastewater Flow	The total wastewater stream comprised of all sanitary flow and infiltration and inflow.
Wet Weather Flow	The wastewater flow stream that is comprised of population, employment and SIU contributions with base infiltration from irrigation ditches and streams as well as rainfall dependent infiltration and inflow.
Wastewater Treatment Plant (WWTP)	The facility where all wastewater flow is conveyed to by the collection system and treated to all applicable permits and regulations.

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Executive Summary

Existing Service Area and Collection System

Boulder's wastewater collection system and the 75th Street Wastewater Treatment Plant (WWTP) serve residences and businesses within the Wastewater Utility Service Area (WUSA). The WUSA is comprised of Boulder Valley Comprehensive Plan (BVCP) Area I (within Boulder city limits) and Area II (areas adjacent to the city limits that may be subject to annexation in the future). Areas outside the WUSA boundary are served by other utility districts or septic systems. The resulting WUSA contains approximately 16,340 acres (26 sq. miles) and is shown on Figure ES-1.

There are five sewer basins that contribute wastewater flow to the primary collector and interceptor system and ultimately to the WWTP (Figure ES-1). The five sewer basins and associated collector sewers are listed in Table ES.1.

TABLE ES.1 – SEWER BASINS

Sewer Basin	Area (acres)
Gunbarrel	2803
Fourmile	1677
Goose Creek	5076
Boulder Creek	5234
South Boulder Creek	1551
Total	16,430

The wastewater collection system includes gravity sewers, diversion manholes, one siphon and two lift station/forcemain systems that convey wastewater flow from the five sewer basins to the WWTP. Major features and gravity sewers by pipe size that compose the existing system are depicted in Figure ES-1 and summarized in Table ES.2.

TABLE ES.2 - EXISTING SEWER SYSTEM SUMMARY

Collection System Feature / Sewer Basin	Gravity Sewer (miles)	Diversion Manholes	Lift Stations	Forcemains	Siphons
Gunbarrel	46.7	3	1 (City-owned)	1 (City-owned)	1
Fourmile	45.4	1	0	0	0
Goose Creek	119	9	0	0	0
Boulder Creek	118	10	0	0	0
South Boulder Creek	34	7	1 (Private)	1 (Private)	0

Land Use and Flow Projections

A summary of the population and employment projections for the WUSA is shown in Table ES.3 below. The 2007 Denver Regional Council of Governments (DRCOG) Traffic Analysis Zones (TAZ) data was used to represent existing conditions in the Wastewater Collection System Master Plan (WWCSMP) as it was based on census data and provided good correlation with the BVCP. To be consistent with the 2007 WWTP Master Plan, projections for future employment and population were based on data from that document. As a result, buildout condition (2030) population and employment values presented in the 2007 WWTP master plan were used for this analysis.

TABLE ES.3 – 2008 WWCSMP PROJECTIONS FOR WUSA

Year	2008	2015	2020	2025	Buildout (2030)
Population	110,092	119,072	122,529	124,266	128,162
Employment	100,598	128,918	134,381	136,706	155,864

Total average dry weather flow (ADWF) or base flow projections in the collection system for existing and future conditions are comprised of population, employment and Significant Industrial User (SIU) contributions. The population and employment are based on 2007 DRCOG data for existing conditions, and 2003 DRCOG data for future conditions. The SIU contributions are based on 2006/2007 flow data from each user adjusted for domestic flow. In addition to existing (2008) and buildout (2030) conditions, flow projections were developed for intermediate years including 2015, 2020, and 2025 for information purposes. Table ES.4 presents the ADWF projections used as the basis of the WWCSMP analysis. It should be noted these ADWF values do not reflect collection system hydraulics including hydrograph attenuation and pump station influences. As a result, the collection system hydraulic model results are anticipated to vary slightly when compared to the values in the table below.

TABLE ES.4 – AVERAGE DRY WEATHER FLOW PROJECTIONS

Year	2008	2015	2020	2025	Buildout (2030)
Population ADWF (mgd)	11.3	12.1	12.5	12.7	13.1
Employment ADWF (mgd)	5.0	6.5	6.7	6.8	7.8
SIU ADWF (mgd)	0.6	0.6	0.6	0.6	0.6
Total ADWF (mgd)	**16.9**	**19.2**	**19.8**	**20.1**	**21.5**

Collection System Analysis

The primary source of data that was used for the collection system model development and analysis was Boulder's sanitary sewer Geographic Information System (GIS) layers for manholes and sewer pipes. This database was provided to HDR in November of 2007 and formed the basis of all subsequent work. Combined, the two GIS layers represent 9,596 manholes and 9,671 sewer main pipe segments, ranging in size from 4" to 60" in diameter.

Gravity sewers are typically classified as local, collector and interceptor sewers. Local sewers have diameters that are typically less than 10" and convey wastewater from relatively small service areas (20 acres +/- and less). Local sewers have numerous service line connections collecting wastewater from individual customers. Collector sewers have diameters that typically range between 12" and 24". Collector sewers convey flow from multiple local sewers and also include individual service line connections, although not as many as local sewers. Interceptor sewers typically have very few, if any, individual service line connections and convey wastewater from connections with collector sewers to the WWTP.

Many of Boulder's local sewers provide service to relatively large areas with some local sewers serving areas up to 100 acres in size and/or highly developed areas. These small diameter local sewers are an integral part of the gravity sewer system. As a result, these local sewers that serve large areas have been termed "local collectors" for purposes of this study. *The scope of this study was to analyze the hydraulic capacity of interceptor, collector and local collector sewers*. Additional collection system features included in the model and analysis included lift stations, forcemains, diversion manholes and siphons. The modeled collection system is shown on Figure ES-2.

The collection system pipes with identified capacity limitations, established from the model results, were examined to identify likely hydraulic issues under the various flow scenarios. There are a total of 138 pipes in the analyzed collection system with hydraulic deficiencies identified. A problem identification and characterization process was completed to better understand the nature and extent of these problems. The modeled collection system and system capacity problems are shown on Figure ES-3.

Recommended Collection System Improvements

The recommended system improvements that resolve the existing and future capacity issues are shown on Figure ES-4. This figure includes both improvements that address both Type A and Type B problems. The conveyance system analysis separated the hydraulic problems into two categories; Type A and Type B Type A problems consist of a series of problem pipes that are hydraulically connected to one another. Type B problems are isolated hydraulic restrictions that are not hydraulically connected to other problem locations or series of problem pipes.

The recommended improvements were grouped in three tiers to establish implementation priority:

- Tier 1 projects address Type A problems and have the highest priority;
- Tier 2 projects also address Type A problems but have lower priority compared to Tier 1;
- Tier 3 projects address Type B problems which have the lowest priority.

The improvement priorities were assigned based on a number of qualitative factors including the flow conditions in which they occur (existing versus future), extent of the problem, potential for sanitary sewer overflows (SSOs) and service lateral backups, ease of constructability, and

relative benefit over other improvement projects. The relative benefit takes into account the amount of pipe replaced compared to the extent of the problem remedied. These factors were summarized in the problem characterization tables in Section 5 of this report. The resulting implementation priorities and associated estimates of capital construction cost are shown in Table ES.5.

Table 7.2 summarizes the implementation priorities as developed in Section 6 along with estimates of capital construction costs. Itemized capital cost estimate worksheets are included in Volume 2 of this report.

TABLE ES.5 CAPITAL PROJECT IMPLEMENTATION RECOMMENDATIONS

Problem Priority	Improvement ID	Location	Capital Cost
Tier 1	Boulder Creek 2	Colorado Ave and 28th St	$733,000
Tier 1	Goose Creek 1/1A	Iris Ave and 19th St	$1,203,000
Tier 1	Goose Creek 3	Spruce St and 24th St	$482,000
Tier 1	Goose Creek 5	Arapahoe Ave and 55th St	$2,559,000
		TIER 1 TOTAL	**$4,977,000**
Tier 2	Boulder Creek 1	Colorado Ave and 28th St	$1,653,000
Tier 2	Boulder Creek 3	Arapahoe Ave and Foothills Pkwy	$1,939,000
Tier 2	Boulder Creek 4	Valmont Rd and 61st St to WWTP	$12,356,000
Tier 2	Goose Creek 4	Pearl St, Valmont Rd and Mishal Rd	$3,928,000
Tier 2	Gunbarrel 1	Boulder Supply Canal & Left Hand Ditch	$1,116,000
Tier 2	Gunbarrel 2	Jay Rd and Boulder Supply Canal	$939,000
Tier 2	South Boulder Creek 1	Baseline Rd and 55th St	$733,000
		TIER 2 TOTAL	**$22,664,000**
		TIER 3 TOTAL[1]	**$3,786,000**
		TOTAL ALL PROJECTS TOTAL	**$31,427,000**

[1] Tier 3 costs represent approximately 10 localized improvement projects

O&M Review and Recommendations

The WWCSMP project team reviewed the collection system operations and maintenance (O&M) procedures. The purpose of this O&M procedure was to review the current state of collection system O&M practices and evaluate potential increases in service levels due to trends in the regulatory environment in the western United States. In addition, the 2008 QualServe peer review program and self assessment survey evaluated the Utility's overall performance, efficiency and customer service as well as maintaining industry best management practices.

Both the QualServ program and the WWCSMP O&M review found that the Gravity System's Maintenance group operates and maintains the collection system such that it continues to provide a high level of service to its existing customers.

Boulder developed a methodology for determining the mileage and cost of the 20-year CIP for rehabilitating wastewater pipes and manholes. This methodology was based on spreadsheet model that characterized pipe failure as a function of time to assist in forecasting long-term budgetary needs for rehabilitation of sanitary sewer pipe. This analysis resulted in a recommendation for an annual manhole and sewer pipe rehabilitation budget of $850,000. This methodology was given an independent review which recommended that an annual sewer rehabilitation budget of $500,000 would be adequate for the 20-year planning period.

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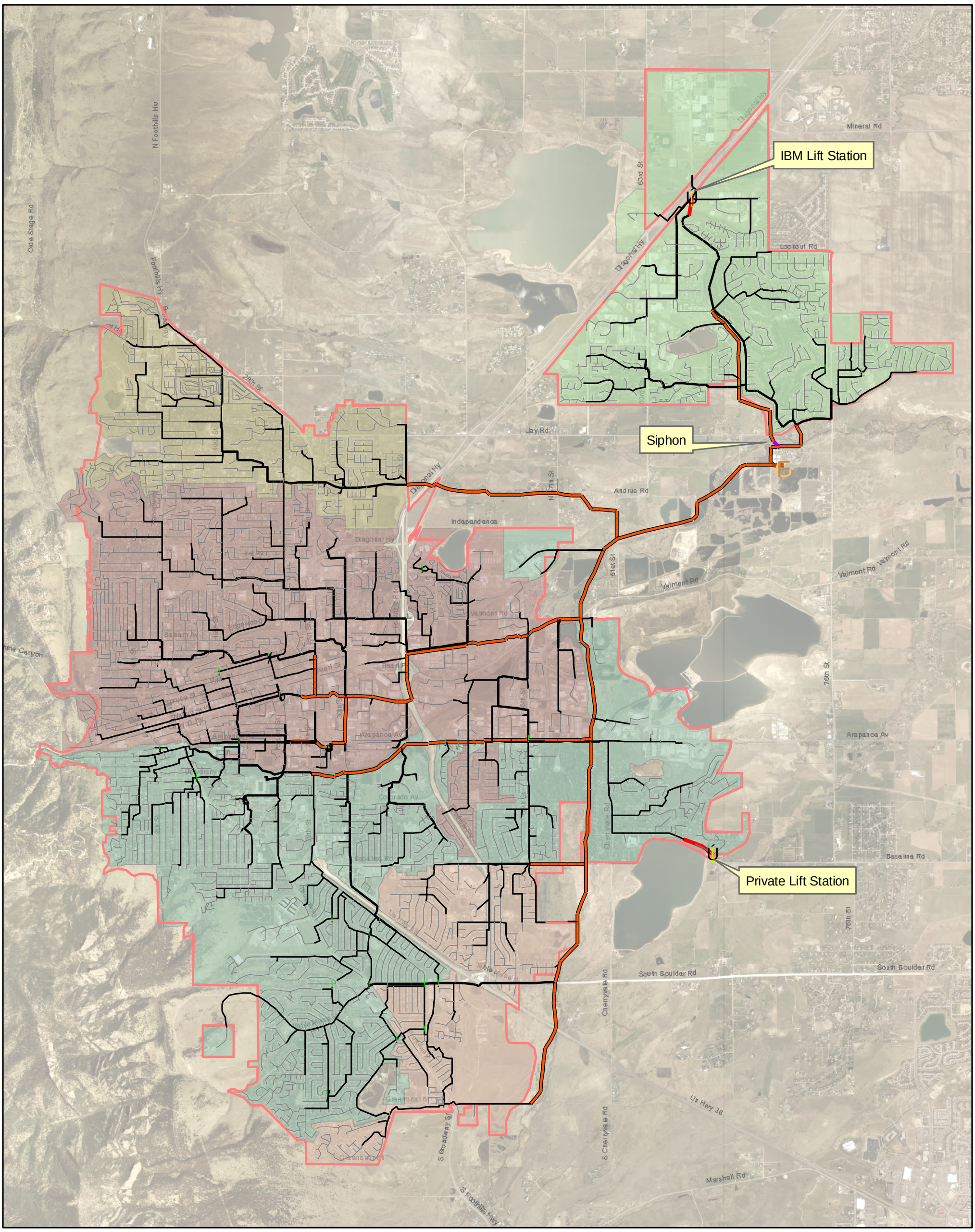

Legend

1 inch equals 4,000 feet

Existing Sewers

- Interceptor
- Collector
- Local Collector
- Local
- Coll/Int (Siphon)
- Forcemain

Manholes

- Div MH
- Flow Split MH
- Lift Station
- WWTP

Sewer Basins

- Gunbarrel
- Fourmile
- Goose Creek
- Boulder Creek
- South Boulder Creek

WUSA

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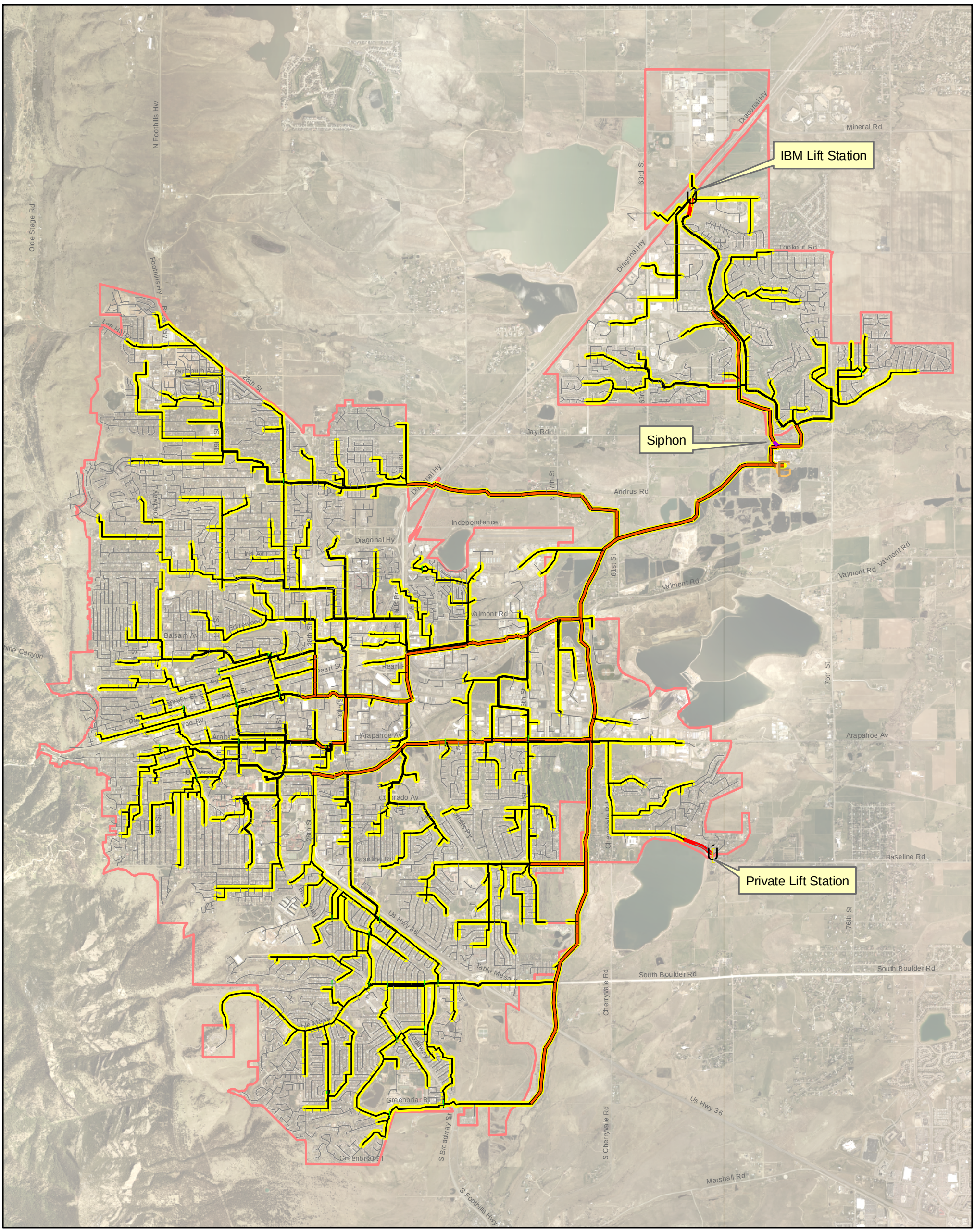
Existing Sewer System and WUSA

Figure ES-1

Boulder Wastewater Utility Master Plan



Legend

1 inch equals 4,000 feet

Existing Sewers

- Analyzed System
- Interceptor
- Collector
- Local Collector
- Local
- Coll/Int (Siphon)
- Forcemain

Manholes

- Div MH
- Flow Split MH
- Lift Station
- WWTP
- WUSA

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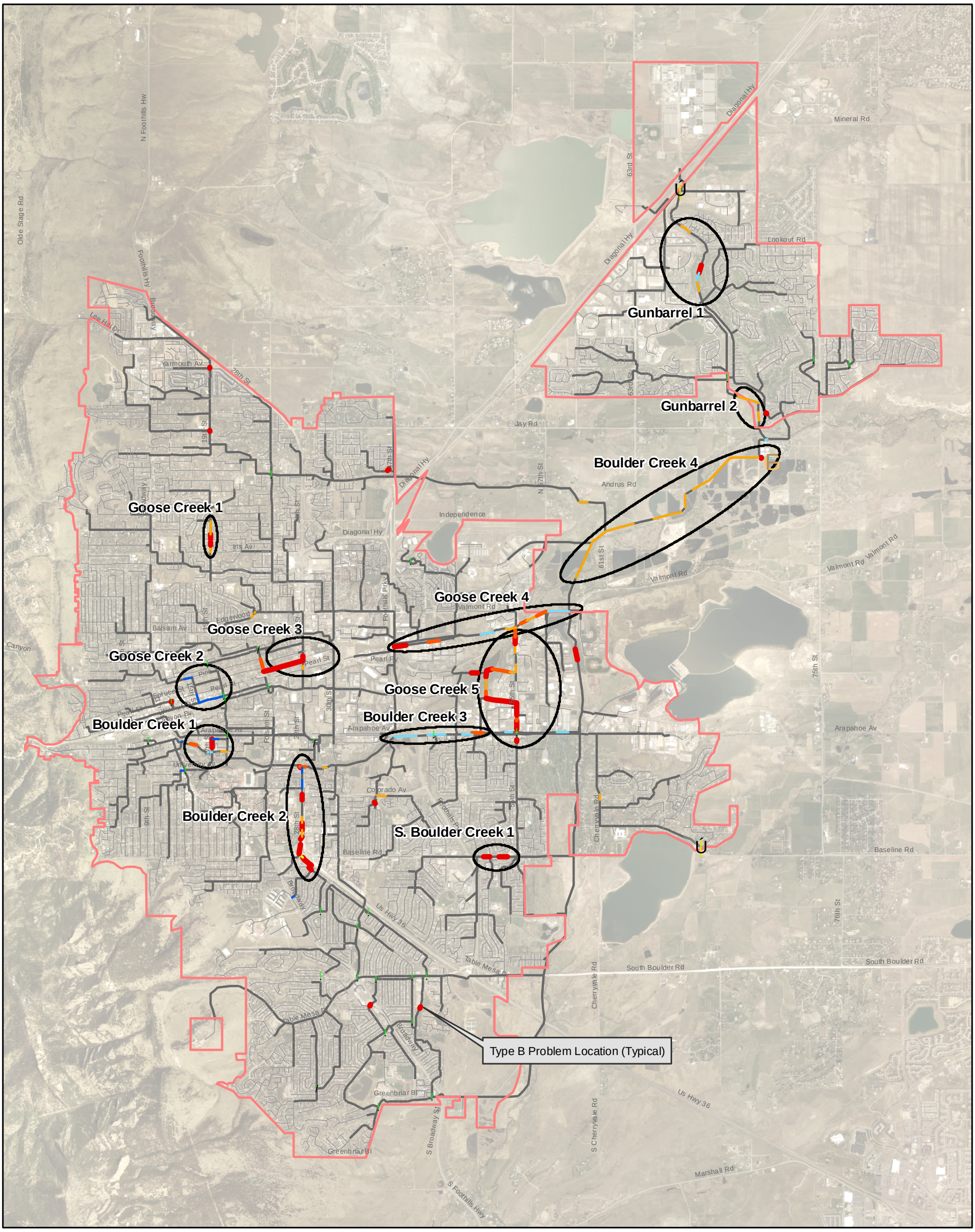
Analyzed Collection System

Figure ES-2

Boulder Wastewater Utility Master Plan



1 inch equals 4,000 feet

Legend

Existing Sewers

- Local System (not analyzed)
- Analyzed System

Major Features

- Flow Split MH
- Div MH
- Lift Station
- WWTP

Problem Scenario

- Future PDWF
- Future PDWF + Future PWWF
- Existing PDWF + Future PDWF
- Existing PWWF + Future PWWF
- Exsiting PWWF + Future PWWF + Future PDWF
- All Scenarios

- Problem Locations (Type A)
- WUSA

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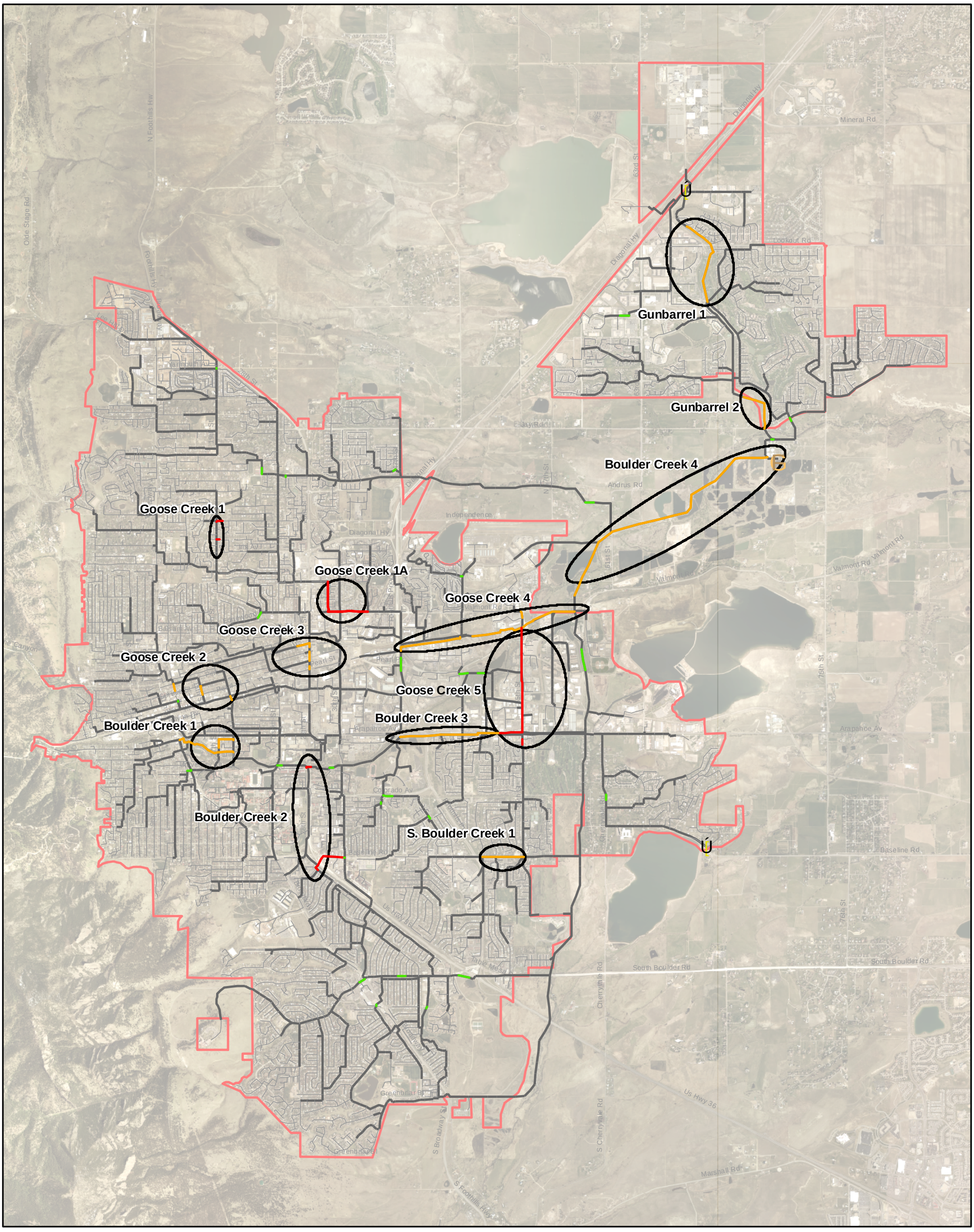
Collection System Capacity Problems

Figure ES-3

Boulder Wastewater Utility Master Plan



1 inch equals 4,000 feet

Legend

Existing Sewers

- Local System (not analyzed)
- Analyzed System

Major Features

- Lift Station
- WWTP

Improvement Priority Tier

- 1
- 2
- 3
- WUSA Boudary

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Implementation Plan with Recommended Improvements

Figure ES-4

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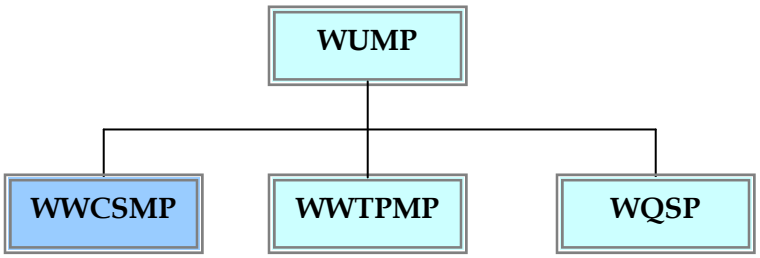
Boulder Wastewater Utility Master Plan

SECTION 1

Introduction

The Wastewater Utility Master Plan (WUMP) is the overarching planning document that is intended to present key issues, projects and budgets for the collection system, wastewater treatment plan and, water quality programs. The WUMP is supported by the Wastewater Treatment Plant Master Plan (WWTPMP), the Water Quality Strategic Plan (WQSP), and this Wastewater Collection System Master Plan (WWCSMP). *This document addresses the wastewater collection system through development of a master plan that addresses issues associated with the capacity of the collection system capacity issues and collection system operations and maintenance programs.*



The primary goals of the WWCSMP are to identify capacity problems within the collection system and develop a prioritized list of recommended capital projects to resolve the capacity limitations. These goals were met through the following tasks:

- Develop land use projections within the Wastewater Utility Service Area (WUSA) and associated wastewater flows
- Develop a computer model of the sewer collection system based on the city's Geographic Information System (GIS) data
- Analyze the existing collection system under existing and future land use conditions
- Identify capacity problems within the collection system
- Develop improvement alternatives and identify recommended improvement projects
- Prioritize the recommended improvements and develop planning level estimates of capital construction cost.

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SECTION 2

Existing Collection System

The city of Boulder's wastewater collection system consists of over 370 miles of sewer pipe that collect and convey wastewater to the wastewater treatment plant (WWTP) located along Boulder Creek at 75th Street. The purpose of this section is to summarize the existing collection system features and the associated sewer basins that make up Boulder's WUSA.

2.1 Wastewater Utility Service Area

Boulder's wastewater collection system and the 75th Street WWTP serve residences and businesses within the WUSA. The WUSA is comprised of Boulder Valley Comprehensive Plan (BVCP) Area I (within Boulder city limits) and Area II (areas adjacent to the city limits that may be subject to annexation in the future). Areas outside the WUSA boundary are served by other utility districts or septic systems. The resulting WUSA contains approximately 16,340 acres (26 sq. miles) and is shown on Figure 2-1.

2.2 Sewer Basins and Sewersheds

There are five sewer basins that contribute wastewater flow to the primary collector and interceptor system and ultimately to the WWTP (Figure 2-2). The five sewer basins and associated collector sewers are listed in Table 2-1.

TABLE 2.1 – SEWER BASINS

Sewer Basin	Area (acres)
Gunbarrel	2,803
Fourmile	1,677
Goose Creek	5,076
Boulder Creek	5,234
South Boulder Creek	1,551
Total	16,430

Sewersheds are a smaller division of a sewer basin and are typically used to assist in wastewater flow allocation to the hydraulic model. Sewersheds were delineated using Boulder's GIS coverages for sewer mains, sewer services, parcel boundaries and topography. The delineation was done manually in GIS. Boulder's collection system is fairly complex in terms of system connectivity. There are several locations within the system where a local collector pipe parallels a trunk line or interceptor. A review of the service lateral coverage indicated that in many of these parallel systems, the service lateral connected to the local collector pipe. It was also observed that trunk lines and/or interceptors can pass through a sewershed that drains to a separate trunk line system. These connectivity issues reflect the necessity of detailed sewershed delineation.

The sewershed delineation did not define the boundaries to exclude typical non-sewered areas (parks, open space, streets, etc.) as these areas will be considered in the generation of sanitary flows within each sewershed. However, the exception to this approach was for large non-sewered areas such as highway right-of-way and large lakes. These large non-sewered areas were not included in the sewershed boundary definition.

The resulting delineation produced 485 sewersheds (Figure 2-3) with an average area of 33.6 acres. Sewershed areas ranged from 5 acres in the high density corridors along Broadway and Canyon Boulevard to 400 acres in undeveloped designated locations. A majority of the large sewersheds included significant portions of non-sewered areas.

2.3 Existing Collection System Features

The wastewater collection system includes gravity sewers, diversion manholes, one siphon and two lift station/forcemain systems that convey wastewater flow from the five sewer basins to the WWTP. Major features and gravity sewers by pipe size that compose the existing system are depicted in Figure 2-1 and summarized in Table 2.2.

TABLE 2.2 - EXISTING SEWER SYSTEM SUMMARY

Collection System Feature / Sewer Basin	Gravity Sewer (miles)	Diversion Manholes	Lift Stations	Forcemains	Siphons
Gunbarrel	46.7	3	1 (City-owned)	1 (City-owned)	1
Fourmile	45.4	1	0	0	0
Goose Creek	119	9	0	0	0
Boulder Creek	118	10	0	0	0
South Boulder Creek	34	7	1 (Private)	1 (Private)	0

2.3.1 Gravity Sewers

Gravity sewers are typically classified as local, collector and interceptor sewers. Local sewers have diameters that are typically less than 10” and convey wastewater from relatively small service areas (20 acres +/- and less). Local sewers have numerous service line connections collecting wastewater from individual customers. Collector sewers have diameters that typically range between 12” and 24”. Collector sewers convey flow from multiple local sewers and also include individual service line connections, although not as many as local sewers. Interceptor sewers typically have very few, if any, individual service line connections and convey wastewater from connections with collector sewers to the WWTP.

Many of Boulder’s local sewers provide service to relatively large areas with some local sewers serving areas up to 100 acres in size and/or highly developed areas. These small diameter local sewers are an integral part of the gravity sewer system. As a result, these local sewers that serve large areas have been termed “local collectors” for purposes of this study. *The scope of this study is to analyze the hydraulic capacity of interceptor, collector and local collector sewers*. Figure 2-2 shows the gravity sewer system by pipe classification. A summary of the gravity sewer system length by pipe classification is shown in Table 2.3.

TABLE 2.3 - EXISTING SEWER SYSTEM BY PIPE CLASSIFICATION					
Sewer Basin	**Local Sewers (miles)**	**Local Collectors (miles)**	**Collector Sewers (miles)**	**Interceptor Sewers (miles)**	**Basin Area (sq. miles)**
Gunbarrel	29.9	9.7	5.1	2.0	4.4
Fourmile	32.6	8.8	2.0	2.1	2.6
Goose Creek	85.1	25.3	12.1	4.4	7.9
Boulder Creek	76.3	29.6	5.9	6.7	8.2
South Boulder Creek	19.3	10.3	1.9	2.6	2.4
Totals	**243.2**	**83.7**	**27.0**	**17.8**	**25.5**

2.3.2 Diversion / Flow Split Manholes

Boulder's sewer system contains 30 active diversions or flow split manholes which are used to direct flows from the incoming sewers to two outgoing sewers (Figure 2-2). These manholes are used to optimize sewer system capacity by directing flow into either a parallel sewer or into an adjacent sewer system that has additional capacity.

Three of the manholes were identified as diversion manholes within the city's GIS that control and divert flow via weirs or gate structures to the two downstream pipes. Data on two of the three diversion manholes were collected by Boulder maintenance staff in the field and the model was updated accordingly. The remaining diversion manhole was not in a critical area and only affects two local pipes so it was not inspected.

Information on manhole N04W05-92 was collected to better understand how the diversion is operating. However, upon inspection the slide gate on the south side of the manhole that created the diversion was permanently closed and covered with concrete. Previously, flow was diverted east and south using the slide gate. Currently, the flow comes from the north and west into manhole 92 and continues eastward in the 18" pipe. The main channel invert in the manhole is approximately 96 inches from the rim. The model was updated likewise by closing off the 12" pipe (HDR-6275) that runs south from the manhole.

Information on manhole S04W04-89 was collected to better understand how the diversion is operating. The majority of the flow comes from the south and turns eastward flowing down Findley St. During high flow conditions, a portion of the flow can go northward when it spills over a short diversion. The inverts on the south and east side are approximately 99 inches from the rim. The invert on the north side is approximately 98 inches from the rim. The model was updated likewise by raising the invert by one inch on the 8" pipe (HDR-656) leaving the manhole northward.

The remaining 27 diversions are flow split manholes which have two downstream pipes and no additional flow control structures as identified in the GIS. The flow split manholes rely on the downstream pipe hydraulics to control the rate at which flow is directed into the downstream systems. In some instances, the flow split manholes had a downstream pipe that was located 1' to 2' above the primary outlet pipe. These flow split manholes send dry weather flows to the lower elevation, primary outlet pipe while the elevated pipe conveys peak flows experienced in high flow situations (e.g. peak wet weather events).

A review of the GIS data also revealed that 4 flow split manholes had one of the downstream sewers plugged. These plugged flow split manholes are not included in the collector system model as system diversions.

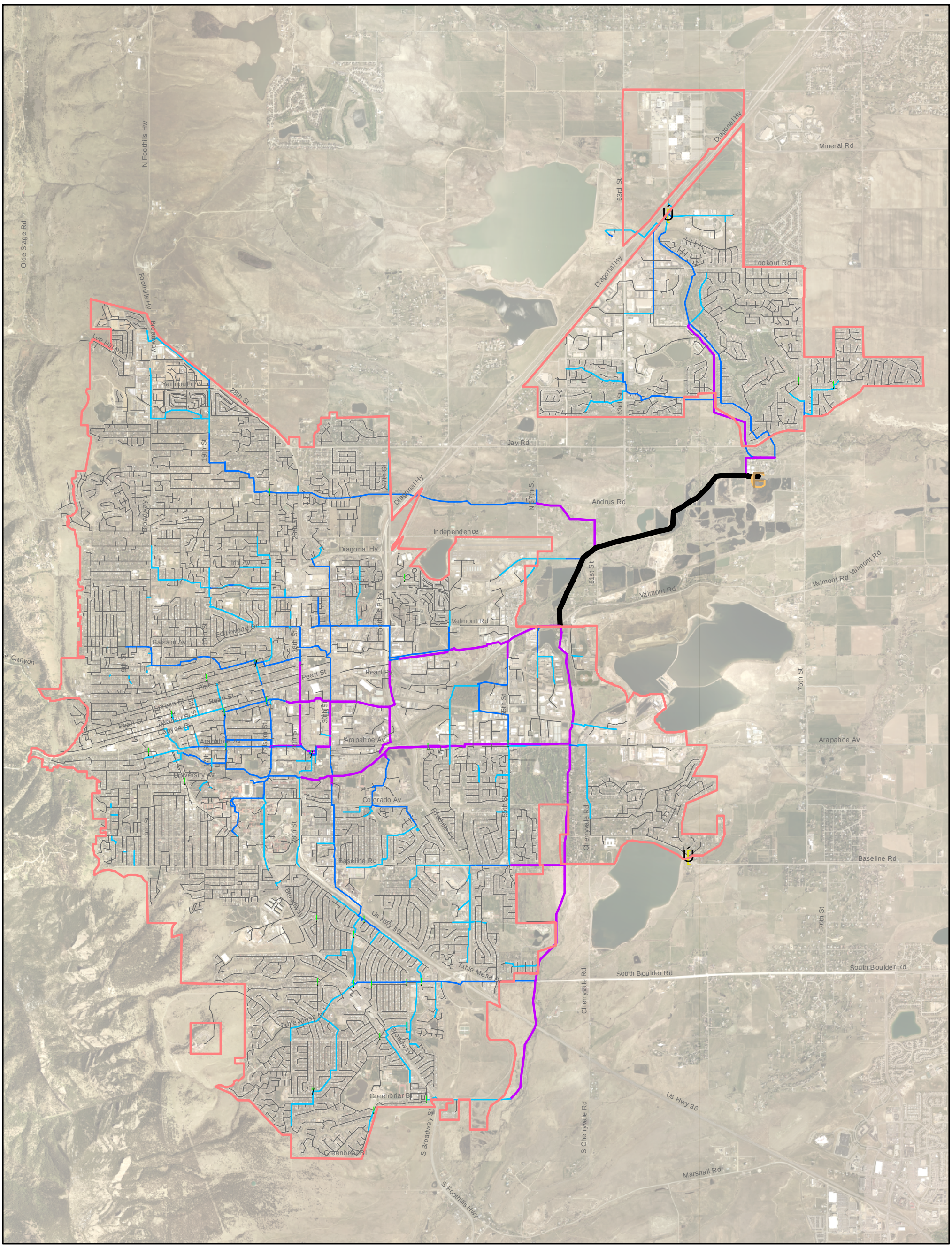
2.3.3 Lift Stations and Forcemains

Two lift stations and forcemains are present within the WUSA. One is City-owned and operated in the Gunbarrel area and the other is privately-owned and operated by Hoover Hills, a small community near Baseline Reservoir. Only the Gunbarrel lift station is modeled; the private lift station and forcemain system is not included in the model. Since the private lift station and forcemain is not owned by the city, it will not be analyzed as part of the WUMP. To handle this area in the model, no loads were placed on the private sewer system manholes although they are included in the model. The cumulative loading of the Hoover Hills private sewer system near Baseline Reservoir, however, was placed at the next manhole downstream of the forcemain.

