BOZEMAN MT

Wastewater Collection System Facility Plan Update

Final Document

December 2024

Adopted by City Commission Resolution No. 5664

AE2S

TD&H Engineering

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Montana.

Name: Zachary E. Magdol

Date: February 25, 2025 Registration Number: 61962



Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

Table of Contents

1.0 Executive Summary

2.0 Definition of Terms and Acronyms

3.0 Data Collection Technical Memorandum

4.0 Manhole Condition Assessment Technical Memorandum

5.0 Wastewater Flow Characterization Technical Memorandum

6.0 Feature Manipulation Engine and GIS Technical Memorandum

7.0 Hydraulic Model Development and Results Technical Memorandum

8.0 Risk Assessment Technical Memorandum

9.0 Capital Improvement Plan Technical Memorandum

10.0 Asset Management Coordinate System Technical Memorandum

11.0 Updating Model Development Loading Technical Memorandum

Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

1.0
Executive Summary

Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

Table of Contents

Chapter 1 Introduction and Purpose....2
Chapter 2 How to Use this Plan....4
Chapter 3 Data Collection....6
Chapter 4 Manhole Condition Assessment Program....7
Chapter 5 Wastewater Flow Characterization....8
Chapter 6 FME and GIS Data Exchange....10
Chapter 7 Hydraulic Model Development and Results....11
Chapter 8 Risk Assessment....12
Chapter 9 Capital Improvement Plan....13
Chapter 10 Asset Management Coordinate System....15
Chapter 11 Updating Model Development Loading....16

Chapter 1 Introduction and Purpose

The City of Bozeman (City) owns and operates a wastewater collection system serving its residents, businesses, and industry. The City continues to experience rapid growth, with an average estimated annual population growth of 4% over the past 15 years. This growth coupled with aging infrastructure presents many challenges to maintaining, operating, and expanding the wastewater collection system.

The City periodically undertakes comprehensive planning efforts to help guide system improvements so that adequate service is provided to the growing community. These planning efforts are referred to as Facility Plans. The previous Wastewater Collection System Facility Plan was completed in 2015. Since the 2015 wastewater facility plan, many of the improvements identified in the facility plan have been completed. As development pressure continues to grow and existing infrastructure ages, the wastewater collection system model and reference planning documents required a comprehensive update to ensure the City can continue to meet its level of service goals and accommodate growth.

In 2020, Advanced Engineering and Environmental Services (AE2S) and TD&H Engineering was selected to complete a multi-phase update of the City's wastewater collection model (Phase I) and wastewater collection facility plan (Phase II). An amendment to the agreement was initiated in June 2023, during phase II of the update, to address the introduction of Montana Senate Bill 382, which included conformance with land use planning act and potential changes to development density.

This document summarizes the planning methods, assumptions, and outcomes for the Facility Plan Update.

The purpose and goals of the specific phases of the Facility Plan Update are outlined below:

Phase I

- Provide recommendations to transition to a uniform coordinate system.
- Complete a comprehensive survey and data collection of assets.
- Develop the basis for a manhole condition assessment program.
- Characterize existing and future wastewater flows.
- Establish the framework processes for future hydraulic model updates.
- Update the existing collection system model, including calibration.
- Establish or verify hydraulic performance standards for system analysis.
- Evaluate existing and future system performance.
- Identify hydraulic deficiencies and mitigation for options.

Phase II

- Complete a wastewater collection system risk assessment.
- Evaluate increased density infill and identify hydraulic deficiencies.
- Develop a general process to update and track system loading.

- Prioritize system improvements surrounding growth, risk, and hydraulic deficiencies.
- Develop a comprehensive capital improvement plan to address near-term and long-term system needs, while continuing to plan for and accommodate the City's growth.

The culmination of the effort provides City staff with the resources and tools to continue meeting the City's strategic plan by fostering a well-planned City, prioritizing improvements for existing and new infrastructure, and ultimately helping guide public funds to the right project at the right time.

This Facility Plan organization diverges from previous versions in that it is divided into nine (9) Technical Memoranda representing the significant and distinct tasks carried out to update the citywide hydraulic model, evaluate existing performance, develop future alternatives, and provide recommendations for the City's Capital Improvement Program. The Facility Plan Executive Summary provides an overview of each Technical Memorandum (TM) digesting and reporting the primary findings and recommendations. The nine (9) Facility Plan Technical Memoranda are as follows:

- Data Collection (TM 3)
- Manhole Condition Assessment Program (TM 4)
- Wastewater Flow Characterization (TM 5)
- Feature Manipulation Engine (FME) and Geographic Information System (GIS) Data Exchange Routine (TM 6)
- Hydraulic Model Development and Results (TM 7)
- Risk Assessment (TM 8)
- Capital Improvement Plan (TM 9)
- Asset Management Coordinate System (TM 10)
- Updating Model Development Loading (TM 11)

As the City continues to grow, new infrastructure is added to the collection system, and old infrastructure is replaced, it is recommended that the hydraulic model be updated annually at a minimum and the Facility Plan be updated or revisited every five years. These ongoing updates will help ensure the City continues to responsibly and proactively plan and maintain public infrastructure.

Chapter 2 How to Use this Plan

This is a planning document and should be referenced in that way. All recommendations in this Facility Plan warrant some additional evaluation prior to implementation. Additionally, the City should undergo routine updates to the collection system hydraulic model and the Facility Plan to ensure its recommendations are still aligned with City priorities, development trends, and community land use plans.

In an effort to make this Facility Plan more usable, below is a summary of the distinct sections (i.e., Technical Memoranda) and offers a suggestion on when and why the reader may wish to reference them in more detail. These summaries are expanded upon in this Executive Summary in the preceding sections.

- The Data Collection Technical Memorandum (TM 3) provides a summary of the data used in this Facility Plan. The reader should refer to this TM to understand the source and types of the geographic information system (GIS) data referenced in the collection system analysis. This section also includes information about the planning GIS data (e.g., land use) and overview maps of the existing collection system.
  - The Manhole Condition Assessment Program Technical Memorandum (TM 4) provides a recommended framework for the City to implement a condition assessment program to help with prioritizing collection system maintenance, rehabilitation, and replacement. This TM is especially useful for City utility staff and can serve as a reference to guide what type of condition data to collect, how to collect it, and the recommended frequency.
  - The Wastewater Flow Characterization Technical Memorandum (TM 5) provides a thorough explanation of the analysis carried out to define existing wastewater flows and project future flows. The reader should refer to this TM to dig into the details of how this Facility Plan defined the various components of wastewater generation (domestic, base groundwater inflow, wet-weather inflow), how future wastewater is estimated and applied to future scenarios. This TM will be especially useful to the development community to understand planning level wastewater flows for various zoning categories and land use types.
- The Feature Manipulation Engine (FME) and Geographic Information System (GIS) Data Exchange Technical Memorandum (TM 6) provides the database and hydraulic model steps to import new collection system information from the City. This TM should be referenced by City staff looking to make a system-wide model update using the City's collection system GIS.
  - The Model Development and Results Technical Memorandum (TM 7) provides thorough documentation on how the citywide hydraulic model was developed including the model network and wastewater allocation. TM 7 describes the City's collection system performance criteria and evaluates how the existing system performs. TM 7 also provides detail on the future condition scenarios evaluated in the hydraulic model and the results. This TM will help the reader understand the basis of the infrastructure improvement recommendations.
- The Risk Assessment Technical Memorandum (TM 8) details the analysis carried out to quantify the risk to existing collection system infrastructure and help prioritize rehabilitation and

replacement (R&R) recommendations. This TM will be especially useful to City utility staff and for the public to understand why R&R is important and how the City plans those projects.

- The Capital Improvement Plan (CIP) Technical Memorandum (TM 9) provides a summary of the recommended improvement projects, their estimated cost, and recommended timing for near-term (0-5) and long-term (6-20) year improvements. In general, this provides the City with a roadmap to address growth, risk, and maintenance related projects in a data driven logical approach.
- The Asset Management Coordinate System Technical Memorandum (TM 10) provides a summary of the current horizontal and vertical coordinate systems used throughout the community and offers recommendations to standardize coordinate systems for the City to help streamline and make consistent the process of moving from development plans > record survey > City's asset management system. This effort is included in this Facility Plan due to previous significant data discrepancies in the City's collection system GIS database.
- The Updating Model Development Loading Technical Memorandum (TM 11) provides a step-by-step process for incorporating new developments into the hydraulic model. The reader should refer to this TM if they are seeking to make model updates based on developer's plans.

Chapter 3 Data Collection

The Data Collection Technical Memorandum (TM 3) provides details about the data used to develop the collection system model and recommendations. There are four overarching categories of data used for this Facility Plan:

1) Survey Data
2) Wastewater Flow Data
3) Operation Data
4) Geographic Information System (GIS) Data

As of July 2020, there were approximately 4,800 manholes in the City's wastewater collection system, most of which included varying degrees of data. In general, most of the manhole information did not include detailed pipe invert information. Approximately 1,400 manholes were field surveyed during the summer and fall of 2020. The surveyed manholes were selected based on pipe diameter (10-inches or greater), material of pipe (i.e., VCP prioritized to verify older infrastructure), and overall contributing area. Field survey included verifying location, documenting rim elevation, measuring depth to incoming and outgoing pipes, and verifying pipe size, direction, and material. The remaining manhole rim elevations were determined using citywide LiDAR. The remaining sewer invert elevations were determined by either interpolation between known points, from minimum pipe slope standards (DEQ 2), or applicable record drawing information.

Wastewater flow monitoring data was collected at six critical interceptors during spring runoff 2020 (April through June). These locations were chosen to enable model calibration of the various sewersheds and based on discussions with City staff to understand priorities based on previous flow monitoring efforts. The six interceptors monitored include the North Frontage Road, Baxter, Davis-Fowler, 27th Ave/Cattail Creek, East Gallatin River, and 19th Ave/11th Ave. In addition to the 2020 monitoring data, historical data was referenced, specifically ongoing efforts carried out by the City and a 2018 effort conducted by Sanderson & Stewart which looked at inflow and infiltration (I&I) in the downtown region.

The operating data referenced in this Facility Plan includes lift station SCADA records, Water Reclamation Facility (WRF) inflow, and water meter records from 2016 through July 2020. The lift station operation data further helped with model calibration and validation. The WRF inflow data was used in model calibration and in developing the various collection system flow components, which is discussed in detail in the Wastewater Flow Characterization Technical Memorandum (TM 5). Water meter records were used to determine the domestic component of wastewater generation, which is also detailed in TM 5.GIS data provided by the City for this Facility Plan included:

- Wastewater collection system network (manholes, gravity main, force main, lift stations)
- Water meter points
- Existing land use
- Future land use
- Tax increment districts overlay

The land use and zoning GIS data used in this Facility Plan are from 2020. Future updates to the City's Growth Policy should be incorporated into future Facility Plan updates.

Chapter 4 Manhole Condition Assessment Program

In response to aging collection system infrastructure and a growing need for efficient asset management, a comprehensive approach to streamline manhole inspection protocols was developed. The Manhole Condition Assessment Program Technical Memorandum (TM 4) summarizes the protocol.

The recommended inspection protocols were developed using the National Association of Sewer Service Companies Organization (NASSCO) industry standards but modified to specifically address the City of Bozeman's needs and limitations. A unique inspection form was developed in Survey 123 that is simple for operators to complete and integrates into the City's asset management system (Granite XP or other GIS databases). The inspection data can also be included in the City's Risk Model which was developed for this Facility Plan and is detailed in the Risk Assessment Technical Memorandum (TM 8). The City will be able to more accurately prioritize R&R improvement projects as more condition data is collected and included into the Risk Model, resulting in a more effective use of the limited maintenance funds.

The Condition Assessment Program also offers a recommended inspection schedule which utilizes the existing asset information such as pipe material and age. There are approximately 1,000 manholes that have been prioritized based on their estimated low remaining useful life (RUL). These manholes represent areas with vitrified clay and asbestos cement pipes. It is recommended that the City inspect these 1,000 manholes over a 5-year period (200 manholes per year).

The proposed modifications to the manhole inspection procedure present a forward-looking approach to infrastructure management. By incorporating immediate data entry, comprehensive risk and condition assessments, and robust data storage and analysis methods, the City is poised to significantly improve its wastewater system management. The initiative not only prioritizes high-risk assets but does so in a manner that is efficient, technologically supported, and aligned with best practice methodologies. As the City moves forward, these strategies will be crucial in managing its infrastructure strategically, ensuring reliability, and optimizing resource allocation within its wastewater collection system.

Chapter 5 Wastewater Flow Characterization

Technical Memorandum 5 provides a comprehensive characterization of the current and expected future wastewater flows in Bozeman. This memorandum forms a foundational component in guiding the strategic planning for sustainable wastewater management, aligning with Bozeman's growth policies and infrastructure demands, and adhering to environmental regulations.

The study area, primarily defined by the Growth Policy Boundary as per the Bozeman Community Plan (Resolution No. 5133, November 17, 2020), encompasses a total area of approximately 45,000 acres, with 13,400 acres within existing City limits. This boundary has been delineated based on current planning documentation, historical facility plans, geographic boundaries, and collaborative discussions with City staff.

The memorandum provides a detailed wastewater flow analysis correlating land use and zoning categories to wastewater production, which are referred to as duty factors. Duty factors, typically referred to in gallons per acre per day, provide a streamlined method to understanding potential wastewater flows from proposed development.

The key findings and recommendations from this analysis include:

- Citywide total annual wastewater flow is generally increasing corresponding to increasing population. It is estimated that the average annual population growth of the past decade is approximately 4%. The average daily and peak hourly wastewater flow at the Water Reclamation Facility from 2015 through 2019 was approximately 5.5 and 10.6 million gallons per day (MGD), respectively. This equates to an average annual per capita flowrate of 117 gallons per capita per day (gpcd).
- The City's collection system experiences relatively high inflow and infiltration (I&I) throughout the spring runoff season and into the early summer. This high I&I is primarily driven by seasonally high groundwater which is prevalent throughout the City but especially within the northwestern portions. This Facility Plan recommends continuing to use the City standard 150 gallons per gross acre per day to represent a constant dry-weather base inflow. A duty factor of 550 gallons per gross acre per day was utilized for planning purposes for wet-weather periods to account for varying conditions.
- A rainfall derived inflow and infiltration (RDII) allocation was evaluated to simulate peak flows and worst-case conditions. The RDII allocation is based on the 25-year NOAA Atlas-2 24-hour design storm, which has a total precipitation depth of approximately 2 inches. This method provides a conservative estimate of RDII but is deemed reasonable given climate change and the age of the collection system leaving it susceptible to higher I&I.
- The R3, R4, R5, B-2M, and REMU zoning categories have recently been coming into the City with higher densities than previously assumed and to account for this increase, a specific sub-analysis was carried out to determine the appropriate duty factors for denser developments. The duty factors for these zones assume densities between 15-20 dwelling units per gross acre.
- Future land use categories were assigned duty factors based on allowed zoning categories described in the 2020 Community Plan. The largest future land use category is Urban

Neighborhood and is assumed to be approximately 9 dwelling units per gross acre with a dry-weather duty factor of approximately 1,400 gallons per acre per day.

- An Infill Scenario was evaluated to understand the impacts from building out the current City limits. This scenario assumes that undeveloped land within the City is developed based on its zoning category or future land use. The Infill Scenario adds an additional 2.8 MGD to the system under wet-weather conditions.
- An Increased Density Scenario was evaluated to understand the impacts of redevelopment occurring at denser land use than existing conditions. This scenario assumes that all existing single-family areas experience a 25% increase in wastewater loading, infill areas develop at 20 dwelling units per gross acre, and B2-M and REMU zones are increased to the R5 duty factor. Additionally, specific areas were adjusted to reflect City staff input on anticipated development. The Increased Density Scenario results in an additional 3.6 MGD in domestic loading over existing conditions. This scenario helps provide a general sensitivity analysis against future growth and helps identify areas to monitor as the City continues to grow.
- This Facility Plan recommends the City continue to use its design standards to set the criteria for sizing wastewater collection infrastructure, which are also consistent with the 2015 Facility Plan. These standards include a domestic wastewater loading value of 64.4 gallons per person per day plus 150 gallons per acre per day for base inflow infiltration and the 10-state-standard population-based peaking factor. This method provides a rational estimate of peak wastewater flow so that sewers can be sized to maintain adequate capacity.

Chapter 6 FME and GIS Data Exchange

The Feature Manipulation Engine (FME) and GIS Data Exchange Technical Memorandum (TM 6) provides a step-by-step process for globally updating the hydraulic model network (i.e., links and nodes) using the City's collection system GIS database. This process is specific to InfoSWMM, the current (as of September 2024) platform for the City's collection system hydraulic model. When, or if, the City shifts to a different hydraulic modeling software, this routine will need to be revised.

TM 6 includes detailed workflows for updating data source files, initializing the model, selecting appropriate scenario, running the InfoSWMM GIS Exchange tool, executing the exchange, verifying the import, and correcting connectivity issues. This Technical Memorandum was developed to assist City staff or future model users in ensuring the model is consistent with most recent City asset information.

Chapter 7 Hydraulic Model Development and Results

The Hydraulic Model Development and Results Technical Memorandum (TM 7) summarizes the methods used and assumptions made to develop the citywide calibrated hydraulic model. TM 7 outlines the design criteria and standards for gravity main, force main, lift stations and other wastewater collection infrastructure. The model calibration was completed using the wet-weather flow monitoring information and is discussed at length in TM 7.

The primary performance criteria driving this Facility Plan include:

- The peak depth to diameter (d/D) ratio for gravity sewer must be no greater than 0.75.
- The minimum allowable velocity in gravity mains is 2.0 feet per second.
- Gravity main shall generally be no deeper than 15 feet and no shallower than 5 feet (depth to crown of pipe).
- Minimum and maximum force main velocities shall be 3 and 8 feet per second, respectively.
- Lift station pumping capacity shall be sized to meet peak flow rate under wet-weather conditions.

Existing conditions were evaluated under dry- and wet-weather conditions. Generally, the collection system meets performance standards. There are some areas that experience surcharging under existing conditions, these areas are summarized in detail in TM 7. Improvements to address these deficiencies were developed in conjunction with the risk assessment and future condition analysis so that cost-effective projects are recommended.

Four future condition scenarios were evaluated using the hydraulic model. These scenarios include Infill, Ultimate Buildout (UBO), Ultimate Buildout West (UBO West), and Increased Density. The Infill Scenario evaluates impacts from development within the current City limits. The UBO scenario evaluates complete buildout of the growth service area boundary and assumes all future wastewater is conveyed to the City's existing Water Reclamation Facility. The UBO West scenario includes the same loading as the UBO scenario but includes wastewater flow diversion to a future hypothetical wastewater treatment facility assumed to be located northwest of the City limits. This scenario optimizes gravity flow and can eliminate the need for several existing and future lift stations but would require substantial planning to establish a new treatment facility. Finally, the Increased Density scenario evaluates increased wastewater generation within City limits to simulate high densities of redevelopment and infill. This scenario assumes the wastewater loading outside City limits is consistent with the UBO scenario. Collection system infrastructure was sized and laid out within each scenario to maintain the City's performance criteria. TM 7 provides figures and detailed descriptions of the future infrastructure.

Chapter 8 Risk Assessment

The Risk Assessment Technical Memorandum (TM 8) summarizes the assessment performed for the City's collection system pipes. The goal of this assessment is to establish a methodical, data-driven, and adaptable framework for evaluation risks of potential sewer system failures. The assessment process uses data from GIS, the hydraulic model, historical stoppages, and CCTV records, along with the InfoAsset Planner® software for modeling.

Risk is calculated using two main criteria, Consequence of Failure (COF) and Likelihood of Failure (LOF), which are combined to assess risk levels for each asset. COF assesses the impact of failure on system operations and LOF estimates the probability of failure based on factors like pipe material, historical issues, and hydraulic performance. COF is primarily based on pipe flow rate. LOF criteria include factors such as pipe material, flow depth-to-diameter ratio, NASSCO defect ratings, repair history, and remaining useful life. Assets with high-risk scores were grouped with other priority assets as identified through the existing and future conditions hydraulic modeling to inform the near-term capital improvements plan.

It is recommended to update this Risk Assessment periodically with new condition inspection data, work order logs, revised GIS, and revised hydraulic model results. This update will likely be required every three to five years.

Chapter 9 Capital Improvement Plan

The purpose of the Capital Improvement Plan Technical Memorandum 9 (TM 9) is to present recommended capital improvement projects aimed at enhancing the hydraulic performance of the existing system, address aging and critical assets, and ensure capacity for future expansion. These recommendations are based on evaluations from hydraulic modeling, risk assessments, and consultations with City staff. TM 9 includes projects to address both near-term (5-year) and long-term (6-20 year) needs, providing detailed descriptions, cost estimates, and implementation considerations. It also revisits previously recommended but unconstructed projects to determine their current relevancy and incorporates them into a comprehensive Capital Improvement Plan (CIP) to ensure efficient and cost-effective allocation of capital resources. ***Table 9-1*** below lists the priority near-term improvement projects, their total project cost in 2024 dollars, and their primary drivers (i.e., existing capacity, risk assessment, or system expansion). TM 9 provides more detail including maps displaying project locations.

Table 9-1 – Summary of Near Term (5-year) Capital Improvement Projects

Project	Total Project Cost	Project Drivers
Project 1 – 19th Ave / Kagy Blvd Interceptor Improvements	$5,291,600	Infill capacity Critical aging infrastructure
Project 2 – Durston Road and 17th Avenue Sewer Main Replacement	$959,900	Critical aging infrastructure
Project 3 – 7th Avenue to Oak Street Sewer Main Replacement	$1,276,400	Critical aging infrastructure
Project 4 – North 11th Avenue Sewer Main Replacement	$574,400	Critical aging infrastructure
Project 5 – Plum Avenue Sewer Main Replacement	$1,326,500	Critical aging infrastructure
Project 6 – 4th Avenue, Babcock Street and Grand Avenue Sewer Main Replacement	$665,000	Existing capacity concerns Critical aging infrastructure
Project 7 – North 9th Avenue, West Villard Street, and South 9th Avenue Sewer Main Replacement	$2,159,300	Critical aging infrastructure
Project 8 – West Harrison Street, 10th Avenue, and Curtiss Street Sewer Main Replacement	$2,478,600	Critical aging infrastructure
Lift Station Project 1 – Valley Center Lift Station	$5,962,700	System expansion
Small Pipe Project 1 – South Black Avenue 6-inch Sewer Main Replacement	$1,817,000	Existing capacity concerns Critical aging infrastructure
Small Pipe Project 2 – South Willson Avenue 6-inch Sewer Main Replacement	$1,721,700	
Small Pipe Project 3 – South Grand Avenue 6-inch Sewer Main Replacement	$1,377,600	
Small Pipe Project 4 – West Olive Street 6-inch Sewer Main Replacement	$691,400	
Small Pipe Project 5 – South 4th Avenue 6-inch Sewer Main Replacement	$961,100	
Small Pipe Project 6 – South 3rd Avenue 6-inch Sewer Main Replacement	$971,800	

Chapter 10 Asset Management Coordinate System

The Asset Management Coordinate System Technical Memorandum (TM 10) provides recommendations for transitioning the City of Bozeman to a uniform coordinate system. The City faces challenges in efficiently managing the substantial data associated with rapid development and City expansion. This memorandum emphasizes the necessity of adopting a consistent vertical and horizontal coordinate system for all drawings and surveys to streamline workflows and enhance data management.

Currently, there is no official policy in place requiring developers to submit digital data covering newly installed City assets. The City has adopted the North American Vertical Datum 1988 (NAVD 88) through Resolution 5113 and Ordinance 2032 for vertical datum but there is no formal resolution establishing a uniform horizontal coordinate system or projection. The lack of consistency has led to significant inefficiencies within City departments.

A citywide horizontal coordinate system should be established. This system will align all future engineering and surveying efforts, ensuring consistency in project execution and data management. The City should continue using NAVD 88 as the uniform vertical datum for all projects. This will standardize elevation data, aiding in more accurate and reliable engineering practices.

It is recommended the City conduct a preliminary engineering study to determine the cost of a GPS survey base station. This base station facility would enhance the accuracy of geospatial data collected throughout the City, supporting surveying and construction projects.

It is also recommended that additional permanent monuments be installed. Durable monuments should be established and maintained across the City at approximately one-mile intervals. These should be placed in safe, accessible locations such as City parks or rights-of-way, and away from overhead impediments to facilitate easier use by GPS. Each monument should be well-documented, including its date of establishment, coordinates, and a description of its location, ensuring their utility for future City projects.

The implementation of these standards and recommendations requires coordinated efforts from City departments and external engineering and surveying firms. Specific measures include setting a citywide horizontal and vertical control network under the supervision of a Licensed Professional Land Surveyor and documenting each control point accurately. Ensuring that all new data submissions adhere to these standards will optimize the City's project efficiency and data integrity.

Chapter 11 Updating Model Development Loading

Technical Memorandum 11 includes a step-by-step workflow for updating the InfoSWMM model with new or additional loading based on development plans. It should be noted that the City may shift to a new platform for its Collection System hydraulic model – if this occurs, TM 6 and TM 11 would need to be refreshed to provide an updated workflow specific to the new platform / hydraulic modeling software.

2.0
Definition of Terms and Acronyms

Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

Definition of Terms and Acronyms

Term	Acronym	Definition
acres	**ac**	
Average Annual Flow	**AAF**	Defined as the total flow for a one-year period divided by the number of days in the year. AAF includes domestic flow, base infiltration flow, and RDII flows.
Base Infiltration	**BI**	A portion of total wastewater flow defined as the portion of wastewater flow that enters the wastewater collection system as a constant flow. The flow varies throughout the year and is influenced by the ground water table and seasonally by spring runoff/snowmelt and by dry or winter conditions.
Montana Department of Environmental Quality	**DEQ**	
Domestic Flow		A portion of the total wastewater flow defined as flow that originates from indoor plumbing and water use including residential, commercial, and industrial activities.
Dry Weather BI		A portion of total wastewater flow defined as ground water that enters the system during the winter months (dry season).
Dry Weather Flow	**DWF**	Defined as the wastewater flow in the collection system that is not affected by rain events. This includes domestic flow and dry weather BI.
Feature Manipulation Engine	**FME**	
Gallons per acre per day	**gpad**	
Gallons per capita per day	**gpcd**	
Gallons per day per inch-diameter-mile of pipe	**gpd/idm**	
Gallons per minute	**gpm**	
Geographic Information System	**GIS**	
Inflow and Infiltration	**I&I**	Inflow and infiltration refers to water that enters the wastewater collection system originating from groundwater, rainfall, and/or snowmelt.
Maximum 30-Day Flow		Defined by taking the 30-day rolling average daily volume of wastewater. The maximum value is reported as the maximum 30-day flow.
Maximum Daily Flow		Defined as the maximum volume of wastewater over a period of one calendar day.
Maximum Hourly Flow		Defined as the maximum volume of wastewater over a period of one hour.
Maximum Monthly Flow		Defined by taking the volume of wastewater for each month and averaging the flow over the number of days in the month. The maximum value is reported as the maximum monthly flow.
Million gallons per day	**MGD**	
Minimum Daily Flow		Defined as the minimum volume of wastewater over a period of one calendar day.
Minimum Monthly Flow		Defined by taking the volume of wastewater for each month and averaging the flow over the number of days in the month. The minimum value is reported as the minimum monthly flow.

Montana State University	**MSU**	
National Association of Sewer Service Companies Organization	**NASSCO**	A professional organization providing standardization, education, technical resources, and advocacy for underground infrastructure operation and maintenance, condition assessment, rehabilitation, and replacement.
Non-Irrigation Demand		Defined as metered water consumption during months that are not impacted from seasonal outdoor water use. Used to define the domestic flow entering the wastewater collection system.
North American Vertical Datum 1988	**NAVD 88**	
Operation and Maintenance	**O&M**	
Optical Remote Sensor	**ORSL**	
Poly-vinyl-chloride pipe	**PVC**	
Rainfall Derived Inflow and Infiltration	**RDII**	Defined as the portion of wastewater flow that originates from rain events. Water that enters the system during and after the storm via inflow and infiltration.
Reinforced concrete pipe	**RCP**	
Supervisory Control and Data Acquisition	**SCADA**	
Wastewater Duty Factor	**WWDF**	Wastewater flow generated per unit area associated with land use or zoning - typically in units of gallons per acre per day.
Water Reclamation Facility	**WRF**	Wastewater treatment plant.
Wet Weather BI		A portion of total wastewater flow defined as ground water that enters the system during the wet months caused by high ground water due to spring runoff.
Wet Weather Flow	**WWF**	Defined as the total wastewater flow during the spring runoff season and includes domestic flow and wet weather BI flow.
Net Area		When discussing land use or zoning, net area refers to the area that is developed and therefore generates wastewater flows. Net area excludes right-of-way, riparian areas, and other protected areas.
Gross Area		When discussing land use or zoning, gross area refers to an area encompassing developable land, potential streets, and protected areas.
Ultimate Build-Out	**UBO**	Complete development of the entire Growth Policy Boundary.
Universal Transverse Mercator Coordinate System	**UTM**	
Urban Renewal District	**URD**	Areas within the City of Bozeman established to encourage redevelopment by leveraging property tax within the district.
Tax Increment Finance Districts	**TIF Districts**	Areas within the City of Bozeman established to encourage development or redevelopment by leveraging property tax within the district.
Vitrified clay pipe	**VCP**	

3.0
Data Collection Technical Memorandum

Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

Table of Contents

Chapter 1 Introduction and Purpose 2

Chapter 2 Survey Data 3

2.1 Collection Methodology 4

Chapter 3 Flow Monitoring Data 6

3.1 Historical Monitoring Data 6
3.2 Spring 2020 Monitoring Data 7
3.3 Monitoring Methodology 10
3.4 COVID-19 Pandemic Considerations 10

Chapter 4 Operating Data 12

4.1 Lift Stations 12

Chapter 5 Water Reclamation Facility Inflow 14

Chapter 6 Water Meter Data (Domestic Water Meter Data) 15

Chapter 7 GIS Data 16

List of Tables

Table 3.1: Summary of Historic and Downtown Wastewater Flow Monitoring Efforts 7
Table 3.2: Summary of Spring 2020 Wastewater Flow Monitoring Efforts 8
Table 3.3: Summary of City Lift Stations 12

List of Figures

Figure 2-1: Surveyed Manholes 5
Figure 3-1: Flow Monitoring Locations 9
Figure 4-1: City of Bozeman Collection System 13

Chapter 1 Introduction and Purpose

The purpose of the Data Collection Technical Memorandum **(TM)** is to describe the data structure, format, collection processes, and methodology required to update the City's Wastewater Collection System hydraulic sewer model. The TM is broken down into the following sections:

1. Collection System Infrastructure **Survey Data**
    a. Rim and Invert Elevations
2. Wastewater **Flow Monitoring Data**
3. Wastewater Collection System **Operation Data**
    a. Lift Station Wetwell Dimensions, Pump Type, Pump Records
    b. Water Reclamation Facility (WRF) Influent flow
    c. Water Meter Data
    d. GIS Data

In addition to this TM describing the data collected, a folder with pertinent digital data files was provided to the City. The folder includes the following information:

- Survey Data
    - Raw manhole survey data in .csv and .dwg format
    - *Note that this data was compiled to include in the hydraulic model and provided through the electronic deliverables associated with TM 5 and TM 7.*
- Flow Monitoring Information
    - Single Excel spreadsheet with compiled 2020 manhole flow monitoring data
    - WRF Inflow Excel spreadsheet
    - Historic (2016-2019) monitoring data in individual Excel spreadsheets (by Others)
- Lift Station Information
    - Excel spreadsheet with compiled list of lift station pump model and serial number
    - SCADA Lift Station Levels at 1 min intervals (2016-2020)
    - *Note that lift station record drawings are available through the City's online portal Infrastructure Viewer: https://gisweb.bozeman.net/Html5Viewer/?viewer=infrastructure*
- Water Meter Data
    - Excel spreadsheets with city-wide water meter information for 2015-2020
- GIS Data Shapefiles
    - Surveyed manhole locations, surveyed pipes, split manholes, monitoring manhole locations

Chapter 2 Survey Data

The City's Wastewater Collection System includes approximately 4,800 manholes and over 230 miles of sewer. In general, a majority of the City's collection system has been constructed from new development, which is required to submit final as-built record drawing information to the City at the end of a project. Typically, the record drawings include manhole invert data, material specifications, and locations of the asset. This information was reviewed and incorporated into the GIS data and model. Sewer invert and size information was taken from the drawings and manually added to the GIS pipe network data. The vertical datum was verified for each record drawing to ensure consistency with GIS and subsequent model data. The North American Vertical Datum 1988 (NAVD 88) is the standard datum used throughout this facility plan unless otherwise noted.

After a detailed review of the City's existing GIS and as-built information it was determined that an additional survey was needed. It was decided by the City to survey approximately 1,400 manholes that lacked definitive invert information. Manholes selected for detailed surveying were prioritized based on pipe diameter (10-inch or greater), material, and overall contributing area, with the larger sewer trunk mains taking precedence. Manholes that were identified that lacked invert and pipe-size information, but did not make the survey prioritization list, were determined by assuming minimum pipe slope based on the Montana Department of Environmental Quality (DEQ) Design Standards for Public Sewage Systems (DEQ Circular 2, 2018). Inverts were computed upstream or downstream from a known invert elevation (i.e., where record drawings or survey was available) by multiplying the minimum pipe slope respective to the sewer size by the GIS pipe length.

Gathering additional detailed survey information was a critical path in developing the hydraulic model. Accurate survey information helps ensure that the hydraulic calculations within the model accurately represent system pipe slope, size, and, ultimately, capacity.

Moving forward, the City is refining its data standards to ensure this information is included in all submittals and is in a user-friendly data format. It is recommended that the City continues to collect invert information, specifically on larger diameter assets, to accurately reflect existing and future pipe capacity within the hydraulic model. ***Figure 2-1*** shows the City's collection system and highlights the surveyed manhole locations. Note that the shapefiles included in the figures were provided to the City as part of the overall electronic deliverable for this Facility Plan. Specific attribute fields within the hydraulic model were added so the City can easily determine whether an invert was surveyed, manually calculated using the 10 state standards method, or obtained from an as-built drawing.

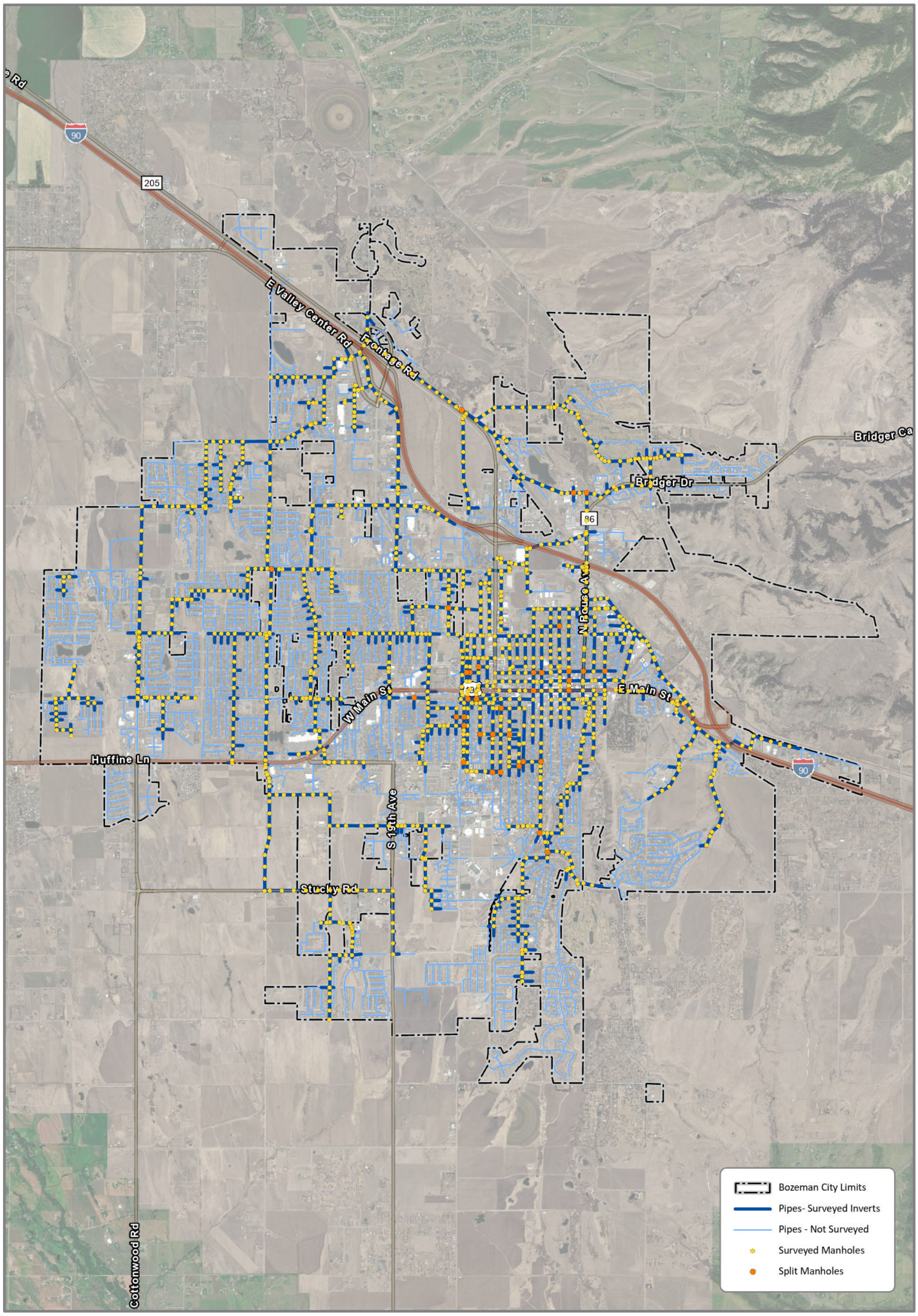
2.1 Collection Methodology

All elevations associated with the survey are in the City's adopted vertical datum NAVD 88. **TM 10** provides a detailed description of the vertical and horizontal datum associated with this project. The field survey was carried out between May and August 2020.

TD&H, a subcontractor of the facility plan update, was contracted to perform the field survey using survey-grade Trimble GPS receiver models R6, R10, & R10-2 with a vertical measurement tolerance of ±0.06 feet. Where GPS measurements were not feasible, a Trimble Robotic Total Station model S7 was used with a vertical tolerance of ±0.03 feet. TD&H measured the top of the visible pipe within the manhole using a Schneider Corp V. Depth measuring tool. This tool uses a Leica Disto model D810 laser measuring device. The manufacturer's specification states a maximum measuring tolerance of 0.08 inches. The V. Depth measuring tool was provided by the City of Bozeman. The stated measurement tolerance for the D810 does not consider human and environmental factors associated with the measurements of underground pipes. The location of some pipes within the sewer manholes prevented the use of the V. Depth measuring tool, so these measurements were obtained using a survey leveling rod. Pipe inverts were calculated using the measured top of pipe elevations and pipe diameters from the City GIS or record drawings. Pipe sizes were field verified at split manholes. Split manholes were surveyed using a LiDAR scanner (Leica BLK360), which generates scaled 3D renderings, enabling the user to measure accurate pipe inverts and pipe sizes.

All inverts, pipe size, and pipe material information was transferred to the GIS data either manually or through the ArcMap "spatial join" tool, which associates information from one data source to another based on a shared location. A point shapefile representing manholes and a polyline shapefile representing pipes with all gathered hydraulic modeling information (rim elevations, invert elevations, pipe size, and pipe material) was compiled to provide integration into the hydraulic model. The model integration process is further described in **TM 6** FME and GIS Data Exchange Routine.

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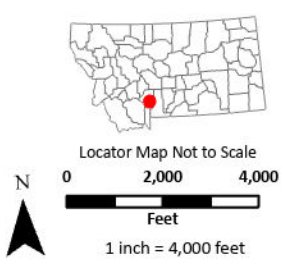


Figure 2.1

SURVEYED MANHOLES

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

Chapter 3 Flow Monitoring Data

3.1 Historical Monitoring Data

The City of Bozeman periodically monitors wastewater flows throughout their system to assess inflow and infiltration (I&I), evaluate system capacity against proposed development, and recalibrate the hydraulic model. Historical flow monitoring data for 2016 through winter 2020 were obtained from TD&H Engineering, who the City has utilized to conduct flow monitoring.

It should be noted that the Midtown Urban Renewal District and the Downtown Urban Renewal District conducted a joint sewer flow monitoring effort in 2018 with Sanderson & Stewart at a number of different manhole locations in the downtown region. The goal of the joint effort monitoring project was to better understand localized I&I associated with the downtown region and the wastewater infrastructure required to serve the Midtown and Downtown Urban districts at full buildout. The downtown metered locations are bolded in ***Table 3.1*** for reference.

Table 3.1 summarizes the historical flow monitoring data.

Table 3.1: Summary of Historic and Downtown Wastewater Flow Monitoring Efforts

MH ID[1]	Location	Sewershed
K0005	Cattail & Vaquero	Baxter Creek
K0147	Cattail & Vaquero	Baxter Creek
L0424	Durston & Enboe	Cattail Creek
L0548	Slough Creek	Cattail Creek
I0421	20th & Durston	Farmers Canal
I0406	Babcock & 19th	Farmers Canal
G0418	10th & Beall	Upper Rouse
G0426	9th & Mendenhall	Upper Rouse
G0520	10th & Olive	Spring Creek
G0583	Babcock & 8th	Spring Creek
F0405	Grand & Villard	Upper Rouse
F0517	Babcock & Tracy	Upper Rouse
F0522	Black & Olive	Upper Rouse
F0433	Beall & Bozeman	Upper Rouse
F0431	**Mendenhall & Bozeman**	**Upper Bozeman Creek**
F0429	Main & Bozeman	Upper Bozeman Creek
E0505	Bogert Park	Upper Bozeman Creek
F0307	**Tamarack & Grand**	**Upper Rouse**
F0312	**Tracy & Aspen**	**Upper Rouse**
F0320	Aspen & Bozeman	Upper Rouse
F0405	**Villard & Grand**	**Upper Rouse**
F0332	**Rouse & Juniper**	**Upper Rouse**
F0328	**Rouse & Cottonwood**	**Upper Bozeman Creek**
E0302	Rouse & Church	Upper Bozeman Creek
D0421	Village Downtown	Upper Bozeman Creek
D0503	Ellis & Highland	Upper Bozeman Creek
G0135	Gallatin Park	East Gallatin River
I0107	Simmental & Baxter	Spring Creek
G0225	**Walmart**	**East Gallatin River**
G0309	**7th & Juniper**	**East Gallatin River**

1 Bold values represent downtown metered locations (Sanderson & Stewart 2018)

3.2 Spring 2020 Monitoring Data

Additional flow monitoring was necessary to fill in data gaps in the historical data set and provide a basis for model calibration. To augment these data gaps, additional wastewater flow was monitored at six locations around the City from April 16, 2020, to June 25, 2020. The additional flow monitoring locations were selected based on where historical data was generally not collected and in locations lower in the overall sewershed (North of Main Street), which corresponded with larger trunk mains that collect substantial wastewater flow from the greater network. It was decided to collect additional data at the Walmart location to bolster the previous data set and quantify flow changes at this particular location.

Figure 3-1 shows the spring 2020, Sanderson & Stewart 2018, and historic monitoring locations utilized in this analysis. ***Table 3.2*** summarizes the flow monitoring location, GIS manhole

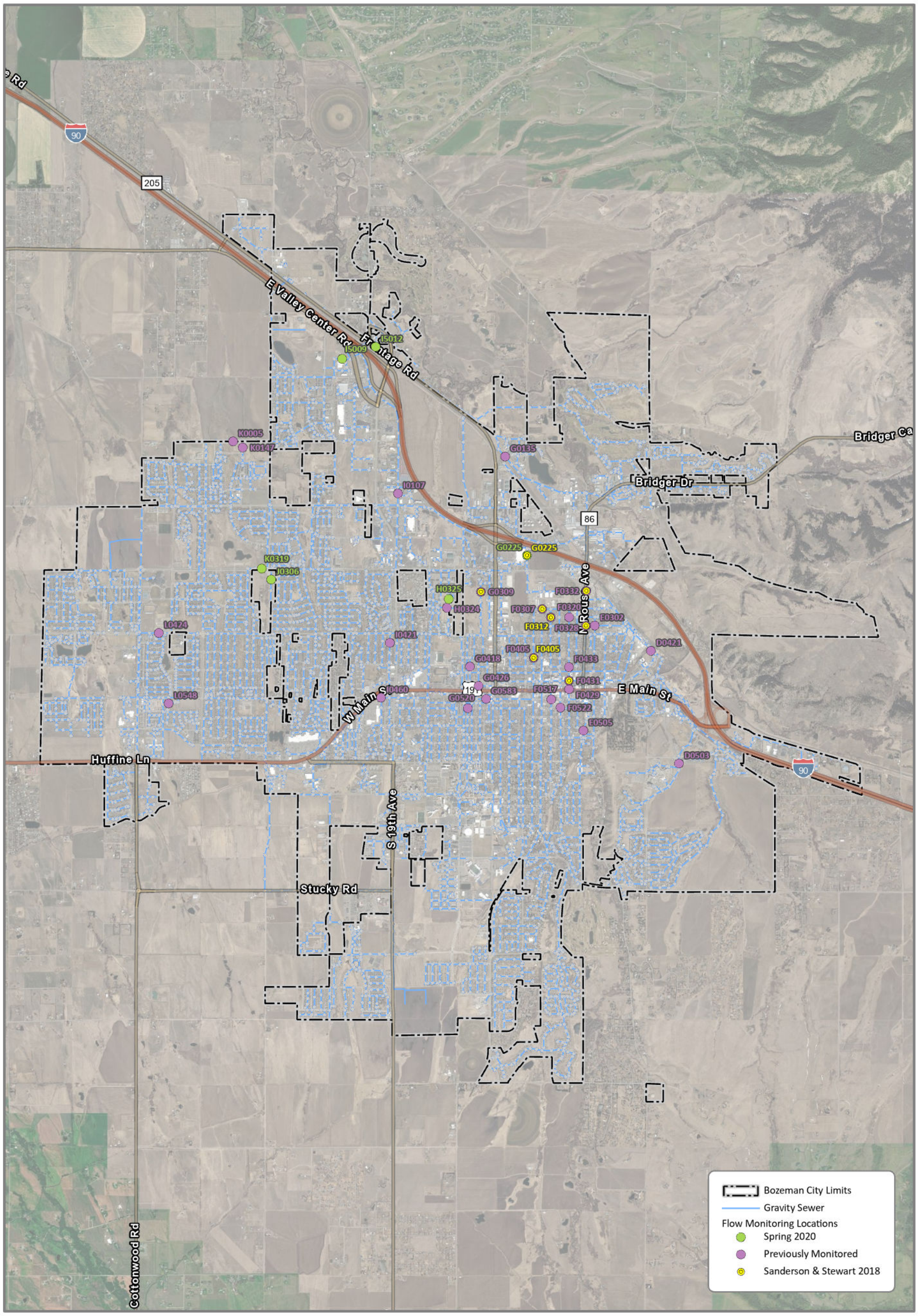
identification number (MH ID), sewershed, year, associated monitoring period, and number of precipitation events observed during monitoring period.

The historical and spring 2020 flow data were used to calibrate the hydraulic model, which is described in **TM 7**.

Table 3.2: Summary of Spring 2020 Wastewater Flow Monitoring Efforts

Location	Trunk Main	MH ID	Sewershed	Year	Period of Monitoring	Number of Precipitation Events+
Frontage Rd	North Frontage Road Interceptor	I5012	East Gallatin River	2020	4/16-6/25 2020	10
Oak & Davis	Baxter Interceptor	K0319	Cattail Creek	2020	4/16-6/25 2020	10
Oak & Davis	Davis-Fowler Interceptor	J0306	Cattail Creek	2020	4/16-6/25 2020	10
Catamount & Valley Creek	27th Ave/Cattail Creek Interceptor	I5009	Cattail Creek	2020	4/16-6/25 2020	10
Walmart	East Gallatin River Interceptor	G0225	East Gallatin River	2020	4/16-6/25 2020	10
Juniper & Oak Park	19th Ave/11th Ave	H0325	Spring Creek	2020	4/16-6/25 2020	10

+ Precipitation event defined as rain event producing at least 0.2 inches



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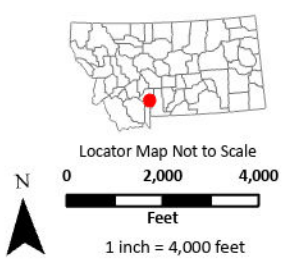


Figure 3.1

FLOW MONITORING LOCATIONS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

During the spring 2020 monitoring period, a number of rainfall events were observed. However, not all rainfall events solicited an I&I response within the system. For modeling and data management purposes, a precipitation event was defined as a rain event that produced at least 0.2 inches of measurable precipitation.

The largest rain event during the spring 2020 monitoring period occurred on June 17; over 0.6 inches of precipitation was produced, and a noticeable I&I response was observed at the flow monitoring locations deployed in the City's collection system. Given the observed I&I response and size of the rainfall event, the June 17 rain event was utilized for the wet-weather calibration period in the hydraulic model.

In addition to the spring 2020 monitoring data, historical monitoring data were used to verify model results and calibrate the Downtown and Midtown areas. The 2018 Sanderson & Stewart monitoring data were specifically used to calibrate the Downtown and Midtown areas. A 1-inch precipitation event that occurred on June 29th 2018, was used to assess and modify wet-weather peaking factors for the areas monitored by Sanderson & Stewart within the hydraulic model.

The wet- and dry-weather model calibrations are described in **TM 7**.

3.3 Monitoring Methodology

The spring 2020 wastewater flow monitoring effort was coordinated with TD&H Engineering. TD&H Engineering, with the help of City staff, ultimately installed and collected flow information at the various locations.

Hach FL900 flow meters with Hach Flo-Dar Sensors were placed in the selected manhole locations as defined in ***Table 3.2.*** Flow monitoring data were recorded at one-minute intervals, downloaded from the devices fortnightly, and reviewed to ensure fidelity. Precipitation data for the monitoring period were collected from the Optical Remote Sensor Laboratory (ORSL) at Montana State University (MSU) at five-minute intervals. Through discussions with the City, the MSU monitoring station was selected due to its proximity to the collection system and metered manholes and its data reliability (consistent record since 2005).

3.4 COVID-19 Pandemic Considerations

Wastewater flow data were collected between April and June 2020 during the COVID-19 pandemic. The consequences of the pandemic, such as the spring quarantine and ongoing restrictions, likely altered the wastewater flow characteristics normally observed in Bozeman. For instance, Montana State University shifted to remote learning before students returned from Spring Break, thereby decreasing wastewater contributions from campus. Many Bozeman businesses instituted work-from-home policies during this time period, and most restaurants had no in-restaurant food service. Given the unique impacts of COVID-19 on sewer flow patterns, City staff, AE2S, and TD&H discussed whether to proceed with flow monitoring prior to

deploying the flow meters in April. Consensus was reached to move forward with collecting flow data, understanding that the primary goal of this effort was to evaluate I&I contributions and calibrate the hydraulic model, both of which are achievable regardless of impacts to dry-weather flow patterns from COVID-19. After collecting flow meter data, an analysis was completed to better understand the potential impacts of the COVID-19 quarantine. April 2019 and 2020 monitoring data were compared to evaluate how COVID-19 affected peak-hour factors. The 2020 peak hour factor was less than 3% lower than in 2019 during dry weather flow – causing negligible change between the diurnal patterns. Based on this analysis, the City decided to use the 2020 data for model calibration.

Chapter 4 Operating Data

4.1 Lift Stations

The City provided lift station data, including:

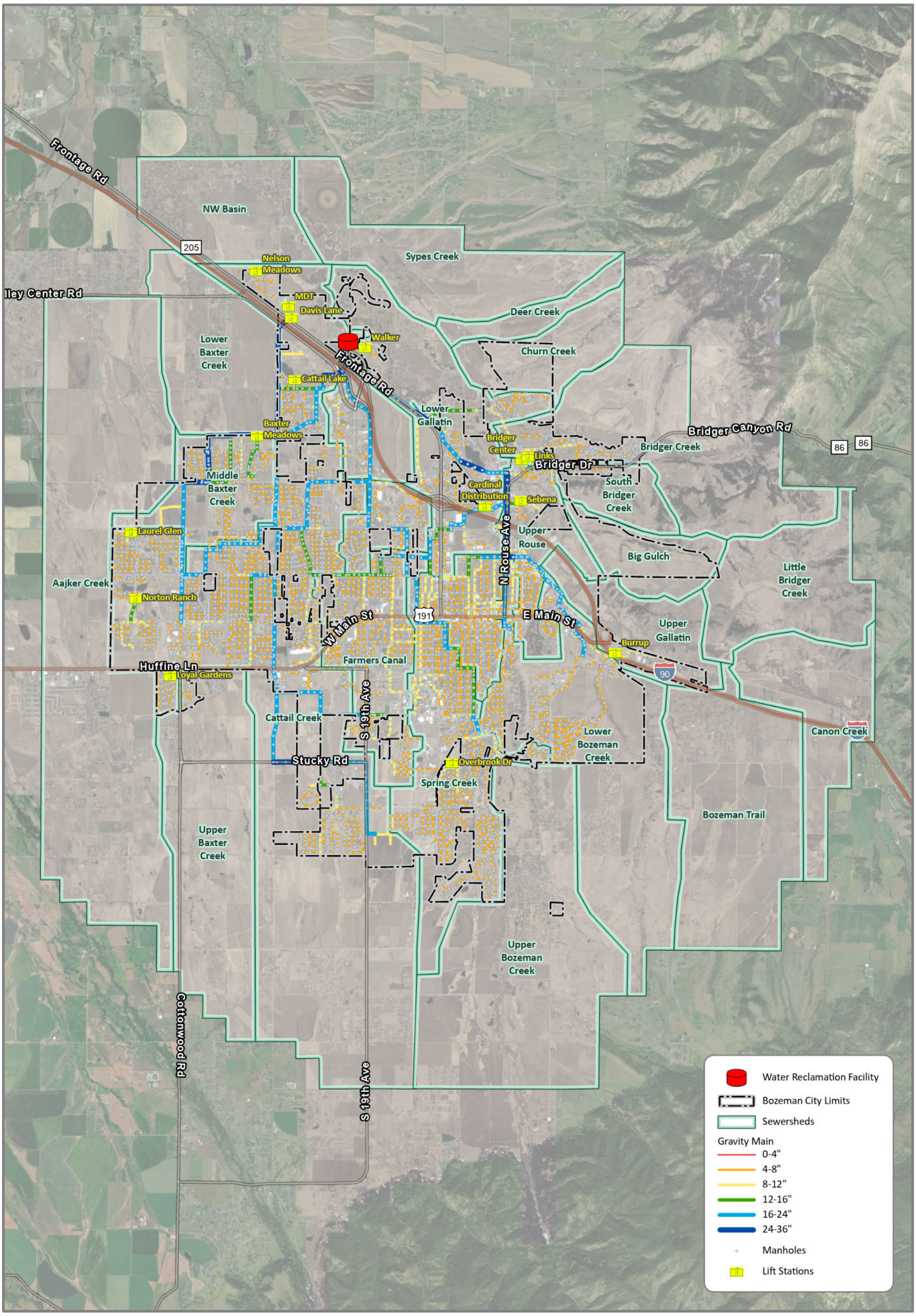
- Lift Station record drawings (provided through Infrastructure Viewer https://gisweb.bozeman.net/Html5Viewer/?viewer=infrastructure)
- Current pump operating set points, model, and serial numbers
- SCADA data records from 2016 through July 2020

Table 3.3 provides a high-level summary of the City's lift stations, including the name, number of pumps, pump manufacturer, and whether the lift station was included in the hydraulic model. The lift station information provided by the City was utilized to update and calibrate the model. ***Figure 4-1*** shows the existing lift stations and associated sewershed.

Table 3.3: Summary of City Lift Stations

Lift Station Name	Number of Pumps	Pump Manufacturer	Lift Station Owner	Station Included in Model (Yes/No)
Baxter Meadows	3	Flygt	City	yes
Bridger Center	2	Hydromatic	City	yes
Burrup	2	Flygt	City	yes
Cattail Lake	2	Flygt	City	yes
Davis Lane	3	Flygt	City	yes[2]
Laurel Glen	2	Flygt	City	yes
Loyal Gardens	2	Flygt	City	yes
Norton Ranch	3	Flygt	City	yes
Water Reclamation Facility	N/A	N/A	City	no[3]
Cardinal Distribution	-	-	Private	no[1]
Links	2	-	Private	yes
MDT	2	Pentair	Private	yes
Nelson Meadows	2	Flygt	Private	yes
Overbrook Dr.	2	-	Private	yes
Seebna	2	-	Private	yes
Walker	2	-	Private	yes

[1] No infrastructure modeled upstream
[2] Not operational during flow monitoring or calibration period
[3] End of network



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Figure 4.1

CITY OF BOZEMAN COLLECTION SYSTEM

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

Chapter 5 Water Reclamation Facility Inflow

The City provided inflow data for the Water Reclamation Facility (WRF) from 2016 through July 2020 in five-minute increments. ***Figure 3.4*** shows the average monthly WRF inflow annually from 2016 through July 2020. April through June inflow is significantly higher due to the influence of groundwater inflow and rainfall-derived infiltration, this was especially pronounced in 2018 and 2019. The WRF data were used to calibrate the hydraulic model, specifically downstream hydraulic and I&I conditions observed during periods of wet weather.