The IBM lift station in Gunbarrel was built in 1975 and has a pumping capacity of roughly 2.8 million gallons per day (mgd) with 1 primary pump, 1 lag pump, and 1 emergency backup pump. The forcemain is 12” in diameter and approximately 800 feet long overcoming around 42 feet of elevation. The wetwell dimensions are 6’-4” wide by 20’-4” long by 14’ high with a capacity of 13,475 gallons. The pumps were modeled as design point curves using pump curve as-built data and design flow of 975 gpm with 55 feet of head. A k-value of 5.67 was assigned to the lift station to account for minor headlosses associated with piping, valves and fittings within the lift station. No information on the lift station controls was provided by Boulder so they were based on likely operation and effect on the WWTP influent flow hydrograph. The primary pump control was set to turn on at 6 feet depth and off at 2 feet depth. The lag pump control was set to turn on at 10.5 feet depth and off at 4 feet depth.

2.3.4 Siphons

The Boulder system contains one siphon to convey flow from the Gunbarrel sewer basin under Boulder Creek to the WWTP (Figure 2-2). The siphon is approximately 730 feet in length and has an elevation of 13 feet to overcome. The siphon was included in the system model.



1 inch equals 4,000 feet

Legend

WUSA Boundary

Existing Sewer Features

- Div MH
- Flow Split MH
- Lift Station
- WWTP

Existing Sewers

- 4" - 8"
- 10" - 12"
- 15" - 21"
- 24" - 36"
- 42" - 60"

O

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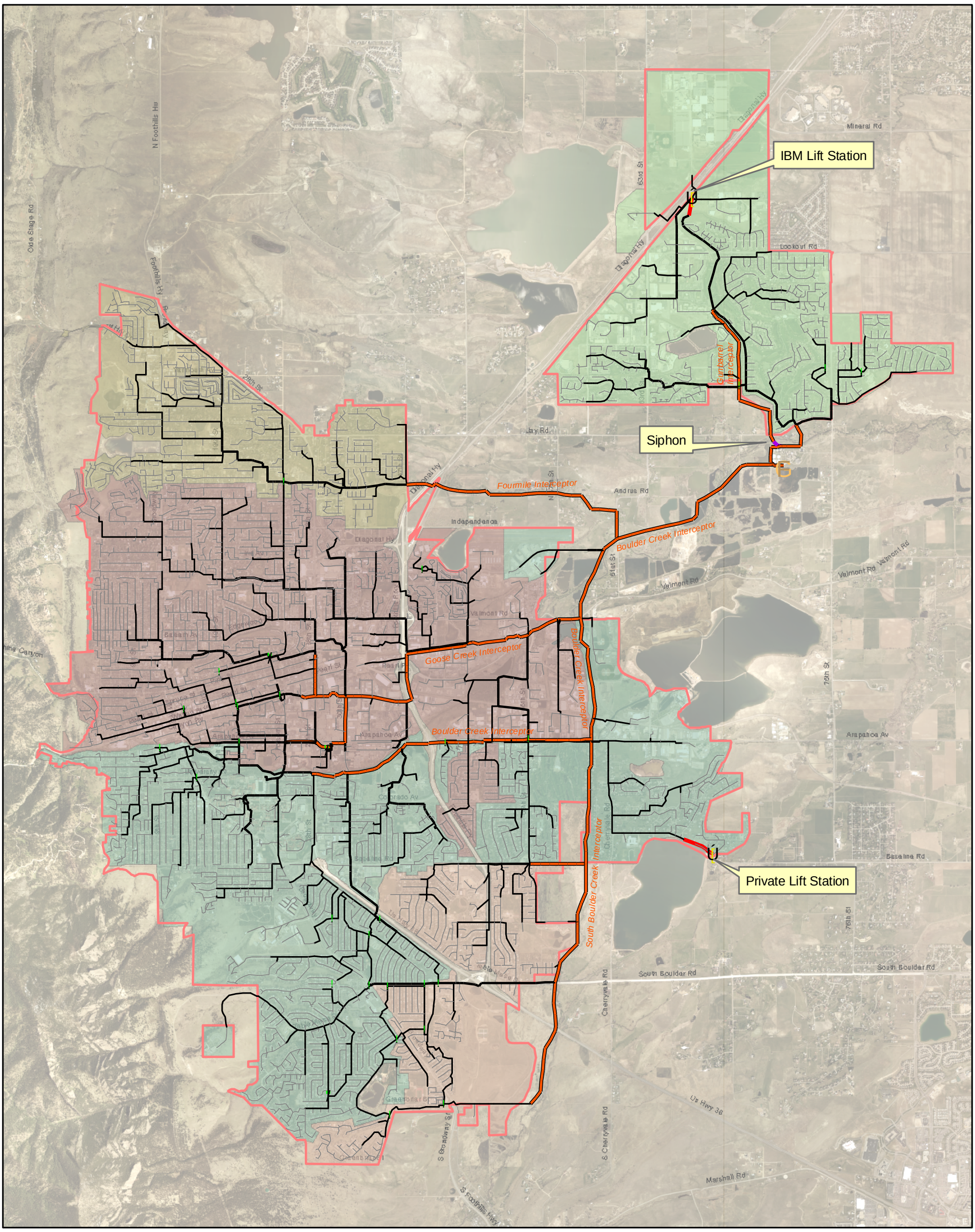
WUSA and Gravity Sewers by Pipe Size

Figure 2-1

Boulder Wastewater Utility Master Plan



Legend

1 inch equals 4,000 feet

Existing Sewers

- Interceptor
- Collector
- Local Collector
- Local
- Coll/Int (Siphon)
- Forcemain

Manholes

- Div MH
- Flow Split MH
- Lift Station
- WWTP

Sewer Basins

- Gunbarrel
- Fourmile
- Goose Creek
- Boulder Creek
- South Boulder Creek

O

Sewer Basins and Gravity Sewer by Pipe Classification

Figure 2-2

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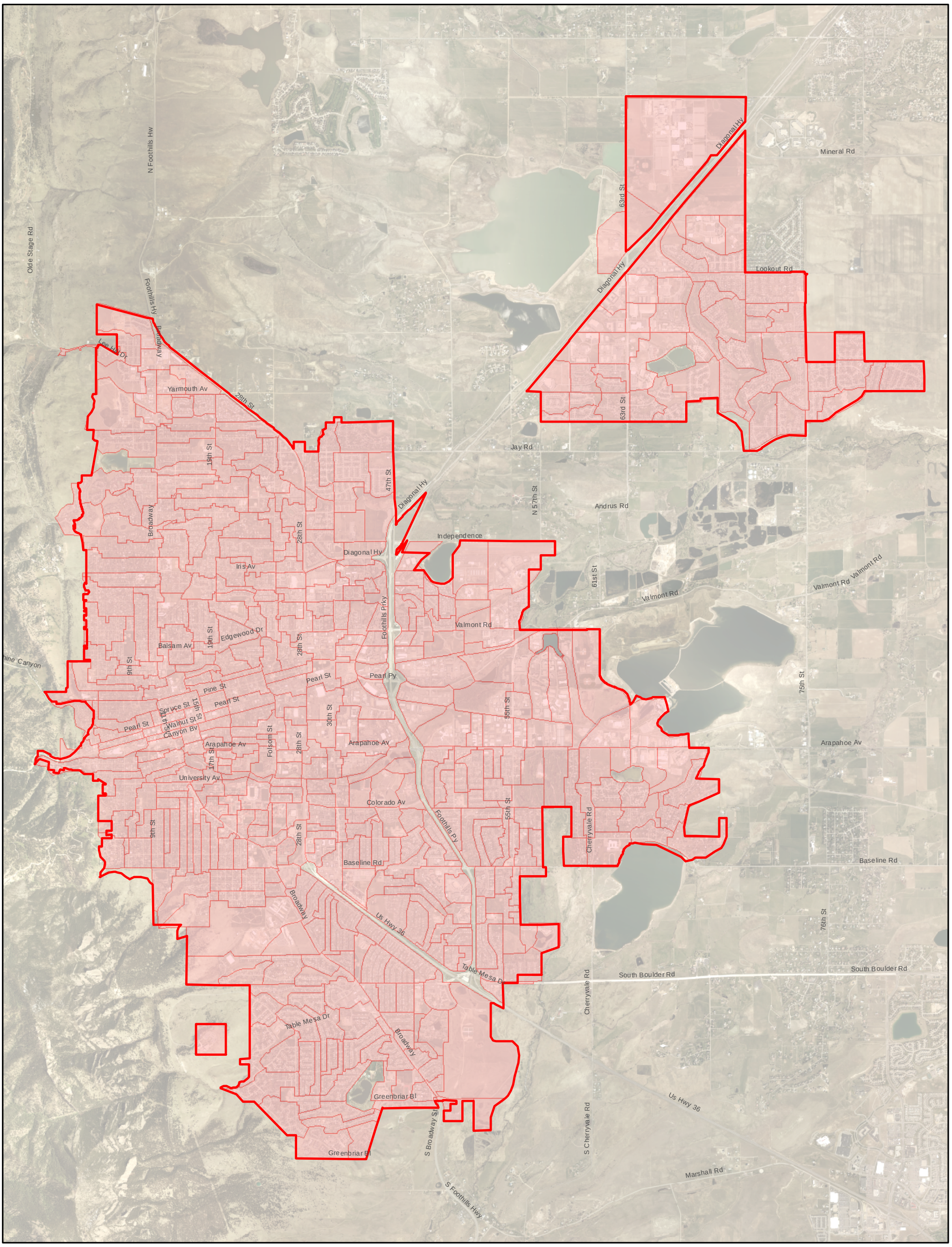

1 inch equals 4,000 feet

Legend

- WUSA (BVCP Areas I & II)
- Sewersheds (484)

0

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Sewersheds in WUSA

Figure 2-3

Boulder Wastewater Utility Master Plan

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SECTION 3

Planning Projections

The purpose of this section is to present planning projections for both population and employment within the service area. The population and employment planning projections were spatially distributed across the WUSA based on Transportation Analysis Zone (TAZ) GIS data and through an identification of areas of high development potential. Sanitary flow is assigned to the spatial land use data using population and employment unit flow factors. The sanitary flow projections were used as the planning basis for system modeling and improvement recommendations.

3.1 Existing Planning Documents

There are three prominent planning documents that establish population and employment projections for the WUSA. These documents include consideration for both existing and future land uses, as well as historical and projected population trends. However, the three documents are inconsistent in the projected numbers of population and employment. A summary of each document is provided to note their differences and to establish which planning document should be used as a basis for the WUMP.

3.1.1 2007 DRCOG Traffic Analysis Zones (TAZ)

The Denver Regional Council of Governments (DRCOG) releases annual planning data for small area estimates of population and employment. The DRCOG provided 2007 Traffic Analysis Zones (TAZ) data that were available for use in evaluating the planning projections within the WUSA. The TAZ data were provided by the DRCOG in GIS format. For this study the TAZ data were intersected with the WUSA boundary in GIS to determine the population and employment within the WUSA. A summary of the 2007 DRCOG TAZ data for the WUSA is found in Table 3.1 below.

TABLE 3.1 - 2007 DRCOG TAZ PROJECTIONS FOR WUSA

Year	2005	2015	2030	2035
Population	109,215	121,473	129,424	133,579
Employment	99,537	103,240	107,084	108,611

The 2007 TAZ landuse model results lowered employment projections for 2035 drastically from previous TAZ data published in 2003. The projections for employment are important as they are one of the primary drivers for sanitary flow projections. While it is hard to determine exactly why projections change year to year without a detailed review of land use model variables, it is important to note the 2007 TAZ data uses state census data for baseline numbers of population and employment. In contrast, previous projections used a forecast value for the baseline numbers. An additional change in the land use model was the 2007 TAZ model used regional competitiveness to allocate population and employment in the forecast. Strong development potential outside of the WUSA may have pulled employment numbers away from Boulder to other municipalities or Boulder County based on the 2007 modeling approach. Thus, there are not strong projections in the 2007 TAZ data for Boulder in employment.

3.1.2 2007 WWTP Master Plan

The 2007 WWTP Master Plan presents and utilizes population and employment numbers from the 2003 DRCOG TAZ analysis. The original 2003 DRCOG TAZ data did not include the buildout projections for 2030. These numbers were projected out from the 2025 numbers in the original TAZ data as a part of the 2007 WWTP Master Plan using the Boulder Valley Comprehensive Plan land use data. A summary of the 2007 WWTP Master Plan projection data for the WUSA is found in Table 3.2 below.

TABLE 3.2 - 2007 WWTP MASTER PLAN PROJECTIONS FOR WUSA

(Based on 2003 DRCOG TAZ)

Year	2005	2015	2020	Buildout (2030)
Population	109,412	116,121	119,500	128,162
Employment	111,062	125,228	130,721	155,921

The 2007 WWTP Master Plan TAZ data show inflated 2005 employment numbers considering the much lower 2008 numbers found in the census based and 2007 DRCOG TAZ data. The difference in 2005 employment numbers is on the order of 11,000 employees.

3.1.3 2008 Boulder Valley Comprehensive Plan (BVCP)

Boulder revises planning projections as part of the Boulder Valley Comprehensive Plan (BVCP) on a bi-annual basis. One key difference in the BVCP planning projections, compared to the TAZ process, is that the BVCP planning projections are not spatially distributed. Recently updated 2008 numbers are available using a 20 to 25 year timeframe for projections. The 2030 employment projections assume the Boulder WUSA will reach buildout by the year 2030 at a growth rate of under 0.5% per year. The 2030 employment projections assume an average annual growth rate of 0.8% per year. A summary of the 2008 BVCP projection data for the WUSA is found in Table 3.3 below.

TABLE 3.3 - 2008 BVCP PROJECTIONS FOR WUSA

Year	2008	Buildout (2030)
Population	113,100	129,600
Employment	100,500	120,800

The 2008 BVCP has much greater growth expectations for employment than the 2007 DRCOG TAZ and 2007 WWTP Master Plan data. Population growth is inline with the other planning documents.

3.1.4 Recommendation and Summary

The differences between the three planning documents needed to be reconciled to reach a rational projection based on realistic growth expectations within the WUSA. Using numbers that are too low will not account for all potential sanitary flow contributions used in the analysis of the collection system and could lead to undersized Capital Improvement Plan (CIP) recommendations. Using numbers that are too high will create sanitary flows that may not occur considering the current trend of decreasing contributing flows and ultimately may cause excessive problem areas and oversized system improvement recommendations. The results of the careful reconciliation are the basis of analysis for the master plan in terms of population and employment projections.

Existing Conditions

The 2007 DRCOG TAZ data included estimates of population and employment for 2005 and 2015. Linear interpolation between these two years was used to estimate values for existing 2008 conditions and resulted in estimates of 111,100 people and 100,830 employees. These results correlate well with the 2008 BVCP population and employment numbers, being within 2,000 and 400 of each other, respectively. Making the same interpolation on the 2003 TAZ population data found in the 2007 WWTP Master Plan results in a correlation to the 2008 BVCP data for population only. The interpolated 2003 DRCOG TAZ data for employment does not agree with the 2008 BVCP employment, being high by approximately 11,000 employees. *As a result, the 2007 DRCOG TAZ data interpolated from 2005 to 2008 was used to represent existing conditions in the WUMP as it was based on census data and provided good correlation with the BVCP.*

Future Conditions

To be consistent with the 2007 WWTP Master Plan, projections for future employment and population were based on data from that document. The projections found in the 2007 WWTP Master Plan, based on 2003 DRCOG TAZ data, do not provide an overly conservative basis of planning as compared to the 2008 BVCP data. In addition, the 2007 WWTP Master Plan data does not underestimate planning projections; especially regarding employment compared to the 2007 TAZ data. The 2003 DRCOG TAZ spatial data was intersected with the WUSA to arrive at the 2015 and 2020 projections below. The buildout condition at 2030 was not included in the 2003 DRCOG TAZ data. As a result, buildout condition (2030) population and employment values presented in the 2007 WWTP master plan were used for this analysis.

A summary of the 2008 WUMP growth projection for the WUSA is found in Table 3.4 below.

TABLE 3.4- 2008 WUMP PROJECTIONS FOR WUSA

Year	2008	2015	2020	2025	Buildout (2030)
Population	110,092	119,072	122,529	124,266	128,162
Employment	100,598	128,918	134,381	136,706	155,864

3.2 Sanitary Flow Projections

3.2.1 Unit Flow Factors

Unit flow factors are used in combination with the WUMP population and employment numbers to reach the sanitary flow projections. Established per capita wastewater flow production values of 102 gallons per day (gpd) per capita and 50 gpd per employee were developed in the 2003 Wastewater Collection System Master Plan Update, were used in the 2007 WWTP Master Plan, and have been adopted for use in the 2008 WUMP. These values are based on historical flow data at the WWTP versus population and employment numbers from 1996 to 2001. It should be noted that these unit flow factor include base infiltration as they are annual average values.

3.2.2 Significant Industrial Users (SIU)

Significant industrial users (SIU) need to be accounted for in the sanitary flow projections. The SIU presented in the 2003 WWCSMP are adopted in the 2008 WUMP, not including three users who went out of business and one no longer permitted to discharge. New users that replace out-of-business SIU include Hain Celestial, Insmed, and Paxis. Boulder provided updated average annual 2006/2007 daily flows that were used to calculate an average flow for each SIU. The flow from all SIU is estimated to be approximately 8% of the total influent WWTP annual average flow in 2006/2007. Two future SIU have been planned for, a future facility near the Western Disposal site and an industry on East Arapahoe across from Hain Celestial.

However, a portion of the SIU flow measurements include domestic waste, depending on the industry and flow meter location. The domestic waste is accounted for in the employment projections, therefore the SIU flows need to be reduced by a percentage to account for only industrial process flow. In the 2003 WWCSMP, employment data and information on meter location for the contributors of combined flow were used to estimate the domestic portion. Assuming there have been no significant changes in employees or meter locations, the percentages are still applicable for the updated average measured flows. For example, of the total SIU flow contribution from Basin #1 at the University of Colorado at Boulder, 75% has been estimated to be domestic and the remaining 25% is assumed to be contributed by process flow. Therefore, the average total flow for 2006/2007 for Basin #1 is 216,656 gpd and the corresponding adjusted average process flow is 54,164 gpd. Based on the adjusted SIU flows, the industrial process portion is approximately 4% of the total influent WWTP annual average flow in 2006/2007.

Table 3.5 and Table 3.6 present the SIU and their service address and adjusted flow for existing and future conditions (2015 and 2030 conditions). Figure 3-1 shows the locations and average annual process flows of the SIU in the WUSA. Due to the uncertainty of industrial process contribution, the SIU process flow contribution will be held constant for existing and future flow scenarios with the exception of the 2 future SIU. Future total SIU flow and process SIU flow is estimated to be approximately 5% and 3%, respectively, of the total influent WWTP annual average flow in 2030. For modeling purposes, the average process flows from each SIU will be placed at the receiving manhole or, if unknown, at the closest manhole to the SIU service address.

TABLE 3.5 - EXISTING SIGNIFICANT INDUSTRIAL USERS (SIU) IN THE WUSA				
Significant Industrial Users (SIU)	**Service Address Of SIU**	**2006/2007 Average Measured Flow, gpd[1]**	**Estimated Percent of Process Flow[2]**	**Estimated Process Flow, gpd**
Amgen Boulder, Inc.	5550 Airport Boulevard	64,357	100%	64,357
Astro Endyne, Co., Inc.	1770 Range Street	79	100%	79
Ball Aerospace and Technologies Corp.	1600 Commerce Street	56,484	87%	49,141
Circuit Images	3155 Bluff Street	10,301	100%	10,301
International Business Machine Corp.	6300 Diagonal Highway	106,160	80%	84,928
Lexmark International, Inc.	6555 Monarch Avenue	36,943	100%	36,943
Department of Commerce Lab	325 Broadway	124,918	74%	92,440
Roche Colorado Corp.	2075 N. 55th Street	23,869	100%	23,869
SAE Circuits Colorado	4840 N. 63rd Street	44,317	100%	44,317
University of Colorado at Boulder				
Basin #1	Folsom - Univ H	216,656	25%	54,164
Basin #2	Euclid - 18th	178,886	25%	44,722
Basin #3	Marine - 30th	58,626	25%	14,656
Basin #4	Colorado - Regen	125,286	25%	31,321
Basin #5	Colorado - Folso	22,623	25%	5,656
Basin #6	Colorado - 28th	299	100%	299
Hain Celestial	6123 Arapahoe Ave.	22,761	100%	22,761
Insmed	2590 Central Ave	6,306	100%	6,306
Paxis	5555 Airport Blv, Ste 200	647	100%	647
Total SIU Flow (gpd)		**1,100,000**		**587,000**

[1] This SIU measured flow contains a combination of domestic and process flow for some SIU.

[2] A percentage was used to estimate the amount of SIU process flow. Domestic flow was estimated and subtracted from the total SIU flow to determine the SIU process flow. The percentage was estimated based on employment data provided by the City and information on meter location.

TABLE 3.6- FUTURE SIGNIFICANT INDUSTRIAL USERS (SIU) IN THE WUSA				
Significant Industrial Users (SIU)	**Service Address Of SIU**	**Future Average Measured Flow, gpd[1]**	**Estimated Percent of Process Flow[2]**	**Estimated Process Flow, gpd**
Amgen Boulder, Inc.	5550 Airport Boulevard	64,357	100%	64,357
Astro Endyne, Co., Inc.	1770 Range Street	79	100%	79
Ball Aerospace and Technologies Corp.	1600 Commerce Street	56,484	87%	49,141
Circuit Images	3155 Bluff Street	10,301	100%	10,301
International Business Machine Corp.	6300 Diagonal Highway	106,160	80%	84,928
Lexmark International, Inc.	6555 Monarch Avenue	36,943	100%	36,943
Department of Commerce Lab	325 Broadway	124,918	74%	92,440
Roche Colorado Corp.	2075 N. 55th Street	23,869	100%	23,869
SAE Circuits Colorado	4840 N. 63rd Street	44,317	100%	44,317
University of Colorado at Boulder				
Basin #1	Folsom - Univ H	216,656	25%	54,164
Basin #2	Euclid - 18th	178,886	25%	44,722
Basin #3	Marine - 30th	58,626	25%	14,656
Basin #4	Colorado - Regen	125,286	25%	31,321
Basin #5	Colorado - Folso	22,623	25%	5,656
Basin #6	Colorado - 28th	299	100%	299
Hain Celestial	6123 Arapahoe Ave.	22,761	100%	22,761
Insmed	2590 Central Ave	6,306	100%	6,306
Paxis	5555 Airport Blv, Ste 200	647	100%	647
East Arapahoe (Across from Hain Celestial)	6123 Arapahoe Ave.	25,000	100%	25,000
Western Disposal (Recycling Facility)	5880 Butte Mill Rd	5,000	100%	5,000
Total SIU Flow (gpd)		**1,130,000**		**617,000**

1 and 2 See footnotes on previous page.

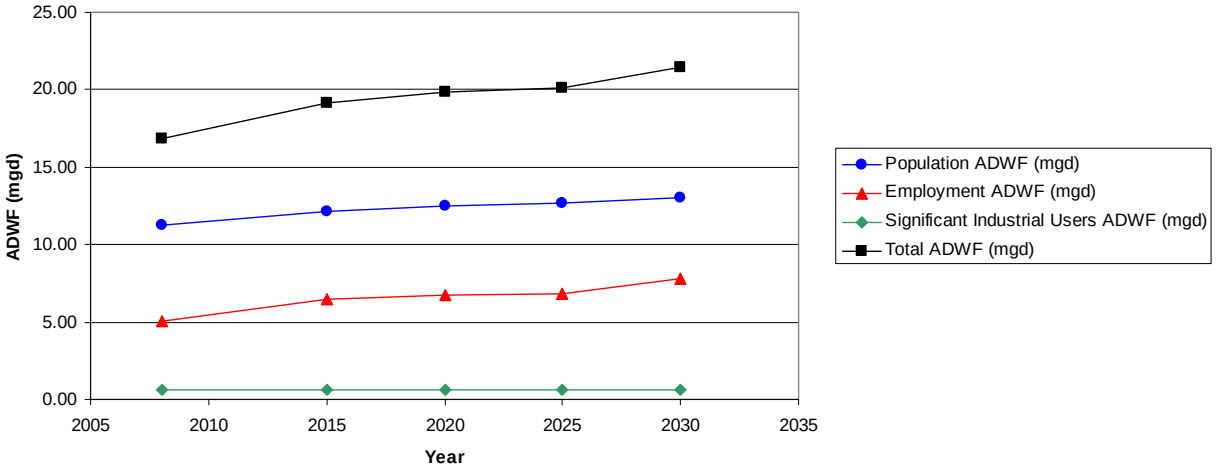
3.2.3 Average Dry Weather Flow Projections

Total average dry weather flow (ADWF) or base flow projections in the collection system for existing and future conditions are comprised of population, employment and SIU contributions. The population and employment contributions are based on the values in Table 3.4, combined with the unit flow factors of 102 gpd per capita and 50 gpd per employee. The SIU contributions are based on 2006/2007 flow data from each user adjusted for domestic flow. In addition to existing (2008) and buildout (2030) conditions, flow projections were developed for intermediate years including 2015, 2020, and 2025 for information purposes. Table 3.7 presents the ADWF projections used as the basis of the WUMP analysis. Figure 3-2 shows the ADWF projections graphically. It should be noted these ADWF values do not reflect collection system hydraulics including hydrograph attenuation and pump station influences. As a result, the collection system hydraulic model results are anticipated to vary slightly when compared to the values in the table below.

TABLE 3.7 – AVERAGE DRY WEATHER FLOW PROJECTIONS

Year	2008	2015	2020	2025	Buildout (2030)
Population ADWF (mgd)	11.3	12.1	12.5	12.7	13.1
Employment ADWF (mgd)	5.0	6.5	6.7	6.8	7.8
SIU ADWF (mgd)	0.6	0.6	0.6	0.6	0.6
Total ADWF (mgd)	**16.9**	**19.2**	**19.8**	**20.1**	**21.5**

FIGURE 3-2 AVERAGE DRY WEATHER FLOW PROJECTIONS



3.3 Infiltration and Inflow Approach

Infiltration and Inflow (I&I) is an important aspect to consider when analyzing system capacity as this flow component of total wastewater flow can be two to three times the amount of the sanitary flow component. With the presence of groundwater, infiltration can influence the system during dry weather. This groundwater induced infiltration is often referred to as base infiltration and is included in the ADWF estimates presented above. During rainfall events, and for a

period afterwards, flows within the collection system rise in response to the storm. This increase in wastewater flow is known as the rainfall dependant inflow and infiltration (RDII). The RDII flow component is combined with peak sanitary flows to define the total wastewater flow that must be conveyed by the wastewater collection system and treated at the WWTP. This peak wet weather flow condition is a worst-case scenario in evaluating a collection system especially in locating capacity restrictions and potential locations for sanitary sewer overflows (SSOs).

3.3.1 Wastewater Treatment Plant Capacity

The existing hydraulic capacity at the WWTP is planned to be 50 million gallons per day (mgd) based on the 2007 WWTP Master Plan. The 50 mgd WWTP hydraulic capacity includes sanitary flows associated with existing condition landuse and anticipated flows due to the system RDII response. As a result, 50 mgd treatment capacity will be the total wastewater flow target for the existing condition scenario as the sewer system will need to be able to deliver that flow rate to the WWTP. The difference between the existing condition dry weather flow (16.9 mgd) and the 50 mgd wastewater flow target was made up with the RDII allowance distributed across the modeled sewer system. The resulting RDII allowance of 33.1 mgd results in a wet weather peaking factor of 3.3. Generally, Boulder's collection system is less sensitive to RDII than systems on the east and west coasts of similar age that experience longer continuous rainfall periods which cause saturated soils and greater inflow.

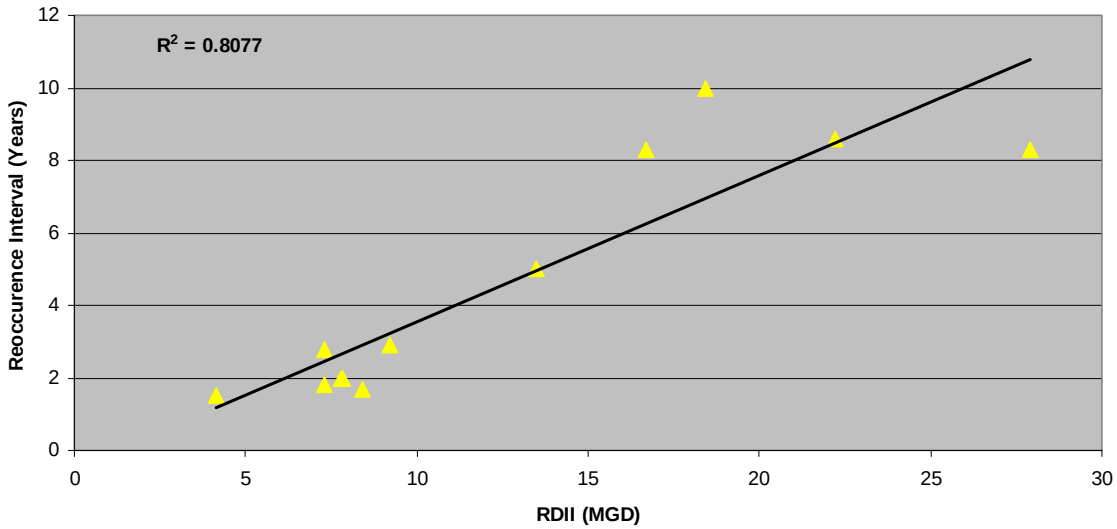
3.3.2 System Wet Weather Flow Response

Flows in the Boulder wastewater collection system increase as a result of significant precipitation events (i.e., 2 year storms and greater). For example, during May 17 1995, 3.5 inches of rainfall occurred, after a period of extended rainfall and saturated conditions, which resulted in a 50 mgd peak flow recorded at the WWTP influent flow meter (maximum capacity of the meter is 50 mgd). More recently, during August 15th – 17th 2008, 2.5 inches fell over a 48-hour period which resulted in 20 mgd recorded at the WWTP. HDR evaluated 20 years of precipitation data to identify storm events that have an impact on RDII measured at the WWTP. According to city staff, rainfall events for storm periods in excess of 24-hours were identified to have the most influence on system response to RDII. HDR compared recorded precipitation data with RDII flow increases at the WWTP influent flow meter to develop a correlation between precipitation and the total peak wet weather flow. In looking at the results of the analysis, the linear relation between the return frequency of the storm events and the corresponding RDII flow results is defined by the following equation:

$$y = 0.4055x - 0.517$$

where y = return frequency of the event and x = estimated wet weather flow increase (mgd). This correlation is shown on Figure 3-3. Based on this correlation and the peak RDII of 33.1 mgd, the 50 mgd wet weather criteria for this project results in the collection system being able to convey flows associated with approximately a 10-year (12.9-year calculated) design storm event.

FIGURE 3-3 PRECIPITATION VERSUS PEAK WET WEATHER FLOW



3.3.3 RDII Flow Allowance

Estimates for total RDII flow response across the system during wet weather were made based on a steady-state, inch-diameter-mile basis. A collection system total of 3,638 inch-diameter miles was established using known diameters and lengths of pipe from the GIS. The RDII allowance is arrived at by taking the wet weather flow increase and dividing by the total inch-diameter miles in the system. The RDII flow allowance was then modeled by applying the total flow increase across the system to each pipe segment in terms of gpd per inch-diameter-mile.

As described above, the design wet weather event modeled is when the WWTP hydraulic capacity is reached. Existing (2008) conditions ADWF is 16.9 mgd and the influent sewer capacity at the WWTP is 50 mgd, therefore the maximum theoretical wet weather flow increase that the existing system can handle at the treatment plant is 33.1 mgd. For buildout conditions it was assumed a negligible amount of additional pipe would be added to the system as the WUSA is not expanding. As a result, for buildout conditions, the 33.1 mgd wet weather flow increase results in a peak flow at the WWTP of 54.6 mgd. An initial RDII allowance of 33.1 mgd or 9,098 gpd/inch-diameter-mile was assigned as a constant flow to the system during model development. This RDII allowance was modified slightly during calibration of the hydraulic model to account for the effects of hydrograph attenuation such that the existing condition peak hour scenario produced 50 mgd at the WWTP.

In the future, as additional temporary flow meter data are obtained, a better understanding of the system response to rainfall can be determined on a subbasin level. As a result, the gpd/inch-diameter-mile I&I allowance should be modified to reflect the system's time varying, dynamic response to rainfall.

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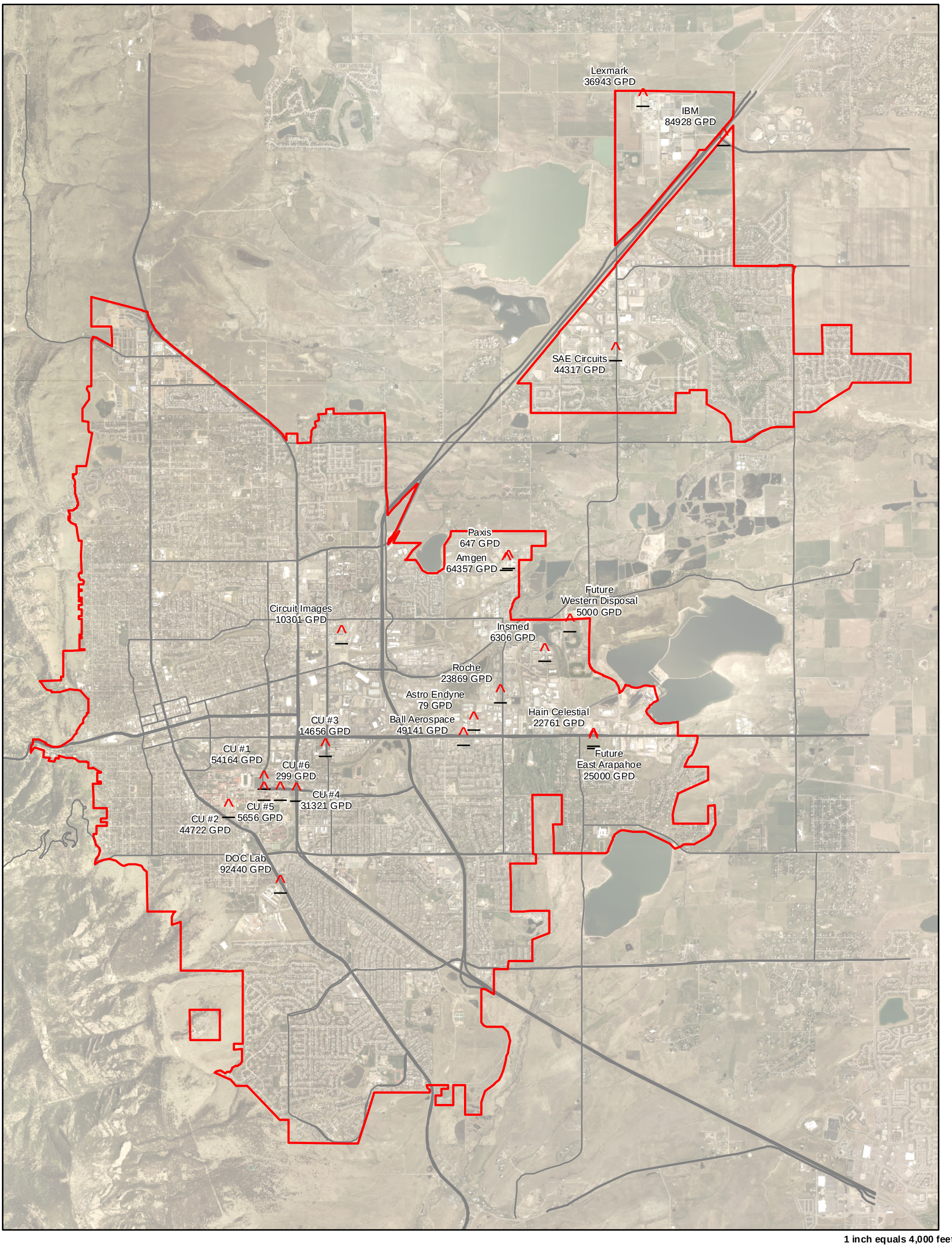

1 inch equals 4,000 feet

Legend

^ Significant Industrial Users (SIU)

WUSA Boundary

0

Significant Industrial Users (SIU)
with Existing Process Flow Estimates

Figure 3-1

HDR
ONE COMPANY | *Many solutions*

Boulder Wastewater Utility Master Plan

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SECTION 4

Model Development and Calibration

A key element to a successful wastewater collection master plan is a detailed collection system model that accurately simulates the conveyance of wastewater flows. Boulder's collection system model includes conveyance elements such as lift stations, diversions, siphons and gravity sewers. The purpose of this section is to summarize the data used to model the conveyance system elements and the model calibration process and results.