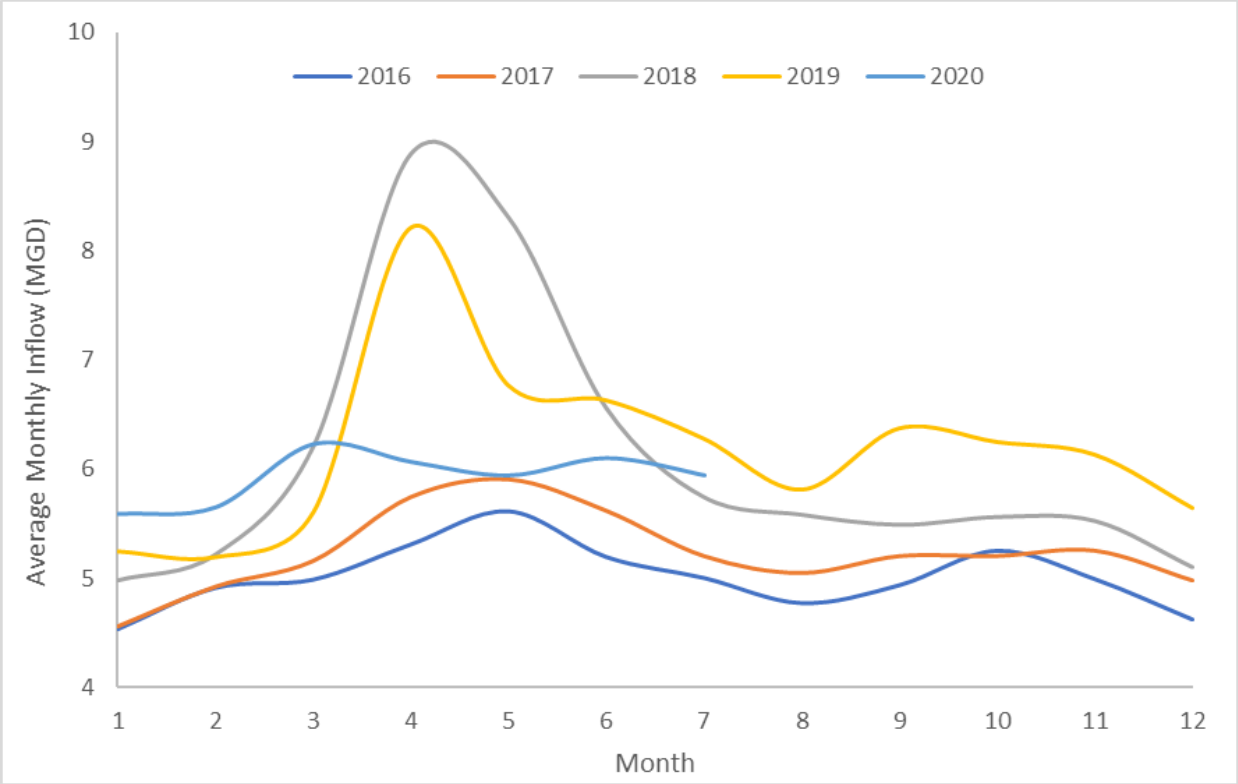


Figure 3.4: Water Reclamation Facility Inflow

It should be noted that the provided WRF influent flow generally correlates with seasonal high groundwater conditions observed within the City. The Montana Bureau of Mines and Geology (MBMG) records historic groundwater elevations for several wells in Bozeman, most of which showed historically high groundwater levels in 2018. The higher groundwater appears to have led to increased infiltration into the City's sewers. Recognizing seasonal high groundwater significantly influences both collection and treatment capacity, inflow from groundwater was incorporated into the wet-weather model scenarios – this analysis and allocation methodology is further discussed in TM 5.

Chapter 6 Water Meter Data (Domestic Water Meter Data)

Water meter data from the City's water utility was compiled from 2015 through 2019. The data was used to establish domestic wastewater flow allocation. The City provided data for all domestic City water meters on monthly billing intervals. The City provided meter locations in a point-feature shapefile. Additional details and analyses of the meter data are provided in **TM 5**.

Chapter 7 GIS Data

The City provided multiple GIS datasets utilized in the model update process. Unless noted otherwise, all GIS data are projected in UTM Zone 12N coordinate system. The data relevant for this project include:

- Wastewater Collection System Network
  - Manholes
  - Gravity mains
  - Force mains
- Water Meters
- Existing Land Use
- Existing Zoning
- Future Land Use
- Tax Increment Districts Overlay

All GIS data for this facility plan update was provided by the City in 2020. The City updated the City's GIS Wastewater Collection System Network database in early 2020 to correct manhole locations, connectivity, and pipe attributes. The City and AE2S developed a feature manipulation engine (FME) to populate the network database with relevant hydraulic modeling parameters. This FME routine and model update methodology are described in detail in **TM 6**. Subsequently, in 2023, a model network update was completed using updated GIS data from the City.

4.0

Manhole Condition Assessment Technical Memorandum

Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

Table of Contents

Chapter 1 Purpose and Need 2
Chapter 2 NASSCO Standards 3
Chapter 3 Overview of Recommended Program 4
Chapter 4 Recommended Inspection Schedule 6
Chapter 5 Recommended Data Synthesis and Analysis 8
Appendix A – Recommended Inspection Form 9
Appendix B – Survey 123 Workflow 11
Appendix C – Manhole Imaging Technology 12

List of Figures

Figure 4-1: Recommended Inspection Phasing Plan 7

Chapter 1 Purpose and Need

This Manhole Condition Assessment Program (MCAP) has been established to help the City of Bozeman collect and synthesize manhole asset condition information. The City currently collects closed circuit television (CCTV) data for wastewater pipes but has yet to implement a standard practice for evaluating manhole condition.

The purpose of the MCAP is to provide the City staff with tools to help make informed data-driven decisions on infrastructure operation, maintenance, and replacement. The City's wastewater collection system includes infrastructure dating back to the early 1900s. Much of the aging infrastructure is located within areas of the City with higher population density (e.g., downtown) and the consequence of failure is greater. These areas are also experiencing development pressure.

The City also experiences development pressure on the west end, where groundwater levels are known to be high. This can lead to increased operation and maintenance (O&M) costs and decrease the expected life of infrastructure. Manholes are susceptible to structural defects and can be significant sources of inflow and infiltration (I&I). The addition of unwanted I&I can lead to excessive wastewater flows and decrease the system's overall capacity .

The MCAP will evaluate every manhole within the City with priority given to aging manholes and manholes in areas with high groundwater and risk of I&I. Assessments performed on new manholes will serve as condition baselines for future inspections. Manhole condition assessments can be time-consuming and difficult to objectively complete. To streamline inspections and improve consistency throughout the process, it is beneficial to follow an established standard.

It is recommended that the City begin with simple manhole inspections collecting basic condition information as outlined in **Appendix A** (modified National Association of Sewer Service Companies Organization (NASSCO) inspection form). At a minimum, it is recommended that the City establish an inspection protocol that is both simple and meaningful. Documenting both the structural condition as well as operation and maintenance issues on a 1 to 10 scale will help ensure the data collected will be compatible with future full scale NASSCO inspections should the City decide to go that route.

Chapter 2 NASSCO Standards

The National Association of Sewer Service Companies Organization (NASSCO) helps set industry standards for the condition assessment of sewer infrastructure. The Manhole Assessment Certification Program (MACP) focuses on condition scoring/codes for the assessment of sewer manholes.

The MACP inspection form is broken into two types of inspections, which are described below:

- **Level 1 MACP -** "A level 1 MACP inspection will allow utility owners to gather basic condition assessment information to evaluate the general condition of a manhole, and to gather enough information to determine if a comprehensive Level 2 inspection is appropriate. A level 1 inspection can be completed without the use of any special equipment or manned entry into a manhole."
- **Level 2 MACP -** "The purpose of a Level 2 MACP inspection is to gather detailed information to fully document all existing defects, determine the condition of a manhole, and to provide specific information to recommend or specify corrective actions. Level 2 inspections should be carried out via man-entry, camera, measurement tools, and /or other specialized equipment."

MACP provides comprehensive protocols and standards for managing and evaluating asset conditions. Many of the procedures within the MACP standards require a higher level of effort than what may be necessary for the City at this time. For example, the MACP inspection form requires a total of 71 fields of information for City staff to fill out to complete a Level 2 inspection. Capturing data for all 71 fields can be beneficial once a program has been established, however, given the City's current staffing and resources, it is impractical to collect all this data at this time. Therefore, City Staff and AE2S closely evaluated the inspection forms and selected fields that capture the physical conditions of the manholes while also being easy to collect for crews that are completing standard CCTV collection. Furthermore, these fields can be incorporated into a risk assessment to evaluate the overall risk of the asset. Fields included in the customized inspection form include inspection date, surface type, street location, size, and surface material.

Chapter 3 Overview of Recommended Program

The recommended MCAP provides an efficient method of data collection, utilizing tools that will seamlessly integrate into the framework of the risk assessment model. A summary of how this program will operate is provided below:

- A condensed manhole inspection form following NASSCO MACP standards will guide the field inspection protocol. Appendix A shows this condensed form and highlights the recommended data fields to complete during condition assessment inspections.
- The City's current GIS production database of the sewer collection system will be used as the foundation for a Survey 123 application developed by AE2S. ***Appendix B*** shows screenshots of a similar Survey 123 inspection form and summarizes the typical Survey 123 field workflow.
    - The Survey 123 application allows field crews to conduct manhole condition assessments on a City provided mobile device by filling out the form created by AE2S, with the survey results being automatically linked to their respective manholes.
    - The Manhole form will have selectable prepopulated answers/defect codes that align with NASSCO MACP standards. Standard prepopulated forms generally help reduce overall field time and help eliminate human error of incorrectly typing defect codes.
- Photos of the manholes can also be directly loaded from the mobile device into the Survey 123 application.
    - It is recommended to capture images of the manhole using one of these three options. ***Appendix C*** includes a matrix with pros, cons, and costs for alternative imaging equipment:
        - A GoPro camera mounted on a long rod with an externally mounted light.
        - CUES Lite Stick - City-owned manhole inspection imaging technology.
- Insta360 Camera – similar technology to GoPro and provides high- quality 360° still images.
    - The Bluetooth capabilities of the GoPro and Insta360 cameras will allow the field crews to view the defects in real time, and appropriately log the defects in the Survey 123 form.
    - Photos and videos recorded should be geotagged to easily be joined to the appropriate assets in GIS after the completion of the condition assessments.
- With the completion of each manhole inspection, the color coding of the manhole will change from red to green in the Survey 123 web map interface, making it easy to keep track of which inspections have been completed.

- Once the inspections are completed, the results can be imported into InfoAsset Planner where the formal risk assessment will be completed.
- Results from the manhole risk assessment can be provided to City staff for incorporation into ongoing maintenance activities or relevant capital improvements.

Chapter 4 Recommended Inspection Schedule

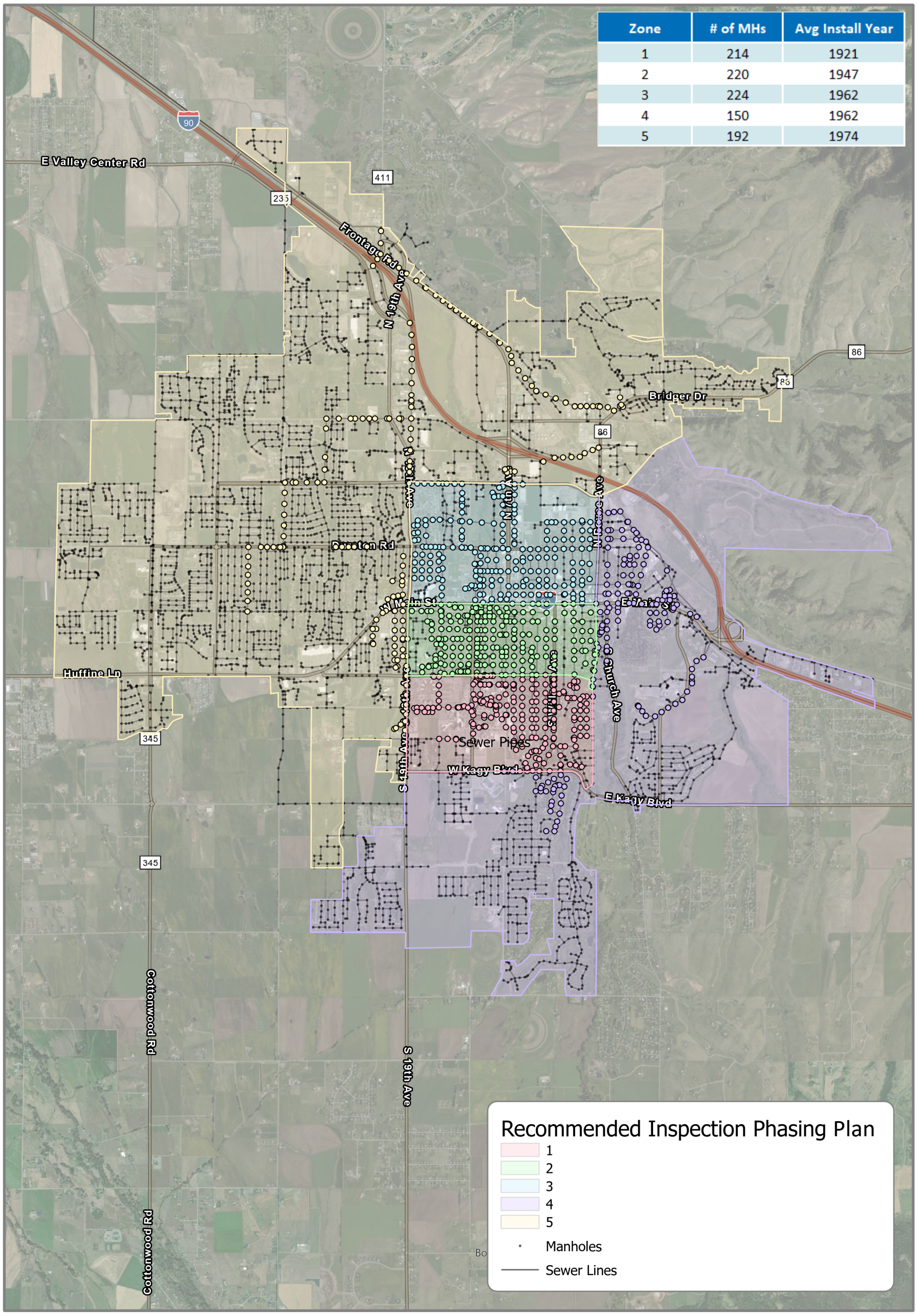
Recognizing that the City's limited operations' resources may not have the additional time necessary to complete an all-inclusive MH inspection program, the recommended inspection process described above is streamlined. This streamlined inspection process will provide the City with the necessary flexibility to use in-house staff or contractors with minimal training to conduct the field inspections. While the ideal situation would be to have staff NASSCO trained and certified, this represents a significant investment of time and resources. To get this initial MCAP up and running initially, we recommend the City train staff to recognize basic structural defects in a manhole. This could include documenting cracks and their severity, any visible infiltration with an estimate of the flow rate, and other visual defects that simply require an observant eye. After the program is up and running, the City should conduct a review of the compiled data set and assess if revisions should be made to the assessment/collection procedure going forward.

To further increase the efficiency and usefulness of MCAP, a preliminary inspection schedule was developed that prioritizes the most susceptible infrastructure. The inspection phasing plan is based on infrastructure age and material, which are generally related in the City, with the oldest portions of the collection system being either vitrified clay (VCP) or asbestos cement (AC) pipe. The City's Wastewater Collection System includes approximately 4,800 manholes. There are approximately 1,000 manholes within the system connected to VCP and AC pipes. It is recommended to inspect 20% (approximately 200) of these manholes each year over the next 5 years. Manholes with the lowest remaining useful life (RUL) should be inspected first. RUL can be found by subtracting the current year from the sum of the installation year and the estimated material lifecycle of the asset. For example, if the current year is 2021, the RUL of an AC pipe installed in 1980 would be approximately 9 years since AC pipe has an estimated lifecycle of 50 years.

Following the completion of the 5-year initial inspection schedule and subsequent development of the manhole risk assessment, it is recommended to use the results from the risk assessment to create rehabilitation and replacement (R&R) and new inspection schedules for manholes and provide scheduled updates to the risk assessment with new collected data.

Figure 4-1 shows a map of the collection system with priority manholes categorized by inspection zone. Zoning prioritization is based on a preliminary risk analysis that ranks manhole condition based on infrastructure age and is limited to only the manholes connected to VCP and AC pipe.

Zone	# of MHs	Avg Install Year
1	214	1921
2	220	1947
3	224	1962
4	150	1962
5	192	1974



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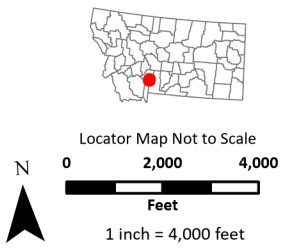


Figure 4.1

RECOMMENDED INSPECTION PHASING PLAN

WASTEWATER COLLECTION SYSTEM FACILITY PLAN
Bozeman | Gallatin County, MT

Date: 7/30/2021

Chapter 5 Recommended Data Synthesis and Analysis

Managing the data from any infrastructure inspection program can become a hassle if a standard procedure is not established at the program's inception. Regardless of the camera option the City chooses to utilize (GoPro, Insta360, etc.), it is important that personnel performing manhole inspections complete the inspection form onsite. By completing the inspection form onsite, this avoids the risk of accumulating mountains of inspection footage to be reviewed and synthesized at some future date in the office. With the streamlined inspection program recommended in this memorandum, the data feeding the future risk assessment will be the completed inspection forms, not the actual photos/footage. Similar to the City's Granite XP database, the manhole inspection results will be tied to the City's manhole ID, making it simple to view and compile results in a spreadsheet or GIS interface.

It is recommended to utilize large external hard drives (2 TB+) to store the footage from the inspections. Best practice would be to have at least two external hard drives, with one acting as a backup in case of data corruption or loss. If the City chooses the GoPro option, cloud-based storage is available for an annual fee.

It is also recommended that the City incorporates regularly scheduled reviews of the data collected to ensure quality assurance. After the initial 5-year inspection schedule is completed, it is recommended that the City consider incorporating all mandatory data fields outlined in both Level 1 and Level 2 of the original MACP inspection form for new manholes inspections. The increased details of the original MACP inspection form can provide a more robust condition assessment and a more accurate risk assessment.

The end goal with MCAP is to help the City prioritize limited time and resources on the manhole assets that pose the highest risk, as quantified from both the likelihood and consequence of failure. To accomplish this goal, the recommended fields from the MACP inspection form can be compiled using Survey 123 as outlined in this memo, or by simply expanding what's currently collected in CityWorks, as the City has indicated is a possibility.

The upcoming Wastewater Collection System Facility Plan Update will include a detailed risk assessment and CIP update of the current wastewater pipes. It is recommended to update the wastewater pipe risk assessment after 5 years so that both risk assessments can be used in unison in future planning. The combination of the wastewater pipe and manhole risk assessments will enable the City to better prioritize and plan CIP and R&R projects moving forward.

Appendix A – Recommended Inspection Form

Appendix A provides the recommended manhole condition assessment inspection form. This inspection form is to be used by the City of Bozeman staff when completing manhole inspections. The form has been condensed from the NASSCO MACP inspection form. Each number corresponds to the number listed in the official inspection form. Additional numberings in the official inspection form that designate either Level 1 or Level 2 MACP inspection have been removed.

General Information

1. Surveyed By	11. Date	12. Time

Location

22. MH/Access Point No.	23. Street	26. Surface Type

Manhole

33. Evidence of Surcharge

Cover

47. Size	49. Size Width	50. Cover Material
56. Cover Condition		

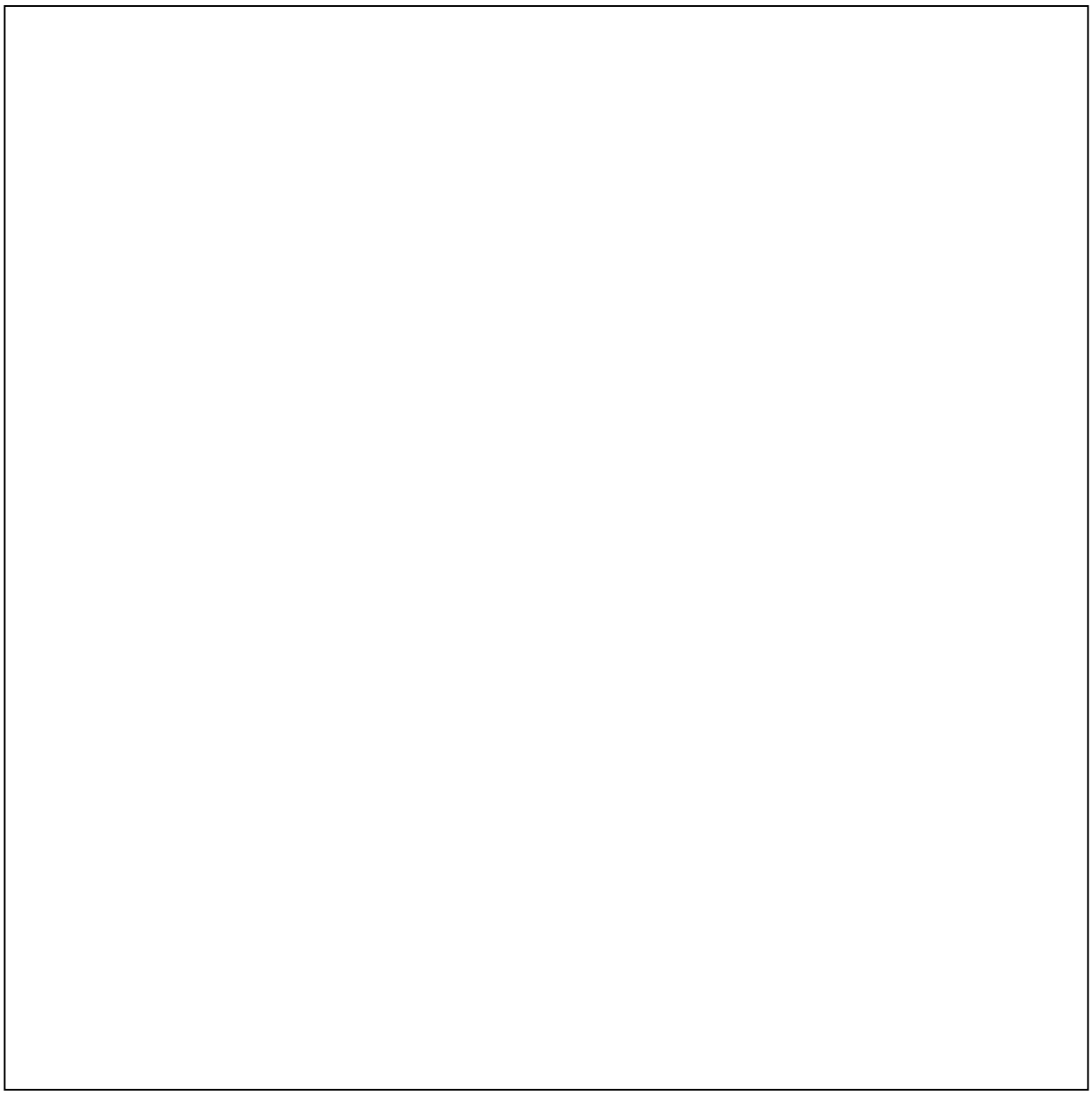
Cover Adjustment Ring	Frame	Chimney
61. Ring Condition	68. Frame Condition	81. Chimney Condition

Cone	Wall	Bench
87. Cone Condition	94. Wall Condition	98. Bench Condition

Channel

103. Channel Condition

Sketch



Appendix B – Survey 123 Workflow

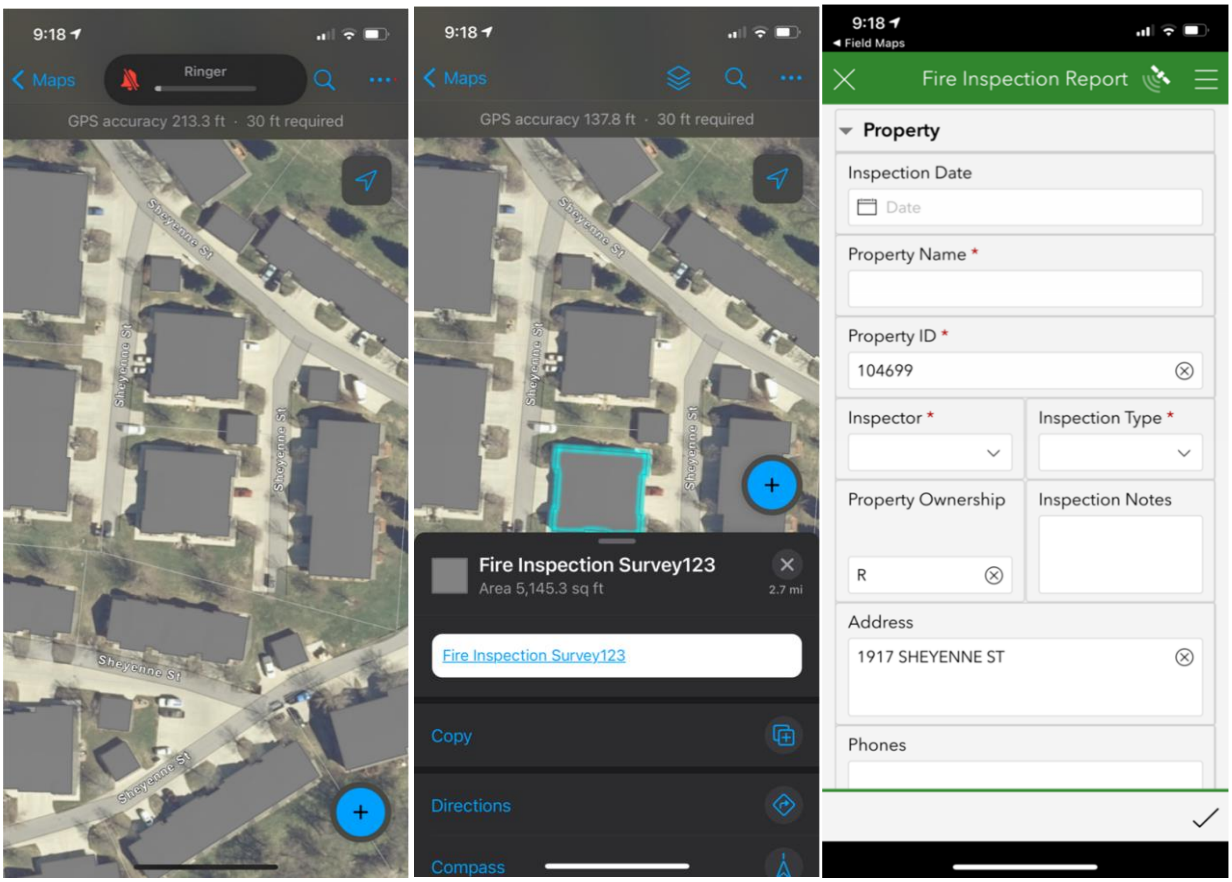
Appendix B provides brief instructions on how to complete a survey in Survey 123. The steps are as follows:

1) From a phone or tablet, click on a selectable element (i.e., manhole) preloaded into a map.
2) Select survey form and fill out the condition assessment fields that have been preloaded into Survey 123 application.

- Use a Bluetooth-enabled GoPro or similar (e.g., Insta360) to capture images and upload to each manhole inspection form.

3) Once completed, the application automatically saves the information. The form can then be reviewed or downloaded for further post-processing.

The figure below shows an example of how the Survey 123 process can be configured for various fieldwork applications.