The primary source of data the collection system analysis is Boulder's sanitary sewer GIS layers for manholes and sewer pipes. This database was provided to HDR in November of 2007 and formed the basis of all subsequent work. Combined, the two GIS layers represent 9,596 manholes and 9,671 sewer main pipe segments, ranging in size from 4" to 60" in diameter. Other GIS data that were used in the analysis included sewer services, parcels (tax lots), land use, topography, roadway, population estimates (by Traffic Analysis Zone, TAZ), storm and water utilities, streets, etc.

4.1 Data Verification and Collection

Following a comprehensive review of the GIS database, it was determined that significant amounts of data were missing from the pipe and manhole layers needed for collection system modeling. To address the many data gaps, a process was defined to identify, resolve and/or recommend additional survey to fill each data gap. The data verification process, presented in detail in TM 2.1 – Data Review and Data Collection Plan, addressed data issues such as unknown pipe diameters, missing rim elevations and missing invert elevations. All data revisions were tracked in the pipe and manhole GIS data layers.

To resolve the missing invert elevation data gaps, data verification process resulted in a prioritized data collection. The data collection plan identified 140 key manholes requiring field survey to determine pipe invert elevations. Field survey effort resulted in obtaining pipe invert data for 63 manholes. The remaining manholes were not able to be surveyed due to access issues or not being able to locate the manhole in the vicinity of the GIS feature location. The remaining missing invert data were assigned manually and identified as such in the GIS. The manual process of assigning inverts used engineering judgment which considered factors such as 1) adjacent and connection system depth, 2) ground slope and connecting sewer slopes, and 3) minimum pipe slopes.

Additional steps were taken to validate Boulder's collection system network including system connectivity and pipe profiles. The pipe network was reviewed by city staff during the model development phase to validate system connectivity and sewershed definition. Pipe profiles were evaluated by verifying pipe slopes, manhole rim elevations, pipe cover, and interceptor profiles. Slopes which were negative or excessively positive (greater than 15%) were identified and pipe inverts were adjusted to correct the slope if required. Pipe cover was checked for shallow pipes less than 3 feet at manholes using the city's DEM and adjacent pipe cover. Manhole rim elevations were checked for irregularities, such as elevations causing excessively deep or negative pipe cover at manholes; such elevations were adjusted as necessary using detailed elevation data. Finally, within the model environment, all the interceptor profiles were checked for irregularities such as breaks in continuous elevation fall downstream; such irregularities along the interceptor profiles were corrected as necessary.

4.2 Software Selection

Several software vendors that offer hydraulic modeling packages were evaluated in detail and included MWHSoft, Pizer, Bentley, Wallingford Software, DHI Group, and XP Software. The key to selecting the proper modeling software is a balance between methods of hydraulic calculation (flow routing, I&I), applicable features, and cost. The advantages and disadvantages to each depend on the quality of data available for building the model of the wastewater system and features required to complete the goals of the master plan.

The software evaluation process resulted in InfoSewer being identified as the most appropriate tool for analyzing Boulder's collection system. InfoSewer fits the current modeling needs for the WUMP and allows for future refinement of the model by the Utilities Division based on future system improvements, flow monitoring data and operations/maintenance input. This package includes many time-saving features including being an ArcGIS-based platform for integration of Boulder's GIS data and having all the standard ArcGIS tools directly available. The software calculates semi-dynamic hydraulics capturing flow attenuation, locations of surcharging and simplified backwater conditions. In addition, InfoSewer provides the appropriate method accounting for I&I for this project and modeling wet weather flow scenarios. Comparatively, InfoSewer's cost versus program features is of good value considering the specific wastewater system modeling requirements for Boulder's system.

4.3 Modeling Approach

The modeling approach for the WUMP uses data from all the pipes and manholes that exist in Boulder's system to develop an "all pipes" model. The benefits of an all-pipes model include increased accuracy in allocating wastewater flows to the sewer system, improved capture of actual flow attenuation in upper reaches of system, and simplifying the task of adding to and updating the system with survey data in the future.

Although the entire system will be modeled, some of the system will not be analyzed as part of the WUMP. Due to the trend of less accurate or missing information in the local 8 inch pipe system, this portion of the system will not be analyzed in the evaluation phase of the project. The missing information could cause inaccurate results and therefore misidentified problem areas. As redevelopment occurs within the local system, missing system data can be collected and the accuracy of the local system model thereby increased. *The scope of this project was to analyze the local collector, collector and interceptor systems for hydraulic capacity.* The limits of the analyzed system are shown on Figure 4-1.

Additional survey information gathered in the local system where data are missing can be loaded into the model in the future. In addition, new land use scenarios can be added to the model to simulate proposed developments and missing data can be obtained during the development review process. The accuracy of the data for the local and extended systems will increase over time as these data gaps are filled in and the results in these areas can be more examined thoroughly at that time.

4.3.1 Model Scenarios

A total of four model scenarios were established to represent the existing and future flow conditions in the system. Modeling existing and future conditions allows for locating current problems as well as predicting where future growth may cause additional problems. For each of the two flow conditions, a dry weather and a wet weather scenario were created. The dry weather model scenario for this analysis was assumed to occur during the irrigation season to reflect the base infiltration component of the total wastewater flow that occurs as a result of the irrigation ditch groundwater influence.

4.3.2 Data and Basis of Hydraulic Model Construction

To construct the hydraulic model, pipes and manholes were imported into model directly from the processed GIS data. A one-way import function from GIS manhole and pipe data to the model database was kept to maintain the integrity of GIS data as the master source for model data input. Connectivity and general direction of flow was verified in the model. The Gunbarrel IBM lift station wetwell, pumps and control information was populated in the model. Siphon, forcemain, and diversion manhole (open and plugged) functions were all set and verified in the model.

4.4 Spatial Allocation of Sanitary Flow

Wastewater flows were distributed to manholes across the system to establish system loading for both the existing and future conditions. The total wastewater flow in the system is a combination of sanitary flow and rainfall dependant infiltration and inflow (RDII). This section addresses the sanitary flow allocation process.

To spatially distribute the sanitary flows across each TAZ boundary for flow allocation in the model, a flow density approach was used. Flow density captures ADWF in gallons per day per acre across the system for the existing and future flow projections. The flow density was arrived at by dividing the ADWF for each TAZ polygon by the sewered area of that polygon. This approach accounts for the non-sewered areas within the TAZ boundaries and proportions flow to the sewered area. The flow density is passed down within each TAZ boundary for flow allocation via smaller Thiessen polygons developed around collection system nodes (manholes) which were limited to the sewershed boundaries.

4.4.1 Non-Sewered Areas

Non-sewered areas were developed by compiling relevant Boulder GIS layers including city parks, undevelopable lands, high hazard flood areas, and lakes. In addition, HDR developed a right-of-way GIS layer by extracting features from the city's parcel GIS and included this layer in the non-sewered area group of layers. These were merged to form a single non-sewered areas GIS layer, shown in Figure 4-2. The non-sewered area accounts for approximately 36% (6,016 acres) of the WUSA. These non-sewered areas were intersected with the sewershed Thiessen polygons to account for portions of each that are not sewered and concentrate the flows to the areas which have or may, in the future, have sewer service.

4.4.2 Existing Conditions

As noted previously, for existing conditions, the 2007 DRCOG TAZ data was used to identify the base condition of population and employment across the WUSA. As shown in Table 3.7, population and employment projections increase within the WUSA through buildout. However, when comparing the trend of population and employment projections spatially on a TAZ boundary basis, it was observed that many TAZ boundaries actually showed a decrease in employment and/or population between the 2008 and the future 2015 and 2030 conditions. This was a direct result of using the TAZ data from two different model sources (2003 TAZ model versus the 2007 TAZ model). Through discussions with Boulder and HDR staff, it was agreed that this decrease in population and employment in these regions is not a realistic or appropriate basis of planning for the WUMP. It was determined that, although the aggregate population and employment values within the WUSA as a whole are valid for existing conditions, an alternate approach to spatially distributing the resulting sanitary flow from the existing population and employees was required to analyze the existing collection system.

Spatial Distribution of Sanitary Flows Using Water Meter Data

Water meter data, provided by Boulder, including monthly flows and the spatial location of those flows was used as the basis of existing conditions sanitary flow distribution. Winter water meter data is characteristically equal to an average month's dry weather flow with the absence of infiltration resulting from irrigation ditches and increased groundwater levels for local streams. As a result, the monthly water-use records from December 2005 are considered the most accurate spatial representation of existing flow contribution. The difference between the monthly water meter consumption records and the WWTP influent flow meter data is the base infiltration flow component described in the following section.

Water Meter and WWTP Influent Flow Meter Comparison

The average daily water meter consumption in the WUSA for December 2005 was 9.9 mgd and the average daily WWTP influent for the same time period was 12.5 mgd. Base infiltration was assumed to account for the 2.6 mgd difference. Meters were spatially joined to the 2003 TAZ boundaries to establish water consumption on the same basis as the population and employment projections. Base infiltration was distributed by the ratio of sewered area across the TAZ boundaries within the WUSA. The water consumption recorded at the meters plus the base infiltration was developed to equal the 2005 ADWF. To reach existing conditions (2008) ADWF of 16.3 mgd, the difference between 2005 and 2008 ADWF was allocated by weighted average of population and employment for each TAZ boundary. Flow densities were calculated for the existing conditions based on the 16.3 mgd ADWF and are shown on Figure 4-3.

4.4.3 Future Conditions

For future conditions, the spatial distribution of population and employment from the 2003 DRCOG TAZ data was available up to the year 2025. So, for the intermediate projection years (2015, 2020, 2025), the projections contained in the TAZ data were used. However, for buildout conditions (2030), the 2007 WWTP Master Plan employment and population projects were used. The population and employment projections were not spatially referenced for buildout conditions. Therefore, the spatial distribution of the growth to reach buildout was accomplished using the development densification process described in the following section.

Development Densification Approach

To distribute population and employment growth from the 2025 spatial data to buildout projections, a development densification process was used. This process identified the undeveloped or underdeveloped parcels as compared to the landuse zoning. The current land classification from the GIS parcel data was compared with the future zoning GIS data. Parcels that became more dense (e.g., low density residential to mixed use) were flagged. These parcels were grouped by predominant zoning classification into 15 potential growth areas (development densification areas) to reflect the increased density experienced within Boulder through parcel redevelopment. Through discussions with City staff, each densification area was given one of the following predominant land uses: commercial/industrial, residential, or mixed. The difference in population and employment numbers between 2025 and buildout were then assigned by area-weight to these densification areas. Figure 4-4 shows the densification areas and their associated land use classification.

Flow Density by TAZ Boundary

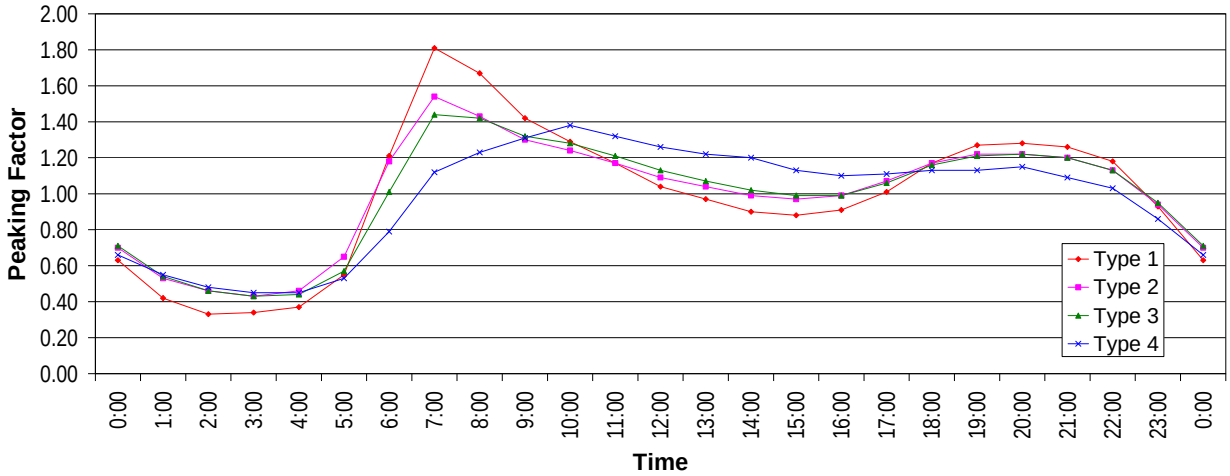
Flow densities were calculated to distribute the buildout (2030) ADWF conditions across the TAZ boundaries. Figure 4-5 shows the flow density for each TAZ boundary in the WUSA at buildout. Comparing the flow densities between existing and future conditions illustrates the areas where growth, densification and coinciding flow increases are projected to occur.

4.5 Predominant Land Use and Diurnal Patterns

Land use classifications based on zoning in the parcel data provided by Boulder were used to develop predominant land use classifications for each sewershed. These predominant land uses were used to assign diurnal patterns to each sewershed. Four general land use classifications were defined based on the numerous and detailed future zoning categories found in the parcel data. The four general land use classifications included commercial/industrial, mixed use, multi-family residential and single family residential. The parcel data was intersected with the theissen polygons and the future zoning with the greatest area within each polygon was assigned as the predominant land use. Figure 4-6 shows the predominant land uses across the WUSA.

Instead of using peaking factors typically associated with steady state flow analysis, diurnal patterns for each contributing flow were used to more accurately assess the system hydraulics. Using diurnal patterns allows for the model to simulate capturing the hourly change in sanitary flow across an extended period. Extended period simulations for this project included 5-day periods used in model calibration and 24-hour periods used in the capacity analysis. The diurnal patterns matched with predominant land uses give each sewershed and theissen polygon unique peaking characteristics that better simulate actual flow contribution over an extended time period. Figure 4-7 shows the weekday for each of the predominant land uses. These patterns were adopted from similar collection system master plans for use as a starting point for the WUMP analysis. Note the diurnal patterns were modified slightly during the model calibration phase (see Section 4.8).

FIGURE 4-7 LANDUSE BASED DIURNAL PATTERNS (UNCALIBRATED)



Type 1: Predominantly Single Family Residential Land Use
Type 2: Predominantly Multi-Family Residential Land Use
Type 3: Combination of Residential and Commercial (Mix-Use) Land Uses
Type 4: Commercial, Industrial and School Land Uses

4.6 Significant Industrial Users

The Significant Industrial Users (SIU) within the collection system were identified and presented in Section 3.2. These flows were included in the model for existing and future scenarios and were assigned to the nearest downstream manhole and assigned a commercial/industrial diurnal curve.

4.7 Inflow and Infiltration

In Section 3.3, the point was made that I&I is a key component to analyzing the collection system. As discussed previously, base infiltration is included in the unit flow factors and therefore included in the sanitary flow component. The RDII flow component, however, is accounted for separately in the model and simulates a rise in system flows in response to a storm event.

The exact response of Boulder's system to RDII across the system is not well understood. To allocate RDII across the system, a steady state allowance based on units of gallons per day per inch-diameter-mile was included in the model for each sewershed theissen polygon. The initial RDII allowances were globally assigned to all pipes with pipe diameter-length factors of a 9,098 gpd/inch-diameter mile. Calibration will validate and determine necessary adjustments by location and magnitude of the initial I&I allowances.

4.8 Model Calibration

Calibration was completed for existing conditions using recent historical monitoring data from the WWTP and temporary flow meters installed in 2004. The calibration process first involved comparing WWTP meter data to the initial model results for dry weather conditions. That comparison resulted in adjustments to the initial model parameters. Following the WWTP meter calibration stage, key temporary flow meters were then used for dry weather calibration. Because the temporary flow meters did not capture flow response during rainfall events, wet weather calibration was not possible at these locations.

After the model was developed and before the calibration process was completed, a number of items were validated inside the model environment to ensure proper collection system operation including:

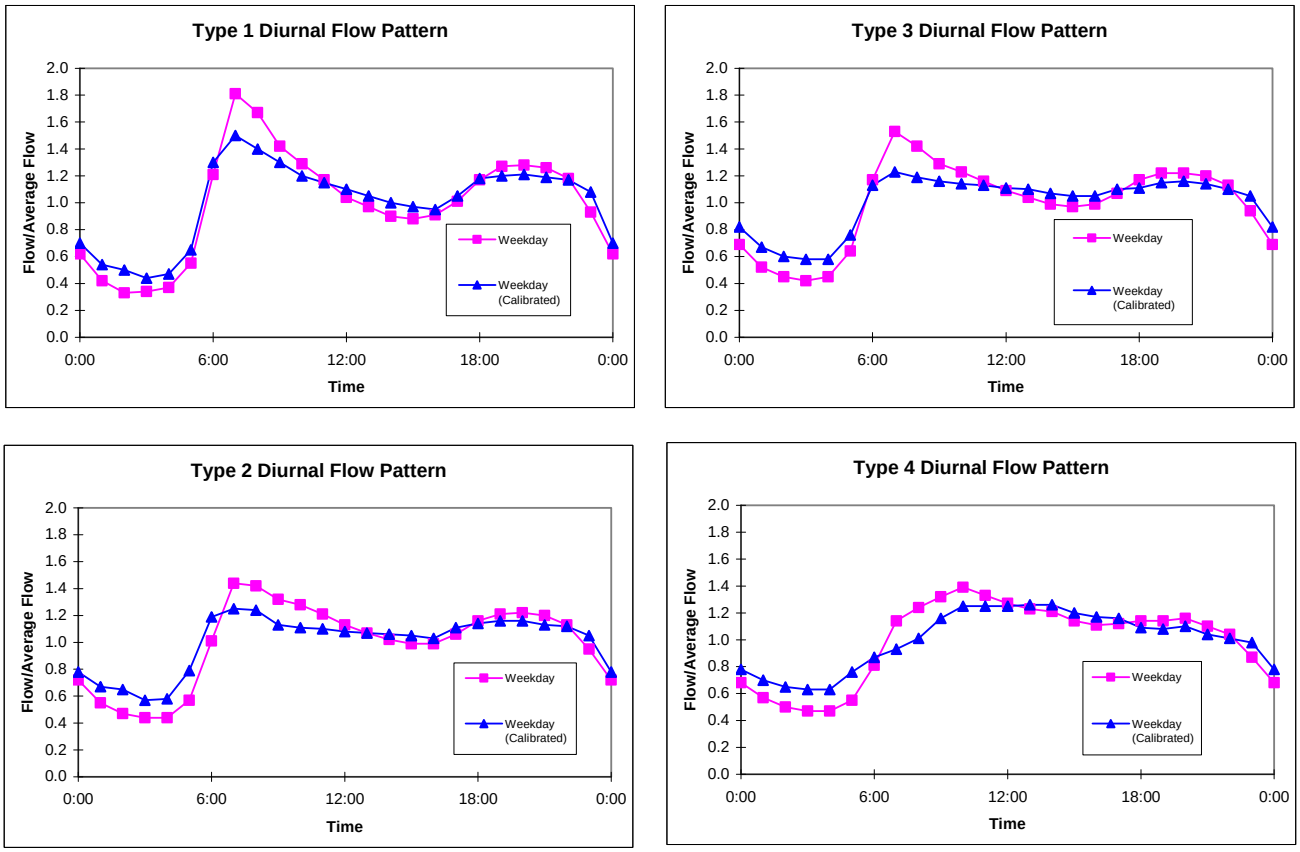
1. Behavior and controls of the Gunbarrel pump station, wetwell, and forcemain;
2. Behavior of the siphon and diversion manholes;
3. Examining interceptor profiles for irregularities; and,
4. Other data validation exercises as discussed in Section 4.1.

4.8.1 Dry Weather Calibration - WWTP

The initial comparative analysis results between the uncalibrated model and influent meter at the WWTP showed model results were high considering hydrograph peak and volume. The modeled peak flows at the plant were high by as much as 18% and hydrograph volume difference high as much as 16% when compared to the WWTP influent meter. Initial results from the uncalibrated model at the temporary flow meters were comparatively quite high by up to 60% peak and 100% hydrograph volume.

Since the hydrograph volumes and average day flows were close at the treatment plant, within 0.9 mgd in April 2007, the sanitary unit flow factors of 50 gpd per capita and 102 gpd per employee, were considered acceptable. However, the hydrograph shape was identified as needing adjustment in the model to better fit the flow meter data. As a result, the original diurnal patterns were flattened to fit hydrograph shape seen at the WWTP and also lessening the flow difference during peak hour. Figure 4-8 presents the original versus calibrated diurnal patterns.

FIGURE 4-8 CALIBRATED DIURNAL FLOW PATTERNS

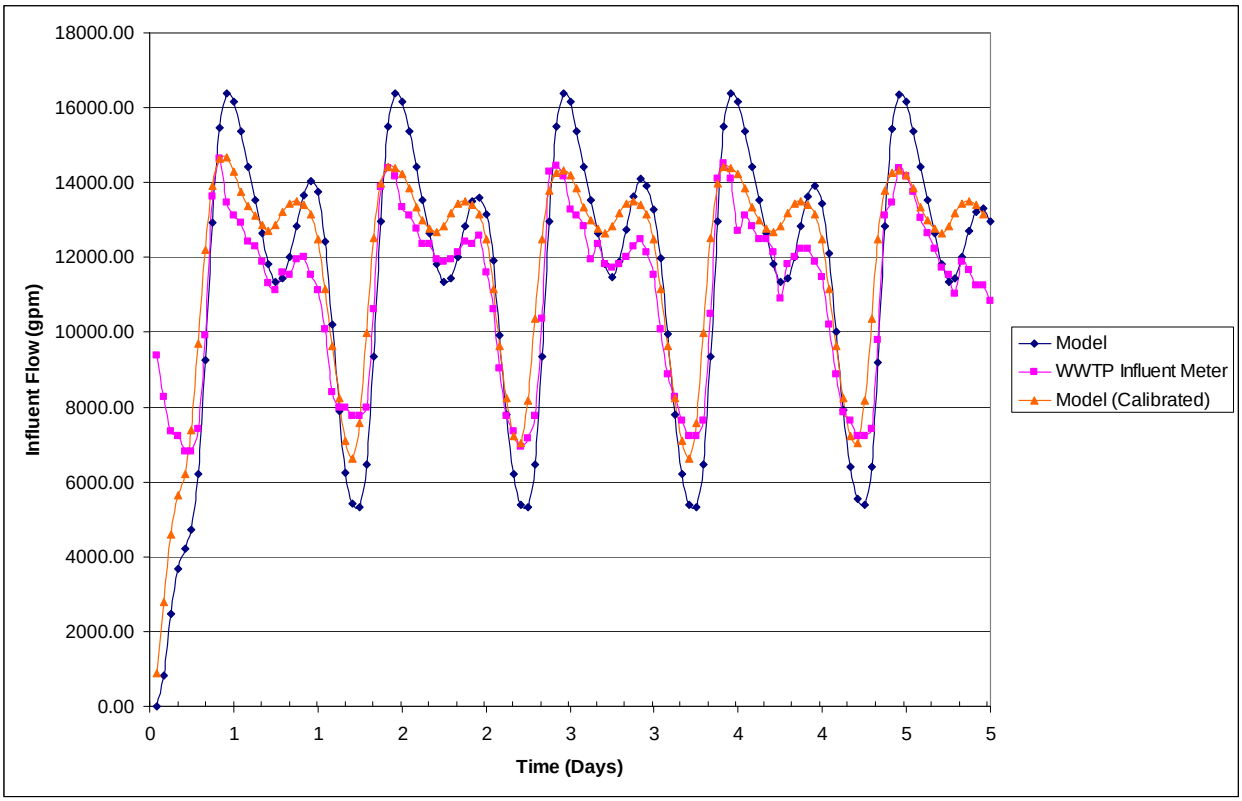


Type 1: Predominantly Single Family Residential Land Use
Type 2: Predominantly Multi-Family Residential Land Use
Type 3: Combination of Residential and Commercial (Mix-Use) Land Uses
Type 4: Commercial, Industrial and School Land Uses

At the WWTP, the calibrated model results show an improved fit of hydrograph peak and shape as compared to the initial, un-calibrated model. Table 4.1 shows the model results compared against the WWTP Meter Data. Figure 4-9 shows the calibration results for the April 2007 calibration dates.

TABLE 4.1 - CALIBRATED RESULTS AT WWTP INFLUENT METER				
Time Period	**Meter -Average Flow (mgd)**	**Model - Average Flow (mgd)**	**Peak Difference (%)**	**Hydrograph Volume Difference (%)**
Jan. 14-18, 2008	14.4	16.9	4	15.6
Apr. 23-27, 2007	16.0	16.9	0	5.3
Jun. 18-22, 2007	15.5	16.9	4.9	8.5
Sept. 10-14, 2007	14.1	16.9	8.2	18.2

FIGURE 4-9 APRIL 23-27, 2007 - WWTP INFLUENT METER - MODEL CALIBRATION RESULTS



4.8.2 Dry Weather Calibration – Temporary Flow Meters

From late April through early June of 2004, temporary flow meters were installed and monitored in 31 manholes across the City as part of a routine cycle of system-wide flow monitoring. No more recent data exists to provide a better fit for existing (2008) condition scenarios. In addition, the flow meters did not capture any significant storm events during the monitoring period that could be used to assist in wet weather calibration. However, the irrigation ditches were flowing during the monitoring period so the groundwater-induced infiltration component of I&I is likely present in the flow meter data. Due to the nature of a varying land use distribution within the system, most of the sewer basins and associated flow meters, recorded flows are influenced by a mix of land uses. The flow data captured at Flow Meter 2 (located at the WWTP) in 2004 averaged 14.6 mgd or 2.3 mgd lower at the WWTP than the ADWF (16.9 mgd) under existing 2008 model flow conditions.

Six meters were chosen to complete a comparison analysis and assist as a tool for calibration of the model. Factors taken into account while choosing the meters include:

1. Locations being at the downstream end of interceptors to capture representative flows from individual sewer basins or groups of sewer basins;
2. Locations upstream of flow split manholes and away from pump station influences in order to calibrate land use driven flow data and not system hydraulics; and,
3. Locations in interceptors which carry a large quantity of flow that dampens the inherent variability of field data especially in upstream reaches of collection system.

The six chosen meters have adequate flow data through the monitoring period to perform the comparative analysis and model calibration. The meter locations shown in Table 4.2 in addition to the WWTP influent meter (Flow Meter ID 2) correspond to the locations shown on Figure 4-10.

TABLE 4.2 - SELECTED FLOW METERS FOR CALIBRATION

Flow Meter ID	Unique Manhole ID	Approximate Meter Location	Pipe Diameter (inches)	Average Flow (mgd)	Dates Selected for Comparison
5	N04E018	W of Valmont Rd. & Butte Mill Rd. Intersection	36	4.5	May 17-21, 2004
12	S03E012	W of Cherryvale Rd. & South Boulder Rd.	27	0.12	May 24-28, 2004
15	N03W0138	NW of 55th St. & Arapahoe Ave.	30	1.7	April 27-May 1, 2004
23	N07W027	E of Foothills Parkway & Diagonal Hwy. Intersection	21	0.94	Jun. 7-11, 2004
25	N08E0415	NE of 63rd St. & Jay Rd.	15	0.33	Jun. 7-11, 2004
30	N03W0461	N of 30th St. & Arapahoe Ave.	30	0.88	May 24-28, 2004

Table 4.3 shows the model results compared against the temporary flow meter data. At the temporary flow meters, the hydrograph shape of the temporary flow meter data compared with model results was good. However, even after calibration, four of the six temporary flow meter locations differ outside the project's calibration goals. There are a few possible explanations of this occurrence including:

1. The existing 2008 flow conditions utilized in the model have a total ADWF of 16.9 mgd at the WWTP compared with only 14.6 mgd over the period of temporary flow monitoring conducted in 2004 at the meters of concern. The difference of 2.3 mgd likely accounts for a portion of the variance between the meter data and model results.
2. The effects on wastewater flow from groundwater-induced infiltration along irrigation ditches. Since the characterization of the effects of groundwater on the system is largely

unknown, for this model the groundwater-induced base infiltration was assigned globally across the system within the sanitary unit flow factors of 102 gallons/capita/day and 50 gallons/employee/day.

3. Groundwater infiltration adjacent to buildings and below grade parking structures in certain parts of the city is currently being pumped into sanitary sewer system and could significantly add to the system base flow in specific locations including the downtown area along Boulder Creek.
4. The temporary flow monitoring data may be outdated and not representative of current land use conditions.

TABLE 4.3 - CALIBRATED RESULTS AT TEMPORARY FLOW METER

Flow Meter ID	Meter -Average Flow (mgd)	Model - Average Flow (mgd)	Peak Difference (%)	Hydrograph Volume Difference (%)
5	5.5	8.6	35	59
12	0.12	0.15	8	20
15	1.9	3.8	3	34
23	1.5	1.0	46	35
25	0.37	0.42	1	15
30	1.14	0.69	- 70	- 38

The modeled flow in all but one of the six meters is higher than the meter data indicating the model is conservative. The overall difference between model results and temporary flow meter data is considered adequate for this planning study given 1) the conservative nature of the model results 2) the relatively small amount of flow under scrutiny, compared to system total, and 3) overall system calibration at the WWTP is well within standard modeling tolerances.

4.8.3 Wet Weather Calibration

Wet weather-calibration is completed to validate the rainfall induced I&I allowance established in Section 3.3. Only a limited wet weather calibration is possible since flow monitoring results and I&I studies have not been successful in detailing the collection system's response to RDII. The system can only be calibrated to peaks seen in the at the WWTP influent meter during storm events and not volume calibration due to these I&I limitations. Additionally, as stated above, the temporary flow meter data from 2004 lacks significant rainfall event data that could be used in wet weather calibration. Therefore, the purpose of the wet weather calibration for this project is to validate rainfall vs. I&I relationship established in Section 3.3 and match the modeled peak-hour flow to the peak hour flow at the WWTP.

The peak flow target for wet weather calibration is 50 mgd which is the capacity of the WWTP influent interceptor sewer. The peak flow of 50 mgd will occur in conjunction with the existing (2008) ADWF sanitary flow conditions. The initial system-wide I&I allowance for this condition was established at 9,098 gpd/inch-diameter mile.

The initial results of wet weather calibration using a RDII allowance of 9,098 gpd/inch-diameter mile with existing flow conditions show a resulting peak-hour at the treatment plant of 54.1 mgd. As a result, approximately 4.1 mgd of RDII allowance needed to be removed from the model to bring the peak-hour model results down to 50 mgd.

By adjusting the RDIII allowance on a pipe basis in areas outside the 100-year flood plain, the area less affected by RDII, the peak of the wet weather hydrograph can be reduced to 50 mgd. There are a total of 1,194 inch-diameter miles of pipes within the 100-year flood plain and Figure 4-11 depicts the locations of the collection system within these areas. Approximately 4.1 mgd of I&I in the remaining 2,642 inch-diameter miles of pipe outside the 100-year floodplain was removed from the model. *This resulted in an I&I allowance of 7,607 gpd/inch-diameter mile for pipes outside the 100-year floodplain and 9,098 gpd/inch-diameter miles for pipes inside the 100-year floodplain.* The calibrated wet weather increase of 25.6 mgd in average daily flow is roughly equal to a 10-year design storm.

4.9 Calibration Conclusions and Recommendations

The results of the dry weather calibration process give a better hydrograph and peak-hour fit of model results versus flow meters especially in regards to the WWTP influent meter. All of the 5-day periods selected for the WWTP influent meter were within the calibration goals for the project. Only two of the temporary flow meters were within calibration criteria with the remaining four outside the criteria keeping in mind a difference of 2.3 mgd ADWF at the WWTP between the meter flow data and the model. Although, the hydrograph shape for all the temporary flow meters matched the model results well. The wet weather calibration process captured an existing scenario 50 mgd peak at the WWTP corresponding to the hydraulic capacity of the influent interceptor. By modifying the initial I&I allowance presented in Section 3.3, a calibrated I&I allowance allowed the wet weather model to be calibrated to this peak. The calibrated wet weather scenario is roughly equivalent to a 25-year system response to RDIII.

Given the difficulties encountered in the temporary flow meter calibration process, it is recommended that a detailed inflow and infiltration study be performed to better assess the system's response to rainfall and non-rainfall induced infiltration. The items below are recommendations that may assist in improving future model calibration attempts.

1. Perform in-depth I&I study to characterize system-response to various frequencies of storm events. Consider include strength of sewage (BOD) testing and analysis in study to estimate percentage of groundwater (inflow and pumped) and RDII within flow streams during dry weather compared to wet weather.
2. Install semi-permanent flow meters in locations strategically placed across the system to capture wet weather events to better understand system response to wet weather events and to help define diurnal curves for the system on a sewer basin level during dry weather weathers.
3. Evaluate flow meter data during dry weather periods when the irrigation ditches are running and when they are not to define the influence that these ditches have on groundwater-induced base infiltration.
4. Evaluate water meter data and dry weather temporary flow meter data to better define the sanitary unit flow factors for population and employment.