Appendix C – Manhole Imaging Technology

Appendix C provides a summary of the available manhole inspection equipment.

Equipment	Pros	Cons	Cost	
Leica BLK360 Imaging Scanner	3D scanner with integrated spherical imaging system and thermography panorama sensor system Captures 360,000 individual measurements every second as it rotates 360 degrees over the course of 3 minutes Open the images in any design software of choice	Cost Not easy to position down in the manhole	$19,000	
Sealife Fisheye Lens Camera	Waterproof to 200 feet/60 meters Video and still images Flashlight and video lights Wide perspective Weight: 1lb	Camera is specific for underwater photos	$730 Camera $600 Lens	
Hero8 Black Go-Pro with Equipment	Four lenses: Narrow, distortion free Linear, Wide and Super View View -12MP + SuperPhoto with improved HDR Video: 4K60 Waterproof: 33ft (10m) Auto Upload to the Cloud Wifi+Bluetooth	Does not take measurements while videoing	$300 GoPro +$50 Light Mod	

Equipment	Pros	Cons	Cost	
AutoFlex Video Inspection System with Macro Lens	Mighty Cam 1080p Auto Focus Camera 18" Flexible Arm with Table Clamp Allows manual adjustment of image capture Magnification range of 3X-80X at a 6 in. working distance 360 ball joint allows the camera to be rotated to any angle	Not waterproof	$1,940	
Vision Engineering MCH-001/MCS-005/6X	Mantis compact series stereo microscope visual inspection system w/ universal stand & 6X magnification lens 3D viewing Dust cover 16 pounds	Not waterproof Cannot video in the dark	$1,920	
City Owned Imaging Device CUES Lite Stick	Portable Video Inspection Camera Built-in wireless video transmitter and battery in the pole Operates with TV unit's existing monitor, VCR, and data system Record distance and information on a videotape if utilizing an optional VCR LED lighting for the dark Includes a fiberglass extendable telescoping pole, 6'-18' depth	No zoom option	None (City owned technology)	

5.0

Wastewater Flow Characterization Technical Memorandum

Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

Table of Contents

Chapter 1 Introduction 3

Chapter 2 Study Area 4

2.1 Study Area Boundary and Description 4
2.2 Existing Land Use and Zoning Conditions 8
2.3 Infill Zoning and Future Land Use 9
2.4 Urban Renewal Districts and Tax Increment Finance Districts 11

Chapter 3 Population 12

3.1 Existing and Projected Population 12

Chapter 4 Historic Wastewater Flows and Loading 14

4.1 Historic WRF Flows 14
4.2 Wastewater Flow Analysis 18

4.2.1 Domestic Flow based on Metered Customer Water Usage 18
4.2.2 Ground Water Infiltration 21
4.2.3 RDII Analysis 24
4.2.4 Summary of Existing System Model Loading 25

4.3 Population and Per Capita Loading Analysis 25

Chapter 5 Wastewater Flow Characterization 27

5.1 Existing Land Use Wastewater Duty Factors 27
5.2 Existing Zoning Wastewater Duty Factors 29
5.3 High Density Residential, Urban Renewal, and Tax Increment Financing Districts 31

5.3.1 R-3, R-4, R-5 Wastewater Duty Factors 31
5.3.2 URD and TIF Wastewater Duty Factors 32

Chapter 6 Wastewater Flow Projections and Recommended Duty Factors 33

6.1 Future Wastewater Flow Analysis 33

6.1.1 Infill Wastewater Flow Analysis 33
6.1.2 URD and TIF Redevelopment Wastewater Flow Analysis 35
6.1.3 Ultimate Build-Out (UBO) Wastewater Flow Analysis 35
6.1.4 Increased Density Scenario 37

6.2 Wastewater Flow Analysis Summary 39
6.3 Wastewater Flow Recommendations for Planning and Design 39

List of Tables

Table 2-1: Land Use Classification within City Limits (as of July 2020) 8
Table 2-2: Zoning Classification within City Limits (as of July 2020) 9
Table 2-3: Infill Area by Zoning Designation (as of July 2020) 10
Table 2-4: Growth Area by Land Use Designation (as of July 2020) 10
Table 2-5: URD and TIF Summary (as of July 2020) 11
Table 3-1: City of Bozeman Historic Population 12
Table 3-2: City of Bozeman Projected Population 13
Table 4-1: WRF Inflow Summary 15
Table 4-2: Detailed WRF Flow Summary (MGD) 16
Table 4-3: Detailed WRF Flow Summary (gpcd) 17
Table 4-4: Metered Water Use Summary (MGD) 20
Table 4-5: Ground Water Flow Analysis at the WRF (MGD) 24
Table 4-6: Daily Wastewater Loading Summary for Existing System Model Scenarios (MGD) 25
Table 4-7: AAF and DWF per Capita Flow Rates 26
Table 5-1: Wastewater Duty Factors by Existing Land Use Classification 28
Table 5-2: Wastewater Loading Duty Factors by Zoning Classification 30
Table 5-3: R-3, R-4, R-5 Wastewater Planning Numbers 32
Table 5-4: URD and TIF WWDF Summary (gpad) 32
Table 6-1: Infill Wastewater Loading 34
Table 6-2: URD and TIF Wastewater Loading 35
Table 6-3: Future Land Use Correlated to Zoning Classification 36
Table 6-4: Future Land Use Wastewater Loading (summary of land use outside of 2020 City Limits Boundary – see Figure 2-3) 37
Table 6-5: Increased Density Scenario Wastewater Loading Summary 38
Table 6-6: Summary of Overall System Wastewater Flow Parameters 39
Table 6-7: Summary of Existing and Buildout Wastewater Loading (MGD) 39
Table 6-8: Summary of Recommended Duty Factors for Zoning and Future Land Use Classes 41

List of Figures

Figure 2-1: Wastewater Collection Facility Plan Study Area Boundary 5
Figure 2-2: Zoning Designations for Infill Area 6
Figure 2-3: Ultimate Build-Out (UBO) Land Use Designations 7
Figure 4-1: Average Annual Flow (2010 – 2019) 14
Figure 4-2: WRF Average Annual Wastewater Flow Components 20
Figure 4-3: MDT Monitoring Well Static Water Level Data 22

Chapter 1 Introduction

Wastewater characterization involves the analysis of existing wastewater flows to better understand the City's wastewater generation trends. Wastewater characterization is necessary to assess the capabilities of the City's existing facilities to adequately address current wastewater demands and ensure the design and functionality of proposed wastewater system components can sufficiently accommodate future wastewater needs. This memorandum provides an overview of the City's historical wastewater generation trends and metered water usage applied to land use and zoning classes.

In addition, this memorandum presents the City's projected future wastewater needs under ultimate-build (UBO) conditions. Wastewater generated under UBO conditions is important to understand in order for the City to address future growth concerns as well as appropriately size the infrastructure in both existing and future areas to accommodate growth.

Chapter 2 Study Area

Defining the study service area for the wastewater collection system model update is necessary to provide a framework to 1) define system capacity milestones, 2) develop appropriate phasing of capital improvements, and 3) strategically integrate improvements with existing infrastructure. The ultimate goal of this approach is to maximize the economic benefit of the improvements.

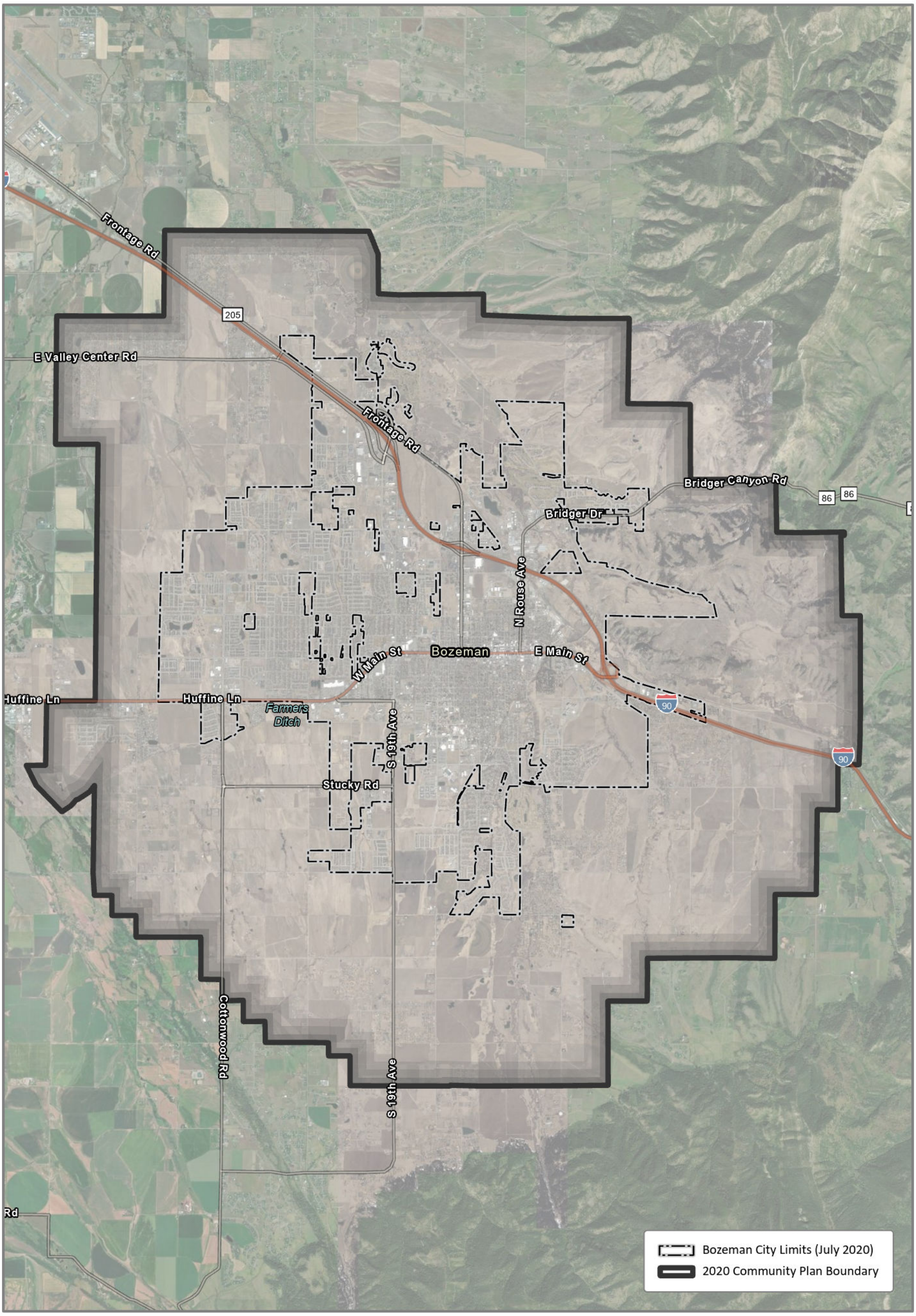
2.1 Study Area Boundary and Description

The study area was developed by reviewing current planning documentation, considering recently completed facility plans, evaluating geographical boundaries, and having discussions with City staff. Ultimately, this resulted in using the City's Growth Policy Boundary as the study area to ensure consistency with other planning efforts. The Growth Policy Boundary was established in the Bozeman Community Plan – Adopted by the Bozeman City Commission (Resolution No. 5133, November 17, 2020). ***Figure 2-1*** shows the Growth Policy Boundary and current City limits. This results in a final ultimate build-out (UBO) service area of approximately 45,342 acres, of which 13,393 acres are located within the current City limits.

Future land use estimates were developed as follows:

- The 2020 Bozeman Community Plan was used to identify future land use for the service area outside of the existing municipal City boundary.
- Areas located within the municipal City boundary that are currently vacant or undeveloped are considered infill.
- Designations for infill areas were populated using existing City zoning classes.
- Future land use information for this study was provided by the City in a GIS database that contained mapped polygons and attributes.
- Communication with City staff confirmed land use designations for future development; the City also provided information with respect to identified known land use changes for known Urban Renewal Districts (URD) and Tax Increment Financing (TIF) Districts. These two districts are identified as areas that will continue to redevelop with higher density than existing conditions and are analyzed further in this study.

Figure 2-2 and ***Figure 2-3*** present the infill zoning designations and future land use for areas outside the existing municipal City boundary, respectively.



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Coordinate System: NAD 1983 UTM Zone 12N | Edited by: DVoeller | C:\Data\Projects\WAFS\B\Bozeman\05097-2018-006\GIS\Bozeman Wastewater Collection Facility Plan - Mapping and Analysis.aprx | TM5 2-1 Study Area

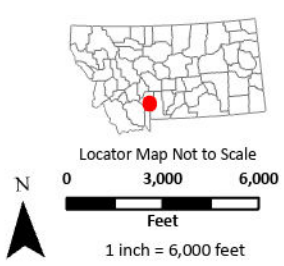
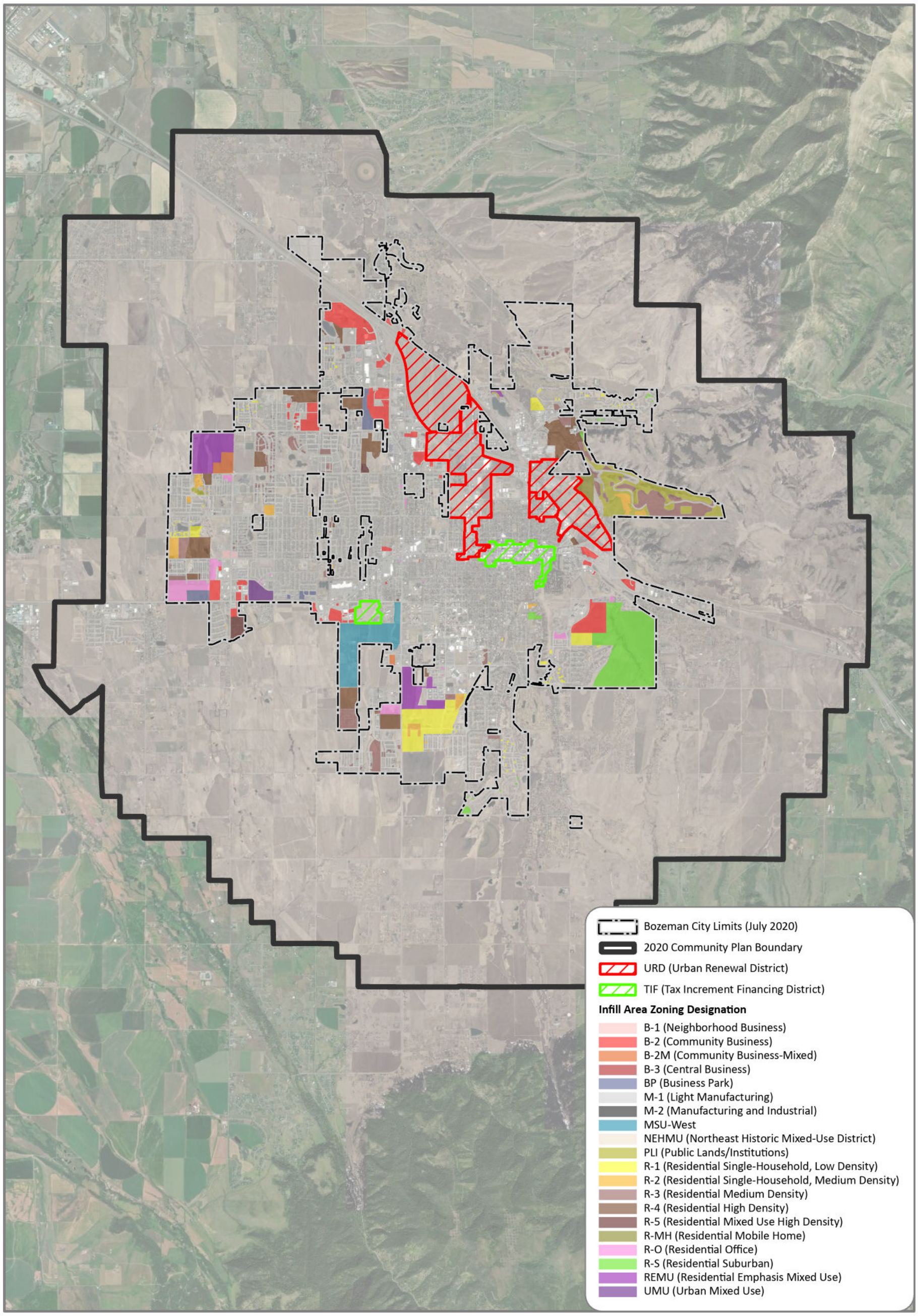


Figure 2-1

WASTEWATER COLLECTION FACILITY PLAN
STUDY AREA BOUNDARY

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024



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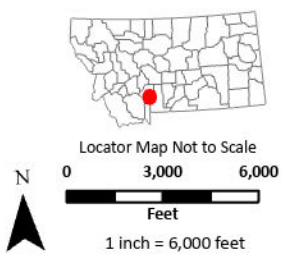
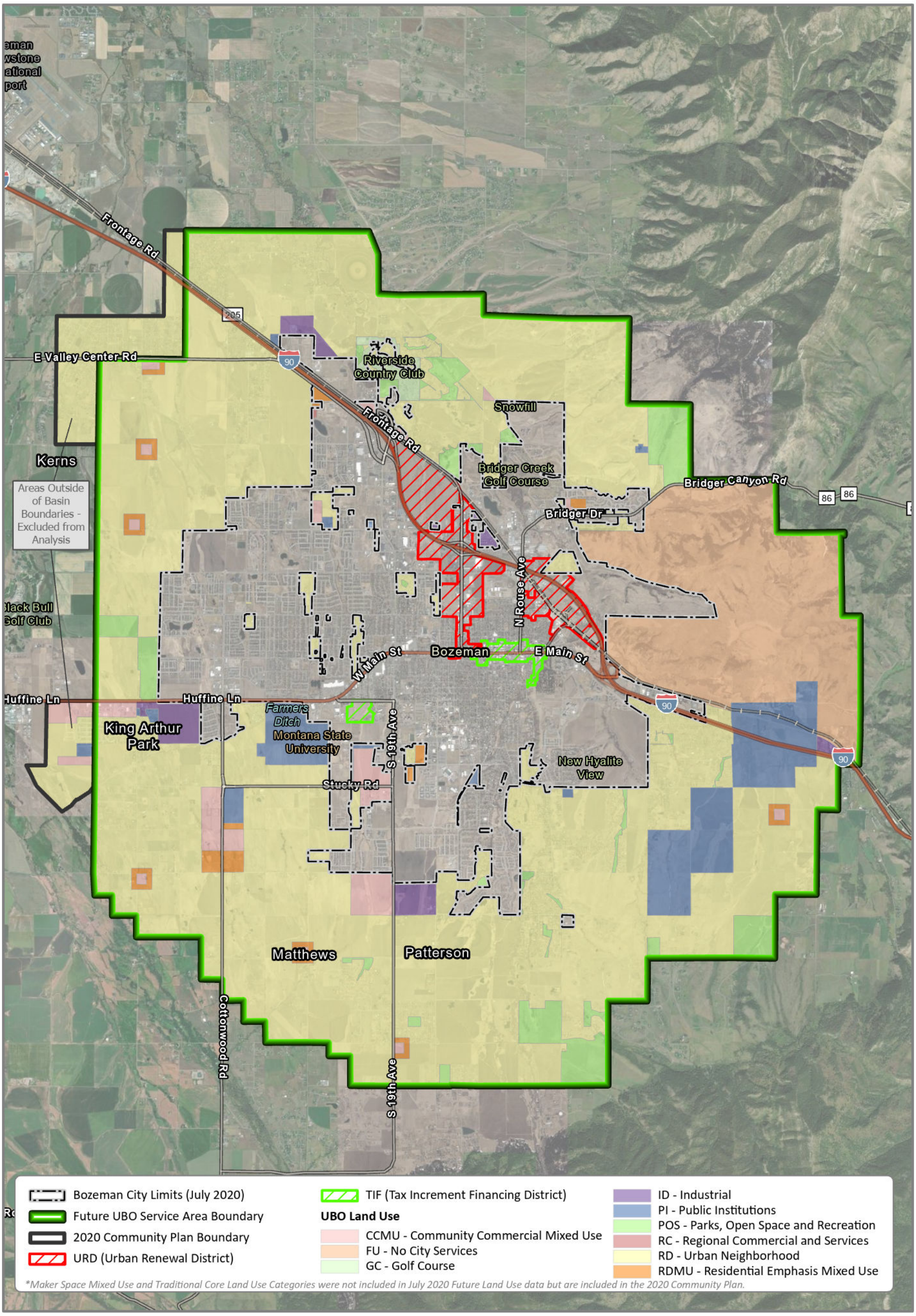


Figure 2-2

ZONING DESIGNATIONS FOR INFILL AREAS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024



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Coordinate System: NAD 1983 UTM Zone 12N | Edited by: DVoeller | C:\Data\Projects\WAFS\B\Bozeman\05097-2018-006\GIS\Bozeman Wastewater Collection Facility Plan - Mapping and Analysis.aprx | TM5 2-3 UBO Land Use



Figure 2-3

ULTIMATE BUILD-OUT (UBO) LAND USE DESIGNATIONS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

2.2 Existing Land Use and Zoning Conditions

Table 2-1 summarizes the existing land use designations and acreages (based on net area) within the City limits and the total acreage within the data set used to analyze existing wastewater loading duty factors. Net area was used because of the format in which the City's Existing land use shapefile was provided to AE2S where right-of-way (ROW) was excluded from each land use polygon. Existing land use duty factors were calculated to understand demands and help inform future planning but were not used to allocate wastewater flows. The model analyses (both existing and future) rely on zoning duty factors for allocation. Zoning Classification duty factors were used to allocate wastewater flows in the model for infill areas as well as to establish future land use duty factors. The development of these duty factors is discussed in more detail in ***Chapter 5***. ***Table 2-2*** summarizes current City zoning classifications and acreages (based on gross area) within City limits used to analyze wastewater loading duty factors. Zoning Classifications are in gross area because of the format in which the City's zoning shapefile was provided to AE2S where zone polygons include ROW.

Table 2-1: Land Use Classification within City Limits (as of July 2020)

Land Use	Land Use Description	Area* (ac)	Percent of Total
ROW	*Right-of-Way*	*2,446*	*23.2%*
CA	Commercial/Auto	126	1.2%
CR	Commercial/Rental	500	4.7%
HM	Hotel/Motel	81	0.8%
LM	Light Manufacturing	358	3.4%
MIXED	Mixed Use	285	2.7%
RB	Restaurant/Bar	48	0.5%
PFP	Public Facility/Park	513	4.9%
AP	Administrative/Professional	245	2.3%
CHURCH	Church	94	0.9%
DTR	Duplex/Triplex Residential	339	3.2%
MHMP	Mobile Home/ Mobile Park	87	0.8%
MFR	Multi-Family Residential	764	7.2%
SFR	Single-Family Residential	2,007	19.1%
SEF	School/Educational/Facility	293	2.8%
GOLF	Golf Course	178	1.7%
RR	Rural Residential	68	0.6%
POS	Parks or Open Space	1,491	14.1%
MSU	Montana State University	615	5.8%
	Total	**10,537**	**100.0%**

*Total area excludes undeveloped and vacant land. Total City area as of July 2020 = 13,400 acres

Table 2-2: Zoning Classification within City Limits (as of July 2020)

Zoning	Zoning Description	Area* (ac)	Percent of Total
R-S	Residential Suburban District	568	5.6%
R-1	Residential Single-Household Low Density District	1,630	16.0%
R-2	Residential Two-Household Medium Density District	739	7.3%
R-3	Residential Medium Density District	1,752	17.2%
R-4	Residential High-Density District	521	5.1%
R-5	Residential Mixed-Use High-Density District	11	0.1%
R-O	Residential-Office District	388	3.8%
R-MH	Residential Manufactured Home Community District	90	0.9%
B-1	Neighborhood Business District	63	0.6%
B-2	Community Business District	919	9.0%
B-2M	Community Business District- Mixed	137	1.3%
B-3	Central Business Park District	150	1.5%
M-1	Light Manufacturing District	817	8.0%
M-2	Manufacturing and Industrial District	422	4.1%
BP	Business Park District	181	1.8%
NEHMU	Northeast Historic Mixed-Use District	38	0.4%
UMU	Urban Mixed Use	7	0.1%
REMU	Residential Emphasis Mixed Use	51	0.5%
PLI	Public Lands and Institutions District	1,301	12.8%
MSU**	Montana State University	401	3.9%

*Area based on total gross area for each zoning class, less vacant and undeveloped land.
**MSU area represents Montana State campus area east of South 19th Avenue as of July 2020.

The wastewater duty factor analysis throughout this Facility Plan (both existing and future) rely on 2020 land use and zoning information provided by the City. There have been some changes to zoning and land use classifications since 2020 but these changes will not impact the system-wide wastewater characterization for the City.

2.3 Infill Zoning and Future Land Use

Table 2-3 summarizes the infill zoning designations which are based on current City zoning classifications and acreages. Both infill and future land use information will be incorporated into the hydraulic model in the future buildout scenario. ***Figure 2-2*** presents the classifications for City infill zoning designations.

Table 2-3: Infill Area by Zoning Designation (as of July 2020)

Zoning	Zoning Description	Infill Area* (ac)
R-S	Residential Suburban District	388
R-1	Residential Single-Household Low Density District	233
R-2	Residential Two-Household Medium Density District	86
R-3	Residential Medium Density District	328
R-4	Residential High-Density District	338
R-5	Residential Mixed-Use High-Density District	30
R-O	Residential-Office District	111
R-MH	Residential Manufactured Home Community District	34
B-1	Neighborhood Business District	10
B-2	Community Business District	368
B-2M	Community Business District- Mixed	36
B-3	Central Business Park District	1
M-1	Light Manufacturing District	125
BP	Business Park District	59
UMU	Urban Mixed Use	32
REMU	Residential Emphasis Mixed Use	214
PLI	Public Lands and Institutions District	232
MSU West	Montana State University	211
	Total	2,836

*Infill acreage excludes areas that are located within the URD and TIF districts.

Table 2-4 Summarizes the growth area land use classifications and gross acreages based on the 2020 Bozeman Community Plan. ***Figure 2-3*** presents the future land designations assoacted with areas outside the existing municipal City boundary.

Table 2-4: Growth Area by Land Use Designation (as of July 2020)

Growth Area Land Use	Land Use Description	Growth Area (ac)
RC	Regional Commercial and Services	6
GC	Golf Course	178
FU	No City Services	4,044
ID	Industrial	479
RD	Urban Neighborhood	22,908
CCMU	Community Commercial Mixed Use	780
RDMU	Residential Mixed Use	346
PI	Public Institutions	1,809
POS	Parks and Open Land	1,400
	Total	31,949

2.4 Urban Renewal Districts and Tax Increment Finance Districts

Table 2-5 summarizes the urban renewal districts and tax increment finance districts as identified by the City. The area presented is gross acreage. The additional wastewater loading from redevelopment of these areas will be added to the model in the buildout scenario. ***Figure 2-2*** presents the areas associated with URD and TIF districts.

Table 2-5: URD and TIF Summary (as of July 2020)

District	Area (ac)
Midtown URD	460
North Park URD	345
North East Neighborhood URD	52
Pole Yard URD	273
Downtown TIF	128
South Bozeman Tech District TIF	45

Chapter 3 Population

3.1 Existing and Projected Population

Past and projected Bozeman population trends can be found in ***Table 3-1*** and ***Table 3-2***, respectively. ***Table 3-1*** summarizes Bozeman's historic population trends from 1960 to 2020. ***Table 3-2*** displays the City of Bozeman's projected population over the next 40 years with an assumed growth rate of 4.0% annually. The population growth rate of 4% is based on the approximate average growth over the past seven years – this rate is being used in other ongoing planning efforts by the City. This growth rate provides a conservative estimate for planning purposes and will set the basis for future water and wastewater planning efforts.

Table 3-1: City of Bozeman Historic Population

Year	Bozeman Population	Annual Growth Rate (%)	Source
1960	13,361	-	2015 WW Facility Plan
1970	18,670	4.0	2015 WW Facility Plan
1980	21,645	1.6	2015 WW Facility Plan
1990	22,660	0.5	2015 WW Facility Plan
2000	27,509	2.1	2015 WW Facility Plan
2010	37,280	3.6	2015 WW Facility Plan
2011	38,116	2.2	2015 WW Facility Plan
2012	38,753	1.7	2015 WW Facility Plan
2013	39,860	2.9	2015 WW Facility Plan
2014	41,631	4.4	2015 WW Facility Plan
2015	43,327	4.1	Census
2016	45,187	4.3	Census
2017	46,907	3.8	Census
2018	48,437	3.3	Census
2019	49,831	2.9	Census
2020	53,293	6.9	Census

This analysis was conducted during COVID-19 and the period of high development pressure that followed the pandemic – future growth will likely ease off to more stable levels. Recent estimates by the City show growth at 2.5%. However, this Facility Plan uses a conservative estimate for growth projections which is appropriate for planning large infrastructure projects.