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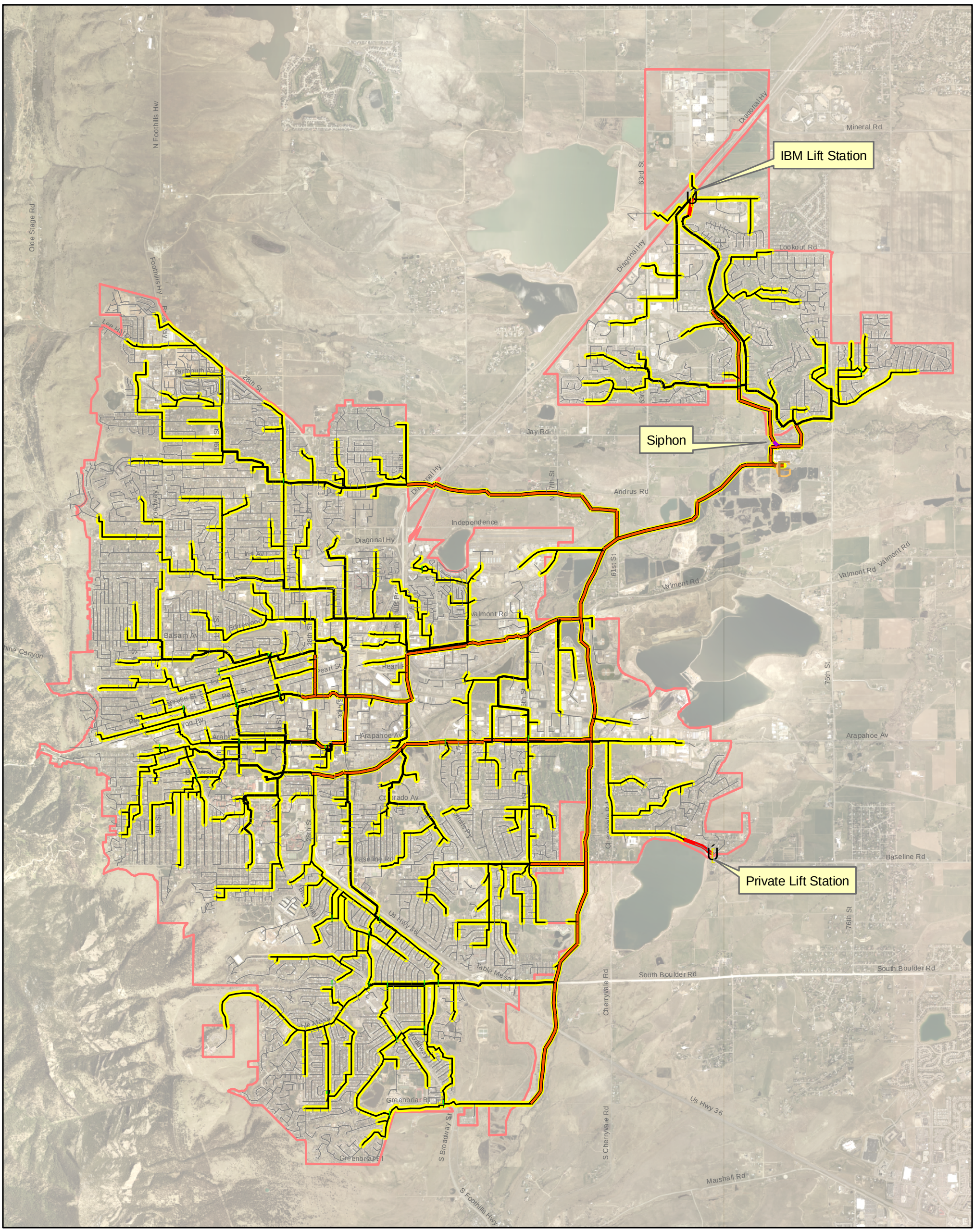

Legend

1 inch equals 4,000 feet

Existing Sewers

- Analyzed System
- Interceptor
- Collector
- Local Collector
- Local
- Coll/Int (Siphon)
- Forcemain

Manholes

- Div MH
- Flow Split MH
- Lift Station
- WWTP
- WUSA

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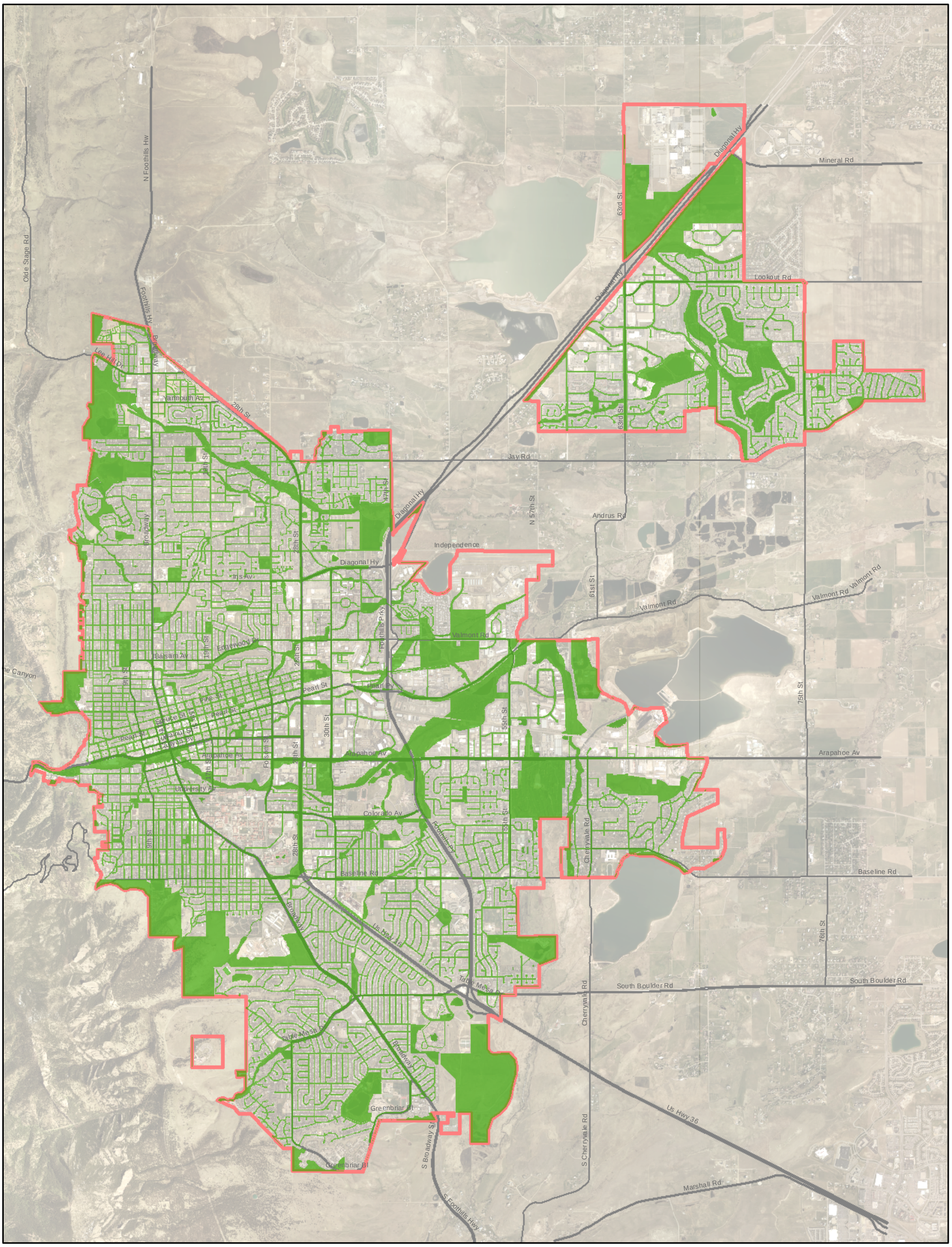
Limits of Analyzed Collection System

Figure 4-1

Boulder Wastewater Utility Master Plan



1 inch equals 4,000 feet

Legend

WUSA (BVCP Areas I & II)

Non-Sewered Area

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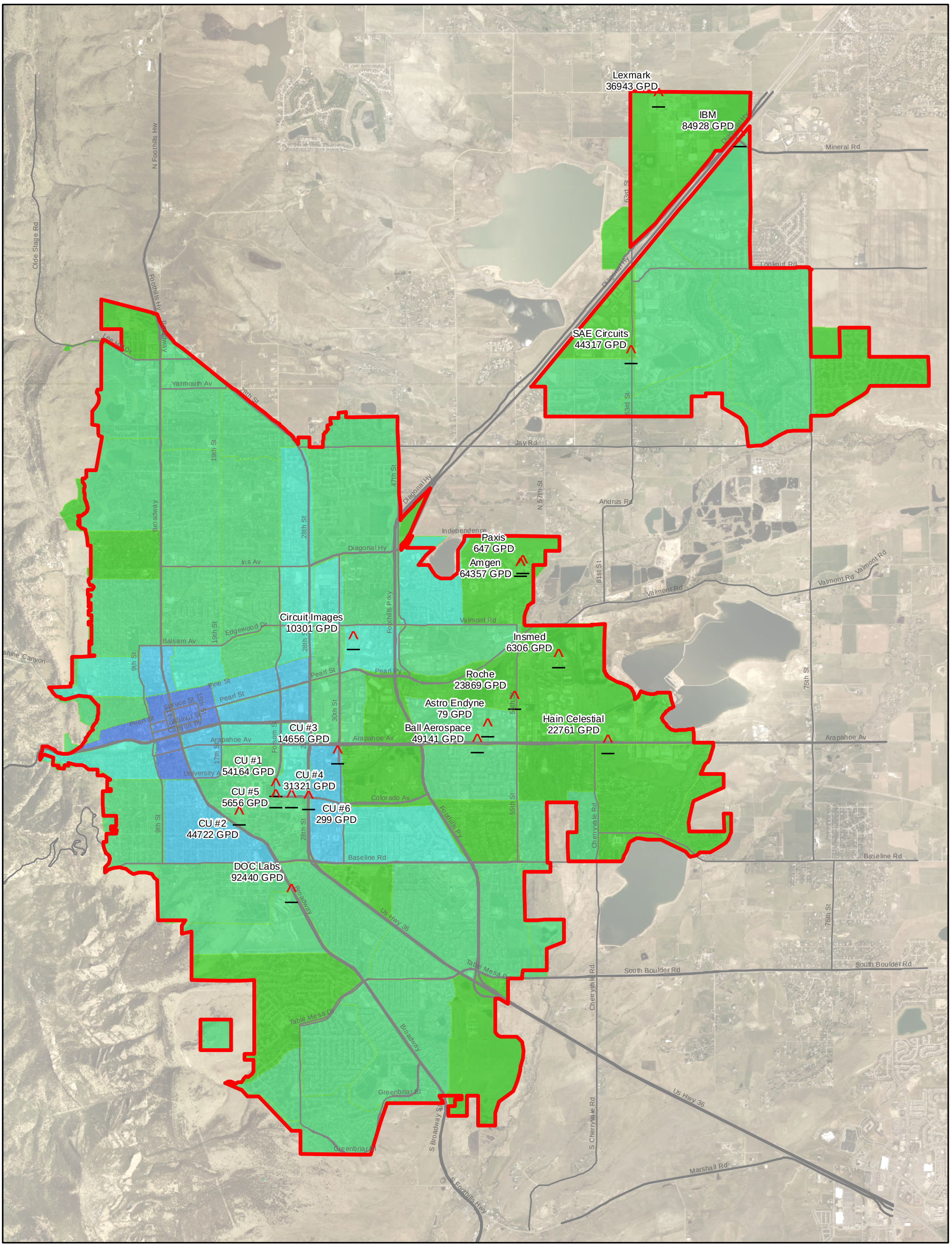
Non-Sewered Area in WUSA

Figure 4-2

Boulder Wastewater Utility Master Plan



Legend

WUSA (BVCP Areas I & II)

Significant Industrial Users (SIU)

Existing Flow Conditions (GPD/ACRE)

- 254 - 1000
- 1001 - 2000
- 2001 - 3000
- 3001 - 4000
- 4001 - 8000
- 8001 - 14000

1 inch equals 4,000 feet

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Existing ADWF Density by TAZ Area

Figure 4-3

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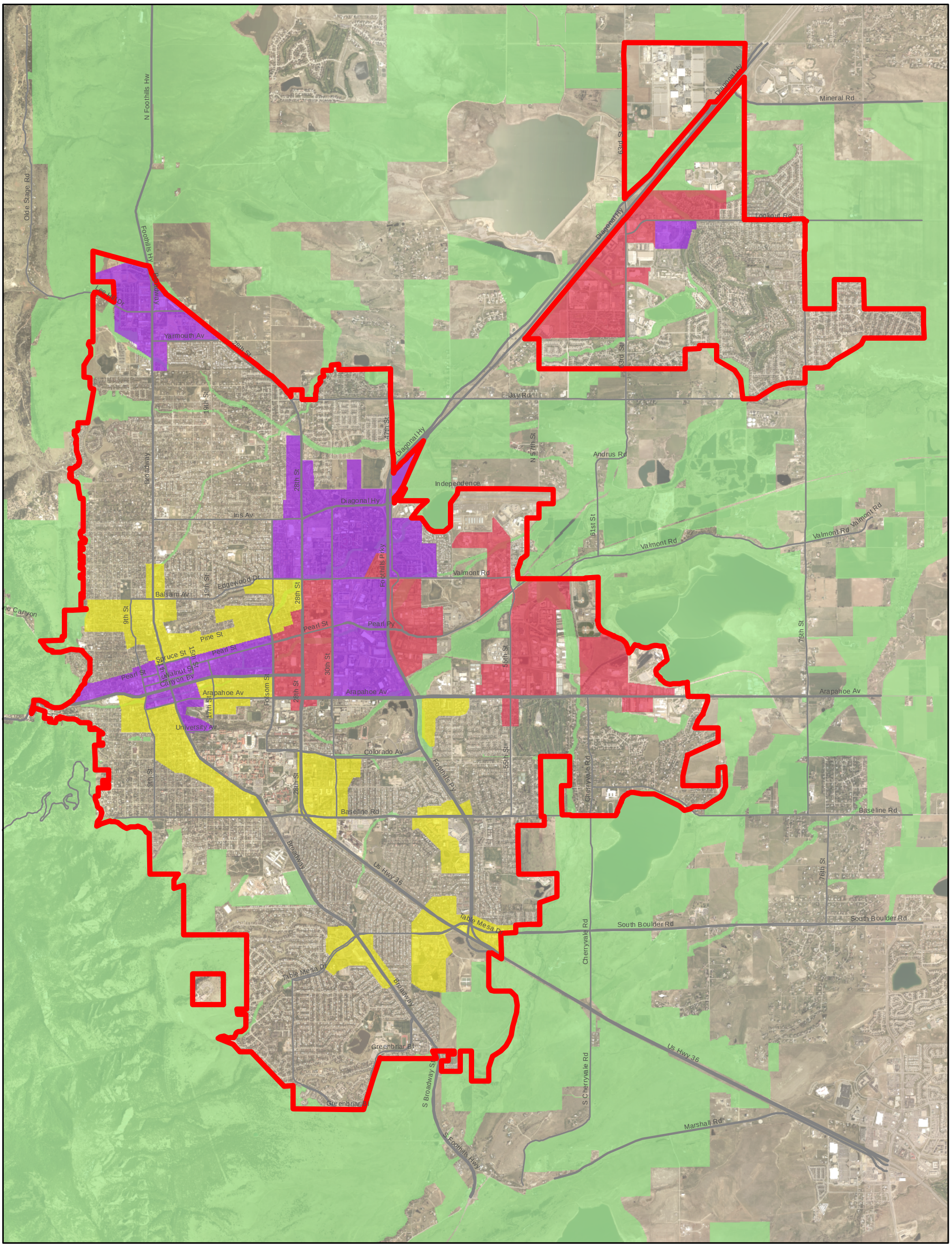
Note: SIU flows are not included in flow polygons.

Boulder Wastewater Utility Master Plan



Legend

1 inch equals 4,000 feet

Densification Areas

Prominent Land Classification

- Commercial/Industrial
- Mixed
- Residential
- Undevelopable Land
- WUSA (BVCP Areas I & II)

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Densification Areas and Undevelopable Land

Figure 4-4

Boulder Wastewater Utility Master Plan

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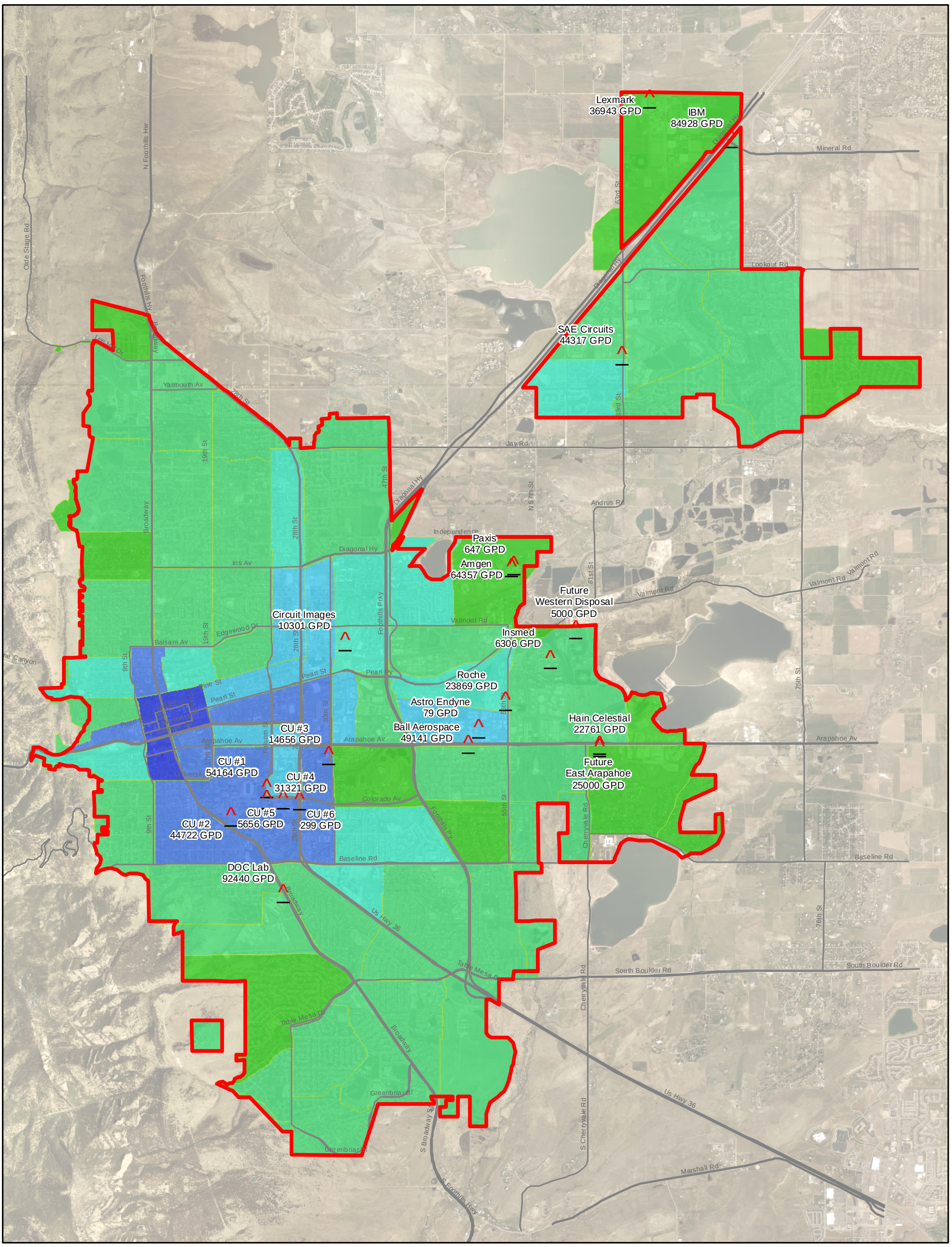

Legend

WUSA (BVCP Areas I & II)

Significant Industrial Users (SIU)

Buildout (2030) Flow Conditions (GPD/ACRE)

- 305 - 1000
- 1001 - 2000
- 2001 - 3000
- 3001 - 4000
- 4001 - 8000
- 8001 - 14000

1 inch equals 4,000 feet

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Note: SIU flows are not included in flow polygons.

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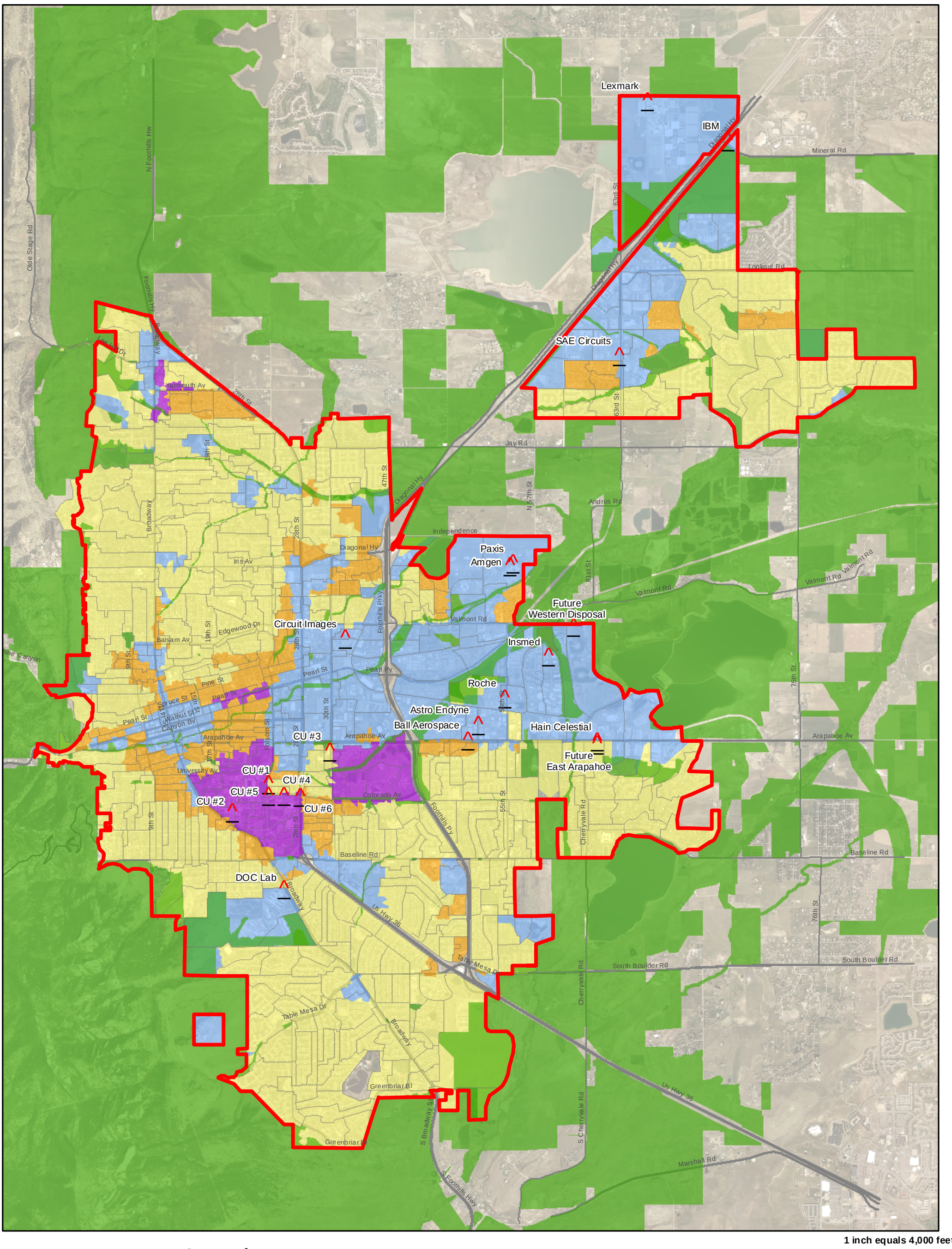
Buildout (2030) ADWF Density by TAZ Boundary

Figure 4-5

Boulder Wastewater Utility Master Plan



1 inch equals 4,000 feet

Legend

- WUSA (BVCP Areas I & II)
- Significant Industrial Users (SIU)
- Sewersheds

Predominant Landuse

- Commercial/Industrial
- Multi-Family Residential
- Mixed Use
- Single Family Residential
- Non-Sewer Area/Undevelopable

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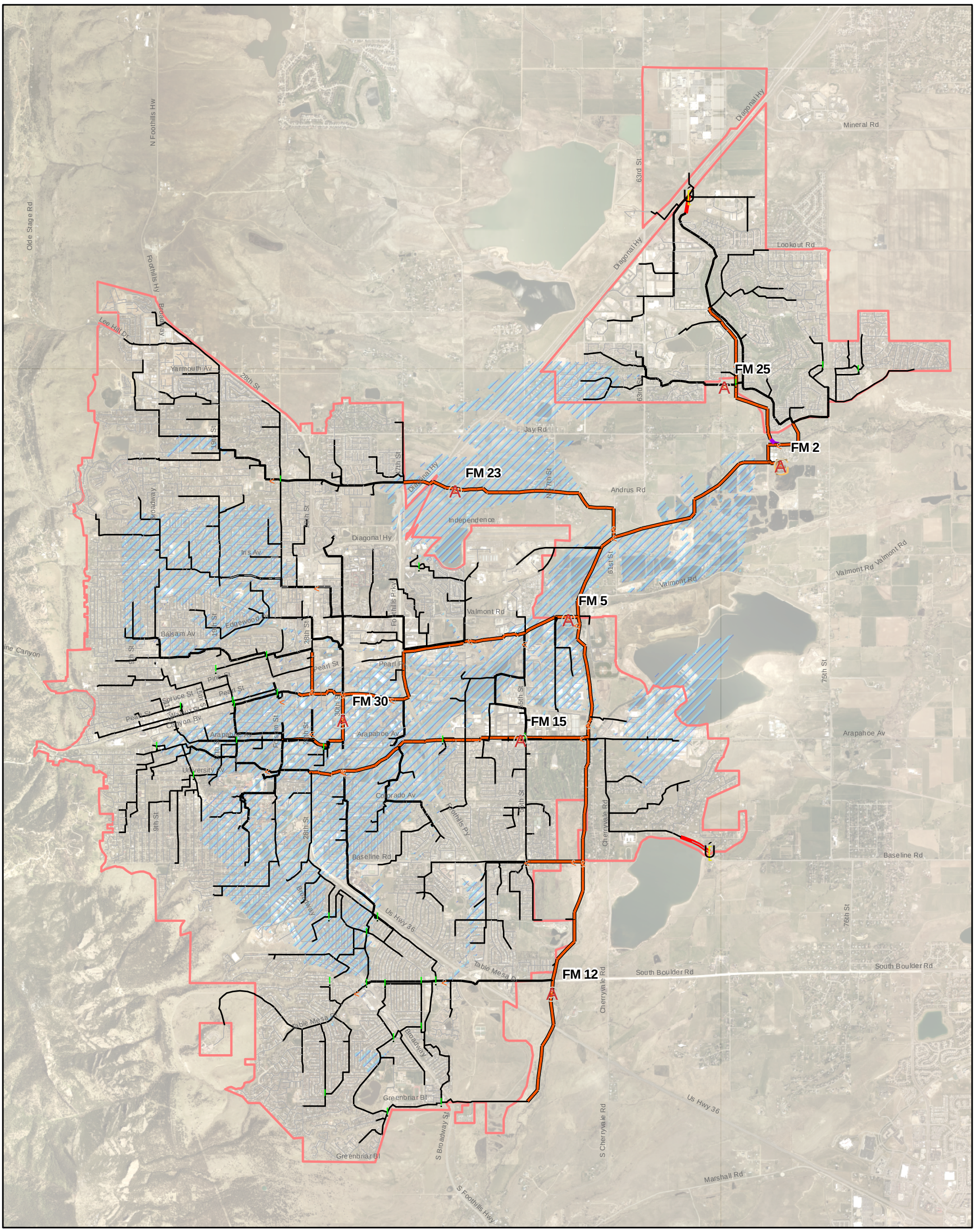
Predominant Land Use by Sewershed

Figure 4-6



1 inch equals 4,000 feet

Legend

Manholes

- Div MH
- Lift Statn
- WWTP
- Flow Meter for Calibration
- Flow Meter (Not Used)

Existing Sewers

- Interceptor
- Collector
- Local Collector
- Local
- Coll/Int (Siphon)
- Forcemain

- WUSA
- Shallow Groundwater

O

Selected Temporary Flow Meter Locations for Model Calibration

Figure 4-10

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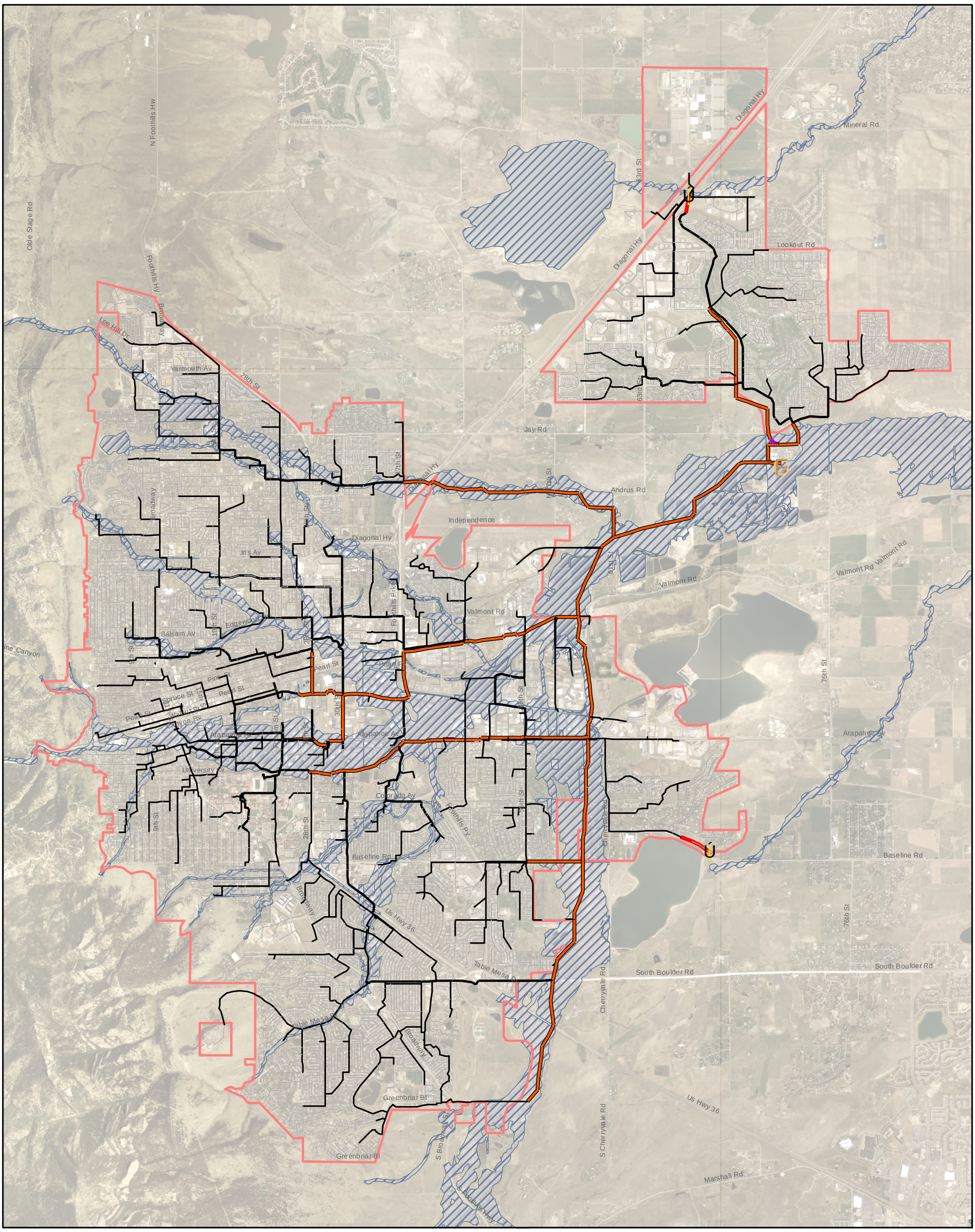

1 inch equals 4,000 feet

Legend

Manholes

- Lift Statn
- WWTP
- WUSA Boudary
- Areas of Incresed RDII Allowance

Existing Sewers

- Interceptor
- Collector
- Local Collector
- Local
- Coll/Int (Siphon)
- Forcemain

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RDII Allowance Areas

Figure 4-11

Boulder Wastewater Utility Master Plan

SECTION 5

Conveyance System Analysis

The purposes of the conveyance system analysis were to 1) document the analysis of the existing collection system during dry weather and wet weather flows and 2) to identify and characterize hydraulic capacity issues. By analyzing the existing collection system under existing and buildout flow conditions against the established system analysis criteria, problem areas were identified for both land use scenarios. Characterizing the system problems assisted in developing and prioritizing system improvement alternatives and recommendations.

5.1 System Analysis Criteria

A hydraulic analysis using the calibrated collection system model enables locating problem areas during dry weather and wet weather scenarios both under existing and buildout conditions. Only the pipes identified in the analyzed system as previously discussed were included in the capacity analysis. To accomplish the analysis, project capacity criteria were developed based on discussions with city staff and Boulder's Design and Construction Standards (DCS). These criteria also aided in the development of system improvements to verify that the problems have been resolved. Problem identification criteria are based on full-flow (or percentage thereof) within pipes and with surcharge conditions at manholes being identified as system problem locations.

The criteria remain the same for existing and future buildout scenarios but differ between peak dry weather and peak wet weather flow scenarios. The problem identification criteria established for this project are comprised of the following:

1. Local Collector / Collector System (8" - 24")
    a. Sanitary sewer overflows (SSO) prohibited
    b. Peak-hour dry weather - flow equal to depth of one-half of the full pipe (50% d/D)
    c. Peak-hour wet weather - flow depth equal to the full pipe (100% d/D)
2. Interceptor (> 24") System
    a. Sanitary sewer overflows (SSO) prohibited
    b. Peak-hour dry weather - flow equal to depth of 70% of the full pipe (70% d/D)
    c. Peak-hour wet weather - flow depth equal to the full pipe (100% d/D)

The interceptor system has a greater peak-hour dry weather criteria value since the interceptor system is larger than the collector system and equal flow increases do not affect the flow depth as drastically in the interceptors compared to the local collector and collector system pipes. Additionally, the interceptors typically have greater flow depth versus pipe diameter (d/D) values during normal dry weather conditions. For the collector system, the design criteria set forth in the DCS, Section 6 - Wastewater Design, Paragraph 6.06 (A) (2) are the same as presented above for peak-hour, although the DCS does not differentiate between dry and wet weather conditions.

5.2 Model Results

The model results were compared against the analysis criteria to locate potential hydraulic problems within the system. Results from the calibrated model were obtained from the four scenarios which include existing and buildout dry weather and wet weather conditions. The model results were recorded during peak-hour flows for each individual pipe to capture the worst-case loading scenario throughout the system. In other words, the maximum d/D that occurred in the pipes during the entire scenario run was used as the results for analysis. In the upstream sections of the system, this could happen as early as 7 to 8 am, but at the downstream end the maximum d/D occurs around 11am. These model results represent the greatest stress placed on the collection pipes during each scenario. Manhole freeboard depth was also taken from the model results to locate possible SSO risk. A summary of peak-hour flows at the WWTP are shown in Table 5.1 for each of the four scenario runs.

Table 5.1 – Summary of Peak Hour Flows at WWTP

Scenario	Existing Dry Weather	Existing Wet weather	Buildout Dry Weather	Buildout Wet weather
Total System Flow (mgd)	**20.7**	**50.0**	**25.8**	**55.3**

The model results are depicted in Figures 5-1, 5-2, 5-3, and 5-4 for existing dry weather, existing wet weather, buildout dry weather, and buildout wet weather scenarios. Potential problem pipes based the established criteria and manholes with freeboard of less than 1 foot are highlighted. Manholes with freeboard of less than 1 foot are considered at-risk for SSOs.

5.3 Problem Identification and Characterization

The collection system pipes with identified capacity limitations, established from the model results, were examined to identify likely hydraulic issues under the various flow scenarios. There are a total of 138 pipes in the analyzed collection system with hydraulic deficiencies identified. A problem identification and characterization process was completed to better understand the nature and extent of these problems.

5.3.1 Problem Identification

The hydraulic problems were separated into two categories: Type A and Type B. Type A problems consisted of a series of under capacity pipes that were hydraulically connected to one another. Type B problems are isolated hydraulic restrictions that are not hydraulically connected to other problem locations or series of problem pipes. Type A problems accounted for 84% of the problem pipes or a total of 116 pipes with a cumulative length of approximately 7 miles of pipe. Type B problems accounted for the remaining 16% of problem pipes or a total of 22 pipes with a cumulative length of approximately 0.7 miles of pipe. Both Type A and Type B problems will have system improvement recommendations developed and estimates of capital cost prepared. It is envisioned that Type A problems will be identified as recommendations for capital improvements while the Type B problems will be addressed through coordination with development activities, system repair and rehabilitation (R&R) work, or replacement with other city department CIP projects.

A total of twelve Type A problems locations or groups were identified based on the relative proximity of the problem pipes and hydraulic connectivity (Figure 5-5). Each problem group was

given an identification location named by the sewer basin which contained the problem pipes followed by an identification number.

During the initial problem identification process, it was observed that the system hydraulics for several Type B problems was based on assumed/interpolated pipe data. The interpolated inverts or assumed diameters were assigned as the field survey did not obtain data at these locations. Because the Type B problem pipe are not hydraulically connected to a series of other problem pipes, the identified problem pipes were over-ridden due to the assumed nature of the base data. The Type B problem over-rides were noted in the GIS removed from the problem identification process for further data investigations and analysis.

5.3.2 Problem Characterization – Type A Problem Locations

Type A problem locations were characterized using a set of descriptive categories to better understand the nature, extent, and hydraulics of the problems for the eventual development of improvements. Table 5.2 identifies the descriptive categories and what they entail in helping to define the problem groups. Tables 5.3 through 5.14 characterize each of the problem groups utilizing the descriptive categories.

TABLE 5.2 PROBLEM CHARACTERIZATION CATEGORIES AND DEFINITIONS	
Location:	Identifies the sewer basin, major street intersection or adjacent feature.
Pipe Classification:	Identifies if the pipes are categorized as local collector, collector or interceptors. If the system is an interceptor or collector that is located along a creek corridor, the manhole lid condition (sealed or un-sealed) will be noted.
Diameter Range:	Summarizes the pipe diameters.
Material Types:	Summarizes the pipe material types.
Install/Rehab Date:	Identifies the average or predominant installation date of the pipes and also notes is segments have been recently rehabilitated through the O&M program.
Problem Extent (Existing):	Summarizes the total length of problem pipe under existing dry and wet weather flow scenarios.
Problem Extent (Buildout):	Summarizes the total length of problem pipe under buildout dry and wet weather flow scenarios.
Manhole SSO Risk (Existing):	Summarizes the number of manholes that have less than 1 foot of freeboard under the existing wet weather flow scenario. This information will not include manholes that are sealed.
Manhole SSO Risk (Buildout):	Summarizes the number of manholes that have less than 1 foot of freeboard under the buildout wet weather flow scenario. This information will not include manholes that are sealed.
Number of Services:	Identifies the number of sewer services connected to the problem pipes.
Calibration Confidence:	Identifies the calibration confidence in the vicinity of the problem area based on the results from the dry weather calibration of temporary flow meters. A qualitative ranking from low to medium to high is assigned to each problem area depending on accuracy of model versus meter flow. Problem areas not in the vicinity of a calibration flow meter are assigned a medium calibration confidence ranking. The calibration confidence ranking represents model confidence during the dry weather scenarios only since the temporary flow meter calibration was based on dry weather. Because of this, only the dry weather portion of the total flow and associated flow difference between temporary flow meter and model is represented during wet weather flow which establishes the greatest potential for capacity problems.
Data Confidence:	Summarizes the number of manhole inverts that did not have survey or as-built data and were then interpolated for modeling purposes. This category is presented as a percentage of the total number of manholes within the problem area. Data confidence of 100% indicates that all manhole invert data was obtained from as-built or survey data and was not adjusted as part of the network validation process.
Accessibility:	Identifies if the problem pipes are generally located in roadways, creek/stream corridors or other alignment conditions.
Comments:	Provides a brief problem assessment considering the characterization findings for each category.

TABLE 5.3 PROBLEM CHARACTERIZATION - BOULDER CREEK 1	
Location:	Boulder Creek Sewer Basin - Athens St and 17th St
Pipe Classification:	Local Collector and Collector along Boulder Creek (manholes sealed in High Hazard Zone)
Diameter Range:	8” - 15”
Material Types:	PVC, VC
Install/Rehab Date:	Install: varies (Unknown – 1981) / Rehab: none
Problem Extent (Existing):	ADWF: 356 feet, WWF: 902 feet
Problem Extent (Buildout):	ADWF: 880 feet, WWF: 1,350 feet
Manhole SSO Risk (Existing):	0
Manhole SSO Risk (Buildout):	0
Number of Services:	30
Data Confidence:	65% (Inverts adjusted on three of seven pipes, survey obtained for one pipe)
Calibration Confidence:	Medium
Accessibility:	Boulder Creek Corridor; Local and Arterial Roads
Comments:	Most of the problem pipes have relatively flat slopes which are causing deep pipe flow. Only one pipe segment is along Boulder Creek. Less overall problem pipe length than other locations. Flow conditions causing problems range from existing dry weather flows to only buildout wet weather conditions.