Table 3-2: City of Bozeman Projected Population

Planning Period	Year	Population*
Existing	2020	53,293
Year 5	2025	63,952
Year 10	2030	76,742
Year 15	2035	92,090
Year 20	2040	110,508
Year 25	2045	132,610
Year 30	2050	159,132
Year 35	2055	190,958
Year 40	2060	229,150

Assumed growth rate is 4.0%

Chapter 4 Historic Wastewater Flows and Loading

4.1 Historic WRF Flows

Two primary considerations in this evaluation of flow are average annual flow and dry weather flow. Average Annual Flow (AAF) is calculated by taking the annual wastewater influent flow volume divided by the number of days each year. The AAF 10-year historic average is 5.3 million gallons per day (MGD). ***Figure 4-1*** shows the general trend of AAF for the City of Bozeman over the past decade. Detailed analysis presented in the following sections focuses on five years of data from 2015 – 2019 which has an AAF of 5.5 MGD. The past five years were selected as the basis of planning because the data better represent the current system dynamics and trends better than a longer period with more historic data.

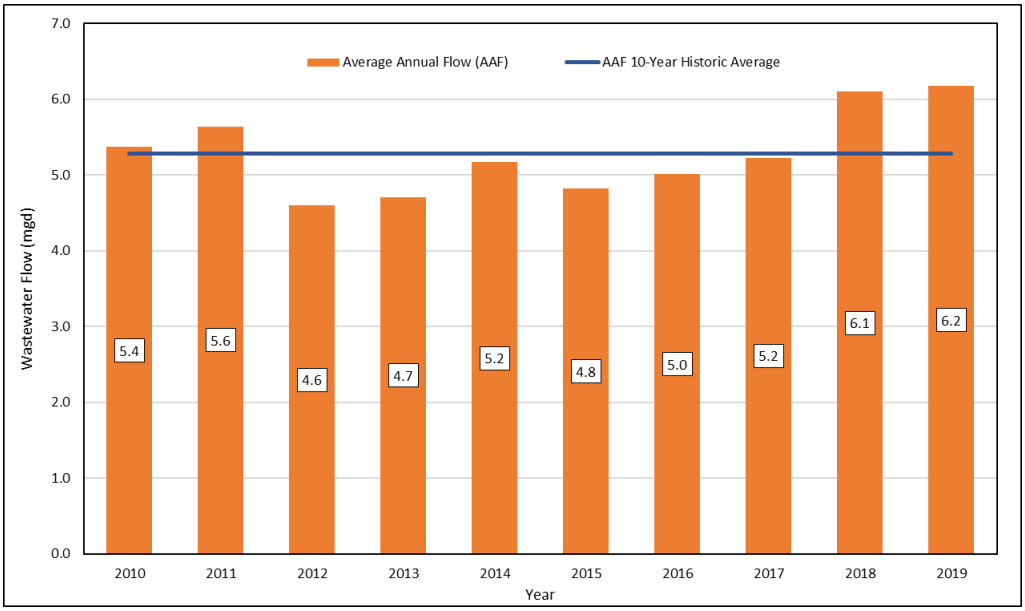


Figure 4-1: Average Annual Flow (2010 – 2019)

Dry Weather Flow (DWF) is the average flow that occurs on a day not influenced by rainfall. DWF is determined by selecting days on which several conditions are met including the following:

- No rainfall occurred on that day
- No rainfall occurred on the preceding days
- Flow volumes were within a specified range:
  - not less than 85 percent of the average
  - or more than 115 percent of the average.

Table 4-1 summarizes the DWF and AAF from 2015-2019. For this analysis, dry weather flow was calculated from the average WRF influent flow from the seasonal winter months of November through February and reported for the year starting in November. For example, the DWF for November 2015 was calculated as the average of the flows reported for November and December of 2015 and January and February of 2016.

Table 4-1: WRF Inflow Summary

Year	Average Annual Flow (MGD)	Dry Weather Flow (MGD)	Maximum Monthly Flow (MGD)	Maximum 30 day* Flow (MGD)	Maximum Daily Flow (MGD)	Peak Hourly Flow (MGD)
2015	4.8	4.7	5.2	5.2	5.9	7.5
2016	5.0	4.8	5.6	5.6	5.9	9.6
2017	5.2	5.1	5.9	6.1	7.0	9.5
2018	6.1	5.3	8.9	9.5	11.5	14.0
2019	6.2	5.8	8.2	8.3	9.7	12.2
Average	5.5	5.1	6.8	6.9	8.0	10.6

*30-day rolling average.

Monthly detailed analysis of the WRF flow is presented in tables ***Table 4-2*** and million gallons per day (MGD) and in ***Table 4-3*** as gallons per capita per day (gpcd). Monthly WRF flow is presented showing the season variations of flow at the WRF. The following observations are derived from the detailed analysis:

- **Average Annual Flow (AAF):** From 2015 – 2019, the City had an average AAF of *5.5 MGD*.
- **Dry Weather Flow (DWF):** From 2015 – 2019, the City had an average DWF of *5.1 MGD*.
- **Maximum Monthly Flow:** From 2015 – 2019, the City had an average Maximum Monthly Flow of *6.8 MGD*. The highest flow month occurred in April 2018 at *8.9 MGD*.
- **Maximum 30-day Flow:** From 2015 – 2019, the City had an average Maximum 30-day Flow of *6.9 MGD*. It is recommended that the City use the highest 30-day flow period from the review period for planning purposes which occurred between April and May of 2018 at *9.5 MGD*.
- **Maximum Daily Flow:** From 2015 – 2019, the City had an average maximum daily flow of *8.0 MGD*. It is recommended that the City use the highest daily flow (11.5 MGD) from the review period for planning purposes to account for wet years, potential impacts from climate change, and provide conservatism.
- **Maximum Hourly Flow:** From 2015 – 2019, the City had an average maximum hourly flow of *10.6 MGD*. It is recommended that the City use the highest hourly flow (14.0 MGD) from the review period for planning purposes to account for wet years, potential impacts from climate change, and provide conservatism.

Table 4-2: Detailed WRF Flow Summary (MGD)

Month	2015	2016	2017	2018	2019	Avg.
January	4.7	4.5	4.6	5.0	5.2	4.8
February	4.9	4.9	4.9	5.2	5.2	5.0
March	4.7	5.0	5.2	6.2	5.6	5.3
April	4.4	5.3	5.7	8.9	8.2	6.5
May	4.9	5.6	5.9	8.3	6.8	6.3
June	4.9	5.2	5.6	6.6	6.6	5.8
July	4.9	5.0	5.2	5.7	6.3	5.4
August	5.2	4.8	5.0	5.6	5.8	5.3
September	5.1	4.9	5.2	5.5	6.4	5.4
October	5.0	5.3	5.2	5.6	6.2	5.4
November	4.9	5.0	5.3	5.5	6.1	5.4
December	4.4	4.6	5.0	5.1	5.6	5.0
Average Annual Flow (AAF)	4.8	5.0	5.2	6.1	6.2	**5.5**
Minimum Monthly Flow	4.4 (Apr)	4.5 (Jan)	4.6 (Jan)	5.0 (Jan)	5.2 (Feb)	**4.7**
Maximum Monthly Flow	5.2 (Aug)	5.6 (May)	5.9 (May)	**8.9 (Apr)**	8.2 (Apr)	6.8
Maximum 30-Day Flow (rolling average)	5.2	5.6	6.1	**9.5**	8.3	6.9
Minimum Daily Flow (December 25th for all years)	3.4	3.6	4.0	4.2	4.7	**4.0**
Maximum Daily Flow	5.9 (Sept 16)	5.9 (May 21)	7.0 (May 18)	**11.5 (Apr 24)**	9.7 (Apr 10)	8.0
Maximum Hourly Flow	7.5 (Mar 6)	9.6 (May 21)	9.5 (Sep 8)	**14.0 (Apr 23)**	12.2 (Apr 9)	10.6
Dry Weather Flow (DWF)	4.7	4.8	5.1	**5.3**	5.8	5.1

Tabulated **bold** values represent recommended planning numbers.

Table 4-3: Detailed WRF Flow Summary (gpcd)

Month	2015	2016	2017	2018	2019	Average
January	108	100	97	103	105	103
February	112	109	105	108	104	108
March	108	110	110	128	112	114
April	102	118	122	184	165	138
May	113	124	126	172	136	134
June	112	115	120	135	133	123
July	113	111	111	119	126	116
August	119	106	107	115	117	113
September	119	109	111	113	128	116
October	115	116	111	115	125	116
November	113	111	112	114	123	115
December	102	102	106	105	113	106
Average Annual Flow (AAF)	111	111	112	126	124	117
Minimum Monthly Flow[1]	102	100	97	103	104	101
Maximum Monthly Flow[1]	119	124	126	184	165	144
Maximum 30-day Flow (rolling average)	121	130	140	219	191	160
Minimum Daily Flow[1]	79	80	85	86	95	85
Maximum Daily Flow[1]	137	131	148	238	194	170
Maximum Hourly Flow[1]	173	213	202	289	245	224
Dry Weather Flow (DWF)	108	106	109	109	115	109
Population	43,327	45,187	46,907	48,437	49,831	-

[1] See Table 4-2 for associated month/date

4.2 Wastewater Flow Analysis

The data presented in ***Table 4-2*** was used to analyze the three main components that comprise wastewater flow at the WRF. The three components to wastewater flow are generally described as follows and discussed in more detail in the following sections:

- ***Domestic Flow****:* The portion of wastewater flow that originates from domestic water use including residential, commercial, and industrial activities. Domestic flow is considered to be relatively steady throughout the year and can be estimated from indoor metered potable water use, calculated during non-irrigation months.
- ***Base Infiltration (BI)***: The portion of wastewater flow that originates from ground water and can vary by season and is influenced by the depth of the ground water table.
- ***Rainfall Derived Inflow and Infiltration (RDII):*** The portion of wastewater flow that originates from rainfall events and enters the collection system via inflow and infiltration.

4.2.1 Domestic Flow based on Metered Customer Water Usage

Water meter records are used to estimate the domestic flow portion of wastewater flow which originates from domestic, commercial, and industrial water use. The City measures water consumption through customer water meters. Historical water meter records from 2015 through 2019 were evaluated to determine overall customer water consumption, water demand by land use class and zoning, per capita usage, and seasonal variations in demand.

Table 4-4 summarizes the metered water customer analysis in MGD. The summary shows metered customer non-irrigation demand which was calculated by taking the average monthly customer demand for November through February. This method assumes that there is no irrigation during winter months which is a conventional assumption for states in northern U.S. It is also standard convention for American cities to assume that this non-irrigation season demand is near equivalent to base domestic wastewater flow. These terms are defined in more detail below:

- **Non-Irrigation Demand:** is defined by taking an average of the daily flows for a period of the year that is not influenced by irrigation. Non-irrigation demand is calculated seasonally during winter months. For example, the non-Irrigation demand calculated for 2015 is calculated as the average flow from Nov/Dec 2015 and Jan/Feb 2016. From 2015 – 2019, the City had an average non-irrigation demand of *3.6 MGD*.

- **Domestic Flow:** the Non-Irrigation Demand of **3.8 MGD** will be used as the base domestic flow allocated within the hydraulic model. The metered water demand showed a range of non-irrigation demand during the review period from 3.3 to 3.8 MGD. Therefore, it is recommended to assess the existing wastewater collection system using a non-irrigation demand of 3.8 MGD as the domestic wastewater flow.

Figure 4-2 shows the comparison between the non-irrigation demand (domestic flow) and the WRF wastewater inflow. Domestic flow seems to be on a slight upward trend, likely due to population increase. Inflow and infiltration contribution to the total WRF inflow was calculated for wet-weather and

dry-weather periods and account for a large portion of annual flow to the WRF. The methods used to calculate WWF and DWF I&I are discussed in more detail in ***Sections 4.2.2 and 4.2.3***.

Table 4-4: Metered Water Use Summary (MGD)

Month	2015	2016	2017	2018	2019	Average
January	3.1	3.1	3.2	3.6	4.0	3.4
February	3.4	3.5	4.1	4.0	3.9	3.8
March	4.9	3.6	3.4	3.5	3.6	3.8
April	3.6	3.5	3.7	3.5	3.9	3.6
May	4.1	3.9	4.9	4.6	4.2	4.3
June	8.4	7.9	7.5	5.8	6.9	7.3
July	8.3	9.2	9.4	8.3	8.0	8.6
August	8.3	9.3	10.3	10.1	8.2	9.3
September	5.4	6.2	5.8	6.2	5.7	5.8
October	3.6	3.7	3.7	4.1	4.0	3.8
November	3.6	3.7	4.2	4.0	3.8	3.9
December	3.0	3.4	3.0	3.4	3.3	3.2
Average Annual Demand (AAD)	5.0	5.1	5.3	5.1	5.0	5.1
Non-Irrigation Demand (Domestic Flow)	3.3	3.6	3.7	3.8	3.7	3.6

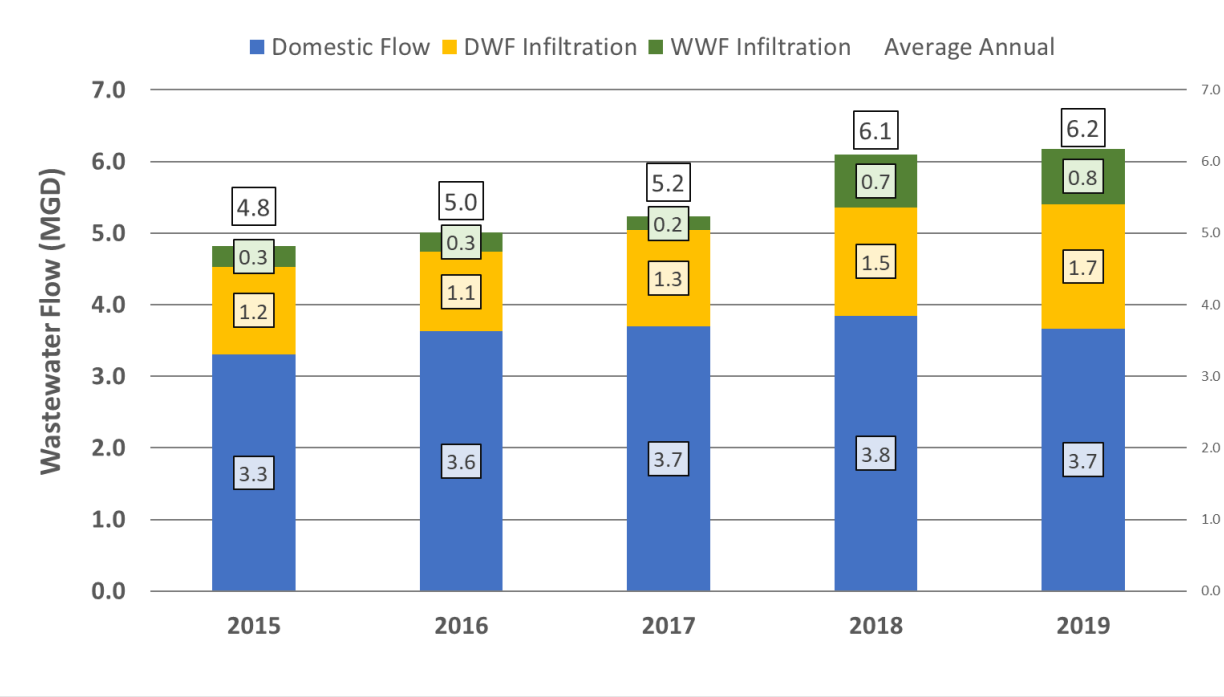


Figure 4-2: WRF Average Annual Wastewater Flow Components

4.2.2 Ground Water Infiltration

Inflow and Infiltration (I&I) is a critical consideration when evaluating collection system capacity. With the presence of groundwater, infiltration can influence the system during dry weather. This is referred to as base groundwater infiltration (BI), which is included in DWF and AAF at the WRF. During and after rain events, flows within the collection system increase in response to the rainfall. This increase in wastewater flow is known as rainfall derived inflow and infiltration (RDII), which is further described in ***Section 4.2.3***. The BI and RDII flow components are combined with diurnal peak domestic flows to define the total wastewater flow conveyed by the wastewater collection system and treated at the WRF. This peak wet weather flow condition is a worst-case scenario and used in evaluating a collection system.

As presented in ***Table 4-2,*** the detailed historic wastewater flow summary shows the range of flows and trends that the WRF experiences over the course of winter, spring runoff, and wet weather seasons. BI varies throughout the year and is influenced seasonally by spring runoff/snowmelt and by antecedent conditions. Average monthly WRF inflow was compared to the non-irrigation monthly metered water use – the difference between the two is assumed to conservatively represent base groundwater infiltration. ***Table 4-5*** shows these values by month for 2015 through 2019. This approach to estimating base groundwater infiltration assumes that there is always some influence on collection system flows from groundwater, and that average flows are representative of this influence. Rain event driven high peak flows are accounted for separately in the RDII approach which is described in ***Section 4.2.3***.

Figure 4-2 provides a visual representation of the average domestic and dry- and wet-weather BI flow components of the WRF inflow. Dry weather BI and wet weather BI were relatively steady between 2015 and 2017. The dry weather BI increase in 2018 and 2019 is likely attributed to a high ground water table.

There is widespread seasonally shallow groundwater (less than 10’ deep) in Bozeman especially within the northwestern portions of the City. As observed in the 2018 and 2019 WRF inflow data, even during the dry-weather months (November through February), the shallow groundwater has a strong influence on wastewater flows in the collection system. Groundwater static water level data from the MDT monitoring well located southeast of the I-90 and 19th Ave interchange (GWIC Well #241692) was examined to confirm and better visualize the correlation between high collection system flows and high groundwater. ***Figure 4-3*** shows the SWL for this well from 2015 through 2022. This data shows April/May groundwater depths as shallow as 2 feet deep with spikes as shallow as 1 foot deep in April 2019. The I-90 and N 19th interceptor runs through this area and likely receives a large amount of I&I during spring.

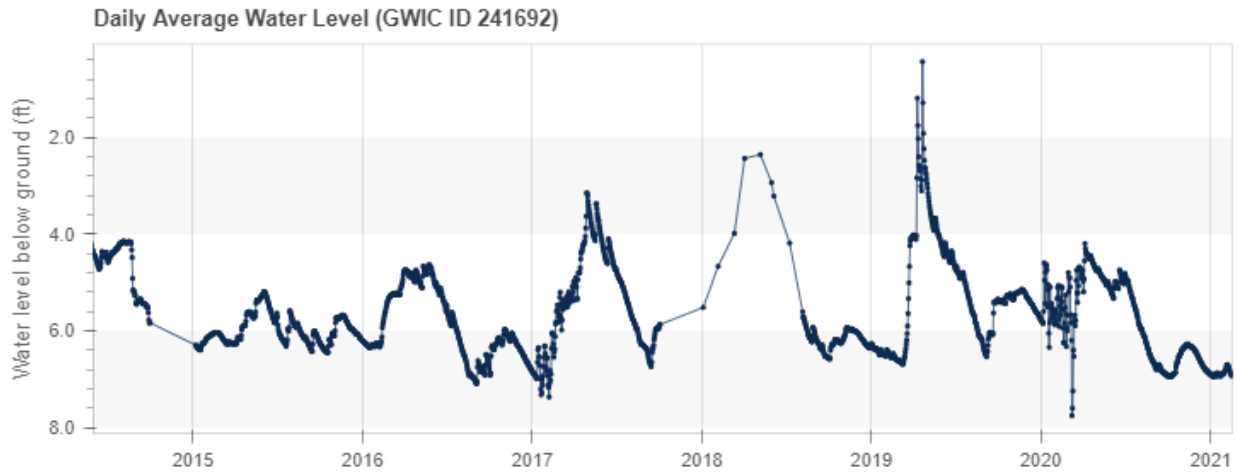


Figure 4-3: MDT Monitoring Well Static Water Level Data

Based on the analysis of WRF inflow, metered water use, groundwater well data, and meetings with City staff, it is recommended that the 2018 average DWF base groundwater infiltration value, 1.5 MGD, be used throughout the collection system. This value provides a conservative and realistic estimation of dry-weather groundwater infiltration for moderately wet years. Additionally, it is recommended that the 2018 wet-weather maximum 30-day rolling average BI, 5.7 MGD, be used for WWF groundwater infiltration throughout the collection system for this Plan. This provides a very conservative estimate of wet-weather flow but is appropriate for evaluating worst-case conditions and is supported by the 2018 data:

- During 2018, the domestic flow (non-irrigation metered water use) was *3.8 MGD* and the dry weather WRF inflow was *5.3 MGD*. The conclusion from this analysis is that on average, ***1.5 MGD*** is contributed to Bozeman's collection system as BI from ground water infiltration during DWF.
- The peak months for WRF I&I are typically April and May primarily as a result of snowmelt and spring rain events. The maximum 30-day flow of BI occurred during April and May of 2018 as the WRF experience an average inflow of *9.5 MGD*. With the assumption that the domestic flow was 3.8 MGD, the estimated BI flow at the WRF during the maximum 30-day flow is ***5.7 MGD***. This equates to 2,525 gpd/idm based on the 2018 collection system pipe network.
- Following completion of this BI analysis, the City requested that additional areas be added to the model that were not represented in the 2018 collection system pipe network – these areas include the Front Street Interceptor, Davis Lane Interceptor, and the Nelson Meadows Lift Station. As a result of these additions, the modeled WWF BI increased proportionally to reflect the added pipe and results in an additional 0.2 MGD, for a total WWF BI of ***5.9 MGD***. Note that the increase in DWF BI from these added pipes is negligible (<0.05 MGD).

To summarize, it is recommended that BI flows be allocated within the model based on the following:

- ***1.5 MGD*** of BI will be allocated into the model for the DWF scenario.
- ***5.9 MGD*** of BI will be allocated into the model for the WWF scenario.

The BI will be allocated based on the size and length of gravity main using the following equation:

$$BI\ duty\ factor = \frac{BI}{\sum_{all\ gravity\ mains}(D\ x\ L)}$$

Where:

BI duty factor = ground water infiltration rate gallons per day per inch-diameter-mile of pipe (gpd/idm)
BI = ground water infiltration (gpd)
D = *Diameter* = pipe diameter (inches)
L = *Length* = Pipe Length (miles)

- BI for DWF: 672 gpd/idm (or 1.5 MGD)
- BI for WWF: 2,525 gpd/idm (or 5.9 MGD)

The City's BI varies considerably during dry and wet weather seasons. While the BI flow rate is high during wet weather, it could be considered excessive according to EPA criteria. The EPA handbook *Facilities Planning, 1981* and the EPA handbook *Procedures for Investigating Infiltration/Inflow EPA 68-01-4913, 1981* state that the non-excessive BI rate should fall within the range of 2,000 to 3,000 gpd/idm for systems with greater than 100,000 linear ft of sewer (Bozeman has over 1.2 million linear ft of sewer).

Table 4-5: Ground Water Flow Analysis at the WRF (MGD)

Month	2015	2016	2017	2018	2019	Average
January	1.4	0.9	0.9	1.1	1.6	1.2
February	1.6	1.3	1.2	1.4	1.5	1.4
March	1.4	1.4	1.4	2.4	1.9	1.7
April	1.1	1.7	2.0	5.0	4.6	2.9
May	1.6	2.0	2.2	4.5	3.1	2.7
June	1.6	1.6	1.9	2.7	3.0	2.1
July	1.6	1.4	1.5	1.9	2.6	1.8
August	1.9	1.2	1.3	1.7	2.1	1.7
September	1.8	1.3	1.5	1.7	2.7	1.8
October	1.7	1.6	1.5	1.7	2.6	1.8
November	1.6	1.4	1.6	1.7	2.5	1.7
December	1.1	1.0	1.3	1.3	2.0	1.3
						Recommended
Average BI during DWF*	1.2	1.1	1.3	**1.5**	1.7	**1.5**
BI during Max Wet Weather Month	1.9	2.0	2.2	5.0	4.6	
BI during Max 30-day Flow	1.9	2.0	2.4	**5.7**	4.6	**5.7⁺**

*Calculated seasonally (i.e., the value for 2015 is calculated with data from Nov/Dec 2015 and Jan/Feb 2016).
⁺The maximum WWF BI over the 5-year span of analysis is 5.7 MGD. The recommended overall existing conditions WWF BI is 5.9 MGD based on applying the unit rate (gpd/idm) calculated under the 2018 conditions to the existing conditions model network.

4.2.3 RDII Analysis

As discussed, the model scenarios have loading comprised of Domestic Flow and BI. In addition, rainfall derived inflow and infiltration (RDII) causes water to enter the collection system. Typically, a design storm is used to simulate RDII and respective peak flow rates that the sewer system has to handle during these particular events.

The RDII design storm used to assess system capacity within the hydraulic model was selected off of a number of different factors, which included the following:

- The purpose and scope of the modeling project
- The availability and quality of rainfall and flow data
- The characteristics and conditions of the sewer system and watershed
- The City's engineering design standards
- The technical and economic feasibility
- The RDII response from monitored areas within the sewer system
- The ability to accommodate for future climate change
- The ability to handle growth changes related zoning changes

Based on these factors and discussions with City staff, a 25-year SCS design storm was used to simulate RDII response and respective peak flow capacity within the hydraulic model.

The design storm used in RDII wet weather analysis is summarized below:

- NOAA Atlas 2, Volume I, 1973
- Recurrence Interval: 25 year
- Depth: 1.99 inches
- Distribution Type: SCS Type I

It should be noted there is no single best method or universally accepted design storm for RDII modeling. Therefore, it is important to recognize that these results may vary from actual real world wet weather storm events.

In general, the RDII design storm selected to assess system capacity is to some extent conservative based on actual observed events. As such, additional flow monitoring and consideration of site-specific characteristics (e.g. high groundwater, zoning changes) and conditions (e.g. pipe age, material, etc.) may influence the timing of specific capacity driven capital improvements.

Additional RDII model results and calibration are discussed in the Model Development and Calibration Technical Memorandum.

4.2.4 Summary of Existing System Model Loading

The summary below provides an overview of the sanitary loads allocated within the model to establish the existing system baseline scenarios.

Table 4-6: Daily Wastewater Loading Summary for Existing System Model Scenarios (MGD)

Scenario	Domestic Flow	Ground Water BI	Total Flow
Dry Weather	3.8	1.5	5.3
Wet Weather	3.8	5.7	9.5

4.3 Population and Per Capita Loading Analysis

Per capita wastewater flows (expressed in gallons per capita per day [gpcd]) were calculated by dividing the WRF influent flow from ***Table 4-1*** by the annual population estimates from ***Table 3-1***. The per capita wastewater flow analysis is presented ***Table 4-7***.

Dry weather flow per capita trends from the last five years appear to be holding relatively steady at around *109.5 gpcd* with an increase noted in 2019. Average annual flows appear to fluctuate based on ground water infiltration previously discussed in ***Section 4.2.2***. The relatively steady dry weather flow is likely attributable to infrastructure improvements, higher efficiency plumbing fixtures, and conservation efforts. The per capita dry weather flow is expected to remain steady.

Average annual flow per person remained steady in the years 2015 through 2017. There was a significant increase in flow for the years 2018 and 2019 notably caused by high groundwater I&I as shown in ***Section 4.2.2***.

Table 4-7: AAF and DWF per Capita Flow Rates

Year	Population	Dry Weather Flow (gpcd)	Average Annual Flow (gpcd)
2015	43,327	108	111
2016	45,187	106	111
2017	46,907	109	112
2018	48,437	109	126
2019	49,831	115	124
Average		109	117

Per capita flow rates based on WRF inflow data

The per capita rate considers all water uses including residential, commercial, industrial, etc., and includes those who commute to the City from the surrounding area for work and visit for commerce and tourism. In addition, the per capita rate also takes into consideration base infiltration. The 2015 Wastewater Collection Facilities Plan used water meter categories to define the portion of per capita wastewater flow generation associated with residential. In 2015, approximately 50% of the City's water meters were categorized as residential which remains consistent with the 2020 meter data; therefore, following the same method previously used, approximately 59 gpcd (50% x 117 gpcd) is the estimated residential wastewater flow generation. The 2015 value was 64.4 gpcd, given the two values are relatively consistent, it is recommended that the City continue to use 64.4 gpcd when designing collection system infrastructure, including for use in the development standards. This value provides an appropriately conservative design standard.