TABLE 5.4 PROBLEM CHARACTERIZATION - BOULDER CREEK 2	
Location:	Boulder Creek Sewer Basin - Colorado Ave and 28th St
Pipe Classification:	Local Collector, Interceptor
Diameter Range:	8”-21”
Material Types:	VC
Install/Rehab Date:	Install: varies (Unknown – 1976) / Rehab: varies (none, 2005, 2006)
Problem Extent (Existing):	ADWF: 2,566 feet, WWF: 2,774 feet
Problem Extent (Buildout):	ADWF: 3,354 feet, WWF: 2,538 feet
Manhole SSO Risk (Existing):	0
Manhole SSO Risk (Buildout):	0
Number of Services:	3
Data Confidence:	84% (Inverts adjusted on two pipes of fifteen, survey obtained for two pipes)
Calibration Confidence:	Medium
Accessibility:	Highway/Major Arterial Road
Comments:	Most of the problem pipes in this group run north to south on 28th St and have relatively shallow slopes which are causing deep pipe flow. Fairly high total length of problem pipe. Existing dry weather flows are causing problems in potentially older pipe constructed with vitrified clay.

TABLE 5.5 PROBLEM CHARACTERIZATION - BOULDER CREEK 3	
Location:	Boulder Creek Sewer Basin - Arapahoe Ave and Foothills Pkwy
Pipe Classification:	Interceptor
Diameter Range:	27-30”
Material Types:	RC
Install/Rehab Date:	Install: varies (unknown – 1997) / Rehab: none
Problem Extent (Existing):	ADWF: 0 feet, WWF: 469 feet
Problem Extent (Buildout):	ADWF: 469 feet, WWF: 2,620 feet
Manhole SSO Risk (Existing):	5
Manhole SSO Risk (Buildout):	5
Number of Services:	0
Data Confidence:	63% (Inverts adjusted on two pipes of seven)
Calibration Confidence:	Medium
Accessibility:	Highway/Major Arterial Road
Comments:	The problem pipes run west to east along Arapahoe Ave. Construction accessibility could be difficult. Problems occur generally at buildout, however there is a risk of SSOs at existing conditions as well.

TABLE 5.6 PROBLEM CHARACTERIZATION - BOULDER CREEK 4	
Location:	Boulder Creek Sewer Basin - Valmont Rd and 61st St to WWTP
Pipe Classification:	Interceptor along Boulder Creek Corridor (manholes sealed)
Diameter Range:	42-60”
Material Types:	RC, DI
Install/Rehab Date:	Install: varies (unknown – 1966) / Rehab: varies (none, 2003)
Problem Extent (Existing):	ADWF: 40 feet, WWF: 9,038 feet
Problem Extent (Buildout):	ADWF: 40 feet, WWF: 9,451 feet
Manhole SSO Risk (Existing):	0 (manholes are sealed)
Manhole SSO Risk (Buildout):	0 (manholes are sealed)
Number of Services:	0
Data Confidence:	100% (Inverts adjusted on zero pipes of twenty-one)
Calibration Confidence:	High
Accessibility:	Creek Corridor
Comments:	The influent sewer to the WWTP is expected to flow full during significant wet weather events and the problems are mainly due to rainfall-induced system increases. Construction access would be very difficult in this area. Given the sealed manholes, no service connections and the difficult access, this capital project should be considered a relatively lower priority.

TABLE 5.7 PROBLEM CHARACTERIZATION - GOOSE CREEK 1	
Location:	Goose Creek Sewer Basin - Iris Ave and 19th St
Pipe Classification:	Local Collector
Diameter Range:	8”
Material Types:	VC
Install/Rehab Date:	Install: Unknown / Rehab: varies (none, 2005)
Problem Extent (Existing):	ADWF: 351 feet, WWF: 1,224 feet
Problem Extent (Buildout):	ADWF: 351 feet, WWF: 1,224 feet
Manhole SSO Risk (Existing):	0
Manhole SSO Risk (Buildout):	0
Number of Services:	11
Data Confidence:	66% (Inverts adjusted on two out of seven pipes)
Calibration Confidence:	Medium
Accessibility:	Arterial Road
Comments:	Problem pipes in this group run north to south and have shallow slopes causing deep pipe flow. The sewer is undersized for the amount of flow seen in the pipes even during existing dry weather conditions.

TABLE 5.8 PROBLEM CHARACTERIZATION - GOOSE CREEK 2	
Location:	Goose Creek Sewer Basin - Lawry Ln and 16th St
Pipe Classification:	Local Collector
Diameter Range:	8-12”
Material Types:	VC, PVC
Install/Rehab Date:	Install: varies (unknown, 1982) / Rehab: none
Problem Extent (Existing):	ADWF: 0 feet, WWF: 0 feet
Problem Extent (Buildout):	ADWF: 1,825 feet, WWF: 1,825 feet
Manhole SSO Risk (Existing):	0
Manhole SSO Risk (Buildout):	0
Number of Services:	30
Data Confidence:	100% (No inverts adjusted)
Calibration Confidence:	Medium
Accessibility:	Local Street and Alleys
Comments:	The pipes in this problem area have quite a few services; however the problem generally occurs only at buildout wet weather conditions. SSO risk is comparatively on the low side. Alley construction will have utility coordination issues. This problem location parallels recommended improvements within the Boulder’s Stormwater Master Plan, which required sanitary sewer relocations.

TABLE 5.9 PROBLEM CHARACTERIZATION - GOOSE CREEK 3	
Location:	Goose Creek Sewer Basin - Mapleton Ave and 28th St
Pipe Classification:	Local Collector, Collector/Interceptor, Interceptor
Diameter Range:	8-24”
Material Types:	VC, RC
Install/Rehab Date:	Install: varies (Unknown) / Rehab: none
Problem Extent (Existing):	ADWF: 195 feet, WWF: 1,446 feet
Problem Extent (Buildout):	ADWF: 740 feet, WWF: 1,446 feet
Manhole SSO Risk (Existing):	0
Manhole SSO Risk (Buildout):	0
Number of Services:	3
Data Confidence:	62% (Inverts adjusted on two of six pipes)
Calibration Confidence:	Low
Accessibility:	Local Road, Highway
Comments:	The pipes in this group are undersized and have shallow slopes for the amount of flow experienced. Most of the problem pipes occur during existing wet weather flow conditions. The problem pipes are downstream of a flow diversion manhole.

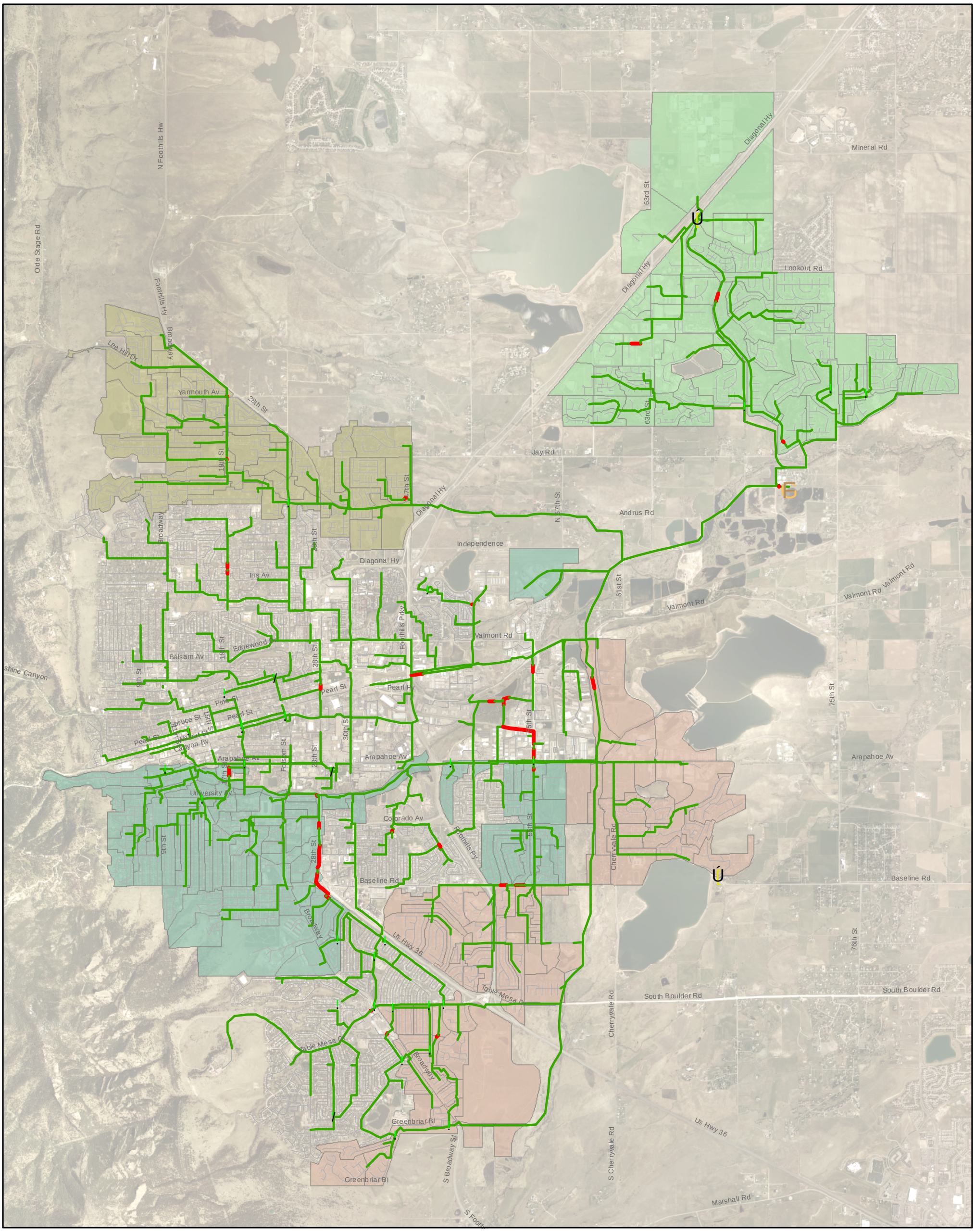
TABLE 5.10 PROBLEM CHARACTERIZATION - GOOSE CREEK 4	
Location:	Goose Creek Sewer Basin - Pearl St., Valmont Rd and Minshal Rd
Pipe Classification:	Interceptor along Goose Creek corridor (some manholes sealed)
Diameter Range:	21-36”
Material Types:	RC, VC
Install/Rehab Date:	Install: varies (Unknown, 1956, 1967) / Rehab: none
Problem Extent (Existing):	ADWF: 487 feet, WWF: 2,725 feet
Problem Extent (Buildout):	ADWF: 1,733 feet, WWF: 4,175 feet
Manhole SSO Risk (Existing):	0
Manhole SSO Risk (Buildout):	0
Number of Services:	1
Data Confidence:	61% (Inverts adjusted on five of twelve pipes)
Calibration Confidence:	Low
Accessibility:	Local and Major Road, Open Space, Stream Corridor
Comments:	The problem pipes in this group are along a stream corridor crossing local streets and major roads. A large amount of problem pipe identified at buildout conditions. Construction accessibility may be difficult.

TABLE 5.11 PROBLEM CHARACTERIZATION – GOOSE CREEK 5	
Location:	Goose Creek Sewer Basin – Arapahoe Ave and 55th St
Pipe Classification:	Local Collector, Collector and Interceptor
Diameter Range:	12-30”
Material Types:	VC, RC
Install/Rehab Date:	Install: varies (Unknown, 1957) / Rehab: varies (none, 1999)
Problem Extent (Existing):	ADWF: 2,953 feet, WWF: 6,470 feet
Problem Extent (Buildout):	ADWF: 4,861 feet, WWF: 6,766 feet
Manhole SSO Risk (Existing):	11
Manhole SSO Risk (Buildout):	13
Number of Services:	16
Data Confidence:	43% (Inverts adjusted on thirteen pipes of twenty-two)
Calibration Confidence:	Medium
Accessibility:	Highway, Major Road, Open Space
Comments:	The pipes in this area are undersized and can not convey existing flow conditions. Large amounts of pipe affected and SSO risk is high. There are a medium number of services that may be affected. Pipe may be aging as well. Data confidence in this area is on the low side. Construction along Arapahoe.

TABLE 5.12 PROBLEM CHARACTERIZATION – GUNBARREL 1	
Location:	Gunbarrel Sewer Basin – Boulder and Left Hand Ditch
Pipe Classification:	Collector
Diameter Range:	18”-21”
Material Types:	VC, PVC
Install/Rehab Date:	Install: varies (1965, 1994) / Rehab: none
Problem Extent (Existing):	ADWF: 347 feet, WWF: 1,284 feet
Problem Extent (Buildout):	ADWF: 347 feet, WWF: 1,628 feet
Manhole SSO Risk (Existing):	0
Manhole SSO Risk (Buildout):	0
Number of Services:	0
Data Confidence:	73% (Inverts adjusted on two of five pipes)
Calibration Confidence:	Medium
Accessibility:	Ditch Corridor, Open Space
Comments:	The problem pipes in this area are having a difficult time handling increasing flow from growth in the north part of the Gunbarrel sewer basin. Construction accessibility would need to be coordinated with the Ditch Company.

TABLE 5.13 PROBLEM CHARACTERIZATION - GUNBARREL 2	
Location:	Gunbarrel Sewer Basin - Jay Rd and Boulder Supply Canal
Pipe Classification:	Interceptor along Canal
Diameter Range:	24”
Material Types:	CC
Install/Rehab Date:	Install: Unknown / Rehab: none
Problem Extent (Existing):	ADWF: 0 feet, WWF: 1,257 feet
Problem Extent (Buildout):	ADWF: 0 feet, WWF: 1,257 feet
Manhole SSO Risk (Existing):	0
Manhole SSO Risk (Buildout):	0
Number of Services:	0
Data Confidence:	61% (Inverts adjusted on one of three pipes)
Calibration Confidence:	High
Accessibility:	Open Space, Canal Corridor
Comments:	Isolated section of pipeline upstream of the Gunbarrel siphon effected during existing and buildout wet weather flow conditions. Relatively low SSO risk.

TABLE 5.14 PROBLEM CHARACTERIZATION - SOUTH BOULDER CREEK 1	
Location:	South Boulder Creek Sewer Basin - Baseline Rd and 55th St
Pipe Classification:	Local Collector, Collector
Diameter Range:	12-15”
Material Types:	VC, PVC
Install/Rehab Date:	Install: varies (Unknown, 1978) / Rehab: none
Problem Extent (Existing):	ADWF: 610 feet, WWF: 610 feet
Problem Extent (Buildout):	ADWF: 610 feet, WWF: 610 feet
Manhole SSO Risk (Existing):	0
Manhole SSO Risk (Buildout):	0
Number of Services:	0
Data Confidence:	100% (Inverts adjusted on zero of two pipes)
Calibration Confidence:	Medium
Accessibility:	Major Road
Comments:	A small section of problem pipes with relatively shallow slopes. Problems occur under all flow conditions. No services connections.



Legend

1 inch equals 4,000 feet

Existing Sewers

- Local System (not analyzed)

Major Features

- Div MH
- Flow Split MH
- Lift Station
- WWTP

Problem Pipes

- < 0.5 or 0.7 d/D Criteria
- > 0.5 or 0.7 d/D Criteria

Manhole Freeboard

- Less than 1 ft

Sewer Basins

- Gunbarrel
- Fourmile
- Goose Creek
- Boulder Creek
- South Boulder Creek

Existing Peak Hour Dry Weather Scenario Model Results

Figure 5-1

Boulder Wastewater Utility Master Plan

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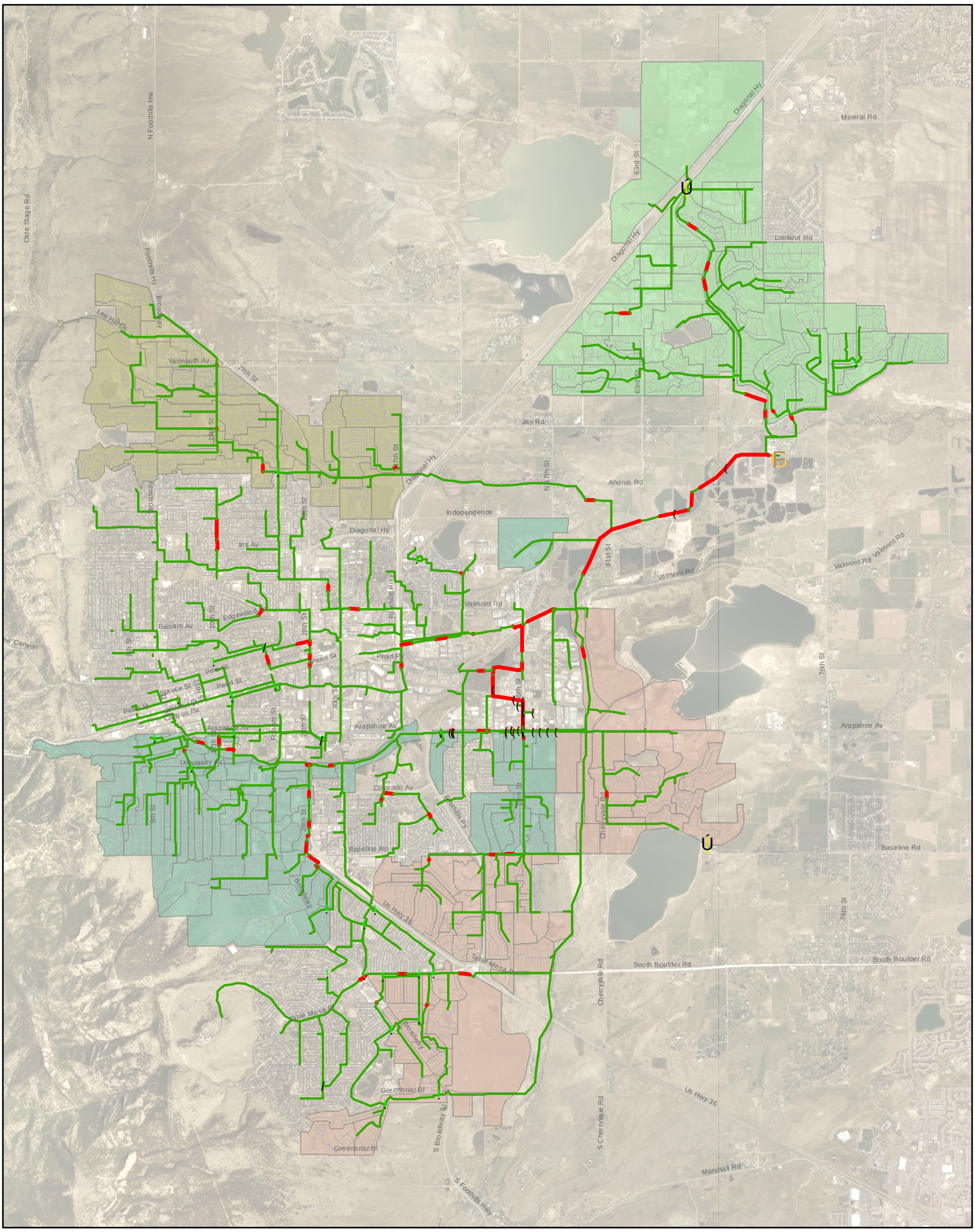

1 inch equals 4,000 feet

Legend

Existing Sewers

- Local System (not analyzed)

Major Features

- Flow Split MH
- Div MH
- Lift Station
- WWTP

Problem Pipes

- < 1 d/D Criteria
- = 1 d/D Criteria

Manhole Freeboard

- Less than 1 ft

Sewer Basins

- Gunbarrel
- Fourmile
- Goose Creek
- Boulder Creek
- South Boulder Creek

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Existing Peak Hour Wet Weather Scenario Model Results

Figure 5-2

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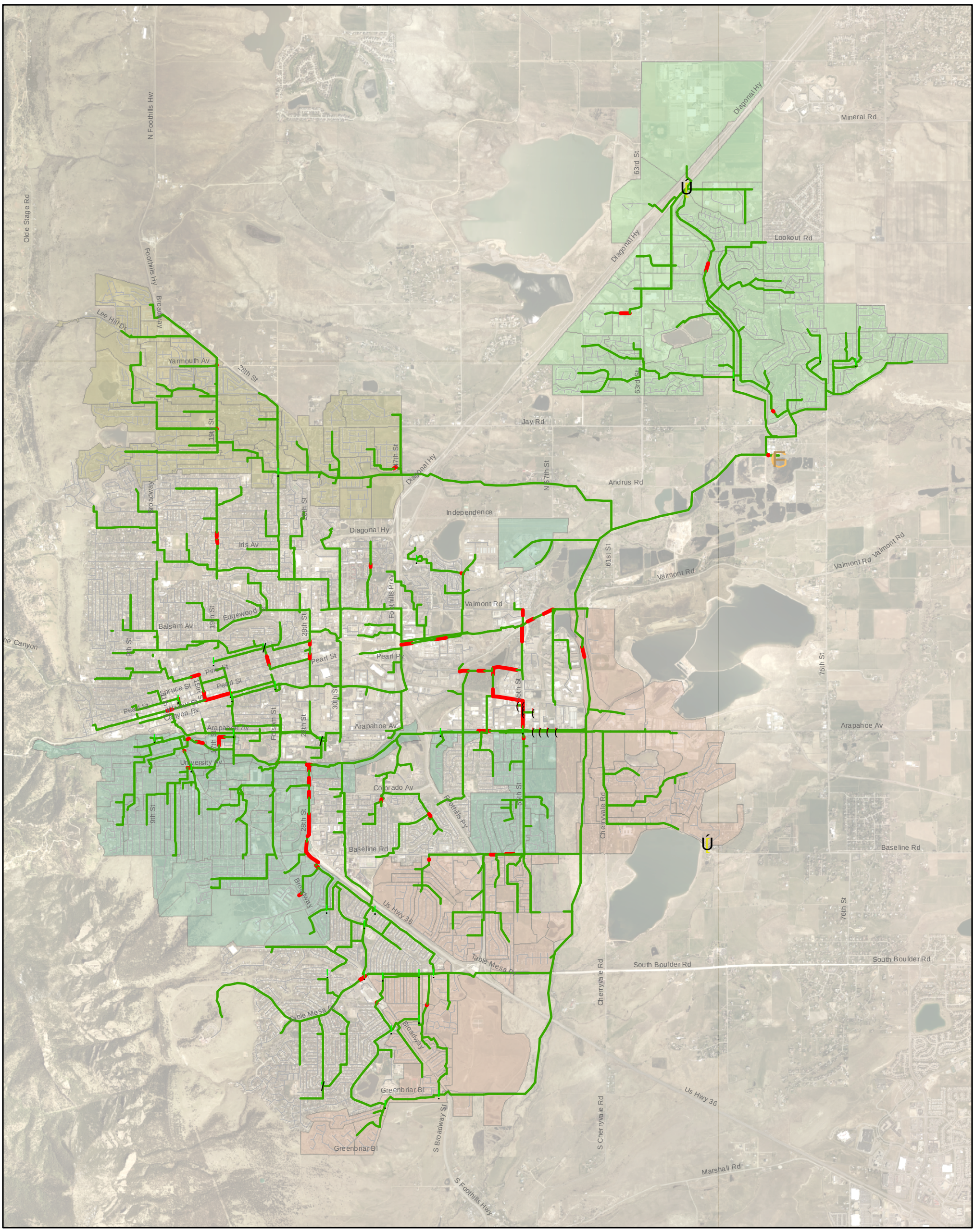
Boulder Wastewater Utility Master Plan



1 inch equals 4,000 feet

Legend

Existing Sewers

- Local System (not analyzed)

Major Features

- Flow Split MH
- Div MH
- Lift Station
- WWTP

Problem Pipes

- < 0.5 or 0.7 d/D Criteria
- > 0.5 or 0.7 d/D Criteria

Manhole Freeboard

- Less than 1 ft

Sewer Basins

- Gunbarrel
- Fourmile
- Goose Creek
- Boulder Creek
- South Boulder Creek

Buildout Peak Hour Dry Weather Scenario Model Results

Figure 5-3

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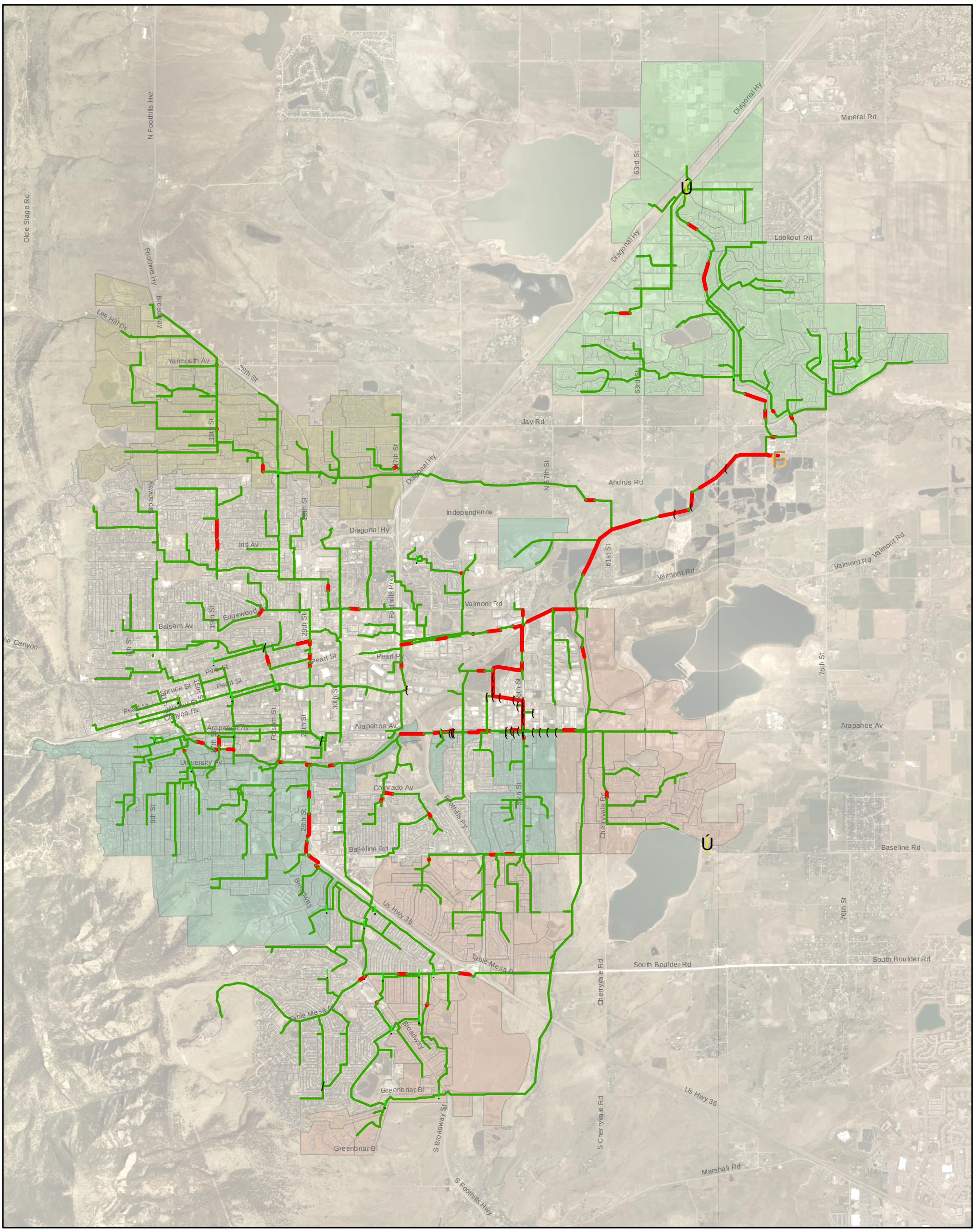

1 inch equals 4,000 feet

Legend

Existing Sewers

- Local System (not analyzed)

Major Features

- Flow Split MH
- Div MH
- Lift Station
- WWTP

Problem Pipes

- < 1 d/D Criteria
- = 1 d/D Criteria

Manhole Freeboard

- Less than 1 ft

Sewer Basins

- Gunbarrel
- Fourmile
- Goose Creek
- Boulder Creek
- South Boulder Creek

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Buildout Peak Hour Wet Weather Scenario Model Results

Figure 5-4

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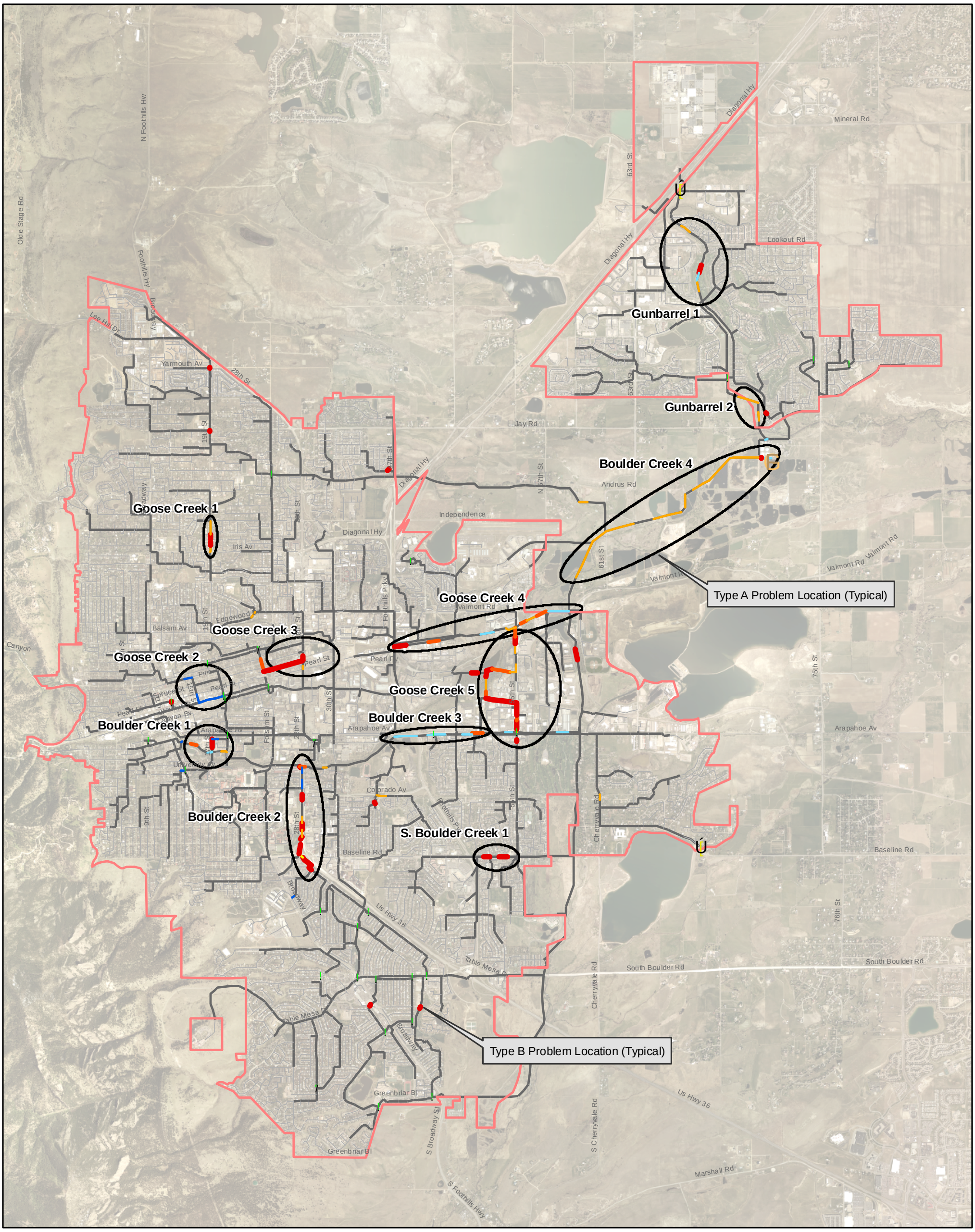

1 inch equals 4,000 feet

Legend

Existing Sewers

- Local System (not analyzed)
- Analyzed System

Major Features

- Flow Split MH
- Div MH
- Lift Station
- WWTP

Problem Scenario

- Future PDWF
- Future PDWF + Future PWWF
- Existing PDWF + Future PDWF
- Existing PWWF + Future PWWF
- Exsiting PWWF + Future PWWF + Future PDWF
- All Scenarios

- Problem Locations (Type A)
- WUSA

O

Type A and Type B Capacity Problem Locations

Figure 5-5

Boulder Wastewater Utility Master Plan

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SECTION 6

System Improvement Recommendations

In the Conveyance System Analysis Section, the hydraulic problems were separated into two categories; Type A and Type B. Type A problems consisted of a series of problem pipes and that were hydraulically connected to one another. Type B problems are isolated hydraulic restrictions that are not hydraulically connected to other problem locations or series of problem pipes.

6.1 Improvement Alternatives

Detailed alternatives were developed for the Type A problems as these capacity issues were more significant in flow and extent than the Type B problems. Because the Type B problems were not hydraulically connected to other problem pipes, improvements for these capacity issues were resolved with increases in pipe diameter.

6.1.1 Type A Problem Alternatives

Type A problem locations were characterized using a set of descriptive categories to better understand the nature, extent, and severity of the problems for the eventual development of improvements. Improvement alternatives for Type A problem locations were developed for each problem location to correct these hydraulic issues. Improvements were designed to convey the flow conditions during buildout wet weather and checked against analysis criteria for buildout dry weather. This design approach protects the improvements against future system loading conditions in addition to alleviating existing hydraulic problems.

Using the model, improvements developed for the alternatives were verified by checking that the hydraulic problems were remedied and the analysis criteria was met for each of the buildout flow scenarios. Alternatives developed include pipe replacement, parallel collection pipes, and flow diversions. Figures 6-1 and 6-2 show Alternative 1 and Alternative 2 improvements respectively, with the type of improvement thematically mapped. If there was not an option to develop a second alternative for a particular problem area, then Alternative 1 improvements were shown in Figure 6-2 for that problem area.

Multiple factors were considered in developing each alternative. Although each problem area had unique constraints and required a different set of improvements, a number of common themes were followed:

- To minimize capital expenditures, the existing infrastructure was used to the maximum extent possible.
- Diversions alternatives were investigated wherever possible with surrounding collection system infrastructure and controlling topology.
- Land acquisition, in terms of size and ownership and potential development pressures, was considered when locating system improvements.
- Where feasible, system improvements were located in public property and/or right-of-way.
- Improvements were developed to address each problem area starting at the downstream end and working upstream. This process ensures that only hydraulically deficient pipes were addressed, as opposed to pipes that have

adequate capacity but experience surcharging due to downstream bottlenecks.

During the development of alternatives for Goose Creek 1, the improvements caused downstream hydraulic problems to arise near 29th St and Valmont Rd. A new problem location was created and labeled Goose Creek 1A to address these new problem pipes. Goose Creek 1A was addressed along with Goose Creek 1 and is captured in its fact sheet since addressing one problem created another that needed attention. However, the costs were developed separately to capture the costs associated with each problem location.

6.1.2 Type A Alternative Evaluations

Alternative fact sheets were used to summarize information regarding each problem and corresponding alternatives which were used to qualitatively evaluate the alternatives. Each fact sheet includes the problem area identification code that can be referenced to TM 7.1 System Improvement Plan included in Volume 2 of this report. The recommended alternative for the problem area was noted on each fact sheet. Table 6.1 provides the alternative summary categories for the fact sheets that were used to document the improvement alternatives considered.

Table 6.1 Problem Summary and Improvement Alternatives - Fact Sheet Definitions	
Problem Summary	
Location:	Identifies the sewer basin and major street intersection or adjacent feature.
Problem Summary:	Summarizes the system problems as developed using the problem identification criteria.
Improvement Alternatives	
Alternative Summary:	Provides a narrative of the components for each alternative developed. This includes a description of alignment corridors, pipe diameters and lengths, and other improvement-related information needed to implement the project.
Technical Data:	Summarizes the hydraulic data involved with implementing the improvements including expected design flows, pipe slopes, and depth of flow. All values are averages across the pipes for each system.
Land Ownership:	Summarizes existing land ownership and any land acquisition required to implement the alternative.
Permitting:	Summarizes any permitting or mitigation issues likely to be associated with the alternative.
Sewer Services:	Total number of services that will need to be reconnected across improvement area.
Constructability:	Summarizes additional construction issues such as pace of construction due to utility conflicts and surface restoration requirements due to location of improvements.
Bypass Pumping Requirements:	Identifies if bypass pumping is required and what approximate peak flow may be encountered during pumping operations. Temporary

	construction diversions opportunities are recognized where available.
Benefits:	Identifies if the problems are resolved. Also identifies the benefits relative to another alternative described for the same problem location.
Issues:	Identifies issues that would affect construction and maintenance for each alternative. Examples include major utility relocations, high groundwater, significant roadway closures, etc. Also identifies special construction techniques necessary to implement the alternatives. Also identifies if the alternative does not alleviate deficiencies within a problem area.
Recommendation Comments:	Provides a brief narrative on the deciding factors of the recommended improvement alternative.

The identification of the recommended alternative was based a qualitative assessment of the information presented in the fact sheets. In addition, factors including alignment opportunities, utility constraints, land ownership, perceived cost and whether the project could be connected with other planned City capital improvements were also considerations in identifying the recommended alternative.

6.1.3 Type B Problem Improvement Recommendations

Type B problems identified in Section 5 were addressed with pipe replacements and verified with the model. No alternatives were developed for the Type B improvements. Additional Type B problems were addressed which arose from implementing the Type A improvements in the model. Type B pipes whose flow was within 10% of capacity, in other words, having a Q ratio (q/Q) of less than 1.1 were overridden. Additionally, some pipes with edited invert data that had lower Q ratios were overridden since the data confidence is lower. All overridden problem pipes will not show up on the figures but have been kept and marked as overridden in the Type B problem pipe shapefile. Figure 6-3 depicts Type B improvements with the original and replacement pipe sizes. Type B improvement costs will be addressed as one lump sum in the cost estimate section.

6.2 Recommended Improvement and Priorities

The recommended system improvements that resolve the existing and future capacity issues are shown on Figure 6-4. This figure includes improvements that address both Type A and Type B problems.

The recommended improvements were grouped in three tiers to establish implementation priority:

- Tier 1 projects address Type A problems and have the highest priority;
- Tier 2 projects also address Type A problems but have lower priority compared to Tier 1;
- Tier 3 projects address Type B problems which have the lowest priority.

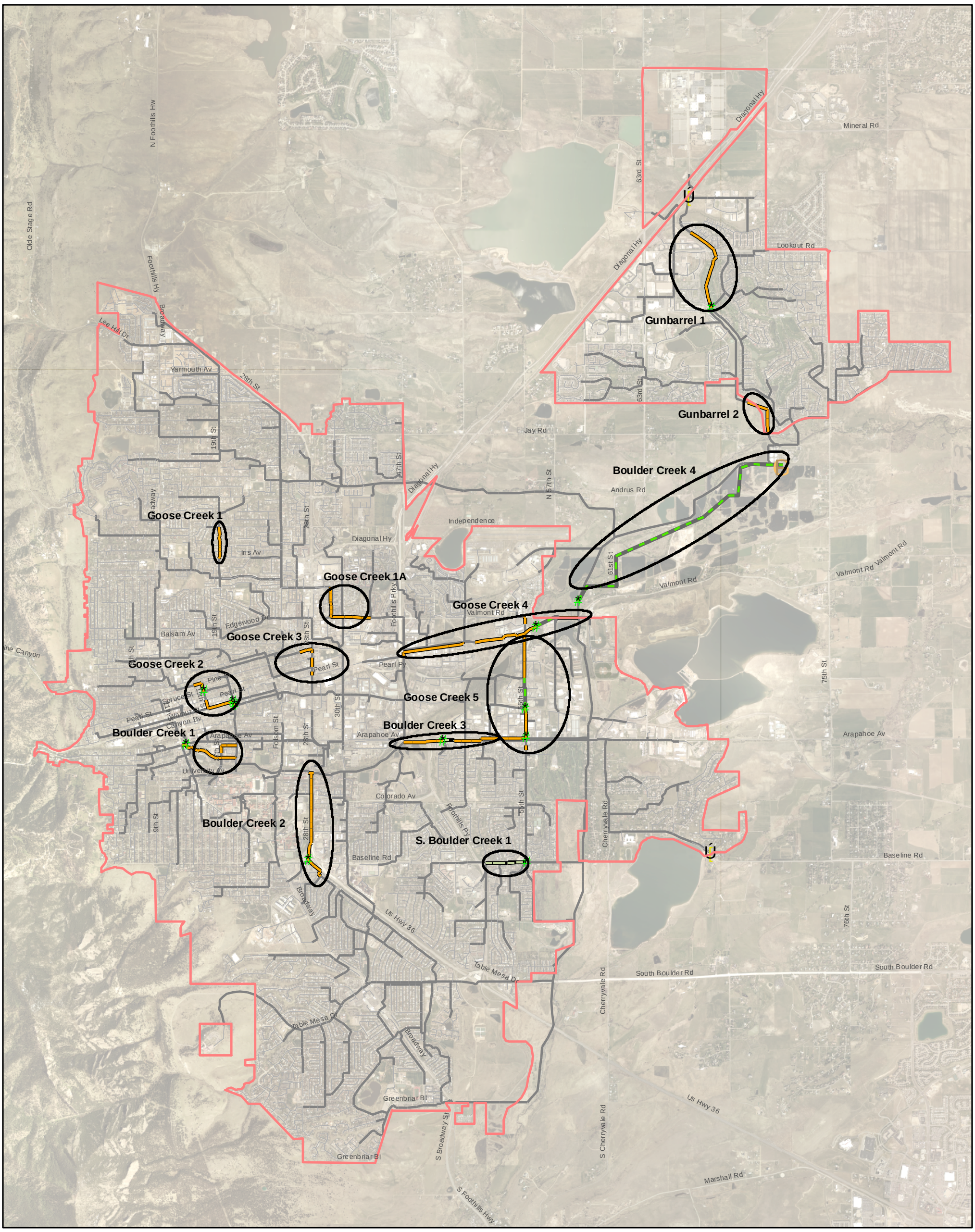
The improvement priorities were assigned based on a number of qualitative factors including the flow conditions in which they occur (existing versus future), extent of the problem, potential for SSOs and service lateral backups, ease of constructability, and relative benefit over other improvement projects. The relative benefit takes into account the amount of pipe replaced

compared to the extent of the problem remedied. These factors were summarized in the problem characterization tables in Section 5 of this report.

Table 6.2 lists each Type A problem area with a relative ranking (low, medium, high) for each of the priority factors based on a comparison between problem areas. Tier 1 or 2 is assigned in the last column depending on the overall outcome of the priority factor ranking with the number of categories containing more high rankings reigning.

TABLE 6.2 IMPROVEMENT PRIORITY RANKING

	Priority Factor Ranking						
Problem Location	**Problem Extent**	**SSO Risk**	**Lateral Backup Risk**	**Construct-ability**	**Relative Benefit**	**Flow Condition**	**Priority Tier**
Boulder Creek 1	Low	Low	High	Medium	Medium	Medium (Existing and Future)	Tier 2
Boulder Creek 2	High	Low	Medium	High	High	High (Existing)	Tier 1
Boulder Creek 3	Medium	Medium	Low	Low	Medium	Medium (Existing and Future)	Tier 2
Boulder Creek 4	Medium	Low	Low	Medium	Low	High (Existing)	Tier 2
Goose Creek 1/1A	Medium	Low	High	High	High	High (Existing)	Tier 1
Goose Creek 2	Low	Low	High	Medium	Medium	Low (Future)	Tier 2
Goose Creek 3	Medium	Low	Medium	Medium	Medium	High (Existing)	Tier 1
Goose Creek 4	High	Low	Low	Medium	Medium	Medium (Existing and Future)	Tier 2
Goose Creek 5	High	High	High	Medium	High	High (Existing)	Tier 1
Gunbarrel 1	Medium	Low	Low	High	Medium	Medium	Tier 2
Gunbarrel 2	Low	Low	Low	Medium	Medium	Medium (Existing Wet Weather)	Tier 2
South Boulder Creek 1	Low	Low	Low	Medium	High	High	Tier 2



1 inch equals 4,000 feet

Legend

Existing Sewers

- Analyzed System
- Local System (not analyzed)

Major Features

- Lift Station
- WWTP
- Flow Split Replacement Manhole

Pipe Improvement Type

- Parallel Interceptor
- Parallel Replacement
- Replacement

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Type A - Alternative 1
System Improvements

Figure 6-1

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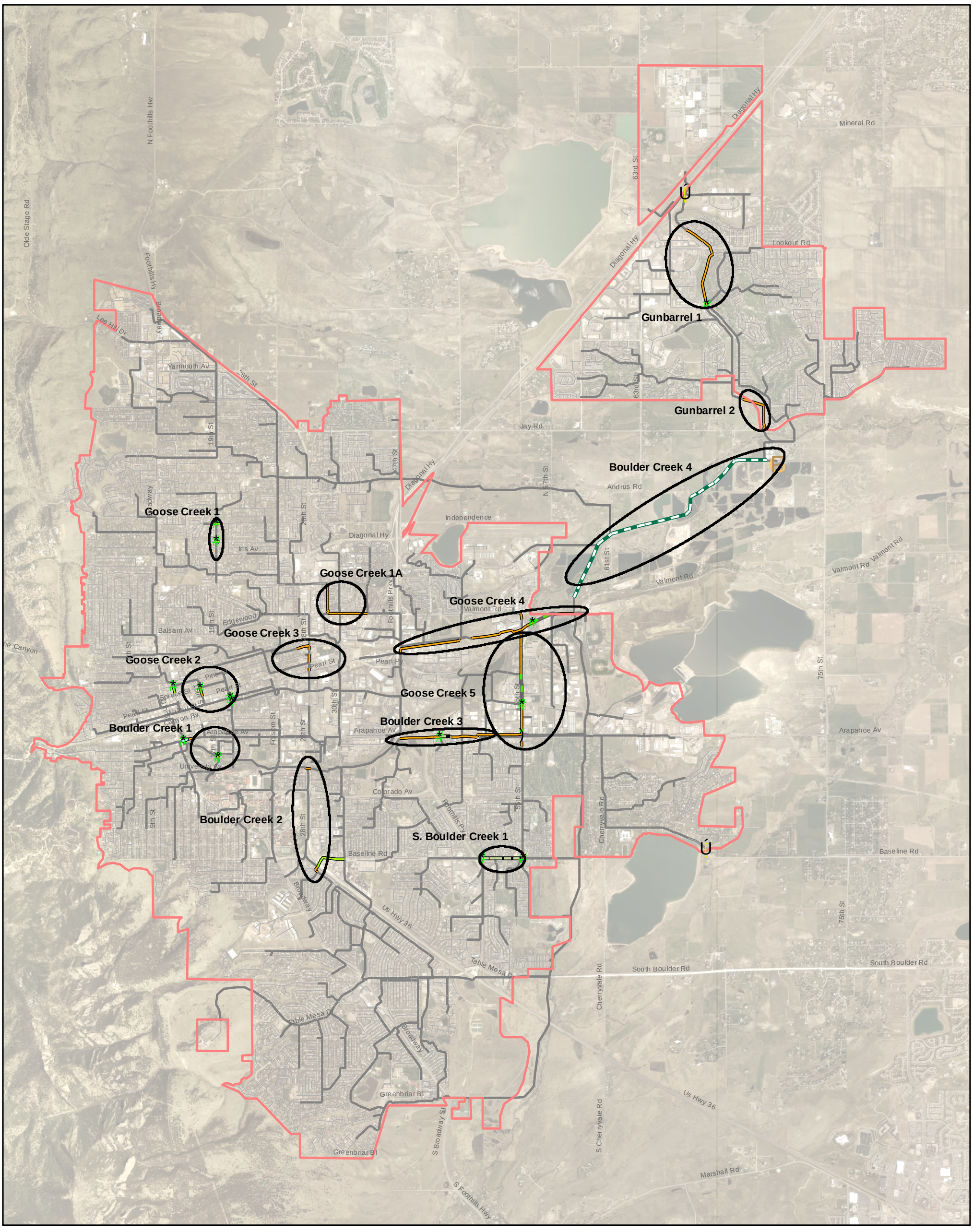

1 inch equals 4,000 feet

Legend

Existing Sewers

- Analyzed System
- Local System (not analyzed)

Major Features

- Lift Station
- WWTP

Manhole Improvement Type

- Diversion Replacement Manhole
- Flow Split Replacement Manhole

Pipe Improvement Type

- Replacement
- Diversion
- Diversion Siphon
- Parallel Interceptor
- Parallel Replacement
- Parallel Interceptor Replacement

O

Type A - Alternative 2 System Improvements

Figure 6-2

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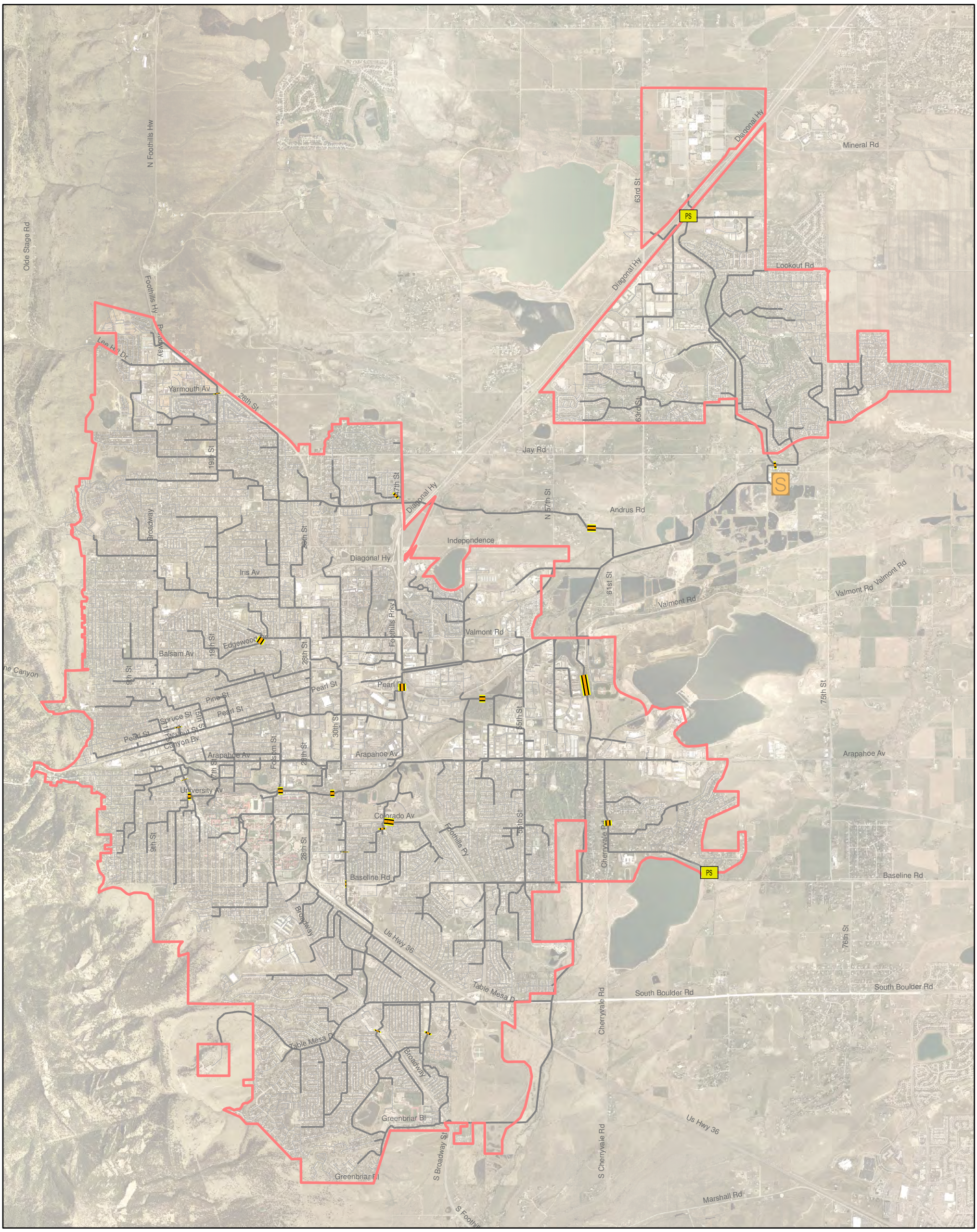

1 inch equals 4,000 feet

Legend

Existing Sewers

Analyzed System

Local System (not analyzed)

Pipe Replacement

WUSA Boundary

Major Features

PS Lift Station

S WWTP

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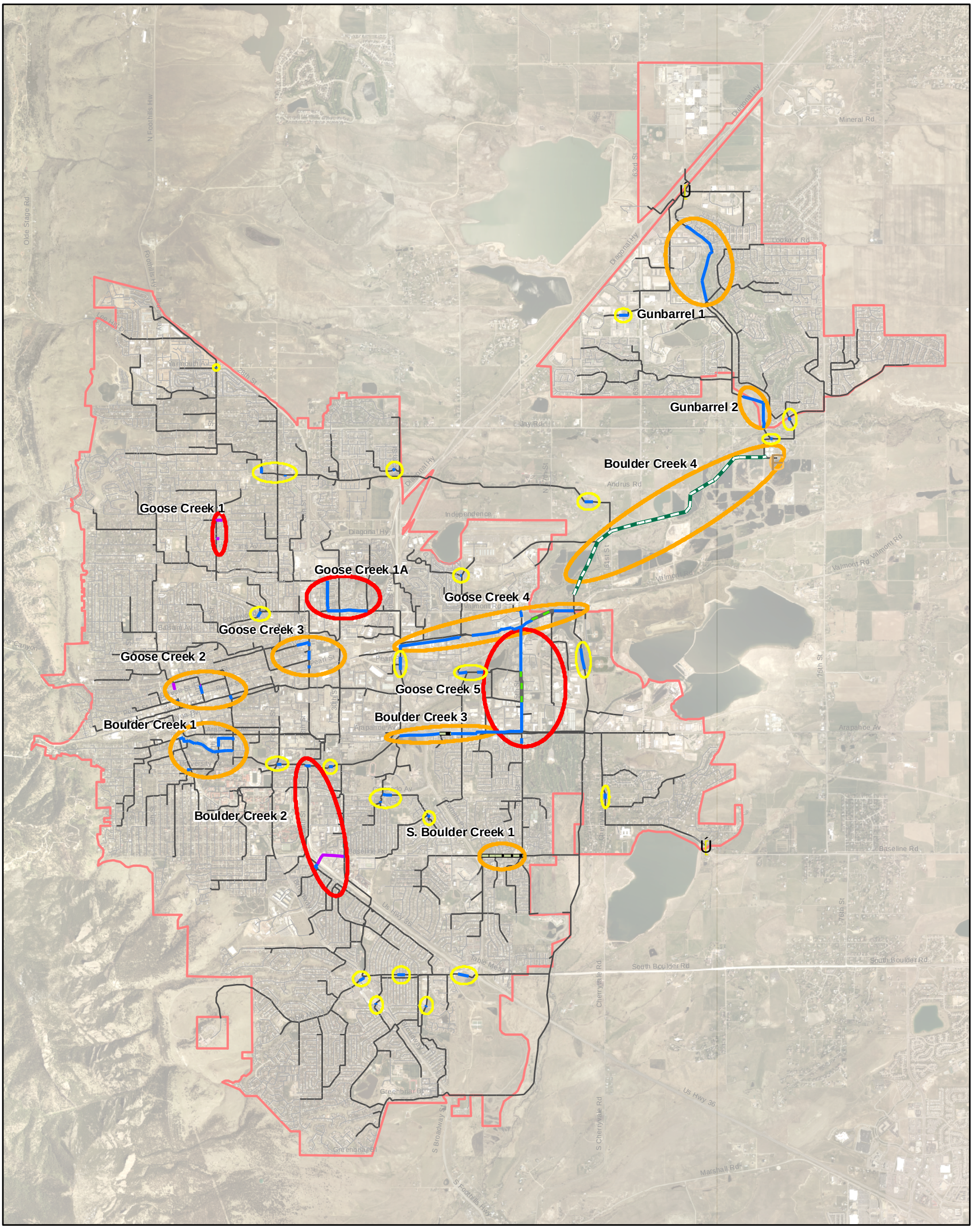
Type B System Improvements

Figure 6-3

Boulder Wastewater Utility Master Plan



1 inch equals 4,000 feet

Legend

Existing Sewers

- Local System (not analyzed)
- Analyzed System

Major Features

- Lift Station
- WWTP

Pipe Improvement Type

- Replacement
- Diversion
- Parallel Interceptor
- Parallel Replacement
- Parallel Interceptor Replacement
- WUSA Boudary

Improvement Priority

- Tier 1
- Tier 2
- Tier 3

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Implementation Plan with Recommended Improvements

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Figure 6-6

Boulder Wastewater Utility Master Plan

SECTION 7

Capital Project Recommendations

The purpose of this section is to document the recommended system improvements and associated capital costs captured within fact sheets. Recommended improvement fact sheets have been developed for the Tier 1 and 2 improvements (Type A problems). The Tier 1 and Tier 2 fact sheets include individual improvement diagrams providing additional detail of the project area. Tier 3 improvements (Type B problems) are captured with a single fact sheet and figure as these projects are isolated system improvements and are relatively minor in terms of scope.

7.1 Estimates of Capital Cost

Itemized cost estimates were developed for each CIP project with an anticipated level of accuracy of +50% to –30% (order-of-magnitude cost estimates). The cost estimate worksheets are included in the appendix for reference. The estimates include capital construction costs and estimated land acquisition costs. Unit costs were obtained from recent bid tabs and *Site Work and Landscape Cost Data, RSMeans®*, and equipment suppliers. Unit costs for pipeline construction, manholes and inlets include material, excavation, and backfill. Surface restoration was developed as a separate cost item. Utility relocation cost were developed as a separate item for sewer line relocations and for watermain lowerings 16" in diameter and greater. Minor utility relocations, including water and sewer service laterals, were accounted for as a percentage of the total construction cost. Quantities for pipes, inlets, manholes, and water quality facilities were obtained from the project GIS.

The cost estimates include a 30% construction contingency and an 18% allowance for engineering and administration. All estimates are in 2008 dollars and equate to an *Engineering News Record, Construction Cost Index* of 8557.

7.2 Implementation Plan

Table 7.1 summarizes the implementation priorities as developed in Section 6 along with estimates of capital construction costs. Itemized capital cost estimate worksheets are included in Volume 2 of this report.

TABLE 7.1 CAPITAL PROJECT IMPLEMENTATION RECOMMENDATIONS

Problem Priority	Improvement ID	Location	Capital Cost
Tier 1	Boulder Creek 2	Colorado Ave and 28th St	$733,000
Tier 1	Goose Creek 1/1A	Iris Ave and 19th St	$1,203,000
Tier 1	Goose Creek 3	Spruce St and 24th St	$482,000
Tier 1	Goose Creek 5	Arapahoe Ave and 55th St	$2,559,000
		TIER 1 TOTAL	**$4,977,000**
Tier 2	Boulder Creek 1	Colorado Ave and 28th St	$1,653,000
Tier 2	Boulder Creek 3	Arapahoe Ave and Foothills Pkwy	$1,939,000

TABLE 7.1 CAPITAL PROJECT IMPLEMENTATION RECOMMENDATIONS			
Problem Priority	**Improvement ID**	**Location**	**Capital Cost**
Tier 2	Boulder Creek 4	Valmont Rd and 61st St to WWTP	$12,356,000
Tier 2	Goose Creek 2	Lawry Ln and 16th St	$302,000
Tier 2	Goose Creek 4	Pearl St, Valmont Rd and Mishal Rd	$3,928,000
Tier 2	Gunbarrel 1	Boulder Supply Canal & Left Hand Ditch	$1,116,000
Tier 2	Gunbarrel 2	Jay Rd and Boulder Supply Canal	$939,000
Tier 2	South Boulder Creek 1	Baseline Rd and 55th St	$733,000
		TIER 2 TOTAL	**$22,664,000**
		TIER 3 TOTAL[1]	**$2,296,000**
		TOTAL ALL PROJECTS TOTAL	**$29,937,000**

[1] Tier 3 costs represent approximately 13 localized improvement projects

7.3 Capital Project Fact Sheets

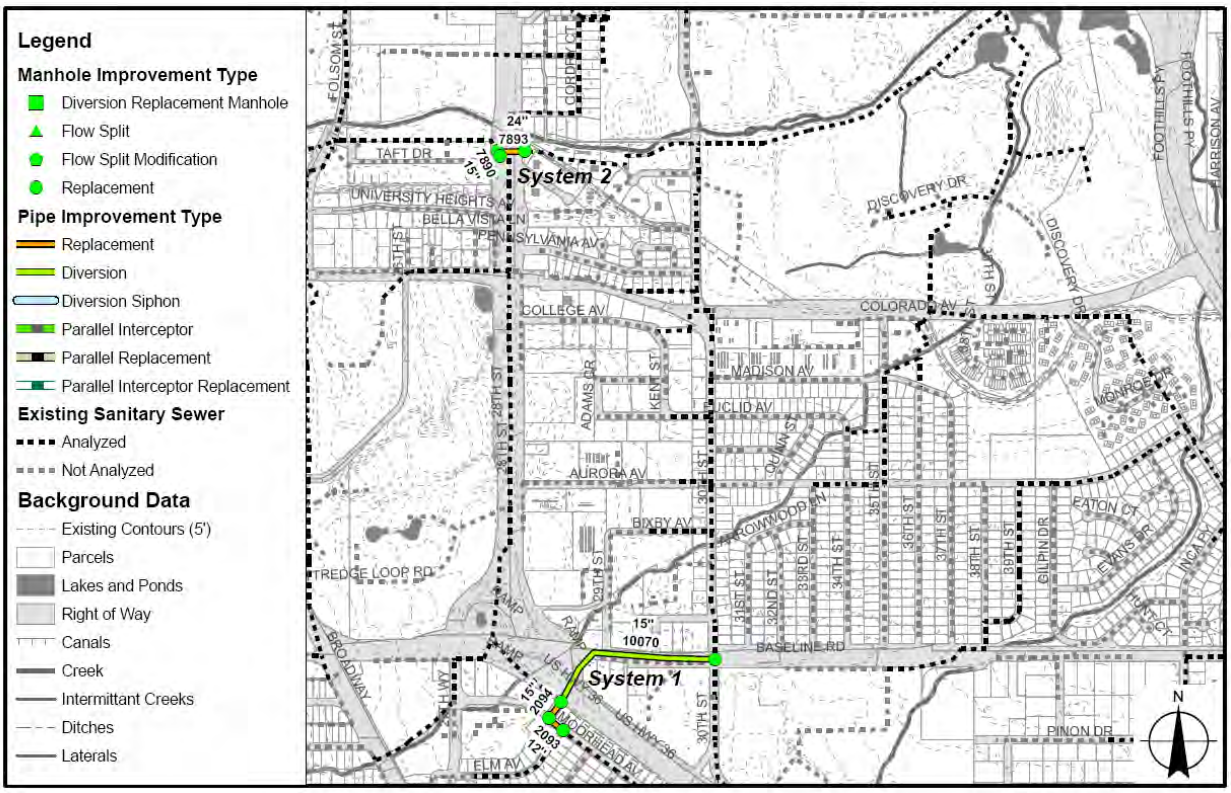
Fact sheets were developed to provide details regarding each of the Tier 1 and Tier 2 improvement areas. In addition, a fact sheet was also developed for the combined Tier 3 improvements. These fact sheets provide the problem area ID, improvement location and alignment, technical data for initiating the design process, land ownership and acquisition needs, implementation issues, and an estimate of the capital construction costs. Flow triggers are included for the interceptor improvements to provide a flow rate when capacity of interceptor is reached and when improvements should constructed. The improvement plan map shown in the fact sheets identify the recommended pipe size and model link ID. The model link ID can be used to query the GIS to determine other design data and evaluate model results as the projects progress into the design phase.

The Data Confidence category within the fact sheets refers to the number of interpolated invert elevations needed to complete the modeling effort; specific information regarding this category is included in the problem characterization tables in Section 5. Similarly, the Calibration Confidence refers to how well model results matched the temporary flow meter data. As noted in Section 5, calibration was performed for dry weather conditions only which are a relatively small fraction of the total wastewater flow the improvements have been designed to convey. As a result, a “Low” calibration confidence is not anticipated to remove the need for the improvement project but rather adjustments in pipe diameters or other hydraulic design elements. *It is recommended that projects with a Low or Medium confidence level in the Calibration and Data categories be refined through data surveys and/or temporary flow monitoring before they are included in the Utilities’ 6-year CIP project list to validate the project elements.*

7.4 Tier 1 Priority Improvements

This section includes fact sheets that provide details for each of the Tier 1 improvement areas.

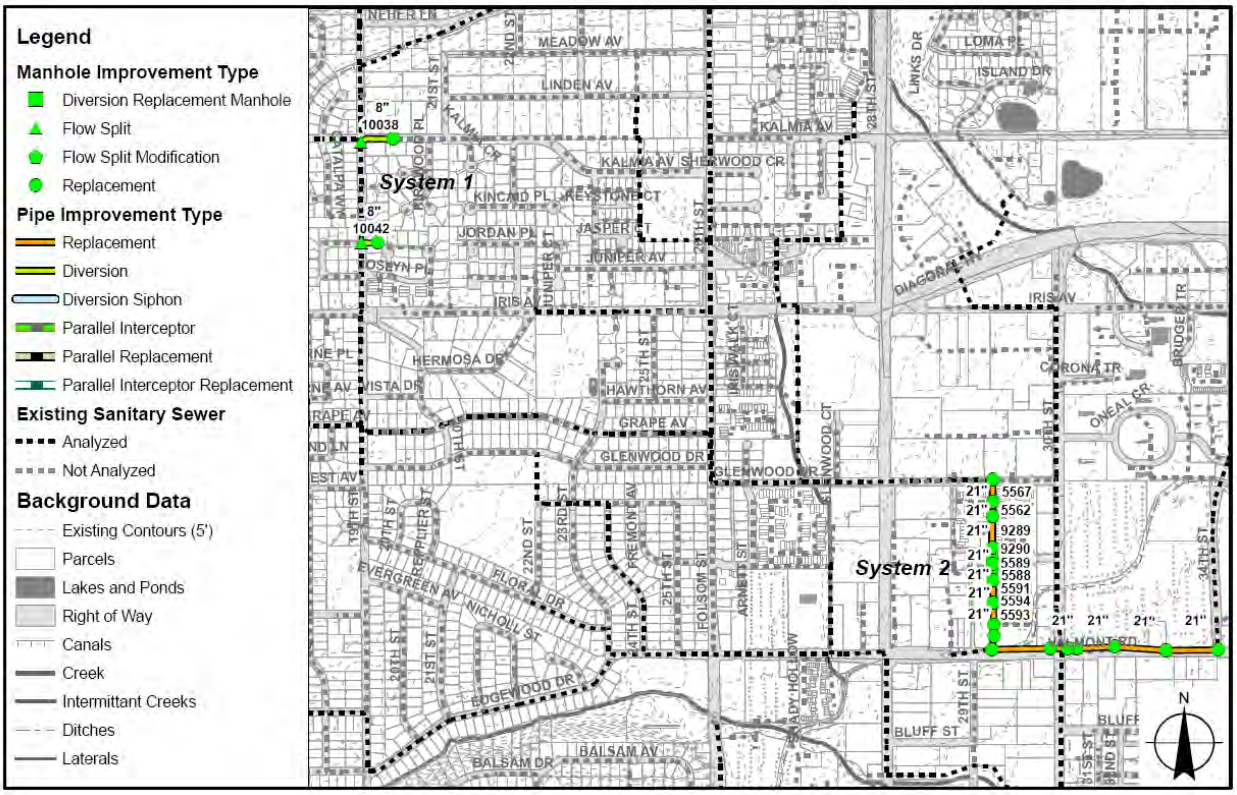
TABLE 7.2 - BOULDER CREEK 2 IMPROVEMENT FACT SHEET	
	Discussion
Improvement Location:	Boulder Creek Sewer Basin - Colorado Ave and 28th St
Problem ID:	**Boulder Creek 2 (Tier 1 Priority Level)**



Improvement Description	<u>Flow Diversion</u> System 1: Replace 145 feet of 8" local collector with 12" and 154 feet of 8" local collector with 15". Install 1,400 feet of 15" along Baseline Rd as a diversion from the 8" local collector that travels north along 28th St. System 2: Replace 39 feet of 8" local collector with 15" and 208 feet of 21" interceptor with 24" along the Boulder Creek Interceptor.
Alternative Recommendation Comments:	The flow diversion alternative is recommended since much less pipe is required than the replacement alternative and a crossing of Skunk Creek is not required.

TABLE 7.2 - BOULDER CREEK 2 IMPROVEMENT FACT SHEET	
	Discussion
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flow ranges from 300 gpm in System 1 to 1,100 gpm in System 2.
Data Confidence:	High
Calibration Confidence:	Medium
Flow Trigger:	3,600 gpm (in 21” interceptor along Boulder Creek)
Land Ownership:	All construction would be within the ROW with the exception of the new 15” diversion along Baseline Rd where ROW acquisition may be required.
Implementation Issues:	Constructability issues due to highway and major roads. Requires construction along Boulder Creek. Bypass pumping of large amounts of flow for System 2. Depending on depth of groundwater present in vicinity, dewatering may be required. Opportunities for parallel replacement of water mains with System 2. Surface treatment of concrete and asphalt pavement.
Capital Cost:	$733,000

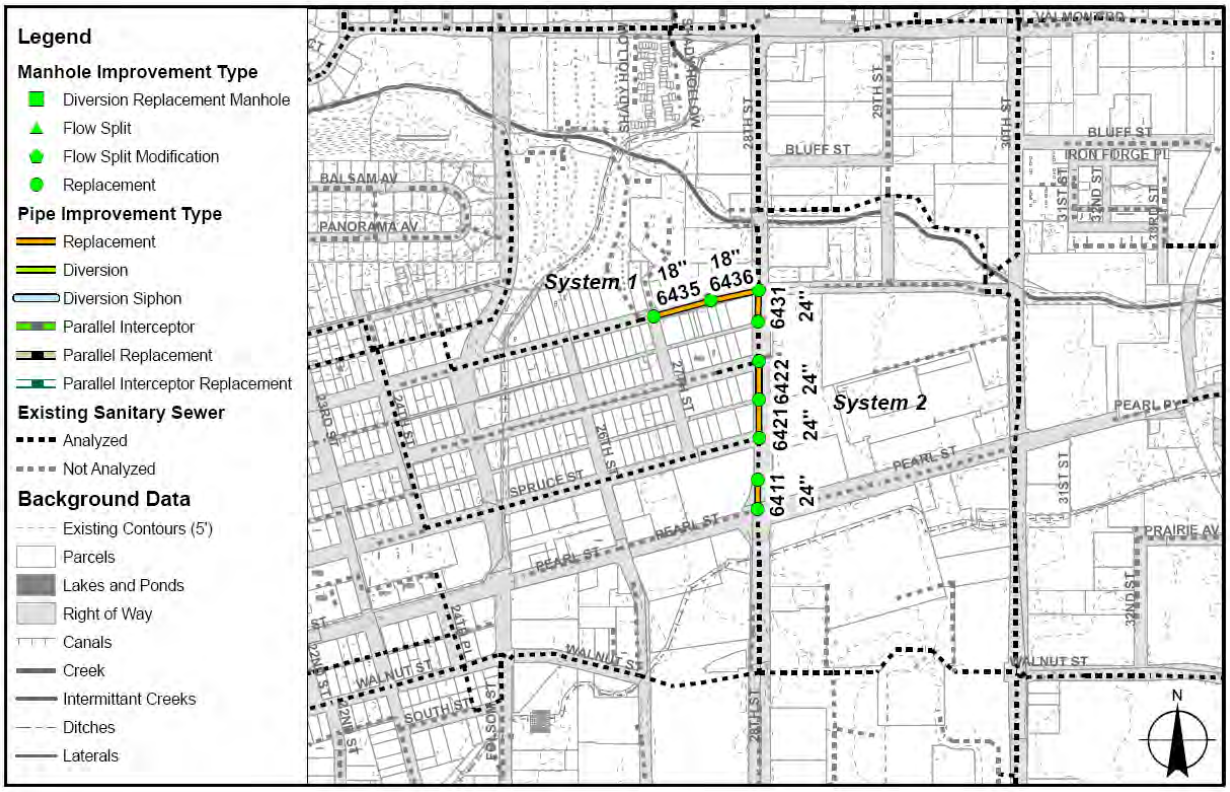
TABLE 7.3 - GOOSE CREEK 1 IMPROVEMENT FACT SHEET	
	Discussion
Improvement Location:	Goose Creek Sewer Basin - Iris Ave and 19th St
Problem ID:	**Goose Creek 1 / Goose Creek 1A (Tier 1 Priority Level)**



Improvement Description	<u>Flow Diversion</u> System 1: Goose Creek 1 - Install 376 feet of 8" local collector pipe as two diversions along side sides to take loading off of problem pipe. System 2: Goose Creek 1A - Replace 3,040 feet of 15" collector/interceptor pipe with 21" between the apartment complexes and along Valmont Rd.
Alternative Recommendation Comments:	The flow diversion alternative is recommended since it requires fewer pipes and bypass pumping. Goose Creek 1A is a replacement only project that is required due to the improvements involved with Goose Creek 1.
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flow ranges from 140 gpm in System 1 to 2,200 gpm in System 2.
Data Confidence:	Medium

TABLE 7.3 - GOOSE CREEK 1 IMPROVEMENT FACT SHEET	
	Discussion
Calibration Confidence:	Medium
Flow Trigger:	N/A
Land Ownership:	System 1: Construction is limited to ROW along local streets System 2: If ROW exists along green space between apartments or condos, then ROW should exist for entire improvement alignment as the rest is in streets.
Implementation Issues:	Constructability issues due to road and green space construction. Improvements cause downstream problems which require additional pipe replacement. Opportunity for parallel water main replacement in Systems 1 and 2. Surface treatment of open space and asphalt pavement.
Capital Cost:	Goose Creek 1 - $137,000, Goose Creek 1A - $1,166,000