Chapter 5 Wastewater Flow Characterization

Chapter 5 expands the wastewater flow characterization by developing demands based on existing land use and zoning classes. Wastewater flow generation defined by land use is a common and useful way of projecting future demands. Chapter 5 defines the baseline (2015 – 2019) wastewater flow duty factors and provides recommendations for establishing future scenarios, which are discussed in more detail in ***Chapter 6***.

5.1 Existing Land Use Wastewater Duty Factors

The first component of the land use projection method was to analyze historic non-irrigation water usage by land use class and land use area to determine domestic flow generation by land use class. Existing land use duty factors were not used to allocate wastewater loading in the model but were calculated to understand loading and help inform future land use analyses. ***Table 5-1*** summarizes the analysis and presents the values as *Domestic Flows*.

The domestic flows do not include ground water I&I. As presented in ***Section 4.2.2***, the dry weather BI and wet weather BI were calculated as *1.5* and *5.7 MGD*, respectively. The I&I duty factor was calculated by taking the total BI divided by the total effective land use acreage of the system. The I&I duty factors were calculated as follows:

- Dry Weather BI Duty Factor: 150 gpad (based on 10,537 acres)
- Wet Weather BI Duty Factor: 550 gpad (based on 10,537 acres)

The I&I duty factors were then added to the domestic flow and presented as the Recommended Dry and Wet Weather Planning Values as shown in ***Table 5-1***. These values are for planning purposes only, a more in-depth discussion on planning and design standards recommendations is provided in ***Section 6.2***

The wastewater duty factors from the 2015 WW Collection Facilities Plan Update are also presented in ***Table 5-1*** for reference. In general, the differences between the 2015 and 2020 values are due to more detailed analysis for 2020 and differences between the City's land use shapefile and designations.

Table 5-1: Wastewater Duty Factors by Existing Land Use Classification

Land Use	Land Use Description	2015 WW Facility Plan Flow (gpad)	2020		
			Domestic Flow Non Irrigation Demand (gpad)	Recommended Dry Weather Planning Value Domestic Flow + Dry Weather BI (gpad)	Recommended Wet Weather Planning Value = Domestic Flow + Wet Weather BI (gpad)
CA	Commercial/Auto	50	670	820	1,220
CR	Commercial/Rental	1,000	370	520	920
HM	Hotel/Motel	6,000	2,050	2,200	2,600
LM	Light Manufacturing	800	230	380	780
MIXED	Mixed Use	1,000	610	760	1,160
RB	Restaurant/Bar	3,500	1,490	1,640	2,040
PFP	Public Facility/Park	25	80	230	630
AP	Administrative/Professional	1,000	420	570	970
CHURCH	Church	360	80	230	630
DTR	Duplex/Triplex Residential	1,232	700	850	1,250
MHMP	Mobile Home/ Mobile Park	1,232	1,600	1,750	2,150
MFR	Multi-Family Residential	1,232	1,080	1,230	1,630
SFR	Single-Family Residential	854	500	650	1,050
SEF	School/Educational/Facility	400	120	270	670
GOLF	Golf Course	30	20	170	570
ROW	Right of Way	0	0	0	0
VACANT	Vacant	0	0	0	0
MSU[+]	Montana State University	2,220	740	890	1,290
RR	Rural Residential	-	-	-	-
POS	Parks or Open Space	-	10	160	560

Calculations based on net area.
[+] MSU land use duty factor based on total campus area, east and west of South 19th Avenue (615 acres).

5.2 Existing Zoning Wastewater Duty Factors

Calculating wastewater duty factors for zoning classes mirrors the methodology used in the land use analysis. Wastewater duty factors for zoning classifications were used to allocate wastewater demand within infill and redevelopment areas. ***Table 5-2*** summarizes the analysis and presents the values as *Domestic Flows and as Dry and Wet Weather Planning Values*.

The wastewater duty factors from the 2015 WW Facility Plan are also presented in ***Table 5-2*** for reference. The 2015 WW Facility Plan used the planning flow numbers as dry weather loading factors. The dry weather loading factors were then increased by 33 percent to obtain wet weather loading factors.

The City currently uses the 2015 WW Facility Plan loading factors with an additional 150 gpad added on the loading factors to represent I&I.

High density residential (R-3, R-4, R-5) were initially analyzed using the method described above. The initial calculations showed that high-density residential developments generally have less flow when compared with low density residential developments. A closer investigation of the City provided GIS data showed that R-3, R-4, and R-5 had significant areas that were not completely built out. The domestic flow duty factor calculation is based on metered water and total acreage. With developments at varying stages of completion, the duty factor calculation was skewed due to the high number of acres. Therefore, alternative analysis presented in ***Section 5.3*** provides for high-density planning numbers.

Table 5-2: Wastewater Loading Duty Factors by Zoning Classification

Zoning	Zoning Description	2015 WW Facility Plan Flow (gpad)	2020 Analysis		
			Domestic Flow Non Irrigation Demand (gpad)	Recommended Dry Weather Planning Value Domestic Flow + Dry Weather BI (gpad)	Recommended Wet Weather Planning Value = Domestic Flow + Wet Weather BI (gpad)
R-S	Residential Suburban District	910	60	210	610
R-1	Residential Single-Household Low Density District	546	280	430	830
R-2	Residential Two-Household Medium Density District	728	490	640	1,040
R-3	Residential Medium Density District	910	420	570	970
R-4	Residential High-Density District	1,456	710	860	1,260
R-5	Residential Mixed-Use High-Density District	-	1,580	1,730	2,130
R-O	Residential-Office District	728	400	550	950
R-MH	Residential Manufactured Home Community District	728	660	810	1,210
B-1	Neighborhood Business District	1,000	1,100	1,250	1,650
B-2	Community Business District	2,000	480	630	1,030
B-2M	Community Business District-Mixed	-	1,000	1,150	1,550
B-3	Central Business Park District	3,000	1,040	1,190	1,590
M-1	Light Manufacturing District	960	100	250	650
M-2	Manufacturing and Industrial District	960	420	570	970
BP	Business Park District	960	130	280	680
NEHMU	Northeast Historic Mixed-Use District	910	470	620	1,020
UMU	Urban Mixed Use	1,456	1,000	1,150	1,550
REMU	Residential Emphasis Mixed Use	1,456	610	760	1,160
PLI	Public Lands and Institutions District	1,030	50	200	600
MSU	Montana State University	2,200	1,140	1,290	1,690

Zoning duty factors computed using gross area for each zone less undeveloped and vacant area.
MSU duty factor computed using gross campus area east of South 19th Avenue and water meters within "MSU" meter classification.
UMU assumes the same duty factor as B-2M Zoning because as of July 2020 there were no meters within UMU classification.

5.3 High Density Residential, Urban Renewal, and Tax Increment Financing Districts

High density and mixed-use developments with multi-family units are becoming more common in Bozeman and across the United States. Based on these trends it was decided to analyze several recently completed high-density residential developments to better understand and develop representative wastewater duty factors for these types of developments. The zoning classes associated with these denser developments in Bozeman are R-3, R-4, and R-5. City staff provided data on several R-4 developments that had been completed and had representative water meter information. The developments selected and further analyzed (Loyal Gardens, Baxter Lane, Graff Street, and Sundance Meadows) were considered by City staff to be representative of development trends. All the developments analyzed are classified as R-4 because the City was not able to identify any R-3 or R-5 areas that were considered fully built-out with representative water meter data.

The metered water use data for the selected developments was reviewed to establish the domestic wastewater duty factors for R-4 Zoning. The average density of dwelling units for the R-4 subdivisions was 19.1 dwelling units per acre. The domestic flow of 48.2 gpcd was calculated based on the number of average units per acre and an assumed population density of 2.17 people per unit. This population density (2.17 people per unit) is from the 2015 Plan which was computed using 2010 census data.

5.3.1 R-3, R-4, R-5 Wastewater Duty Factors

Using the R-4 duty factors developed from the representative developments discussed above, and input from City Planning and Engineering staff, R-3 and R-5 duty factors were extrapolated. ***Table 5-3*** shows the recommended planning numbers for high-density residential zoning areas including domestic flow and dry and wet weather BI. The planning values are based on the following assumptions:

- Dwelling units per acre:
  - R-3: 15 dwellings/ac
  - R-4: 20 dwellings/ac
  - R-5: 20 dwellings/ac
- Domestic flow was calculated to be 48.2 gpcd for the sample R-4 developments provided by the City (and assuming 2.17 people per dwelling units, from the 2015 Facility Plan)
- R-5 commercial flow:
  - 910 gpad was added as the average domestic flow for B-1, B-2, B-2M, and B-3.
- Dry weather BI added to the domestic flow: 150 gpad
- Wet weather BI added to the domestic flow: 550 gpad

Table 5-3: R-3, R-4, R-5 Wastewater Planning Numbers

Zoning	Dwellings per Acre	Domestic Flow (gpad)	Recommended Dry Weather Planning Value Domestic Flow + Dry Weather BI (gpad)	Recommended Wet Weather Planning Value Domestic Flow + Wet Weather BI (gpad)
R-3	15	1,570	1,720	2,120
R-4	20	2,100	2,250	2,650
R-5	20	3,010	3,160	3,560

R-5 Domestic Flow = R-4 domestic flow plus commercial flow (average of B-1, B-2, B-2M, and B-3).

5.3.2 URD and TIF Wastewater Duty Factors

As of 2020, the City of Bozeman had a total of six Urban Renewal Districts (URD) and Tax Increment Financing (TIF) Districts. These are areas established by the City to support economic development through the use of property taxes to fund infrastructure improvements. These six areas (Downtown TIF, Midtown TIF, North Park URD, Northeast Neighborhood URD, Pole Yard URD, and South Bozeman Technology District) will redevelop at a higher density. In order to account for the increased density and wastewater generation for these areas, it was decided with City Planning and Engineering Staff to use the average of the R-3, R-4, and R-5 domestic duty factors and I&I values established in ***Section 4.2*** ***Table 5-4*** summarizes the recommended URD and TIF district duty factors.

Table 5-4: URD and TIF WWDF Summary (gpad)

Zoning	Domestic Flow (gpad)	Recommended Dry Weather Planning Value Domestic Flow + Dry Weather BI (gpad)	Recommended Wet Weather Planning Value Domestic Flow + Wet Weather BI (gpad)
URD or TIF	2,230	2,380	2,780

Chapter 6 Wastewater Flow Projections and Recommended Duty Factors

Historical wastewater flow data is frequently used to project future loading. These future projections are crucial in developing capital improvement plans. Future wastewater loading projections are based on a combination of the following items:

- Historical domestic wastewater flow categorized by zoning class;
- 2020 Bozeman Community Plan future land use characteristics (anticipated land use type, and associated area);
- Discussions with City Engineering and Planning staff; and
- Development of wastewater loading duty factors (WWDFs), which are a measurement of wastewater flow in gallons per day per acre (gpd/ac). Adjustments to the WWDFs can be made based on changes in development plans, water conservation, climate change, or any additional factors that affect the amount of flow.

6.1 Future Wastewater Flow Analysis

Infill, TIF, and URD areas are assigned a duty factor based on their respective zoning. Future land use classes are correlated to zoning classes based on the 2020 Bozeman Community Plan. Area weighted duty factors were then calculated using the associated zones. Area weighting was generally based on current City breakdown of the zones within each land use. The approach to developing future land use duty factors is discussed in more detail in ***Section 6.1.3 Ultimate Build-Out***.

6.1.1 Infill Wastewater Flow Analysis

Table 6-1 summarizes the additional wastewater flow rates expected from infill areas based on the calculated zoning wastewater duty factors. The total additional infill DWF and WWF are estimated to be 2.6 and 3.7 MGD, respectively.

Table 6-1: Infill Wastewater Loading

Zoning	Zoning Description	Infill Area (ac)	Domestic Flow Non Irrigation Demand (gpad)	Recommended Dry Weather Planning Value = Domestic Flow + Dry Weather BI (gpad)	Recommended Wet Weather Planning Value = Domestic Flow + Wet Weather BI (gpad)	Dry Weather Flow (MGD)	Wet Weather Flow (MGD)
R-S	Residential Suburban District	388	60	210	610	0.08	0.24
R-1	Residential Single-Household Low Density District	233	280	430	830	0.10	0.19
R-2	Residential Two-Household Medium Density District	86	490	640	1,040	0.06	0.09
R-3	Residential Medium Density District	328	1,570	1,720	2,120	0.56	0.70
R-4	Residential High-Density District	338	2,100	2,250	2,650	0.76	0.90
R-5	Residential Mixed-Use High-Density District	30	3,010	3,160	3,560	0.09	0.11
R-O	Residential-Office District	111	400	550	950	0.06	0.11
R-MH	Residential Manufactured Home Community District	34	660	810	1,210	0.03	0.04
B-1	Neighborhood Business District	10	1,100	1,250	1,650	0.01	0.02
B-2	Community Business District	368	480	630	1,030	0.23	0.38
B-2M	Community Business District-Mixed	36	1,000	1,150	1,550	0.04	0.06
B-3	Central Business Park District	1	1,040	1,190	1,590	0.00	0.00
M-1	Light Manufacturing District	125	100	250	650	0.03	0.08
M-2	Manufacturing and Industrial District	0	420	570	970	0.00	0.00
BP	Business Park District	59	130	280	680	0.02	0.04
NEHMU	Northeast Historic Mixed-Use District	0	470	620	1,020	0.00	0.00
UMU	Urban Mixed Use	32	1,000	1,150	1,550	0.04	0.05
REMU	Residential Emphasis Mixed Use	214	610	760	1,160	0.16	0.25
PLI	Public Lands and Institutions District	232	50	200	600	0.05	0.14
MSU West	Montana State University	211	1,140	1,290	1,690	0.27	0.36
	Total	**2,836**				**2.6**	**3.7**

Infill Acreage excludes areas that lie with URD and TIF districts.

6.1.2 URD and TIF Redevelopment Wastewater Flow Analysis

Table 6-2 summarizes the additional wastewater flows expected from redevelopment of URD and TIF districts. These areas are expected to ultimately redevelop and increase in density over time. Therefore, the URD and TIF redevelopments assumed higher domestic flows calculated from the high-density R3, R4, and R5 domestic loading analysis established previously in ***Table 5-4***. The domestic flow presented in ***Table 6-2*** is the assumed loading based on an increase in anticipated domestic loading from high density planning values.

The total additional DWF and WWF for the URD and TIF areas are estimated to be 2.6 and 2.8 MGD, respectively.

Table 6-2: URD and TIF Wastewater Loading

District	Area (ac)	Domestic Flow Allocation Increase (MGD)	Future Increase Allocation (MGD)	
			Dry Weather	Wet Weather
Midtown URD	460	0.8	0.8	0.8
North Park URD	345	0.8	0.8	1.0
Northeast Neighborhood URD	52	*Less than 0.1*		
Pole Yard URD	273	0.6	0.6	0.8
Downtown TIF	128	0.2	0.2	0.2
South Bozeman Tech District TIF	45	0.1	0.1	0.1
Total	1304	2.5	**2.6**	**2.8**

URD and TIF areas are assumed to rebuild at density consistent with domestic flow in ***Table 5-4***.
Future allocation includes additional BI flows for North Park, Pole Yard, and Tech Districts. Midtown, Northeast Neighborhood, and Downtown areas have existing BI loading and was not increased.

6.1.3 Ultimate Build-Out (UBO) Wastewater Flow Analysis

This section describes the methods used to assign wastewater loading for the Ultimate Build-Out (UBO) scenario. Future land uses were related to zoning classes using the Bozeman 2020 Community Plan (pg. 58, Correlation with Zoning) and the Future Land Use map (presented in ***Figure 2-3***).

Equivalent wastewater duty factors were calculated for each future land use using an assumed area-weighting of the zoning categories specified in the Bozeman 2020 Community Plan. ***Table 6-4*** summarizes the zoning categories per land use and assumed area-weighting. The weights for each zone are generally based on current City characteristics with some modifications based on input from City Engineering and Planning Staff taking into consideration recent development trends. For example, for Urban Neighborhood (RD), the R-4 and R-5 percentages were increased to provide an appropriately conservative estimate of overall average density for that land use (~9 dwelling units per acre). R4 and R5 are assumed to account for 20% each (40% total) of the 23,000 acres of Urban Neighborhood. ***Table 6-4*** also summarizes the equivalent average residential densities (dwelling units per acre) for each land use based on this analysis.

It should be noted that approximately 70 percent of the future land use area has been classified as Urban Neighborhood. Thus, the vast majority of the additional future flow in the UBO is generated from the Urban Neighborhood land use. If the City refines the future UBO boundary or land use categories, the model should be updated to better reflect wastewater projections.

Table 6-3: Future Land Use Correlated to Zoning Classification

Future Land Use	Land Use Description	Gross Growth Area (ac)	Reference Zoning (from 2020 Community Plan) and Percent of Total Area	Equiv. Avg. Density (dwelling units/ ac)
RC	Regional Commercial and Services	6	25% B-2 | 25% B-2M | 25% UMU | 25% PLI	4.6
GC	Golf Course	178	100% PLI	0.4
FU	No City Services	4,044	NA	0
ID	Industrial	479	30% M-1 | 15.5% M-2 | 6.7% BP | 47.8% PLI	0.9
RD	Urban Neighborhood	22,908	15% R-S | 12% R-1 | 12% R-2 | 5% R-3 20% R-4 | 20% R-5 | 4% R-O | 4% REMU 1.5% R-MH | 1.5% B-1 | 5% PLI	9.2
CCMU	Community Commercial Mixed Use	780	13.4% R-O | 1.8% REMU | 2.2% B-1 31.6% B-2 | 4.7% B-2M | 0.2% UMU 1.3% NEHMU | 44.8% PLI	2.3
RDMU	Residential Mixed Use	346	42.9% R-3 | 12.7% R-4 | 0.3% R-5 9.5% R-O | 1.2% REMU | 1.5% B-1 31.8% PLI	7.4
PI	Public Institutions	1,809	100% PLI	0.4
POS	Parks and Open Land	1,400	100% PLI	0.4

- R-3, R-4, R-5 use the denser duty factors representing more current development trends (see ***Section 5.3***)
- Regional Commercial and Services assumed average of zoning categories (not weighted proportionate to current City because future growth area assumed negligible)
- Equivalent Average Density calculated assuming 64.4 gallons per capita per day and 2.17 people per unit

Table 6-4 summarizes the resulting area-weighted duty factors and total additional wastewater flow for the future land uses within the UBO. Areas are based on the future land use map presented in ***Figure 2-3*** which was developed from the land use shapefile provided by the City in 2020. The future land use shapefile provided by the City represents an unconstrained projection of development – due to wastewater discharge, water supply, and other environmental and land ownership constraints, the actual development characteristics will likely be very different.

The largest future land use is Urban Neighborhood, which is defined as approximately 9 dwelling units per gross acre for the purposes of this Facility Plan. For comparison, the citywide average in 2020 was 6.5 dwelling units per gross acre.

The total UBO additional DWF and WWF are estimated to be 34.2 and 45.3 MGD, respectively. These numbers are presented as a desktop analysis to provide the City with estimates of total wastewater loading under the assumption the entire future growth area develops with similar densities and trends seen in the City within the past 5 years.

Table 6-4: Future Land Use Wastewater Loading
(summary of land use outside of 2020 City Limits Boundary – see Figure 2-3)

Growth Area Land Use	Land Use Description	Gross Growth Area (ac)	Wastewater Duty Factor		Wastewater Total	
			Dry Weather (gpad)	Wet Weather (gpad)	Dry Weather (MGD)	Wet Weather (MGD)
RC	Regional Commercial and Services	6	790	1,190	0.01	0.01
GC	Golf Course	178	200	600	0.04	0.11
FU	No City Services	4,044	-	-	-	-
ID	Industrial	479	280	680	0.13	0.33
RD	Urban Neighborhood	22,908	1,430	1,830	32.6	41.7
CCMU	Community Commercial Mixed Use	780	470	870	0.37	0.68
RDMU	Residential Mixed Use	346	1,180	1,580	0.41	0.55
PI	Public Institutions	1,809	200	600	0.36	1.09
POS	Parks and Open Land	1,400	200	600	0.28	0.84
	Total	**31,949**			**34.2**	**45.3**

Dry weather duty factor includes 150 gallons per acre per day for BI
Wet weather duty factor includes 550 gallons per acre per day for BI
Equivalent population calculated using 64.4 gallons per capita per day and dry weather total flow

6.1.4 Increased Density Scenario

An alternative future growth scenario was evaluated to help City staff understand the impacts of growth under denser conditions. The City recognizes the need to evaluate denser growth due to the recent senate bill SB 382. SB 382 provides an avenue for Montana communities to develop with denser land use. Denser development would increase domestic wastewater loading in the collection system. The Increased Density Scenario helps the City identify potential future pinch-points or system deficiencies. This Increased Density Scenario generally follows these assumptions:

- All single-family residential areas within current City limits experience increased domestic loading by 25%;
- All infill residential zone areas R1, R2, and R3 are increased to R4 density and its respective duty factor;
- Infill B2-M and REMU zoning was increased to R5 density and its respective duty factor.
- Select areas of varying Zoning and Future Land Use types as identified by the City where increased density development is likely to occur.
- Urban Neighborhood land use areas within the 2020 City limit boundary are increased to R4 density; and
- Future land use outside of the current City limits is consistent with the planning as established in ***Table 6-4***.

Increased Density model results are presented in TM7. ***Table 6-5*** summarizes the additional system-wide loading under the Increased Density Scenario.

Table 6-5: Increased Density Scenario Wastewater Loading Summary

Increase Density Area	Increased Domestic Loading*	
	(gpm)	MGD
Increase for Existing Single Family Residential	178	0.3
Increase for Infill Residential Zoning	1,128	1.6
Increase for Urban Neighborhood (within City Limits)	208	0.3
Increase for B2-M and REMU	522	0.7
Increase for select zoning and land use areas.	468	0.7
Total Flow Increase	2,504	3.6

*Average annual flow.

6.2 Wastewater Flow Analysis Summary

Table 6-6 summarizes the overall planning numbers and takeaways for the existing system wastewater flow characterization.

Table 6-7 summarizes the total system loading under each modeled scenario.

Table 6-6: Summary of Overall System Wastewater Flow Parameters

Parameter	MGD	GPCD
Average Annual Flow (AAF)	5.5	117
Minimum Month Flow	4.7	101
Maximum Month Flow	8.9	184
Maximum 30-Day Flow	9.5	219
Minimum Day Flow	4.0	85
Maximum Day Flow	11.5	238
Maximum Hour Flow	14.0	289
Dry Weather Flow (DWF)	5.3	109
Wet Weather Flow (WWF)	9.5	219

Table 6-7: Summary of Existing and Buildout Wastewater Loading (MGD)

	Total System Loading	
	Dry Weather	Wet Weather
Existing Allocation	5.3	9.5
Infill Allocation	2.6	3.7
URD & TIF Allocation Increase	2.6	2.8
UBO Increase	34.2	45.3
Total UBO	**44.7**	**61.3**
Increased Density Analysis Increase	*3.6*	*3.6*

The UBO increase wastewater flow is presented to provide a future growth estimate based on current conditions and previous 5-year trends. The future UBO modeled allocation will be presented in TM 7 Future Conditions.

6.3 Wastewater Flow Recommendations for Planning and Design

It is recommended the City use the wastewater duty factors presented in ***Table 6-8*** below, which list all the zoning classifications and future land use categories and their respective dry-weather duty factors and equivalent residential densities. The residential densities were calculated using a per capita domestic demand of 64.4 gallons per capita per day and 2.17 people per dwelling unit. The per capita

demand and average density are from the 2015 Facility Plan and were determined to be consistent with the updated analysis and appropriate for this Plan.

The wet-weather BI duty factors provide conservative planning numbers by accounting for the 550 gallons per acre per day of groundwater inflow. The wet-weather BI analysis included relatively wet years and is based on the City's existing infrastructure. Because not all portions of the City have shallow groundwater and newer collection system infrastructure decreases inflow susceptibility, it is recommended that the City use the dry-weather duty factors; this approach is consistent with the 2015 Facility Plan, which used an assumption of 150 gallons per acre per day of inflow on top of domestic loading.

These numbers should be used at a planning level only; for instance, they can be used to develop high-level designs and costs for regional lift stations or regional interceptors.

Design Standards Recommendation:

It is recommended that developers continue to use the 64.4 gallons per person per day for base domestic wastewater generation plus the 150 gallons per acre per day and 10-State Standard Peaking unless valid justification and analysis are provided by a registered professional engineer.

If future developers are proposing densities beyond those assumed in this Facility Plan, an individual and separate downstream analysis should be completed to verify the recommended plans conform to the results and recommendations in this Facility Plan.

Table 6-8: Summary of Recommended Duty Factors for Zoning and Future Land Use Classes

Zoning or Future Land Use Classification	Zoning or Land Use Class	Planning Value (gpad)	Equivalent Density (dwelling units per acre)
	Zoning Classifications		
R-S	Residential Suburban District	210	0.4
R-1	Residential Single-Household Low Density District	430	2.0
R-2	Residential Two-Household Medium Density District	640	3.5
R-3	Residential Medium Density District		*15.0*
R-4	Residential High-Density District	2,950	*20.0*
R-5*	Residential Mixed-Use High-Density District	2,950	*20.0*
R-O	Residential -Office District	550	2.9
R-MH	Residential Manufactured Home Community District	810	4.7
B-1	Neighborhood Business District	1,250	7.9
B-2	Community Business District	630	3.4
B-2M*	Community Business District - Mixed	2,950	20.0
B-3	Central Business Park District	1,190	7.4
M-1	Light Manufacturing District	250	0.7
M-2	Manufacturing and Industrial District	570	3.0
BP	Business Park District	280	0.9
NEHMU		620	3.4
UMU	Urban Mixed Use	1,150	7.2
REMU*	Residential Emphasis Mixed Use	2,950	20.0
PLI	Public Lands and Institutions District	200	0.4
MSU	Montana State University	1,290	8.2
	Future Land Use Classifications		
RC	Regional Commercial and Services	790	4.6
GC	Golf Course	200	0.4
FU	No City Services	-	
ID	Industrial	280	0.9
RD	Urban Neighborhood	1,430	9.2
CCMU	Community Commercial Mixed Use	470	2.3
RDMU	Residential Mixed Use	1,180	7.4
PI	Public Institutions	200	0.4
POS	Parks and Open Land	200	0.4

* B-2M, R-5, and REMU zoning districts assume increased density planning values at 20.0 dwelling units per acre for planning purposes. B-2M, R-5, and REMU allow a broad range of use and intensity of development and must be verified by the design engineer.

6.0

Feature Manipulation Engine and GIS Technical Memorandum

Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

Table of Contents

Chapter 1 Data Exchange Routine..... 2

1.1 Update the Data Source Files (GIS output) 2
1.2 Open the GIS Exchange Window..... 3
1.3 Verify/Update Source Data for Each Exchange and Attribute Mapping 5
1.4 Run the Exchanges to Import/Update Junctions and Pipes..... 13
1.5 Update the Map and Append Nodes to Pipes..... 14
1.6 Model Review..... 17

Chapter 1 Data Exchange Routine

The purpose of this technical memorandum is to provide an overview of the process and steps to import and update the wastewater collection system model using the InfoSWMM GIS Exchange Tool. There are 5 main steps to update the model from a GIS database:

- **Step 1:** Update the data source files (GIS output).
- **Step 2:** Open the GIS Exchange Window.
- **Step 3:** Verify/Update source data for each Exchange and attribute mapping.
- **Step 4:** Run the Exchanges to Import/Update junctions and pipes.
- **Step 5:** Update the Map and Append nodes to pipes.
- **Step 6:** Review Tools for Checking General Connectivity.

These steps are covered in detail in this technical memorandum.

1.1 Update the Data Source Files (GIS output)

The City's GIS department will provide updated wastewater collection system pipe shapefiles and manhole shapefiles for the model update. Before exporting data, the GIS department should first address any items identified for review or correction from previous model import processes, as necessary.