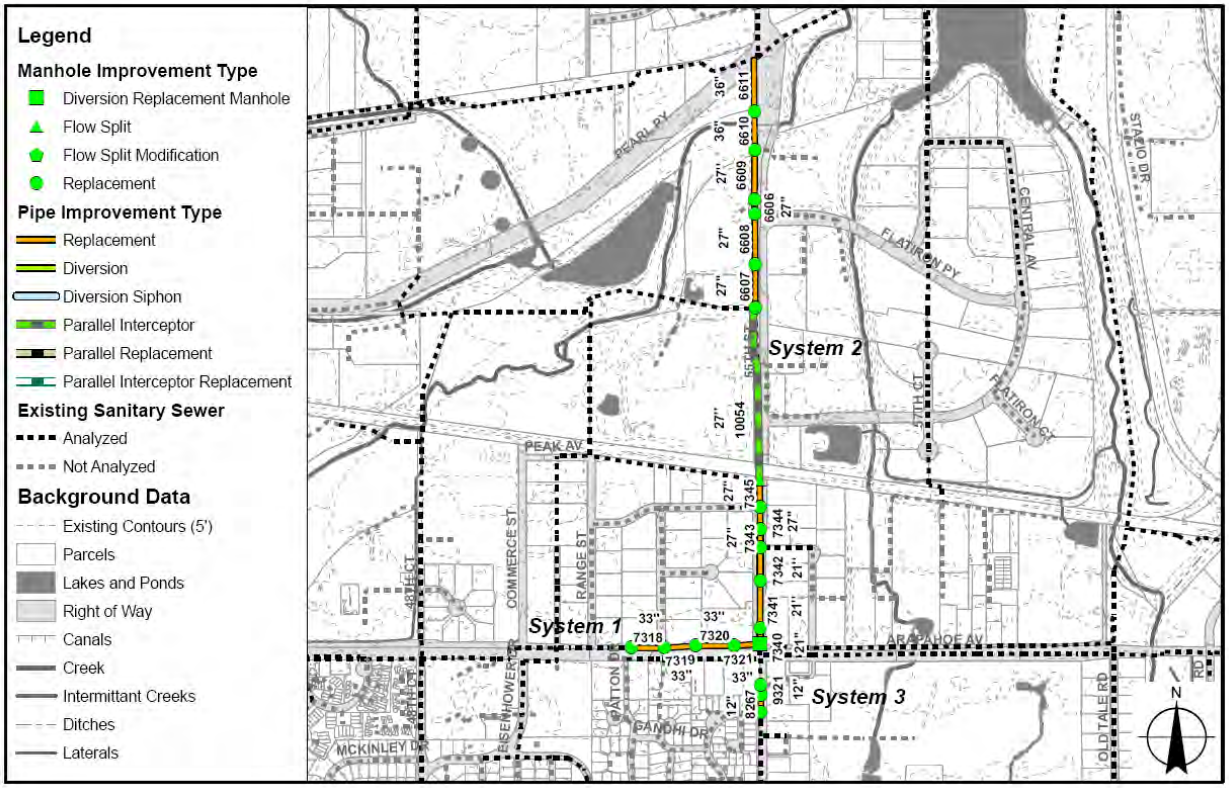
TABLE 7.4 - GOOSE CREEK 3 IMPROVEMENT FACT SHEET	
	Discussion
Improvement Location:	Goose Creek Sewer Basin - Spruce St and 24th St
Problem ID:	**Goose Creek 3 (Tier 1 Priority Level)**



Improvement Description	<u>System Replacement</u> System 1: Replace and re-grade 554 feet of 18" collector/interceptor pipe and replace 162 feet of 18" collector/interceptor pipe with 24" along Mapleton Ave and 28th St. System 2: Replace and re-grade 544 feet of 24" interceptor pipe along 28th St.
Alternative Recommendation Comments:	The system replacement alternative is recommended since a flow diversion alternative was not feasible.
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flow ranges from 1,300 gpm in System 1 to 1,600 gpm in System 2.
Data Confidence:	Medium
Calibration Confidence:	Low

TABLE 7.4 - GOOSE CREEK 3 IMPROVEMENT FACT SHEET	
	Discussion
Flow Trigger:	1,400 gpm (in 24" interceptor along 28th St)
Land Ownership:	If a utility ROW exists along Mapleton Ave and 28th St, all construction would be within the ROW.
Implementation Issues:	Constructability issues due utility conflicts and construction in major roads. High bypass pumping requirements along 28th St. Opportunity for parallel water main replacement. Surface treatment of asphalt pavement.
Capital Cost:	$482,000

TABLE 7.5 - GOOSE CREEK 5 IMPROVEMENT FACT SHEET	
	Discussion
Improvement Location:	Goose Creek Sewer Basin - Arapahoe Ave and 55th St
Problem ID:	**Goose Creek 5 (Tier 1 Priority Level)**



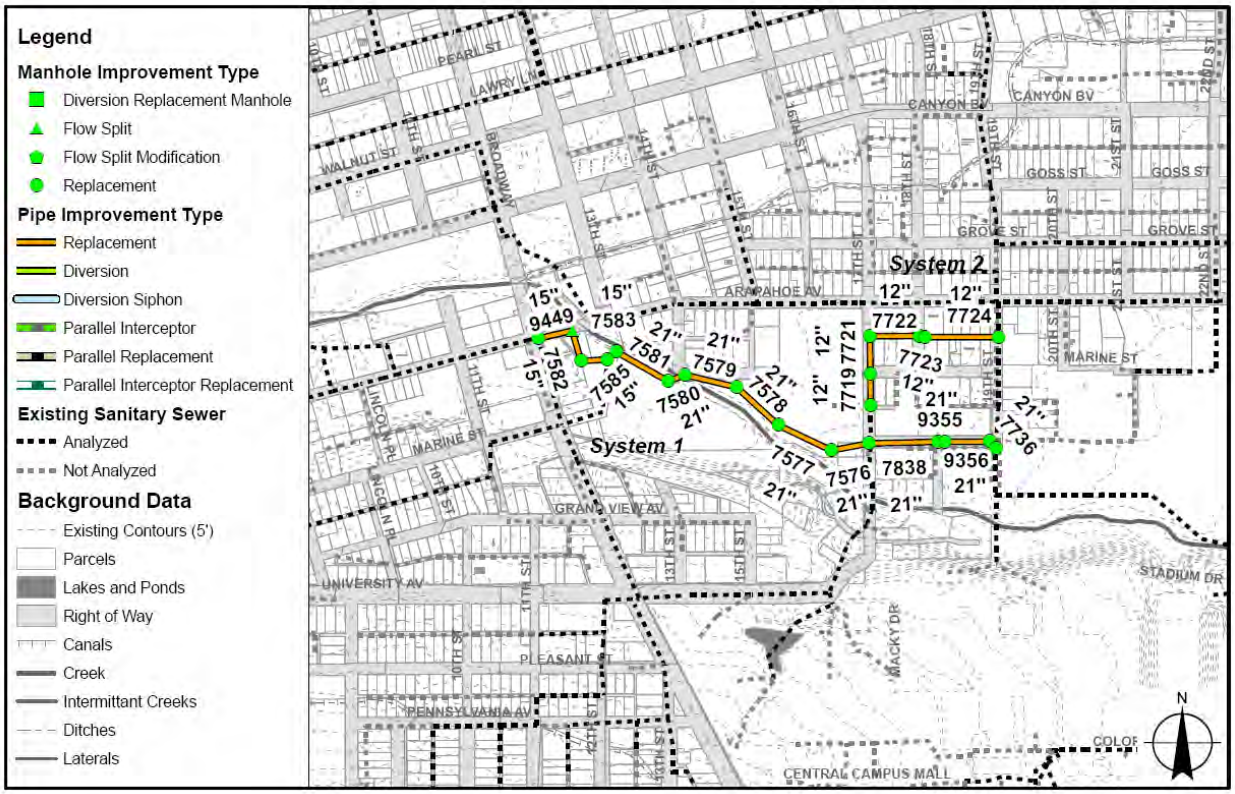
Improvement Description	<u>Parallel Interceptor with Diversion</u> System 1: Replace and re-grade 993 feet of 30” interceptor pipe with 33” along Arapahoe Ave west of 55th St. System 2: Create diversion in MH N03W0139 to east at an elevation of 5222.55 feet. Install of 1,344 feet 27” pipe as a parallel interceptor, replace 744 feet of 15” collector/interceptor pipe with 21”, replace 489 feet of 15” interceptor pipe with 27”, replace 1,225 feet of 21” interceptor with 37”, replace and re-grade 704 feet of 24” interceptor pipe with 36” along 55th St north of Arapahoe Ave. System 3: Replace and re-grade 211 feet of 12” local collector pipe along 55th St south of Arapahoe Ave.

TABLE 7.5 - GOOSE CREEK 5 IMPROVEMENT FACT SHEET	
	Discussion
Alternative Recommendation Comments:	The parallel interceptor with diversion alternative is recommended since smaller diameter pipes are possible compared to the replacement and parallel interceptor alternatives. The diversion alternative also lessens the amount bypass pumping that is required by diverting flow to the east.
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flow ranges from 7,800 gpm in System 1 to 5,700 gpm in System 2 to 600 gpm in System 3.
Data Confidence:	Medium
Calibration Confidence:	Medium
Flow Trigger:	7,100 gpm (in 30" interceptor along Arapahoe Ave)
Land Ownership:	Construction is limited to mostly roads in Arapahoe Ave and 55th St, therefore no land ownership issues is expected.
Implementation Issues:	Constructability issues due major roads and utility conflicts will slow rate of construction. Depending on depth of groundwater present in vicinity of replacement pipe, dewatering may be required. Very high volumes of bypass pumping are required. Opportunity for parallel water main replacement and short section of storm water improvements. Surface treatment of primarily concrete with some asphalt pavement.
Capital Cost:	$2,559,000

7.5 Tier 2 Priority Improvements

This section includes fact sheets that provide details for each of the Tier 2 improvement areas.

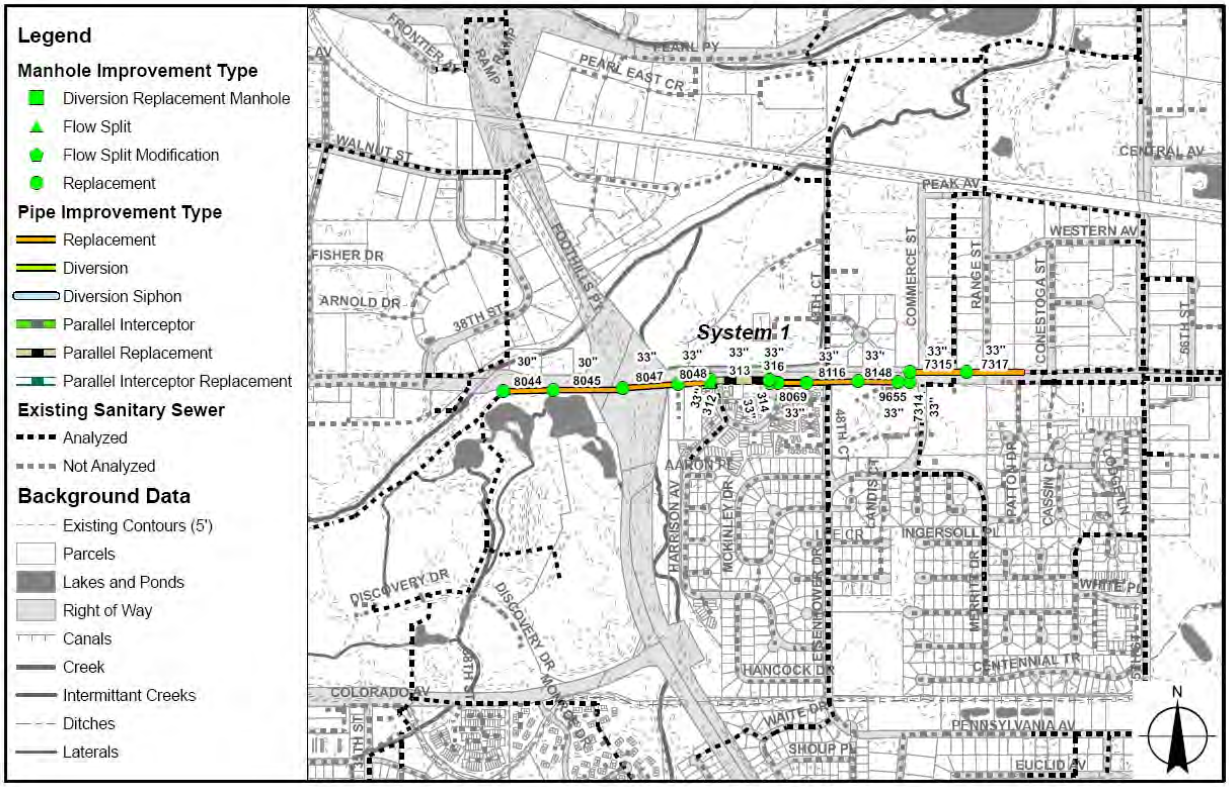
TABLE 7.6 - BOULDER CREEK 1 IMPROVEMENT FACT SHEET	
	Discussion
Improvement Location:	Boulder Creek Sewer Basin - Colorado Ave and 28th St
Problem ID:	**Boulder Creek 1 (Tier 2 Priority Level)**



Improvement Description	<u>System Replacement</u> System 1: Replace 535 feet of 12” collector/interceptor with 15” and 2,120 feet of 15” with 21” along Boulder Creek from Broadway to 19th St. System 2: Replace 1,018 feet of 8” local collector along Marine St with 12”.
Alternative Recommendation Comments:	The system replacement alternative is the recommended alternative to avoid creating a siphon under Boulder Creek for System 1 in the flow diversion alternative. System 2, however, could be a diversion instead of replacement as less pipe is required to alleviate problems along Marine St.

TABLE 7.6 - BOULDER CREEK 1 IMPROVEMENT FACT SHEET	
	Discussion
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flow ranges from 1,500 gpm in System 1 to 500 gpm in System 2.
Data Confidence:	Medium
Calibration Confidence:	Medium
Flow Trigger:	N/A
Land Ownership:	If a utility ROW exists along Boulder Creek, all construction would be within the ROW. Alley behind buildings along Marine St should be accessible but may require special permission from owners.
Implementation Issues:	Constructability issues along a creek corridor especially if ROW not established. Limitations due to alley constructions. Depending on depth of groundwater present in vicinity, dewatering may be required. Opportunity for a short portion of parallel water main replacement. Surface treatment of open space and asphalt pavement.
Capital Cost:	$1,653,000

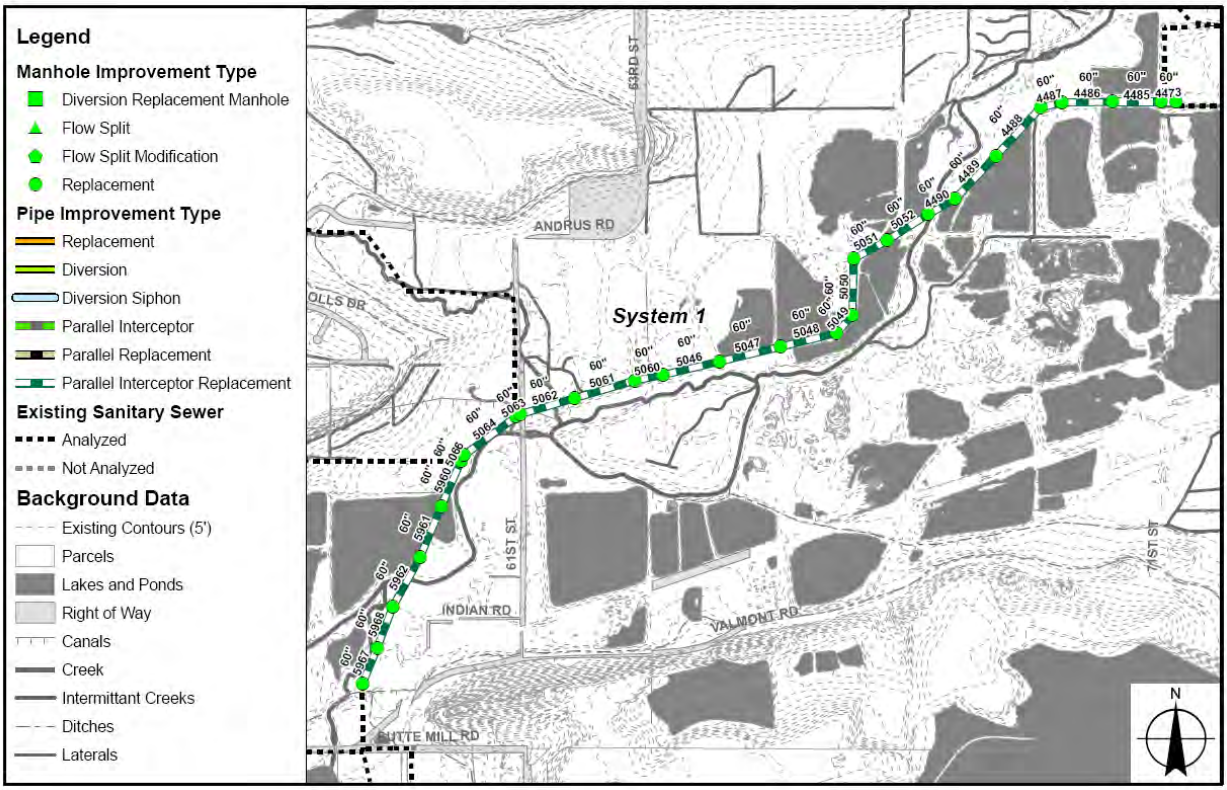
TABLE 7.7 - BOULDER CREEK 3 IMPROVEMENT FACT SHEET	
	Discussion
Improvement Location:	Boulder Creek Sewer Basin - Arapahoe Ave and Foothills Pkwy
Problem ID:	**Boulder Creek 3 (Tier 2 Priority Level)**



Improvement Description	<u>System Replacement</u> System 1: Replace 973 feet of 27” interceptor with 30” and 3,433 feet of 30” interceptor with 33” pipe along Arapahoe Ave.
Alternative Recommendation Comments:	The system replacement alternative is the only feasible alternative since a flow diversion is not possible due to grade issues.
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flow ranges from 7,700 gpm in System 1.
Data Confidence:	Medium
Calibration Confidence:	Medium
Flow Trigger:	5,200 gpm (in 27” - 30” interceptor)

TABLE 7.7 - BOULDER CREEK 3 IMPROVEMENT FACT SHEET	
	Discussion
Land Ownership:	If a utility ROW exists along Arapahoe Ave, all construction would be within the ROW.
Implementation Issues:	Constructability issues due to highway and major roads. Requires crossing Arapahoe Ave and Bear Canyon Creek. Bypass pumping of large volumes of sewage. Depending on depth of groundwater present in vicinity, dewatering may be required for about half of the replacement pipes. Surface treatment of primarily asphalt pavement with some open space.
Capital Cost:	$1,939,000

TABLE 7.8 - BOULDER CREEK 4 IMPROVEMENT FACT SHEET	
	Discussion
Improvement Location:	Boulder Creek Sewer Basin - Valmont Rd and 61st St to WWTP
Problem ID:	**Boulder Creek 4 (Tier 2 Priority Level)**



Improvement Description	<u>Replacement Parallel Interceptor</u> System 1: Install 11,375 feet of 60” pipe as a replacement parallel interceptor to the existing 42” interceptor. The existing 42” interceptor would be de-commissioned or used only during extreme flow conditions with a diversion manhole upstream.
Alternative Recommendation Comments:	The replacement parallel interceptor is the recommended alternative since the original interceptor is aging and the replacement does not depend on the condition of the existing interceptor. The replacement parallel interceptor also allows for emergency capacity during extreme wet weather events by utilizing the existing 42” interceptor for this purpose only.
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flow ranges from 34,000 gpm in System 1.
Data Confidence:	High

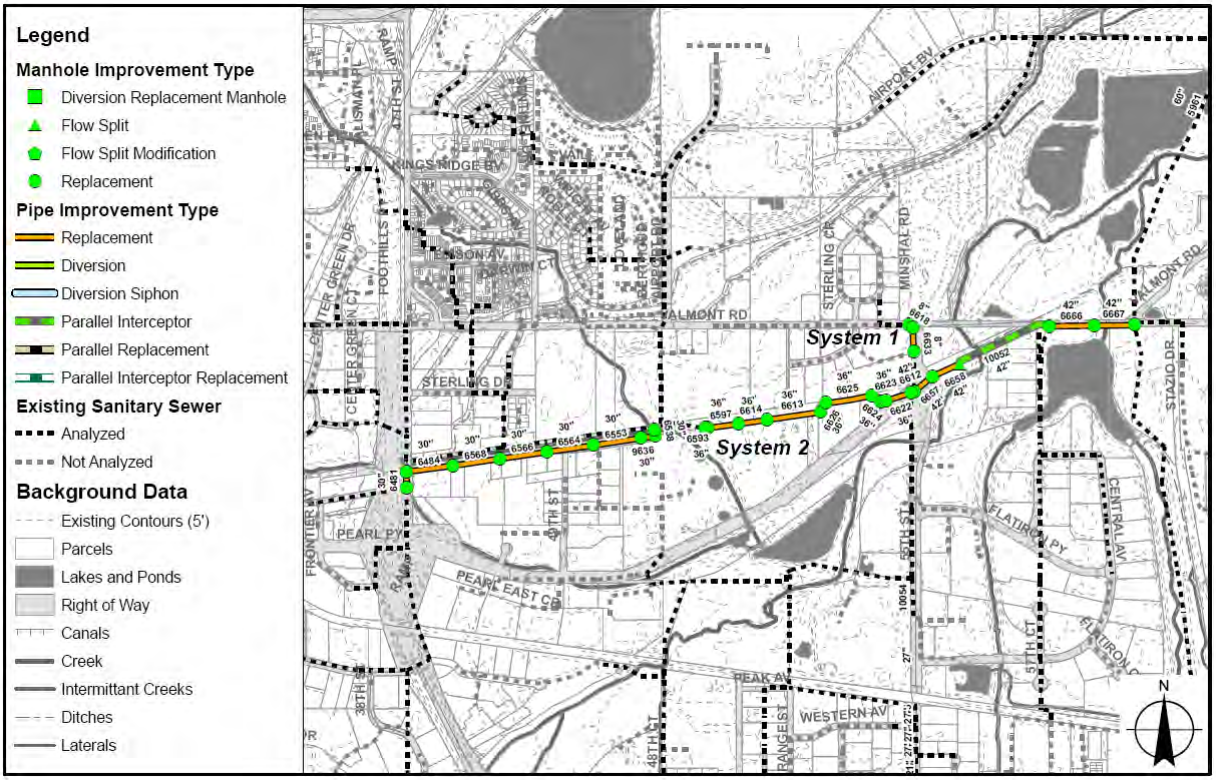
TABLE 7.8 - BOULDER CREEK 4 IMPROVEMENT FACT SHEET	
	Discussion
Calibration Confidence:	High
Flow Trigger:	21,700 gpm (in 42” interceptor) and 38,400 gpm (in 60” interceptor)
Land Ownership:	Depending on the final alignment, ROW purchase may be necessary as the alignment does not follow an established road.
Implementation Issues:	Constructability issues due to alignment along a creek corridor and around existing gravel pits. Requires a crossing of Boulder Creek. Larger pipe diameter is required and therefore higher capital costs occurred as compared with Alternative 1. 60” Influent Interceptor at WWTP still exceeded due to 50 mgd capacity. Depending on depth of groundwater present in vicinity, dewatering may be required. Surface treatment of primarily open space with some asphalt pavement.
Capital Cost:	$12,356,000

TABLE 7.9 - GOOSE CREEK 2 IMPROVEMENT FACT SHEET	
	Discussion
Improvement Location:	Goose Creek Sewer Basin - Lawry Ln and 16th St
Problem ID:	**Goose Creek 2 (Tier 2 Priority Level)**

Improvement Description	<u>Flow Diversion</u> System 1: Install 296 feet of 8" local collector pipe as two flow diversions and replace and re-grade 378 feet of 12" local collector pipe along 13th St and 16th St. System 2: Replace 182 feet of 15" collector/interceptor pipe with 18" along 19th St.
Alternative Recommendation Comments:	The flow diversion alternative is recommended since fewer pipes are required with less construction disturbance in downtown area.
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flow ranges from 230 gpm in System 1 to 1,500 gpm in System 2.
Data Confidence:	High

TABLE 7.9 - GOOSE CREEK 2 IMPROVEMENT FACT SHEET	
	Discussion
Calibration Confidence:	Medium
Flow Trigger:	N/A
Land Ownership:	Construction is limited to roads in 16th and alleys. If utility ROW exists in alleys, then no land ownership issues should be present.
Implementation Issues:	Constructability issues due space restrictions and utility conflicts. Not replacing older VC pipe as in replacement alternative. Opportunity for short portions of parallel water main replacement and storm water improvements. Surface treatment of asphalt pavement.
Capital Cost:	$302,000

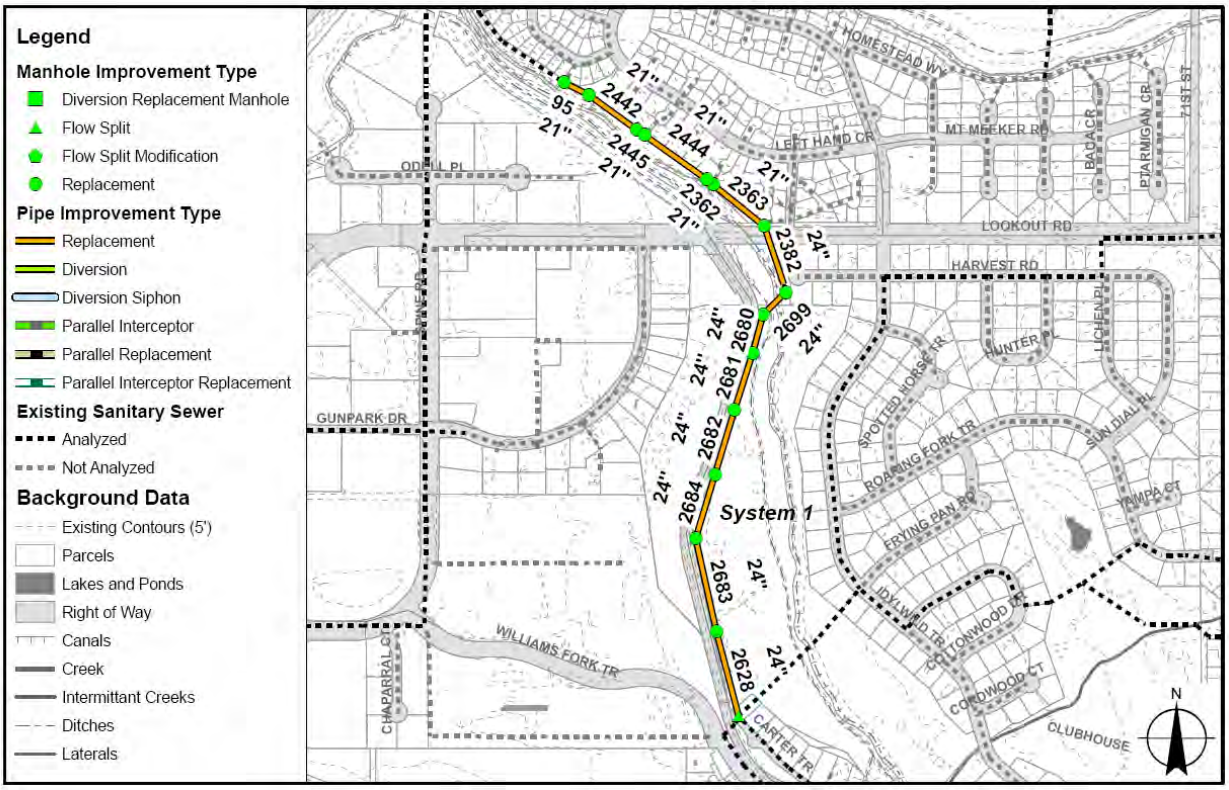
TABLE 7.10 - GOOSE CREEK 4 IMPROVEMENT FACT SHEET	
	Discussion
Improvement Location:	Goose Creek Sewer Basin - Pearl St, Valmont Rd and Mishal Rd
Problem ID:	**Goose Creek 4 (Tier 2 Priority Level)**



Improvement Description	<u>System Replacement</u> System 1: Replace and re-grade 296 feet of 8" local collector pipe along 55th St. System 2: Replace 979 feet of 21" interceptor pipe with 30", replace and re-grade 1,719 feet of 30" pipe, replace 1,212 feet of 27" interceptor pipe with 36", replace and re-grade 1,036 feet 30" interceptor pipe with 36", replace 593 feet of 30" interceptor pipe with 42", replace 888 feet of 36" interceptor pipe with 42", install 1,049 feet of 42" as a parallel interceptor along Pearl St, Goose Creek Corridor, Valmont Pkwy and Valmont Rd.
Alternative Recommendation Comments:	The system replacement alternative is recommended since a flow diversion alternative is not feasible due to topography.
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flow ranges from 100 gpm in System 1 to 13,000 gpm in System 2.

TABLE 7.10 - GOOSE CREEK 4 IMPROVEMENT FACT SHEET	
	Discussion
Data Confidence:	Medium
Calibration Confidence:	Low
Flow Trigger:	3,500 gpm (in 21” interceptor), 7,400 gpm (in 27-30” interceptor), 10,000 gpm (in 36” interceptor)
Land Ownership:	If utility ROW exists in Goose Creek corridor, then no land ownership issues should be present.
Implementation Issues:	Constructability issues due to major roads and creek corridors. Very high volumes of bypass pumping required in System 2. Depending on depth of groundwater present in vicinity of replacement pipe, dewatering may be required. Opportunity for parallel water main replacement in Systems 1 and 2. Surface treatment of open space, concrete and asphalt pavement.
Capital Cost:	$3,928,000

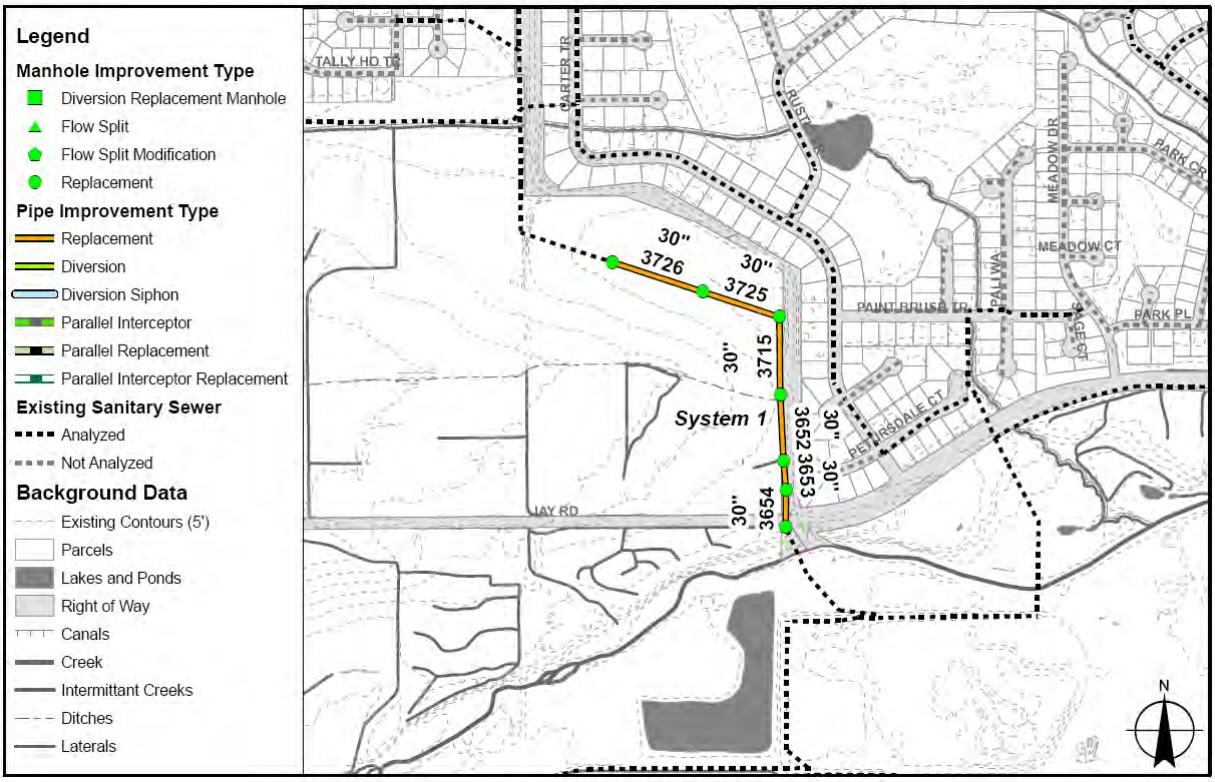
TABLE 7.11 - GUNBARREL 1 IMPROVEMENT FACT SHEET	
	Discussion
Improvement Location:	Gunbarrel Sewer Basin - Boulder Supply Canal and Left Hand Ditch
Problem ID:	**Gunbarrel 1 (Tier 2 Priority Level)**



Improvement Description	<u>System Replacement</u> System 1: Replace 1,268 feet of 18" collector/interceptor pipe with 21" and replace and re-grade 2,623 feet of 21" collector/interceptor pipe with 24" along the Left Hand Ditch and Boulder Supply Canal.
Alternative Recommendation Comments:	The system replacement alternative is recommended since a flow diversion alternative was not feasible due to topography and lack of diversion infrastructure options.
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flow is 1,300 gpm in System 1.
Data Confidence:	High
Calibration Confidence:	Medium

TABLE 7.11 - GUNBARREL 1 IMPROVEMENT FACT SHEET	
	Discussion
Flow Trigger:	1,600 gpm (in 21" collector/interceptor)
Land Ownership:	Construction is limited to mostly roads in Arapahoe Ave and 55th St, therefore no land ownership issues is expected.
Implementation Issues:	Constructability issues due major roads and utility conflicts will slow rate of construction. Depending on depth of groundwater present in vicinity of replacement pipe, dewatering may be required. Very high volumes of bypass pumping are required. Surface treatment of primarily open space with some asphalt pavement. Coordination issues and construction disturbance due to adjacent golf course.
Capital Cost:	$1,116,000

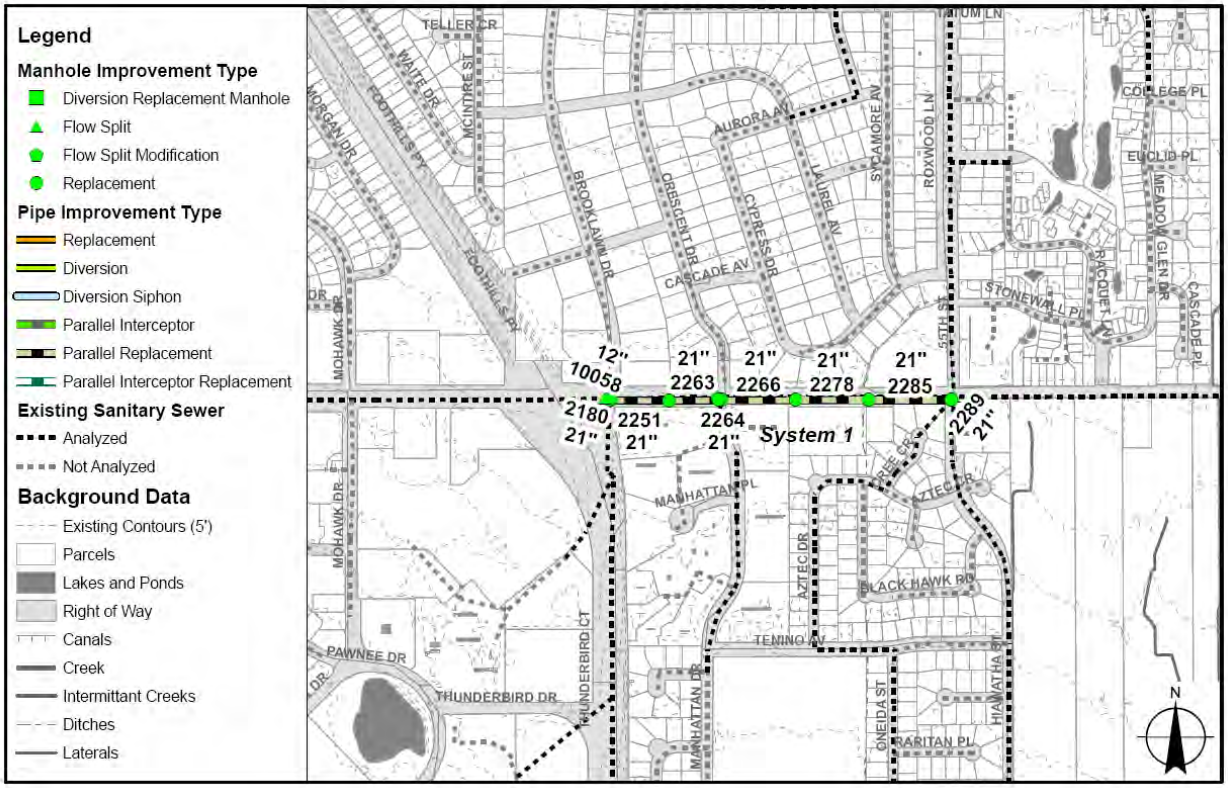
TABLE 7.12 - GUNBARREL 2 IMPROVEMENT FACT SHEET	
	Discussion
Improvement Location:	Gunbarrel Sewer Basin - Jay Rd and Boulder Supply Canal
Problem ID:	**Gunbarrel 2 (Tier 2 Priority Level)**



Improvement Description	<u>System Replacement</u> System 1: Replace 2,007 feet of 24" collector/interceptor pipe with 30" along the Boulder Supply Canal.
Alternative Recommendation Comments:	The system replacement alternative is recommended since the flow diversion options caused an overloaded parallel collector/interceptor and was considered not feasible.
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flow is 3,300 gpm in System 1.
Data Confidence:	Medium
Calibration Confidence:	High
Flow Trigger:	2,300 gpm (in 24" interceptor)

TABLE 7.12 - GUNBARREL 2 IMPROVEMENT FACT SHEET	
	Discussion
Land Ownership:	If utility ROW exists in canal corridor, then no land ownership issues should be present.
Implementation Issues:	Constructability issues due to canal corridor. High volumes of bypass pumping required. Surface treatment of primarily open space with some asphalt pavement.
Capital Cost:	$939,000

TABLE 7.13 - SOUTH BOULDER CREEK 1 IMPROVEMENT FACT SHEET	
	Discussion
Improvement Location:	South Boulder Creek Sewer Basin - Baseline Rd and 55th St
Problem ID:	**South Boulder Creek (Tier 2 Priority Level)**



Improvement Description	<u>Flow Diversion</u> System 1: Install 24 feet of 12" local collector pipe as a flow diversion and replace and re-grade 1,785 feet of 15" collector/interceptor pipe with 21" along Baseline Rd from Foothills Pkwy and 55th St.
Alternative Recommendation Comments:	The flow diversion alternative is recommended since it requires fewer pipes than the system replacement alternative by diverting flow away from problem pipe.
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flow is 1,000 gpm in System 1.
Data Confidence:	High
Calibration Confidence:	Medium

TABLE 7.13 - SOUTH BOULDER CREEK 1 IMPROVEMENT FACT SHEET	
	Discussion
Flow Trigger	N/A
Land Ownership:	Construction is limited to Baseline Rd, therefore no land ownership issues are expected.
Implementation Issues:	Constructability issues due major road construction and utility conflicts. Opportunity for parallel water main replacement. Surface treatment of asphalt pavement.
Capital Cost:	$733,000

7.6 Tier 3 Priority Improvements

This section includes the fact sheet that provides details for the entirety of the Tier 3 improvements.

TABLE 7.14 - TIER 3 (TYPE B PROBLEM) IMPROVEMENT SUMMARY	
	Discussion
Improvement Location:	Improvements are system-wide.
Problem ID:	**Type B Problem Improvements (Tier 3 Priority Level)**

See Figure 6-3 for Type B Improvements.

Improvement Description	System Replacement Replacement of 3,826 feet of pipe ranging from 12 to 42”.
Technical Data:	The entire system is required to convey buildout dry weather and wet weather flows to the established analysis criteria. Expected peak flows range from 20 to 9,300 gpm.
Land Ownership:	Since all improvements are replacements and they should be located in existing ROW, no land acquisition should be necessary.
Implementation Issues:	High volumes of bypass pumping potentially required. Depending on depth of groundwater present in vicinity, dewatering may be required. Mixture of open space, concrete and asphalt pavement surface treatment.
Capital Cost:	$2,296,000

SECTION 8

Collection System Maintenance Review

This section presents the findings of the Gravity Systems Maintenance Program Review and identifies the increases in service level that Boulder may need to implement to comply with trends currently evolving in the wastewater collection system industry. The purposes of this analysis were:

1. to examine the current state of Boulder's operations and maintenance (O&M) practices; and
2. to develop an estimation of increases in service level due to trends in the regulatory environment in the western region.

HDR's analysis is comprised of data collection and review, interviews, and telephone conversations with Boulder staff. Data was collected during an on-site visit on December 18 and 19, 2007. The staff members who were interviewed are knowledgeable in Boulder's collection system O&M practices. This analysis assesses the current programs employed by the City of Boulder's Utility Maintenance group.

8.1 Background

The first sewer mains were installed in 1895 upon the creation of the utility in Boulder. Data stored in the GIS database indicate the oldest pipes where installed in the 1940s. It is not accurately known how many miles of sewers were installed between 1895 and 1940 or if any of these pipes are currently active. The utility does not have installation dates for all of its assets, but has made an assumption on installation date based on age of the developments where the assets are located. Based on these numbers, nearly 1/3 of the system is over 50 years old.

For purposes of this analysis, assumptions for probable changes in the regulatory environment in Colorado will be based on examples recently set in the west. The State of California has developed the Waste Discharge Requirements (WDR) regulation and Arizona has developed Rule C305. These regulations for sanitary sewer systems are similar in content to the Capacity, Management, Operations, and Maintenance (CMOM) regulation proposed but never implemented by the U.S. Environmental Protection Agency (EPA). Even though CMOM was never implemented, the EPA does support such state requirements and has enforced even stricter provisions to reduce or eliminate spills under the provisions of the Clean Water Act.

The WDR contains requirements for monitoring, reporting, developing and implementing Sewer System Management Plans (SSMPs). This regulation affects all municipal sewer agencies in the state with more than one mile of collection system and regulates the discharge of sanitary sewer overflows (SSOs).

The WDR defines an SSO as any overflow, spill, release, discharge, or diversion of untreated or partially treated wastewater from a sanitary sewer system, including:

- Overflows or releases of untreated or partially treated wastewater that reach waters of the United States;
- Overflows or releases of untreated or partially treated wastewater that do not reach waters of the United States; and
- Wastewater backups into buildings and on private property caused by blockages or flow conditions within the publicly owned portion of a sanitary sewer system.

8.2 Project Approach

HDR evaluated City of Boulder's Utility Maintenance performance based on industry knowledge of new regulations in the west. Boulder was evaluated as to whether they would be in regulatory compliance. Recommendations for improvement were made for areas where Boulder would not be in compliance, or where it was felt that business processes should be changed to meet standard industry practices. This analysis is a means of examining systemic factors that have contributed to or caused a gap between the current and future desired state of the system as outlined in the compliance requirements. The analysis process includes an in-depth analysis of the factors that have created the current state and lays the groundwork for improvement planning. This approach ensures that the system improvement process does not jump from identifying the problem areas to proposing and implementing solutions without first understanding the conditions that created the current state.

HDR conducted the analysis in accordance with the following guidelines:

- The research team gathered information and used it to develop desired system performance baselines (or levels of service) that are formed on the indicators mentioned in the analysis;
- The team identified the gaps between the current and future system performance level, and developed a problem statement that summarizes the underlying issues that must be addressed to progress towards full compliance;
- The team developed a root-cause analysis to determine the factors that are crucial for improvement; and
- These factors were then used to develop specific goals, and objectives for the improvement plan to satisfy the goals associated with any future state regulation.

8.3 Sewer System Management Plan

A critical requirement of California's WDR is to prepare a plan and a schedule to properly manage, operate, and maintain all parts of Boulder's sanitary sewer system in order to reduce, prevent, and mitigate SSOs. The WDR requires collection system managers to develop and implement the SSMP document and revise and update it every two years.

This section discusses the elements of the general WDR and HDR's opinion of Boulder's current performance status. Only the sections of the WDR relating to O&M of the system will be evaluated.

8.3.1 Operation and Maintenance Program - Organization and Staffing

<u>Staff</u>

The Utility Maintenance Group has three two-person cleaning crews, two rodding crews and one hydro flushing crew. There is also one three-person construction crew and two one-person CCTV vans and crews. Classifications and positions that support the operations and maintenance programs are as follows:

Wastewater Maintenance Supervisor (1) – Supervises all collection system activities

Maintenance Person IV (1) –This position is the construction crew lead and performs tasks related to the maintenance and repair of the sewer system. This position is the equipment operator for the construction crew.

Maintenance Person III (4) – One of the positions in this classification is on the construction crew and performs tasks related to sewer repairs. The other three positions are the operator's of the two-person maintenance crews. One operates a hydro flushing truck and the other two operate the mechanical rodding equipment.

Maintenance Person II (2) – One of these positions is a crew member on the construction crew and the other is a crew member on one of the rodding crews. These positions perform semi-skilled functions in the maintenance and repair of the sewer system.

Maintenance Person I (2) – These positions are entry-level helpers on maintenance crews. One is a helper on a rodding truck and the other on the hydro flush truck.

TV Operator I (2) – The TV operator positions are one-man crews that videotape and record the condition of 8" to 15" sewer pipes throughout the system.

Types of Crews

As mentioned above, there are three two-person cleaning crews, one three-person construction crew, and a one-person television crew. Crews work Monday through Friday, from 7am to 3:30pm.

The construction crew typically performs manhole maintenance, sewer repairs, and confined space entry. These repairs are based on referrals from the maintenance crews or from the television crew. These are typically issues that either need immediate attention or projects that are too small to warrant inclusion on a CIP.

There are two different types of maintenance crews. There are two mechanical rodding crews and one hydro flushing crew. The hydro flushing crew handles hot spots related to grease twice a year. The remainder of the year that crew cleans the rest of the system. Boulder's goal is to clean the entire system every 18 months. The two mechanical rodding crews handle root related maintenance issues. It is Boulder's goal to rod the entire system every three years.

There is one, one-person CCTV crew. Currently the CCTV crew televises the entire system of pipes, less than 16 inches in diameter every 7-9 years. Having a one-man crew may pose safety issues for crews working in the street. It may also be less efficient due to the time spent setting up traffic control and CCTV equipment.

Workday

Boulder operations and maintenance personnel work five 8-hour days per week, Monday through Friday. The current work order and time management procedures and systems do not allow for a performance assessment.

Productivity

There are no performance measures in place to benchmark productivity of cleaning crews to industry averages for daily production averages per crew. There are no benchmarks established for daily production goals. There are goals established for how frequently the entire system is cleaned. Using the frequency of entire system cleanings and approximating the number of days crews are out cleaning, in general, flushing crews seem to be more productive than industry standards, while rodding appears below average.

8.3.2 Maintain an Up-to-Date Map of the Sanitary Sewer System

Assessment

Boulder currently has two sources for maps of the system. One is paper map books that crews use in the field for navigating to their work orders. Boulder also maintains all system assets in GIS and this is used for planning functions. There is missing data in the GIS database that Boulder is working to complete. Some examples of these are missing installation dates, diameters, materials, and invert and manhole rim elevations. As Boulder crews visit these locations, they are attempting to capture the data to update their database.

The Computerized Maintenance Management System (CMMS) software for generating work orders and managing data is not tied to the GIS system. The CMMS will be addressed further in the following section.

Recommendations

Only one asset database should be maintained for the system and this should be the system that is used for all maintenance activities related to the sanitary sewer system. Maintaining two systems is time consuming and updates may not always be made to both depending on desired use of the group responsible for data maintenance.

Completion of the GIS database should be made a priority. The current practice of correcting discrepancies by submitting a Utility Field Report to the supervisor or planner helps to ensure that the existing GIS database is continually checked against reality.

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Completion of the GIS database should be made a priority. The current practice of correcting discrepancies by submitting a Utility Field Report to the supervisor or planner helps to ensure that the existing GIS database is continually checked against reality.

8.3.4 Routine and Preventive Maintenance

Assessment

Boulder's maintenance program includes cleaning their trouble areas or hot-spots locations every six months, as well as maintenance of the sanitary sewer system whenever an O&M related problem occurs. Boulder uses both hydro flushing and mechanical rodding equipment to clean and remove debris from the sewer system. Boulder's goal is to hydro flush the entire system every 18 months and to mechanically rod the entire system every three years. This means every pipe in the system is maintained an average of once per year. Boulder proactively maintains their buried sewer assets, thus helping to avoid any maintenance problems or SSOs that could result in a threat to the public health and/or a loss of human life. The following sections present findings and suggestions should be considered to refine the preventive maintenance program.

Computerized Maintenance Management System

The current system, Utility Maintenance Management System (UMMS), was built by a board member who still maintains and upgrades the system. UMMS houses asset and some maintenance information for water, stormwater, and sewer assets. Maintenance information collected by field crews and stored in the UMMS includes coded values that categorize manhole problems, the operator's assessment of a pipe's overall condition, and the specific location and type of problem in a pipe. This system is not currently integrated with GIS. CCTV data is collected and entered into the system, and the system has the ability to collect some simplistic findings. As CCTV operators televise sections of pipe events such as lateral tie-ins are recorded as well as significant structural defects are mentioned, but not rated. When events such as blockages or SSOs occur, the Utilities Program Planner maps them in GIS, which is a separate database from UMMS, though the UMMS spill data is frequently exported and joined to the GIS spill points. Also, only "serious" events, such as SSOs, are documented, not general maintenance findings.

Recommendations

UMMS should be updated and more closely integrated with the GIS system, or a new GIS-based CMMS system should be implemented specifically for the sanitary sewer system. This will be discussed further in the following section. UMMS has the ability to generate and track work orders, but since it was created to work with several different utilities, it lacks some of the planning tools that a CMMS geared just for the wastewater industry would include. At a minimum, it should be able to collect maintenance findings by asset and support geographical work scheduling.

UMMS should be updated to store condition data which would be collected on maintenance and inspection visits. Currently, maintenance crews are identifying the pipeline cleaned and recording the type of maintenance performed, but not recording condition findings. This should be corrected by capturing the findings in UMMS. Condition findings should be code-based and not text-based.

Boulder should have all data, such as trouble area cleaning records, root treatment, and others, entered into the UMMS. This database should be the one source for all maintenance-related issues and should be integrated with GIS software for data management and development of work orders. CMMS software should be integrated with GIS in producing map-based work orders so field activities can be planned and performed using the most up-to-date data. Also, planners could query and link data from UMMS to GIS for analysis and long-term planning.

A detailed service request or work order form should be created and provided to crews who maintain the sewer system assets. The work order would be specific to the type of work being performed and would collect code-based findings for each asset maintained. This code-based data would be captured in UMMS and used for planning future maintenance activities and could also be used for analyzing trends in the system or identifying problem spots or grease dischargers.

Boulder should provide training to staff in the effective usage of GIS and CMMS software.

Cleaning Program

The existing collection system pipes are cleaned on a routine basis to minimize the risk of having an SSO, maintain capacity, and to minimize system deterioration and odor generation. An analysis of the last 5 years of SSOs shows the primary causes of SSOs in Boulder are grease buildup from commercial and residential sources, and root intrusion. Cleaning is performed on pipes that have documented grease problems at a frequency of every six months. Pipes with a documented root problem are placed on the chemical root program. Pipes without a documented maintenance-related condition get cleaned at a lower frequency as will be discussed in the following sections.

Hydro flushing is a cleaning method using high pressure water to remove grease, sand, sludge, and many other obstructions from sewer lines. Mechanical rodding is another cleaning method commonly used in Boulder to clean sewer lines. This form of cleaning is specifically targeted at the removal of roots from the system but is also used for the penetration of solid blockages. This equipment uses blades that spin on a heavy-duty cable or rod, used for cutting through roots from trees and bushes or other types of debris. Boulder also contracts with an outside service provider for the application of chemical root inhibitor. Annually between five and eight miles of pipelines are chemically treated for roots.

Each segment of the collection system is hydro flushed once every 18 months and mechanically rodded once every three years. Segments of the system known to have hydraulic problems, or “Hot Spots”, are cleaned more frequently. These areas are typically cleaned on 6 month cycles in May and November. “Hot Spots” are generally near the point where a restaurant discharges into the system. In 2007 Boulder cleaned approximately 22,000 feet of pipe on each of its “Hot Spot” cycles. Interviews with staff and planning personnel confirmed that once a pipe was placed on a “Hot Spot”, there was next to no chance of it ever coming off.

Recommendations

The system is currently being cleaned, on average, once per year, and the City’s cleaning program has resulted in a reduction of SSOs. By comparing this to industry best management practices, this frequency is considered over-cleaning, and it is possible to realize similar effectiveness while cleaning less. Boulder is currently cleaning the entire system on what is normally considered an accelerated cleaning schedule, which is a frequency of less than once every two years. This is considered a high level of service, but also means that crews are most likely cleaning clean pipe. Additionally, there are studies that show that cleaning practices such as hydro-flushing and mechanical rodding can actually cause structural damage to a pipe and reduce the service life of a pipe. Hydro flushing and mechanical cleaning should only be performed to remove roots, grease, or other debris when needed.

As mentioned in the CMMS section, Boulder should move to code-based collection of findings and collection of this data should be stored in an upgraded CMMS. Over the next few cleaning cycles, data could be collected and, most likely, more accurate cleaning frequencies could be developed for the individual line segments. This would allow Boulder to ease away from such an aggressive system-wide cleaning program. This same methodology can be used for

collection of cleaning findings on the current "Hot Spot" schedule. Once the scheduled cleaning is run through several more times, the data collected will help identify the optimal cleaning frequencies which will most likely lessen the cleaning workload. This data collected would allow for a periodic reevaluation of the cleaning frequencies. The schedule can be level loaded throughout the year for all pipes in the system to provide steady work for crews throughout the year.

As Boulder implements the above two recommendations, they will likely modify their cleaning schedule to only clean pipes when they are in need of cleaning. This will result in a reduction of the net feet cleaned per year. Instead of downsizing, the utility should look at moving resources to the repair crew or creating a second repair crew. As will be discussed in the following section, the CCTV crew should be generating repair work that Boulder crews could be repairing. Additionally, as Boulder does less cleaning they may want to consider transitioning from using mechanical rodding equipment to combination jet rodder units. This can be accomplished by replacing one of the mechanical rodders with a combination jet rodder during the next replacement cycle. The combination units are more versatile and more effective.

Large diameter sewer cleaning is an area where there is liability in the future from a regulatory perspective. The probability of a sewer overflow from a large diameter sewer is very small; however, the consequence can be very large. In California, the EPA has required cities such as San Diego and Los Angeles to have a program in place to either clean large diameter sewers periodically or inspect large diameter sewers to determine if cleaning is necessary. Boulder currently does not inspect pipes that are larger than 15" in diameter and rarely cleans pipes that are larger than 18" in diameter. It is recommended that Boulder develop a contingency plan to inspect large diameter sewers over the next 10 years to identify the large diameter sewers that have maintenance or structural issues. Condition assessment of large diameter pipes will most likely require the purchase of new equipment capable of large diameter inspections or should be contracted out to a qualified company.

The majority of maintenance issues in large diameter sewers are the accumulation of debris. This condition is usually exacerbated by flat slopes. Due to the exorbitant cost of large diameter inspections, Boulder should perform an analysis of flow conditions in large diameter sewers to identify the most likely candidates for maintenance defects. This should be used in conjunction with Boulder's CIP prioritization methodology for identifying structural defects. Together, this priority list would be used to create a risk-based inspection program of only the large diameter sewers that either have a higher probability of maintenance or structural issues or have an elevated consequence of failure, such as near high profile public facilities. The program should then be expanded or contracted based on the findings from the initial inspections.

Inspection Program

Utility Maintenance staff performs inspections on all pipes and manholes on a routine basis. These inspections are either visual, to determine the integrity of manholes, or Closed Circuit Television (CCTV) inspections of the distributed assets. Inspection of the entire collection system using CCTV is currently able to be completed approximately every nine years. The CCTV crew inspects sewers less than 16" in diameter. The data collected from CCTV inspections is used to document the condition of the system and plan long-term CIP projects. Additionally, the data is used to identify areas requiring special or immediate maintenance attention, such as blockages or structural damage. When issues arise, maintenance activities are scheduled to repair the damaged segment or relieve the blockage. CCTV video data is stored in a database so that maintenance staff can review it if necessary.

Recommendations

Boulder does not currently have a defect coding system for their CCTV program. They currently have one CCTV crew that notes the defect and what it is but it isn't coded and there is no place to document the severity. It is recommended that Boulder move to an industry recognized defect coding system. This will enable Boulder to collect consistent records if there is turn-over on the CCTV crew as well as becoming a standard for contractors. Should there ever be a need for CCTV inspections to be done by outside contractors; the data collected would be in the same format as Boulder's data. Additionally, collection of code-based defects and severity data allow for the evaluation of the condition of the system as well as the development of long-term CIPs. These coding systems are typically built into the newer inspection software. The current CCTV van is 10 years old and Boulder is about to purchase a new inspection van and equipment. Boulder should identify the coding system that they intend to use prior to making the investment in the new equipment and including the coding system in their specifications.

One such coding system is the Pipeline Assessment Certification Program (PACP). This is a sewer condition coding system and certification program developed by National Association of Sewer Service Companies (NASSCO). The program was developed for the purposes of standardizing the way condition data is classified and how CCTV inspection results are managed. Regardless of whether Boulder chooses a certification program or another recognized classification program, training should be provided initially and periodically to the CCTV crews as well as to any other personnel who might need to use the software or operate the equipment.

Currently the CCTV data is used to identify CIP projects to be contracted out, or it identifies areas that need to be repaired immediately because they are near the point of catastrophic failure. Once a defect coding system is implemented, a full range of projects could be identified that could be repaired by Boulder crews before they reach the catastrophic failure point.

CCTV crews should be used for quality control (QC) on maintenance and repair activities. Quality control on cleaning operations should consist of random evaluation of cleaning quality using CCTV inspection on a spot check basis within one week of sewer cleaning activities. This evaluation should be performed on at least 3 pipes per 100 pipes cleaned per cleaning crew. At current production levels, this would account for approximately 1.25% of the CCTV crew's workload. This can include tandem cleaning and CCTV activities where CCTV crews provide instant feedback to cleaning crews by monitoring cleaning effectiveness using CCTV during cleaning operations. This is a best management practice and can be considered to be both a quality assurance and quality control activity.

Additionally, as mentioned in the prior section, it is recommended that Boulder develop a contingency plan to inspect large diameter sewers over the next 10 years to identify the large diameter sewers that have maintenance or structural issues.

8.3.5 Rehabilitation and Replacement Program

Assessment

When identifying projects to address failing assets, Boulder has primarily been focusing on replacing assets once they reach a critical stage and has a near-term impact on system reliability. Boulder does not have a structured process to analyze the condition of assets to optimize the timing of repair, rehabilitation and replacement projects with a focus on minimizing the long-term cost of asset ownership.

Rehabilitation and replacement projects are identified in two ways. The first is through inspection or maintenance activities identifying structurally unsound pipe and the second is through the hydraulic model in order to identify capacity related issues.

Boulder currently does not have a formal project prioritization or ranking process for all projects. When inspection or maintenance activities identify pipes that require a significant capital improvement, the maintenance staff that has identified the problem notifies the Public Works Utility Project Management Staff of the need for a capital improvement project (CIP) to alleviate the problem. Once Project Management Staff has been notified, they assume responsibility for planning, scheduling, and implementing the CIP. A procedure for this process exists but it has not been formally documented in writing. This is a highly reactive means for identifying CIP needs and is not the best way to manage a system with better than 50% of its assets in excess of 50 years old.

In 2003, Boulder retained services of Brown and Caldwell to revise their Wastewater Collection System Master Plan (WWCSMP). As part of this project, the Hydraulic Model was revised. As a result of the modeling performed for the revised WWCSMP, capacity-based capital improvement needs were identified. These CIP needs have been categorized into four separate classes based on how immanent the need was. It was also recommended that the CIP budget be increased by 50% annually to accommodate these additional CIP needs that were not currently in the 5-year CIP plan.

Recommendations

Boulder should develop a standardized methodology to determine repair, rehabilitation, and replacement needs. With approximately 20 sewer line segments per mile, Boulder's sewer CCTV program quickly produces large amounts of data that should be analyzed in an objective manner for several purposes including capital planning. To assure consistent decision-making in Boulder's sewer repair, rehabilitation and replacement project identification process, it is very important that Boulder processes future CCTV data based on a formal decision process. It is a best practice to have a formal, reproducible repair, rehabilitation and replacement decision process that is documented in a decision flow diagram. This decision process would have decision guidelines that lead the person following the process to a preliminary decision about the pipe segment based on the type, severity and quantity of defects in the line segment. This can be done manually based on the decision flow diagram, or can be an algorithm developed from the diagram.

Boulder should be able to integrate the condition findings with the GIS. Boulder has a relatively complete GIS system. If sewer and manhole inspection and condition assessment data is collected by sewer and manhole asset number, Boulder staff can display the results on the GIS system. This expedites and optimizes the groupings for staff and contractor sewer and manhole repair, rehabilitation and replacement projects.

If a backlog of capital improvement projects develops, it is a best practice to develop a formal project prioritization process to assure the highest risk and/or consequence assets are addressed to assure stakeholders that available resources are focused on the highest priority projects. Criteria that are often considered in prioritization programs include workplace safety, public safety, reliability of service for customers, regulatory compliance, environmental impacts, and discretionary or aesthetic concerns. Weighting factors could be applied to the different criteria to align priorities with the Boulder's mission and goals.

The development of code-based maintenance findings and CCTV inspections that have been centralized in one location should be leveraged to assist in the planning process.

8.3.6 Training

Assessment

Boulder encourages its staff to attend training courses. Wastewater Maintenance staff members are encouraged to obtain the highest level of Collection System Operator Certification available through the Colorado Department of Public Health and Environment. All WWTP operators keep up-to-date certification and registrations for their various licenses and records are kept of training participation by all Utility Maintenance employees.

There is a formal safety training program and all staff members are required to participate. The safety program addresses the following topics; first aid/CPR, confined space entry, trenching and shoring, and defensive driving. Additional specialized trainings are available for field crews for topics such as specialized equipment operation training and asbestos cement pipe repair training.

The City also offers an in-house basic traffic control training annually, ensuring that all new employees are trained in this subject.

Recommendations

Boulder should develop a cleaning crew training program. The cleaning crew training program should have components that focus on improving both the cleaning work process and the cleaning information process. The training program should include the following:

- Conduct training on objectively assessing condition and defect severity of pipes based on maintenance activities. Use photos to train personnel on the difference between light, medium and heavy condition findings (or 1-5 code). Use other objective measures to assess the condition of a pipe.
- Conduct training to properly record the assessment on the work order form
- Conduct formal training in cleaning techniques for each type of equipment.
- Use CCTV while cleaning to provide feedback and training.
- Boulder may want to consider holding a “training academy” where a professional training service comes in and provides thorough equipment and cleaning training.
- Training should also be held for the CCTV coding system that Boulder chooses for their CCTV crews.

8.4 Design & Performance Provisions

Assessment

A key element in the efficient management of the collection system is the provision of well designed and installed sewers and pump stations. New facilities designed and installed with an emphasis on long-term sustainability can greatly reduce maintenance labor and expense. To facilitate this, Boulder has adopted a set of standards for all new facilities. Boulder’s standards are documented in the “Design and Construction Standards for Wastewater Collection Systems”. The “Design and Construction Standards for Wastewater Collection Systems” contain no provisions or information on planned or necessary acceptance inspections.

Recommendations

Boulder should amend the “Design and Construction Standards for Wastewater Collection Systems” to incorporate guidelines for the acceptance inspection of facilities. These inspections include:

Developer Work – This includes all new pipelines, manholes, and smaller pump stations.

Capital Projects – Larger pumping stations and sewer pipelines designed and contracted directly by Boulder.

Boulder should amend the "Design and Construction Standards for Wastewater Collection Systems" to incorporate SOPs for the testing of all new facilities. These SOPs should include provisions for testing requirements and acceptance criteria.

8.5 Overflow Emergency Response Program

Assessment

Currently Boulder responds to emergencies by sending out maintenance crews to the incident location. After hours, the wastewater standby employee is contacted. The spill is quickly assessed and resources are secured to mitigate the spill occurrence. During the mitigation process, the maintenance crews use visual, and sometimes CCTV, inspections to determine the nature and cause of the spill event.

Following an SSO, the CCTV crews will inspect and the section of sanitary sewer main where the stoppage occurred. The Wastewater Maintenance Supervisor, CCTV inspector, and Repair Crew Lead review the tape and attempt to determine the cause of the stoppage, and access any immediate maintenance concerns with the pipeline.

Response to all SSOs is guided by the Sanitary Sewer Overflow Response Plan. This document was put into place by Boulder in August of 2003. This plan is necessary to meet the requirements of the City of Boulder's Wastewater Treatment Plant Permit. The plan includes sections outlining the assessment of a spill, resolution, follow-up, and reporting.

Recommendations

Boulder's Overflow Emergency Response Program meets most of the requirements of California's WDR. The one recommendation for improvement would be to modify existing procedures executed in response to a spill. Current procedures of placing the problem asset on a list for root control treatment or submitting it to engineering as a potential CIPP should be modified to include the possibilities of increasing the maintenance frequency of the problem pipe, or placing it on the "hot-spot" program. If the asset is currently on one of these programs, Boulder should evaluate developing a cleaning frequency that is less than six months. Also, to be in compliance with the CWA, Boulder needs to develop a formal SSO tracking system.

8.6 Fats, Oils, and Grease (FOG) Control Program

One of the major causes of maintenance problems, blockages, and sanitary sewer overflows in Boulder's collection system is grease. Boulder addresses grease in the collection system through two programs: the sewer cleaning program and in the Industrial Pretreatment Program. The sewer cleaning program is discussed in earlier sections.

The purpose of Boulder's Pretreatment program is to ensure that commercial and residential entities are not contributing pollutants to the system. One of the pollutants is grease or oil in levels that would impact the operation of Boulder's collection system. The pretreatment program does not have a formal FOG program.

8.6.1 Installation of Grease Removal Devices

Assessment

Boulder's FOG program is governed by municipal code regulation with specific section relating to fats, oils, and grease. This code establishes a threshold for dischargers of 100 mg/l, or requires a plumbing device for FOG for those who exceed the threshold. Currently the municipal code refers to the International Plumbing Code for the design criteria of grease removal equipment. The municipal code has minimal requirement for grease removal equipment cleaning, which is every 6 months or as needed.

FOG producing facilities are not currently required to obtain permitting from Boulder. FOG producers are identified by Development Services. When applying for permits, applicants fill out a Business Environmental Questionnaire. If the facility generates wastewater, they are required to fill out an industrial waste survey. Any applicant determined to exceed the above mentioned discharge threshold is required to install grease removal equipment (GRE). There is an existing plan check system for restaurants during the initiation phase. Design approval is performed by the Development Review group. During construction, inspection of the GRE is performed by the plumbing inspector.

Recommendations

The FOG municipal code should be modified to require all new grease-producing facilities to install and maintain grease removal equipment (GRE). Any new or remodel of existing facilities that will have a kitchen, cooking equipment, or a food producing facility should contact Boulder to determine the need and size of the grease controlling device. Modifications should be made to the municipal code to allow for the development of a FOG program that can perform inspections and assess violations accordingly. According to California's WDR section vii of the SSMP, the following suggestions shall be included in the FOG ordinance:

- An implementation plan and schedule for a public education outreach program either through the local public newspaper, radio, television advertisements, flyers or newsletters that will promote proper disposal of FOG;
- A list of acceptable disposal facilities and/or additional facilities needed to adequately dispose of FOG generated within its service area;
- A legal authority to prohibit discharges to the sewer collection system and identify measures to prevent SSOs and blockages caused by FOG;
- A requirement to install grease removal devices such as an interceptor or trap, using the most current regulations and design standards (e.g. CPC), maintenance requirements, BMP requirements, record keeping and reporting requirements; and Authority to inspect the grease producing facilities, enforcement authorities, and enforcing penalties to the businesses that violate FOG control measures.

8.6.2 Inspection & Maintenance Program

Assessment

Currently, there are approximately 400 GRE facilities in Boulder. After design approval and inspection during construction, it then becomes the owner's responsibility to regularly inspect and maintain the GRE. Currently, Boulder does not have any staff dedicated to the inspection of the performance and maintenance of an existing GRE. The pretreatment program has responded reactively with additional site inspections, notices of violation, and issuing requirements for plumbing device installation following SSO events. Due to the lack of an inspection and maintenance program, the property owners may have not been maintaining their

GREs. It is possible that food service establishments (FSE) may bypass their grease trap/interceptor and discharge directly into the sewer line.

Recommendations

Boulder should perform a business case for investment in a FOG prevention program. Development of a formal inspection program should be considered to be included in their FOG ordinance. The business case would evaluate the cost of a formal FOG program against the cost of maintenance and potential SSOs or blockages.

The first step in developing the FOG program would be the identification of all of the FSEs that would require grease removal equipment. There is a database that currently keeps this data, but it is incomplete. The database could be used as a starting point and added to over time. The FOG program would work with the operations group to identify grease hot-spots in the system and evaluate the businesses in the area to identify any that should have GREs. Boulder should develop a policy on how to handle existing FSEs that do not have GREs. Additionally, the FOG program needs to work with Development Services to ensure that all new food establishments are entered into the database.

Once data collection of the existing and new facilities is under way, Boulder can focus on developing an inspection schedule for the restaurants as well as recommending maintenance schedules for the facilities GREs. A report or a log should be prepared after each inspection. Depending on the findings of the inspection reports or logs, the facility will be issued a schedule that enables it to achieve compliance with the current regulations. If the facility fails to follow the regulations and/or FOG ordinance, a system of progressive discipline should be defined that will ultimately result in Boulder's ability to shut off the water of non-compliant FSEs.

8.7 Monitoring, Measurement, and Program Modifications

Assessment

Boulder uses a computerized maintenance management system for tracking its maintenance, repairs, and inspections of the sewer system. Additionally, it maintains separate GIS data documenting the locations of SSOs as well as repair and replacement projects. CCTV data is collected to monitor the condition of the system. Maintenance and structural issues are documented and the appropriate crew is assigned to perform the repair or to maintain the pipeline.

Boulder has developed several performance indicators for the maintenance of its sewer system. Boulder has set goals and developed performance measures to document what they are doing to maintain the wastewater collection system and to gauge how well it is being done. Performance measures are calculated annually and documented in the Utility Maintenance Division's annual report. The annual report also documents how the utility is performing against like size agencies in the area.

Currently modifications to the maintenance frequency of pipes in the system are performed in a reactive way. When CCTV crews identify a problem, there is an SSO or blockage, or a customer complaint is received, the Utility Maintenance Division responds to alleviate the problem. This may either be a one-time maintenance event or it may be the inclusion of the facility in the hot-spot program.

Recommendations

Boulder should assign a person to review the SSMP periodically to check its effectiveness and timeliness. This person can prepare regular progress reports documenting the effectiveness, potential changes, and summary of the program activities. Currently Boulder collects a large amount of data about maintenance activities in UMMS. The data is used now as documentation a maintenance event occurred and used to measure progress towards performance goals. As recommended in prior sections of this report, additional information could be gathered during maintenance events about the condition of the pipes. This data could be analyzed and modifications to maintenance activities could be optimized.

8.8 Program Audits and Communication Program

Assessment

California's WDR requires that an agency perform an audit of all programs associated with the SSMP every two years. The audit should identify any deficiencies in the SSMP programs and include the corrective steps to resolve the issues. The audit will help ensure the effectiveness of the SSMP implementation program. The audit should be conducted by a person other than a member of the agency's staff. The auditor should conduct random interviews of the staff in reviewing the SSMP performance.

Recommendations

An effective communication program can keep Boulder from missing the critical SSMP deadlines. Boulder should involve the key stakeholders and the public during the process of developing an SSMP avoiding any controversial discussions on its various elements.

8.9 Conclusions and Recommendations

In general, Boulder has the framework in place that will bring it into general compliance with the terms of the emerging regulations of the Western United States in the near future. Many of the recommendations made here are for the improvement of the maintenance of the utility. These are recommendations that incorporate best management practices and industry standards for the operation of the utility. The challenge for Boulder will be to implement these recommendations to improve the condition of the system. Below is a summary of the recommendations:

1. Maintain an Up-to-Date Map of the Sanitary Sewer System
    - Completion of the GIS database should be made a priority. The current practice of correcting discrepancies by submitting a Utility Field Report to the supervisor or planner helps to ensure that the existing GIS database is continually checked against reality.
2. Computerized Maintenance Management System
    - UMMS should be updated and more closely integrated with the GIS system, or a new GIS-based CMMS system should be implemented specifically for the sanitary sewer system. It should be able to collect maintenance findings by asset and support geographical work scheduling.

- UMMS should be updated to store condition data which would be collected on maintenance and inspection visits. Boulder should have all data, such as trouble area cleaning records, root treatment, and others, entered into the UMMS.
- A detailed service request or work order form should be created and provided to crews who maintain the sewer system assets. The work order would be specific to the type of work being performed and would collect code-based findings for each asset maintained.
- Boulder should provide training to staff in the effective usage of GIS and CMMS software.

3. Cleaning Program
   - The system is currently being cleaned, on average, once per year, and the City's cleaning program has resulted in a reduction of SSOs. Boulder should move to code-based collection of findings and collection of this data should be stored in an upgraded CMMS. Over the next few cleaning cycles, data could be collected and, most likely, more accurate cleaning frequencies could be developed for the individual line segments.
   - The utility should look at moving resources to the repair crew or creating a second repair crew. As will be discussed in the following section, the CCTV crew should be generating repair work that Boulder crews could be repairing. Additionally, as Boulder does less cleaning they may want to consider transitioning from using mechanical rodding equipment to combination jet rodder units.
   - It is recommended that Boulder develop a contingency plan to inspect large diameter sewers over the next 10 years to identify the large diameter sewers that have maintenance or structural issues.
4. Inspection Program
   - It is recommended that Boulder move to an industry recognized defect coding system. This will enable Boulder to collect consistent records if there is turn-over on the CCTV crew as well as becoming a standard for contractors. Training should be provided initially and periodically to the CCTV crews as well as to any other personnel who might need to use the software or operate the equipment.
   - CCTV crews should be used for quality control (QC) on maintenance and repair activities. This evaluation should be performed on at least 3 pipes per 100 pipes cleaned per cleaning crew.
5. Rehabilitation and Replacement Program
   - Boulder should develop a standardized methodology to determine repair, rehabilitation, and replacement needs. To assure consistent decision-making in Boulder's sewer repair, rehabilitation and replacement project identification process, it is very important that Boulder processes future CCTV data based on a formal decision process. This can be done manually based on the decision flow diagram, or can be an algorithm developed from the diagram.
   - Boulder should be able to integrate the condition findings with the GIS.
   - When a backlog of capital improvement projects develops, it is a best practice to develop a formal project prioritization process to assure the highest risk and/or consequence assets are addressed to assure stakeholders that available resources are focused on the highest priority projects.

6. Training
   - Boulder should develop a cleaning crew training program. The cleaning crew training program should have components that focus on improving both the cleaning work process and the cleaning information process. Training should also be held for the CCTV coding system that Boulder chooses for their CCTV crews.
7. Design & Performance Provisions
   - Boulder should amend the "Design and Construction Standards for Wastewater Collection Systems" to incorporate guidelines for the acceptance inspection of facilities. Boulder should amend the "Design and Construction Standards for Wastewater Collection Systems" to incorporate SOPs for the testing of all new facilities.
8. Overflow Emergency Response Program
   - The one recommendation for improvement would be to modify existing procedures executed in response to a spill. Current procedures of placing the problem asset on a list for root control treatment or submitting it to engineering as a potential CIPP should be modified to include the possibilities of increasing the maintenance frequency of the problem pipe, or placing it on the "hot-spot" program.
9. Installation of Grease Removal Devices
   - The FOG municipal code should be modified to require all new grease-producing facilities to install and maintain grease removal equipment (GRE).
   - Modifications should be made to the municipal code to allow for the development of a FOG program that can perform inspections and assess violations accordingly.
10. FOG Inspection & Maintenance Program
    - Boulder should perform a business case for investment in a FOG prevention program. Development of a formal inspection program should be considered to be included in their FOG ordinance.
    - Boulder should identify all of the FSEs that would require grease removal equipment. There is a database that currently keeps this data, but it is incomplete.
    - Boulder should develop a policy on how to handle existing FSEs that do not have GREs. Additionally, the FOG program needs to work with Development Services to ensure that all new food establishments are entered into the database.