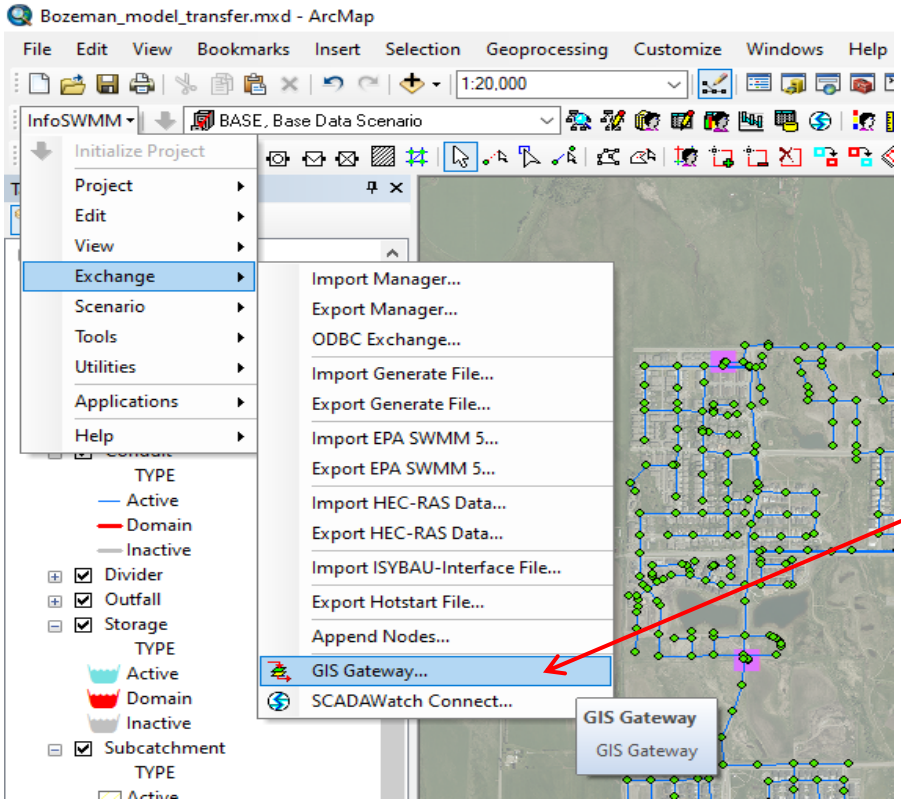
Once the GIS system is ready for export, Use the FME program to export the following shapefiles:

- SHYD_Junction Shapefile that contain all junctions.
- SHYD_Pipe Shapefile that contains all pipes.

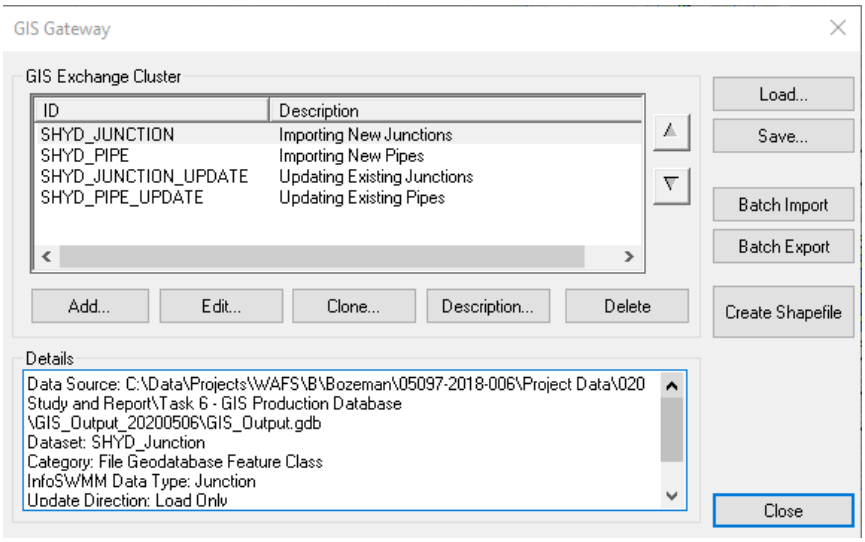
The model uses the following Coordinate system: NAD_1983_UTM_Zone_13N.

1.2 Open the GIS Exchange Window

Open the model .mxd file and initialize the model. Activate an Existing model scenario (i.e. *EXIST_2020_DWF*). Go the *InfoSWMM Menu*, select *Exchange*, and click on the *GIS Gateway*.



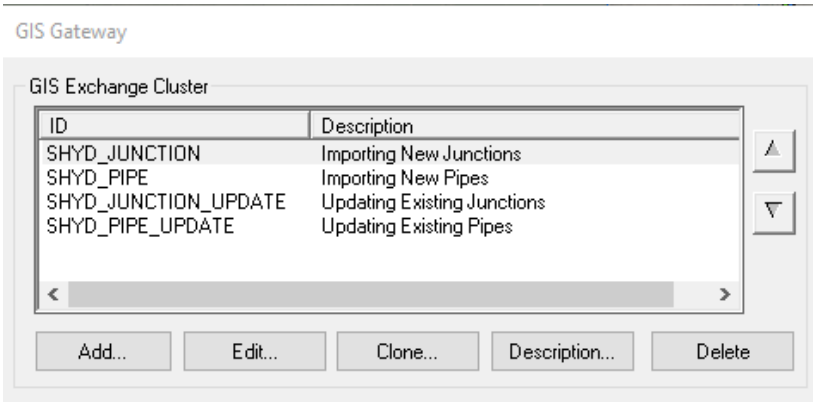
The GIS Gateway window will appear.



The GIS Gateway Window is shown here.

There are four Exchanges listed in the GIS Gateway:

- **SHYD_JUNCTION:** Imports new manholes.
  - i.e. imports manholes and force main nodes that were not previously in the model.
- **SHYD_PIPE:** Imports new pipes.
  - i.e. imports pipes (conduits) that were not previously in the model.
- **SHYD_JUNCTION_UPDATE:** Updates existing model manhole information.
  - i.e. updates manhole rim elevation that was surveyed and entered into GIS.
- **SHYD_PIPE_UPDATE:** Updates existing model pipe information.
  - i.e. updates pipe Manning's n, diameter, and inverts for a pipe that was replaced from 6" to 12".



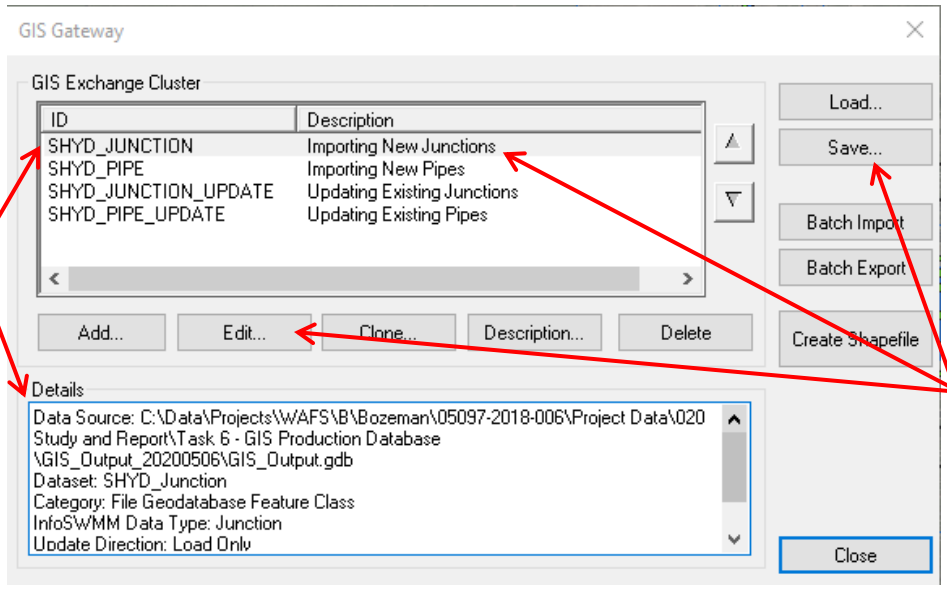
The four Exchanges are shown here in the GIS Gateway Window.

1.3 Verify/Update Source Data for Each Exchange and Attribute Mapping

Step 3A: Click on an Exchange and view the details in the lower window. Verify if the Data source is correct for all Exchanges. If the data source is correct proceed to Step 4. If the source is not correct proceed with Steps 3B through 3F.

Step 3B: If the source data needs to be corrected, click on an Exchange and select Edit. The GIS Exchange Cluster window will appear.

3A: - To View the Details of an Exchange, Select the Exchange and view the window below.



3B: To edit - select the Exchange and click Edit. The GIS Exchange Cluster window will appear. Make sure to click Save after edits are complete.

**After Editing an exchange Click on the Exchange and Click Save.

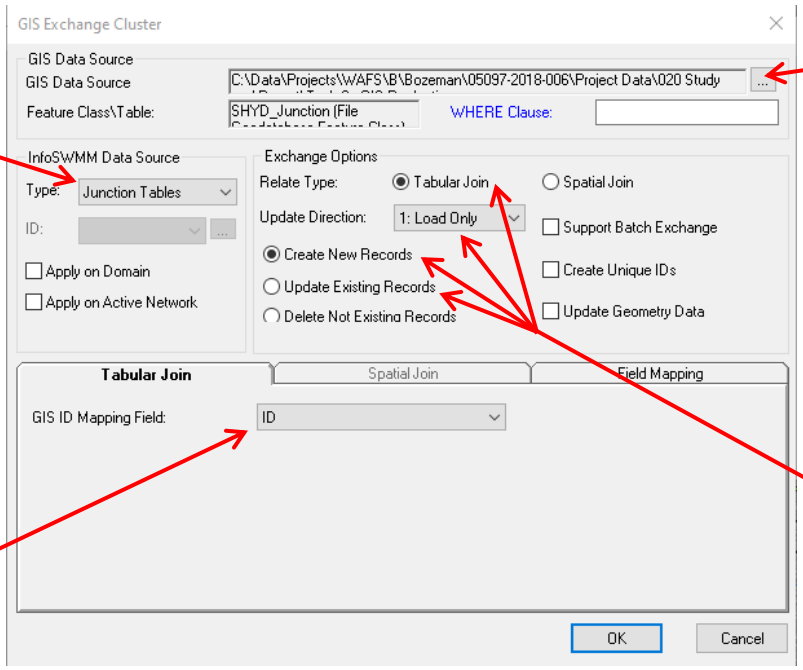
Step 3C: Click the browse button to find and select the source shapefile.

Step 3D: In the InfoSWMM Data Source Area verify that the Type selected is appropriate for the Exchange (i.e. Junction Tables is selected for Junction Exchanges as shown below).

Step 3E: Under the Exchange Options Area, verify that Tabular Join is selected, Load Only is selected, and the appropriate record match is selected (i.e. Create New Records is selected for the SHYD_JUNCTION exchange (importing new junctions).

Step 3F: Once the source file has been corrected, update the GIS ID Mapping Field to the ID field.

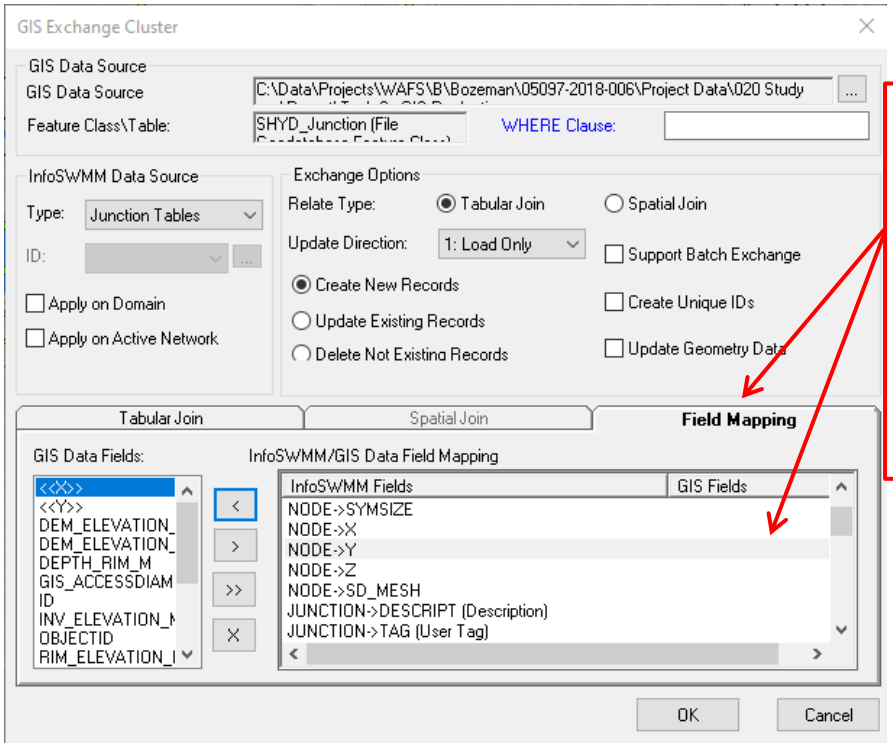
3D: - Verify that the Table Type is appropriately selected for the Exchange. (i.e. Junction tables selected for Junction Exchanges.)



3C: - To update the source file click here, browse to the appropriate source and select the required Shapefile.

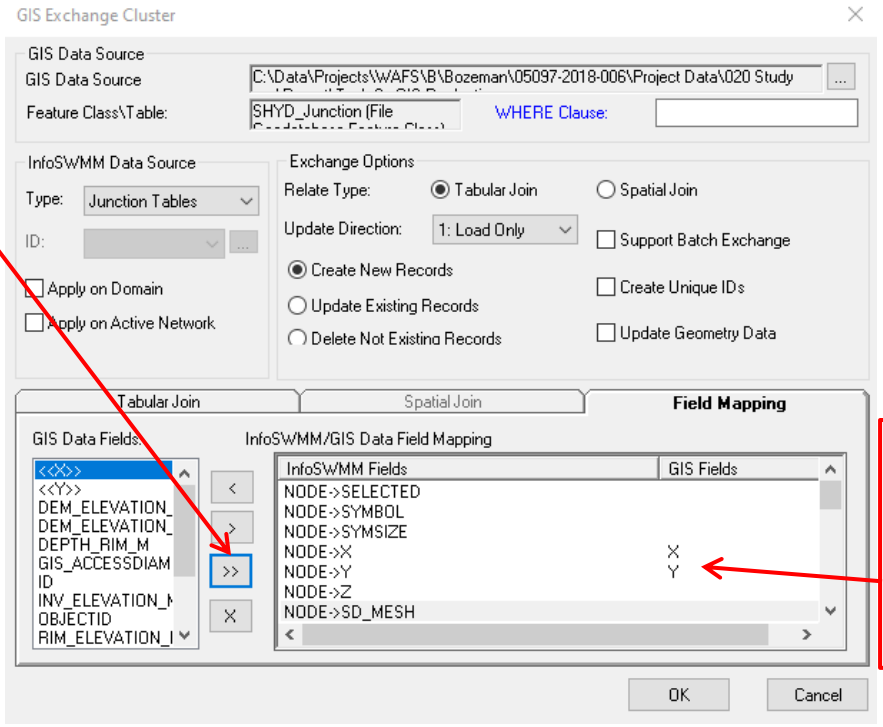
3E: - Under Exchange Options select Tabular Join, Load Only, and the appropriate record match (Create New vs. Update Existing) for the Exchange.

3F: - Select the dropdown button and choose the "ID" field for mapping.

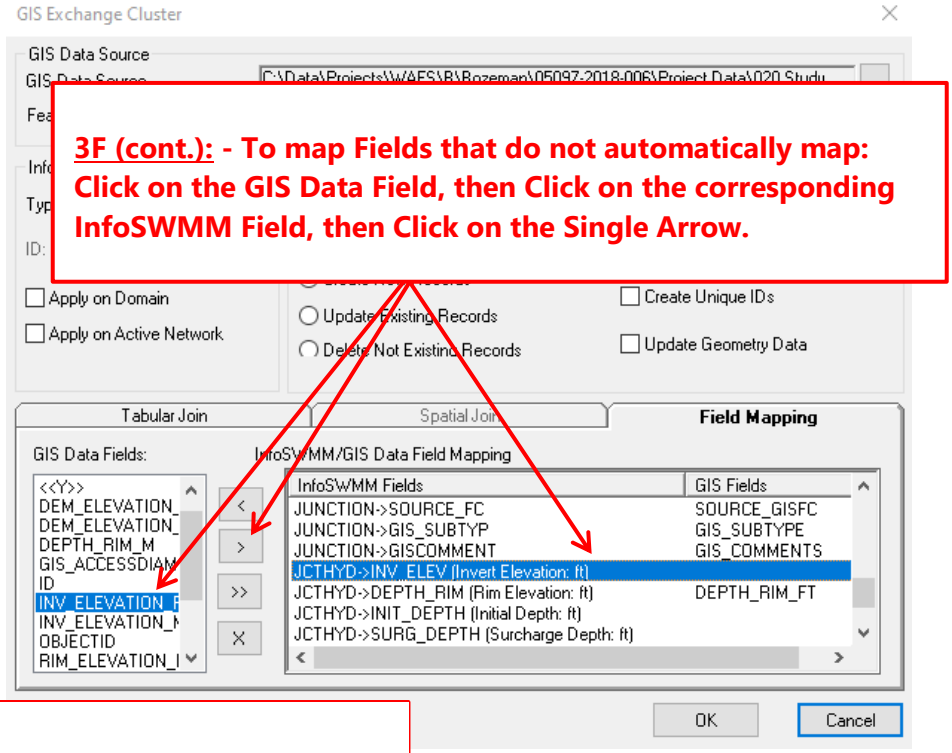


3F (cont.): - Select the Field Mapping Tab to verify attribute mapping. Note this window shows no GIS fields are mapped to the model.

3F (cont.): - Click the Double Arrow button to automatically match attributes from the GIS Data Fields to the InfoSWMM Fields. These will match only if the Field names are titled exactly the same.



3F (cont.): - Note this window shows when the GIS Fields are mapped.



3F (cont.): - To map Fields that do not automatically map: Click on the GIS Data Field, then Click on the corresponding InfoSWMM Field, then Click on the Single Arrow.

3F (cont.): - Once mapped, the Field is removed from the GIS list.

Ensure that the following Fields are mapped for *both* junction Exchanges:

3F (cont.): - Note these junction Fields will not be Mapped.

InfoSWMM Fields	GIS Fields
NODE->SELECTED	
NODE->SYMBOL	
NODE->SYMSIZE	
NODE->X	X
NODE->Y	Y
NODE->Z	
NODE->SD_MESH	
JUNCTION->DESCRIPT (Description)	
JUNCTION->TAG (User Tag)	
JUNCTION->ELEVATION (Ground Elevation: ft)	
JUNCTION->YR_INST (Year of Installation)	YR_INST
JUNCTION->YR_RETIRE (Year of Retirement)	
JUNCTION->ZONE (Zone)	
JUNCTION->PHASE (Phase)	
JUNCTION->BASIN	BASIN
JUNCTION->STATUS	STATUS
JUNCTION->MODEL_TYPE	MODEL_TYPE
JUNCTION->ACCESSDIA	ACCESSDIAMETER
JUNCTION->GIS_FAC_ID	GIS_FACILITYID
JUNCTION->SOURCE_FC	SOURCE_GISFC
JUNCTION->GIS_SUBTYP	GIS_SUBTYPE
JUNCTION->GISCOMMENT	GIS_COMMENTS
JCTHYD->INV_ELEV (Invert Elevation: ft)	INV_ELEVATION_FT
JCTHYD->DEPTH_RIM (Rim Elevation: ft)	RIM_ELEVATION_FT
JCTHYD->INIT_DEPTH (Initial Depth: ft)	
JCTHYD->SURG_DEPTH (Surcharge Depth: ft)	
JCTHYD->POND_AREA (Ponded Area: ft^2)	
JCTHYD->FLOOD_TYPE (Flood Type)	
JCTHYD->SD_COEFF (Flood Discharge Coefficient)	

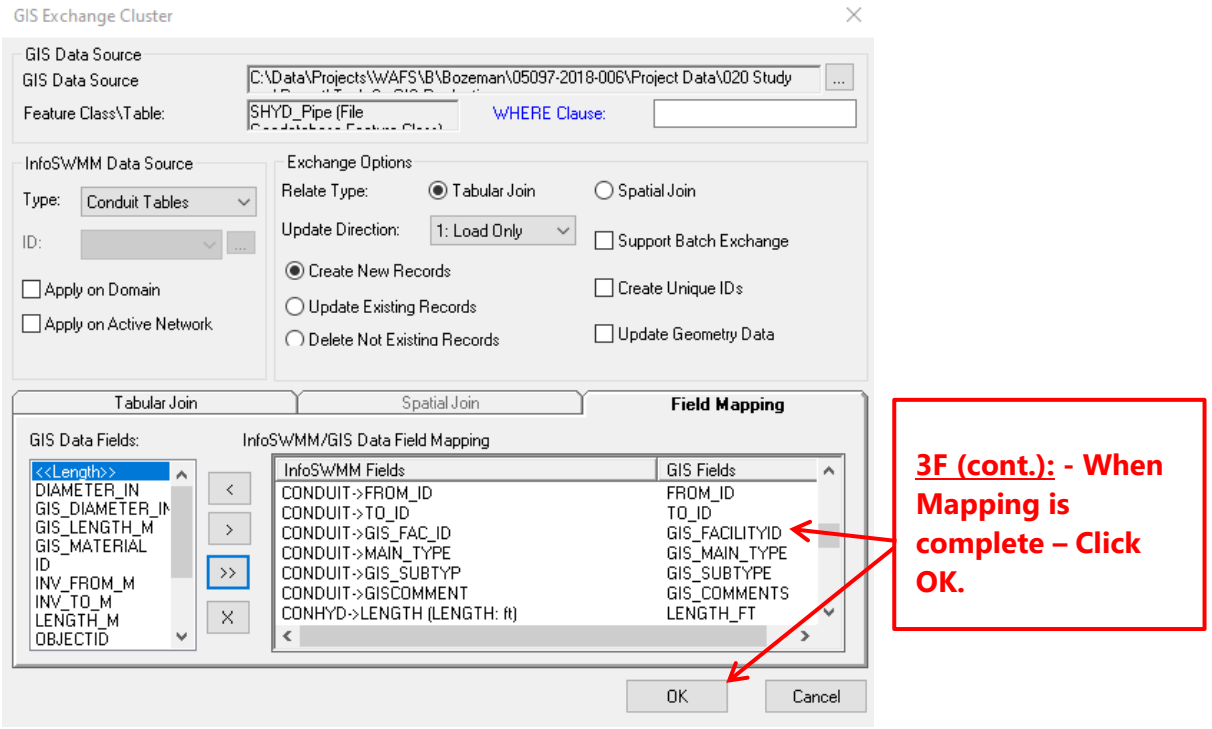
3F (cont.): - Note these highlighted Fields must be mapped.

Ensure that the following Fields are mapped for *both* pipe Exchanges:

3F (cont.): - Note these pipe Fields will not be Mapped.

InfoSWMM Fields	GIS Fields
LINK->FROM	
LINK->TO	
LINK->CAL_LENGTH	
LINK->SELECTED	
LINK->SYMBOL	
LINK->SYMSIZE	
CONDUIT->DESCRIPT (Description)	
CONDUIT->TAG (User Tag)	
CONDUIT->YR_INST (Year of Installation)	YR_INST
CONDUIT->YR_RETIRE (Year of Retirement)	
CONDUIT->ZONE (Zone)	
CONDUIT->PHASE (Phase)	
CONDUIT->BASIN	BASIN
CONDUIT->MATERIAL	MATERIAL
CONDUIT->SLIPLINED	SLIPLINED
CONDUIT->BURST	BURST
CONDUIT->ROUGHNESS	ROUGHNESS
CONDUIT->STATUS	STATUS
CONDUIT->MODEL_TYPE	MODEL_TYPE
CONDUIT->FROM_ID	FROM_ID
CONDUIT->TO_ID	TO_ID
CONDUIT->GIS_FAC_ID	GIS_FACILITYID
CONDUIT->MAIN_TYPE	GIS_MAIN_TYPE
CONDUIT->GIS_SUBTYP	GIS_SUBTYPE
CONDUIT->GISCOMMENT	GIS_COMMENTS
CONHYD->LENGTH (LENGTH: ft)	LENGTH_FT
CONHYD->MANNING (Manning's N)	MANNING_N
CONHYD->UP_DATA (Upstream Invert: ft)	INV_FROM_FT
CONHYD->DN_DATA (Downstream Invert: ft)	INV_TO_FT
CONHYD->INIT_FLOW (Initial Flow: cfs)	
CONHYD->ENTRY_LOSS (Entry Loss Coeff.)	
CONHYD->EXIT_LOSS (Exit Loss Coeff.)	
CONHYD->AVG_LOSS (Average Loss Coeff.)	
CONHYD->FLAP_GATE (Flap Gate Installed)	
CONHYD->SHAPE_TYPE (SHAPE_TYPE)	
CONHYD->GEOM1 (Max Depth: ft)	DIAMETER_FT
CONHYD->GEOM2 (GEOM2: ft)	
CONHYD->GEOM3 (GEOM3: ft)	
CONHYD->GEOM4 (GEOM4: ft)	
CONHYD->BARREL_CNT (Number of Barrels)	
CONHYD->TRANSECT (TRANSECT)	
CONHYD->MAX_FLOW (MAX_FLOW: cfs)	
CONHYD->SHP_CURVE (Shape Curve)	
CONHYD->FORCE_MAIN (Force Main)	FORCE_MAIN
CONHYD->ROUGHNESS (FM Roughness)	FM_ROUGHNESS
CONHYD->CLVT_TYPE (Culvert Code)	
CONHYD->V_ROUGH_TH (Vertical Roughness Thre...	
CONHYD->V_ROUGH (Vertical Roughness)	
CONHYD->SPLS_RATE (Seepage Loss Rate: in/hr)	

3F (cont.): - Note these highlighted Fields must be mapped.



3F (cont.): - When Mapping is complete – Click OK.

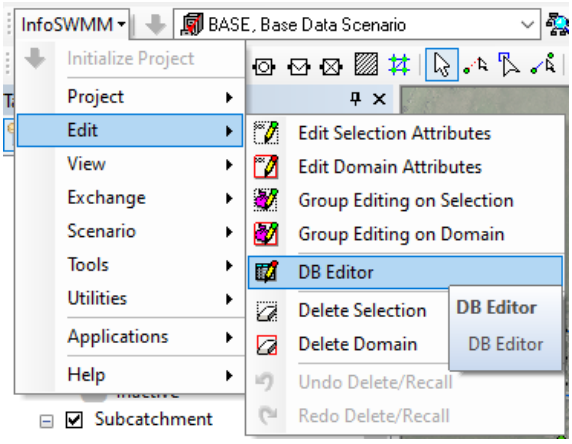
**After Editing an exchange Click on the Exchange and Click Save.

Step 3G: Complete steps 3B through 3F for all Exchanges.

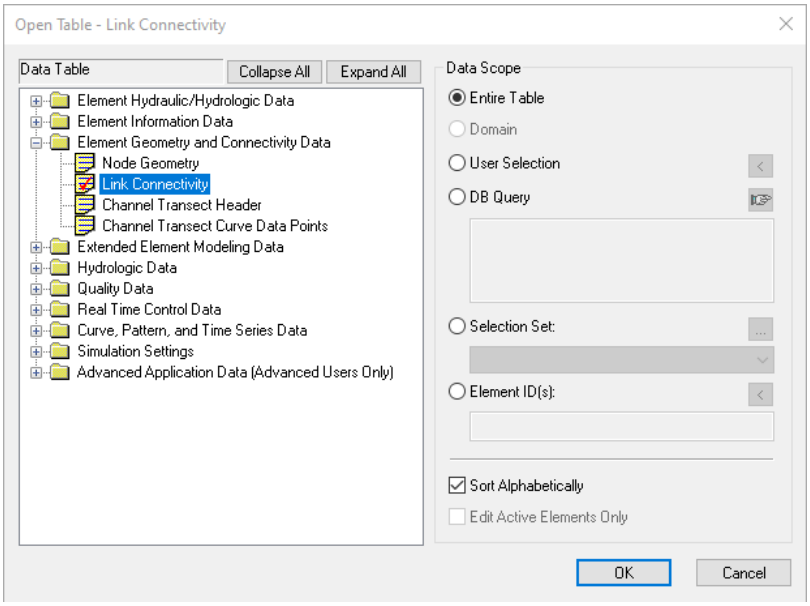
Step 3H: Prepare model database for pipe connectivity update.

Prior to running the Exchanges, the pipe connectivity database within the model will require edits. Perform the following steps.

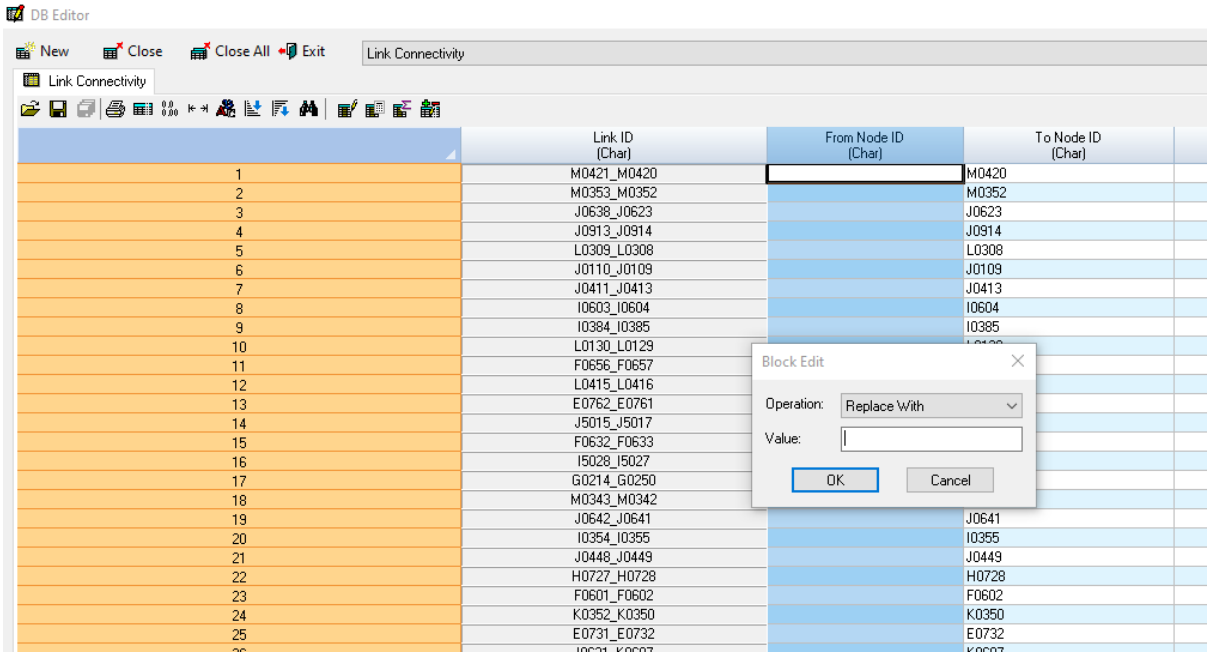
- Close the *GIS Exchange Window*.
- Open the *Database Editor*:



- Select *Element Geometry Data*,
- Select *Link Connectivity*
- Click *OK*:

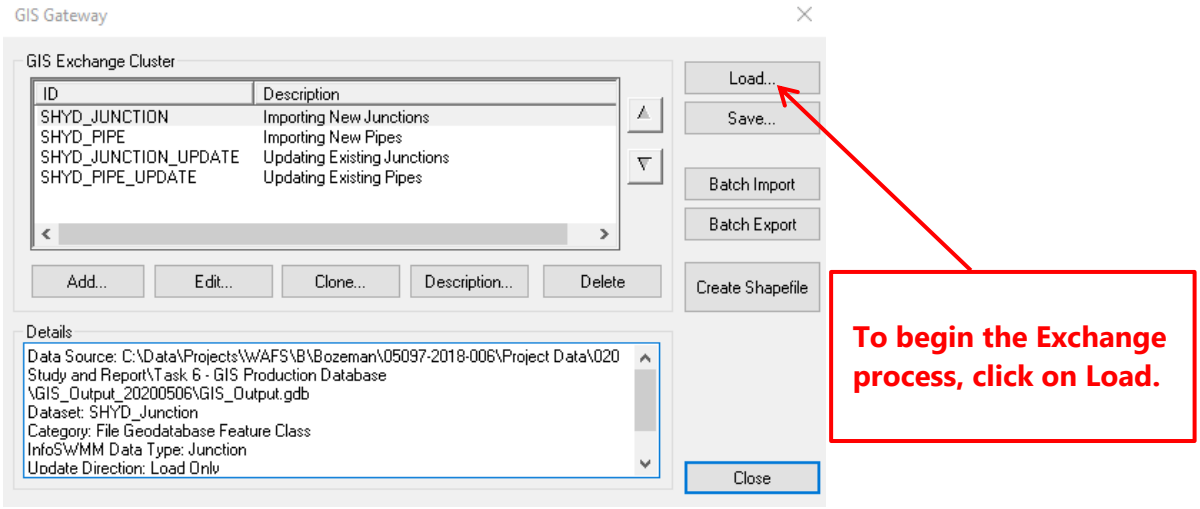


- In the DB Editor Window:
  - Left Click on the ***From*** column header.
  - Right Click and select ***Block Editing***.
  - Choose Operation ***Replace With***.
  - *Delete* any text in the Value field so it is blank.
  - Click ***OK***:
  - Left Click on the ***To*** column header.
  - Right Click and select ***Block Editing***.
  - Choose Operation ***Replace With***.
  - *Delete* any text in the Value field so it is blank.
  - Click ***OK***
  - Click ***Exit***
  - Click ***Yes*** to confirm and save changes in Link Geometry



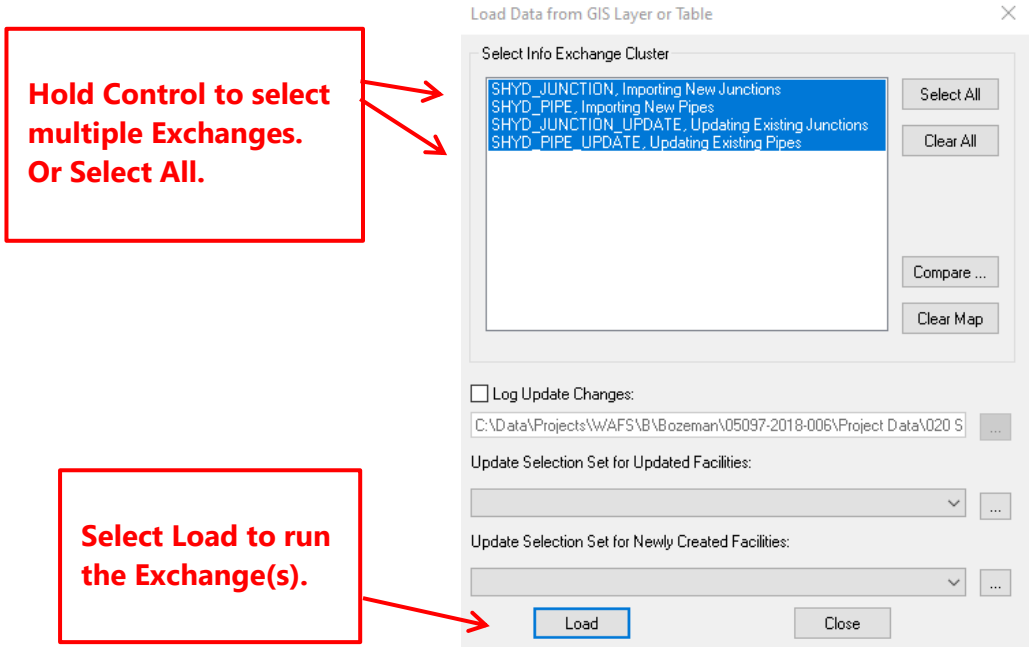
1.4 Run the Exchanges to Import/Update Junctions and Pipes

Step 4A: Re-open the GIS Gateway window and select Load



The Load Data from GIS Layer or Table window will appear. Select the Exchanges to run and Load

- Choose *Select All* to use all Exchanges (recommended for initial update).
- Or: hold Control to pick and choose Exchanges to run (i.e. junctions only).
- Click on Load to run the selected Exchanges.
- Exchanges will then run.



Step 4B: Re-Run the Pipe Update Exchange to update pipe information in Future scenarios.

Note: The model uses different hydraulic data sets for future scenarios. These hydraulic data sets include diameter, roughness, length, minor loss, etc. The Pipe Update Exchange will need to be applied to future modeling scenarios to update the data sets with pipe diameter, roughness, or length originating from pipe replacement data or from GIS data corrections.

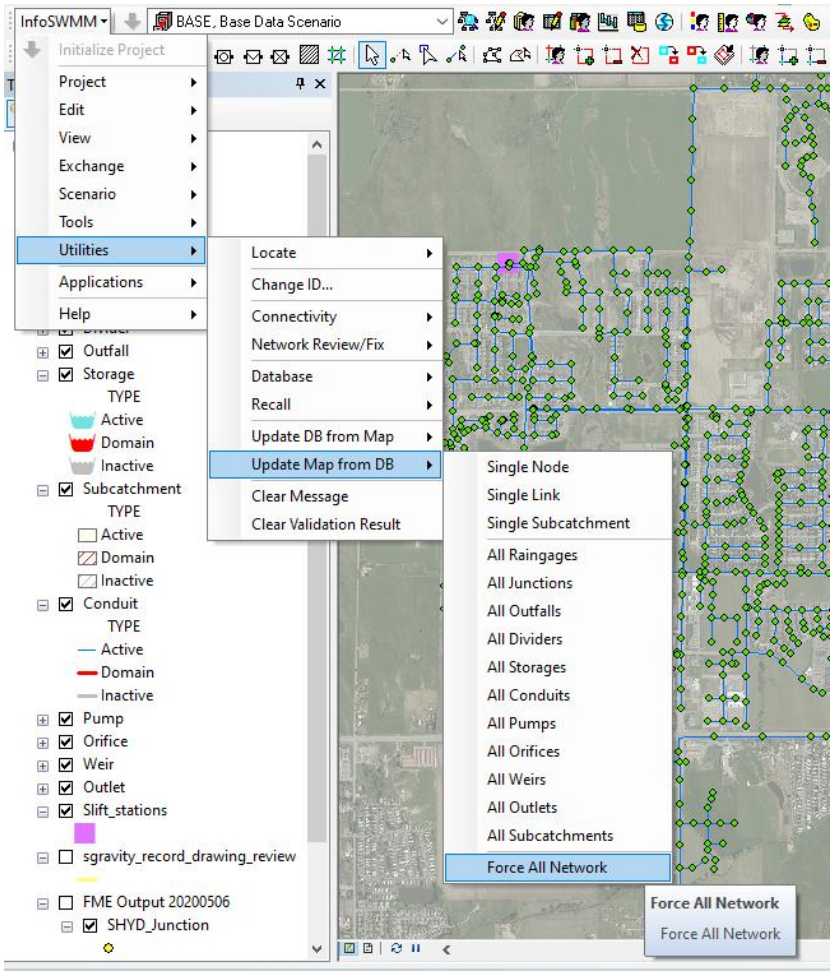
Follow these steps to apply the Pipe Update Exchange to the Future Scenarios:

- Open the Scenario Explorer and Activate the future scenario:
- Open the GIS Gateway as outlined in Step 2.
- Load the PIPE_UPDATE Exchange only and Run.
- Repeat this process and apply the Pipe Update Exchange to all future Scenarios

1.5 Update the Map and Append Nodes to Pipes

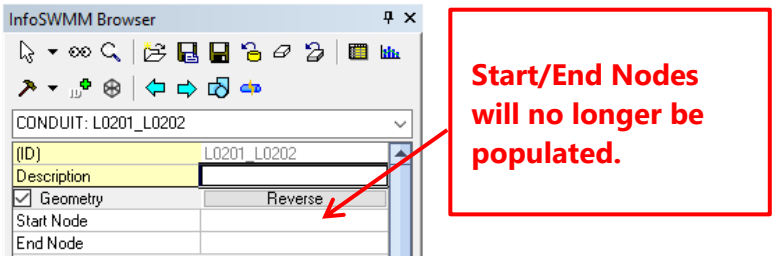
Step 5A: Updating the Map: The import process will update X,Y coordinates of junctions and the alignment of pipes. Follow these steps to update the map from the database and visually see these changes.

- Go to the *InfoSWMM Menu*, select *Utilities*, *Update MAP from DB*, and *Force All Network*.

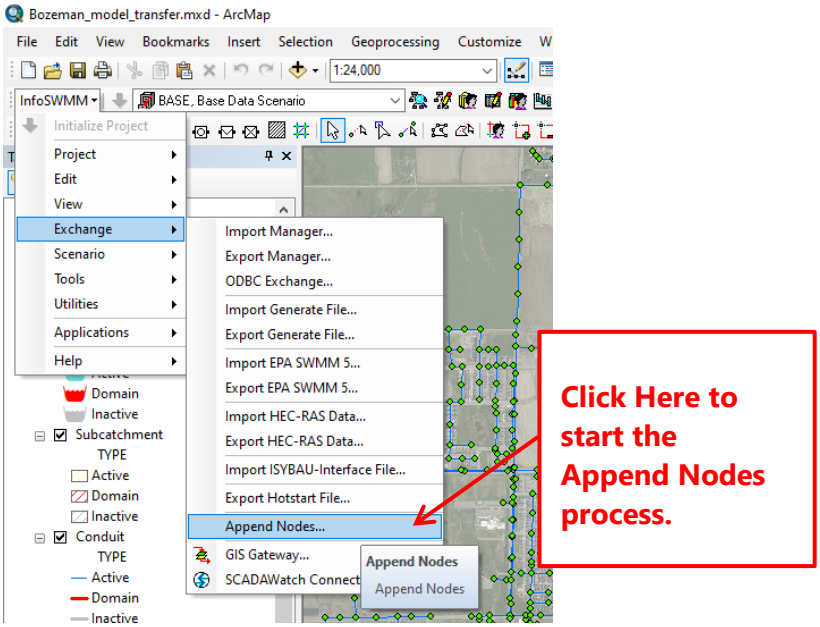


**Note: Step 5A needs to be done prior to Appending nodes in the next step.

Step 5B: Appending Nodes: Following the import process the Start and End Node IDs within the pipe geometry database will need to be updated.

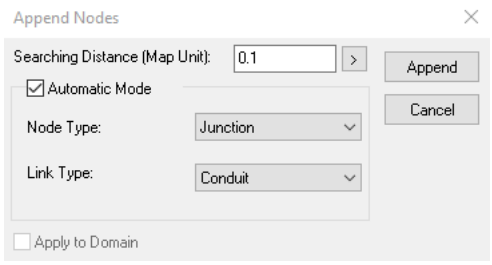


To rectify this issue, go the InfoSWMM Menu, select Exchange, and click on Append Nodes.



In the Append Nodes Window:

- Use the searching distance (0.1) (distance in meters due to map units).
- Utilize Automatic Mode (keep box checked).
- Use the default Node Type as Junction and the default Link Type as Conduit.
- Uncheck Apply to Domain.
- Click Append to run.



1.6 Model Review

This step discusses some of the tools that should be used to check for errors after completing the GIS exchange process. Tools discussed in this step included:

General tools for cleaning/finding errors:

- To access the error cleaning/finding tools go to the *InfoSWMM* drop down menu, then *Utilities*, then *Network Review/Fix*.
    - Additional information is also provided in the *InfoSWMM Help Menu* which can be accessed through the InfoSWMM drop down menu.
    - Note: When using these tools it is generally recommend to NOT allow the program to automatically fix the errors it finds. Use the tools to add the facilities to a domain and review for further review..
- Locate/Fix Nodes in Close Proximity. Use this tool to find nodes that are in close proximity to each other.
- Locate/Fix Pipe-Split Candidates. Use this tool to find pipes that should be connected. A specified distance allows the user to find end nodes that are candidates to split pipes.
- Locate/Fix Crossing/Intersecting Pipes. Use this tool to find pipes that cross each other but do not intersect with a common node.
- Trace Network, Connected Nodes, Upstream Network, or Downstream Network. Use these tools to trace the network. The traced network will be added to a domain. Use trace on the existing system to determine if any newly added pipe is not connected.

General Database Review:

- Review the manhole database to determine if there are missing rim elevations or missing invert elevations. Correct as needed.
- Review the conduit database to determine if there are missing diameter, invert, length, Manning's n values. Correct as needed.

Complete Final Model Review:

- After completing a review of model connectivity try running the Model scenarios and complete the following checks for all scenarios.
    - Review d/D results and compare results from the updated model to the previous model version.
    - Spot Check peak flows at major interceptor locations and at the WRF.
    - Check overall system loading.

7.0

Hydraulic Model Development and Results Technical Memorandum

Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

Table of Contents

Chapter 1 Introduction 5

Chapter 2 Existing Conditions Model Development and Calibration 6

2.1 Data Summary 6
2.2 Model Network Update 7
2.3 Existing Wastewater Flow Allocation 8

2.3.0 Domestic Flow Allocation 8
2.3.1 Base Groundwater Infiltration 9
2.3.2 Rainfall Derived Inflow and Infiltration Loading 9
2.3.3 Summary of System Loading 10
2.3.4 Wastewater Flow Hydrograph 11

2.4 Model Calibration 13

2.4.0 Dry Weather Calibration 13
2.4.1 Wet Weather Calibration 20
2.4.2 Summary of RTK Factors from the 2020 Calibration 27
2.4.3 2018 Midtown/Downtown Metering and Model Calibration 28

Chapter 3 Hydraulic Performance Standards 30

3.1 Gravity Main Design Criteria 30
3.2 Force Main Design Criteria 32
3.3 Lift Station Design Criteria 32
3.4 Peak Hour Design Factors 33
3.5 Dry Weather Criteria 33
3.6 Wet Weather Flow Event (Design Storm) Criteria 33

Chapter 4 Existing System Evaluation 36

4.1 Existing Dry Weather Modeling Analysis 40
4.2 Existing Wet Weather Modeling Analysis 41

4.2.0 Wet Weather Lift Station Analysis 41
4.2.1 WWF Interceptor and Gravity Main Analysis 42

Chapter 5 Existing System Recommendations 50

Chapter 6 Future Conditions Model Development 51

6.1 Model Network Expansion 51
6.2 Scenarios 52
6.3 Future Wastewater Allocation 53

6.3.1 Domestic Flow Allocation 53
6.3.2 Groundwater Baseflow 53

6.3.3 Rainfall Derived Inflow and Infiltration Loading 54
6.3.4 Summary of Future System Loading 54

Chapter 7 Future System Evaluation and Recommendations 56

7.1 Future Conditions Modeling Scenarios 56

7.1.1 Dry Weather Model Conditions 56
7.1.2 Wet Weather Model Conditions 56

7.2 Infill Evaluation and Improvements Summary 57

7.2.1 Modeling Results of Gravity Main and Interceptors for Infill Conditions 57
7.2.2 Infill Interceptor and Gravity Main Improvements 60
7.2.3 Infill Lift Station Summary 62

7.3 UBO Improvements Summary 65

7.3.1 Modeling Results of Gravity Main and Interceptors for UBO Conditions 65
7.3.2 UBO Interceptor and Gravity Main Improvements 70
7.3.3 UBO Lift Station Summary 72

7.4 UBO West Improvements Summary 73

7.4.1 UBO West Interceptor Improvements 73
7.4.2 UBO West Lift Station Summary 74
7.4.3 Modeling Results of Gravity Main and Interceptors for UBO West Conditions 75

7.5 Summary of Lift Stations and Force Main Improvements 78
7.6 Increased Density Improvements Summary 82

List of Tables

Table 2-1: Summary of Base Loading for Existing Conditions Model Scenarios 11
Table 2-2: Summary of Dry Weather Flow Calibration Results 16
Table 2-3: Summary of Wet Weather Calibration Results 23
Table 2-4: Summary of 2018 Rain Event Downtown Calibrated Peak Flows 29
Table 3-1: Summary of Hydraulic Parameters and Design Criteria 35
Table 4-1: Summary of Existing Lift Stations 37
Table 4-2: Summary of Existing Interceptors 38
Table 4-3: Capacity Summary of Existing Lift Stations 41
Table 4-4: Capacity Summary of Existing Interceptors 48
Table 6-1: Summary of Loading for Dry Weather Model Scenarios 55
Table 6-2: Summary of Loading for Wet Weather Model Scenarios 55
Table 7-1: Lift Station Capacity Summary 80
Table 7-2: Capacity Force Main 81

List of Figures

Figure 2-1: Components of a Sewer Flow Hydrograph 12
Figure 2-2: Flow Monitoring Locations 15
Figure 2-3: WRF Metered vs Modeled Dry Weather Flows 17
Figure 2-4: I5012 Metered vs Modeled Dry Weather Flows 17
Figure 2-5: G0225 Metered vs Modeled Dry Weather Flows 18
Figure 2-6: H0325 Metered vs Modeled Dry Weather Flows 18
Figure 2-7: K0319 Metered vs Modeled Dry Weather Flows 19
Figure 2-8: J0306 Metered vs Modeled Dry Weather Flows 19
Figure 2-9: Calibration Storm Event: June 17, 2020 Rainfall Distribution 21
Figure 2-10: WRF Metered vs Modeled Wet Weather Flows 24
Figure 2-11: I5009 Metered vs Modeled Wet Weather Flows 24
Figure 2-12: I5012 Metered vs Modeled Dry Weather Flows 25
Figure 2-13: G0225 Metered vs Modeled Wet Weather Flows 26
Figure 2-14: H0325 Metered vs Modeled Dry Weather Flows 26
Figure 2-15: K0319 Metered vs Modeled Wet Weather Flows 26
Figure 2-16: J0306 Metered vs Modeled Wet Weather Flows 27
Figure 3-1: Design Storm Rainfall Distribution 34
Figure 4-1: Existing Interceptors 39
Figure 4-2: Existing Wet Weather Gravity Main d/D Capacity Analysis 44
Figure 4-3: Existing Wet Weather Interceptor d/D Capacity Analysis 49
Figure 7-1: Infill System Wet Weather d/D Capacity Analysis 59
Figure 7-2: Infill System Improvements 64

Figure 7-3: UBO Interceptor System 66
Figure 7-4: UBO Interceptors and Sewershed Basins 67
Figure 7-5: UBO System Wet Weather d/D Capacity Analysis 68
Figure 7-6: UBO System Improvements 69
Figure 7-7: UBO West System Improvements 76
Figure 7-8: UBO West Wet Weather d/D Capacity Analysis 77
Figure 7-9: Increased Density Wet Weather d/D Capacity Analysis 84
Figure 7-10: Increased d/D from UBO to Increased Density 85

Chapter 1 Introduction

The Hydraulic Model Development and Results Technical Memorandum (TM 7) provides a summary of the data used, methods, assumptions, and results of the model update. TM 7 includes the following sections:

- Existing Conditions Model Development and Calibration;
- Hydraulic Performance Standards;
- Existing System Evaluation; and
- Future Conditions Scenario Development and Recommendations.

Additional details on the proposed improvements and recommendations are provided in the Capital Improvements Plan Technical Memorandum (TM 9).

Chapter 2 Existing Conditions Model Development and Calibration

The City currently uses the Innovyze InfoSWMM software package for modeling the City's wastewater collection system, specifically InfoSWMM Executive Suite 14.7. Previous InfoSWMM versions of the City's collection system model were used as a reference model update, but were not relied upon entirely because of questionable invert elevation data.

2.1 Data Summary

Several historic data sources and references, as well as newly collected data, were used in the model update. TM 3 details these data sources and data collection methods. The following is a list of key data sources used in the update, which include:

- Collection system geodatabase (City of Bozeman, initial updated with 2020, data, and followed by an update with 2023 data);
- Planning land use and zoning GIS data (City of Bozeman, 2020);
- City of Bozeman Wastewater Collection System Model Update (City of Bozeman; 2018);
- City of Bozeman Wastewater Collection Facilities Plan Update Final (City of Bozeman; 2015);
- Collection System Field Survey (TD&H, 2020);
- Bozeman Community Plan 2020 (City of Bozeman, 2020);
- Historic wastewater flow monitoring at WRF and within the collection system (City of Bozeman, 2015 through June 2020.);
- Spring 2020 wastewater flow monitoring (TD&H, 2020);
- Collection system infrastructure record drawings (City of Bozeman);
- Drinking water meter location shapefile (City of Bozeman, 2020);
- Drinking water metered account data (City of Bozeman, 2015 through June 2020);
- Bozeman Climate Plan (City of Bozeman, 2020);
- Climate Vulnerability Assessment and Resiliency Strategy (City of Bozeman, 2019); and
- Midtown/Downtown Sewer Capacity Analysis (Sanderson & Stewart, 2018).
- Baxter Creek Drainage Basin Analysis Technical Memorandum (AE2S, 2022).

2.2 Model Network Update

The following techniques were used to build the framework of the wastewater system model network.

- Model Network Geospatial Updates:
  - **FME Routine:** Feature Manipulation Engine (FME) scripting was used by the City to consolidate relevant available information to import model network elements (e.g., pipes and manholes). TM 6 describes the FME and model import method in detail and provides a step-by-step process to complete the model network update.
  - **GIS Gateway:** TM 6 describes how the GIS shapefiles and InfoSWMM *GIS Gateway* were used to geospatially update modeled sanitary sewer manholes (junctions) and pipelines (conduits).
- Junction and Conduit Elevation Updates:
  The following procedure details the elevation update approach.
  - **Survey:** Survey data was collected along major sanitary sewers by TD&H Engineering. The InfoSWMM *GIS Gateway* tool was used to import all field data into the model based on junction and conduit IDs. Field data populated included:
    - Manhole rim and invert elevations.
    - Conduit upstream and downstream invert elevations.
  - **Record Drawing:** As-built record drawings were used to update lift stations and surrounding developments.
  - **Upstream Invert Calculation:** The InfoSWMM *Upstream Invert Calculator* tool was used to calculate upstream conduit inverts of laterals and collector segments that did not have field survey or as-built data. For these particular inverts that did not have representative information, the nearest known invert (i.e., surveyed or as-built) elevation was used to calculate the missing upstream invert based on the pipe length from the known survey location and then utilizing the 10-states Standards minimum pipe slope for that pipe's known diameter.
  - **Manual Edits or Calculation:** Residual conduit elevations were closely reviewed. If an error was encountered in the model a manual edit or calculation was made estimated based on engineering judgement and best available data. Edits included interpolation between two known inverts and entering manually editing inverts at locations where the upstream invert calculated started.
  - **Manhole Rim Elevation Extraction:** For manholes that did not have survey or as-built data, rim elevations were extracted from the City's digital elevation

model (DEM), and manhole inverts were calculated using the InfoSWMM *Upstream Invert Calculator* tool.

- The model has an attribute field ***INV_NOTE*** to denote the origin of conduit inverts with the following labels: *Surveyed, Record Drawing, Invert Calculator, Manual Edit,* or *Manual Calc*.

2.3 Existing Wastewater Flow Allocation

A wastewater flow and loading analysis was completed with water reclamation facility (WRF) flow data from 2015 through 2019 along with water meter data from the same time period. TM5 describes the wastewater characterization methodology and analyses in detail. This section summarizes the key results and describes the model flow allocation methodology utilized in the development of the model.

- ***Domestic Flow****:* The portion of wastewater flow that originates from residential, commercial, and industrial sources, and also known as sanitary flow. This flow is relatively steady throughout the year and can be estimated from non-irrigation (winter, or indoor) metered water use.
- ***Base Infiltration (BI)***: The portion of wastewater flow that originates from groundwater and can vary by depth of the groundwater table.
- ***Rainfall Derived Inflow and Infiltration (RDII):*** The portion of wastewater flow that originates from rainfall events as inflow and infiltration into the collection system.

2.3.0 Domestic Flow Allocation

Water meter records were used to estimate wastewater flow from domestic (residential, commercial, and industrial) water use throughout the City. Meter coverage is near 100-percent across the City. Historical water meter records from 2015 through 2019 were evaluated to determine overall customer water consumption, water demand by both land use class and zoning, per capita water usage, and seasonal variations in water demand.

- **Non-Irrigation Demand:** Non-irrigation demand was calculated as an average of daily flows during winter months. (i.e. The Non-Irrigation Demand calculated for 2015 is calculated as the average flow from Nov/Dec 2015 and Jan/Feb 2016). From 2015 – 2019 the non-irrigation water demand ranged from 3.5 to 3.8 MGD, with an average of *3.6 MGD* during the five-year period.
- **Domestic Flow:** Non-irrigation demand of **3.8 MGD** was used as the base domestic wastewater flow allocated within the hydraulic model as this was the highest flow calculated for the review period.
- **Allocation:** The domestic flow was allocated (assigned geographically) in the model by using georeferenced water meter points and February 2020 water usage data. The

metered data was allocated to the nearest gravity main and then to the manholes of that gravity main.

2.3.1 Base Groundwater Infiltration

Inflow and Infiltration (I&I) is a critical consideration when evaluating collection system capacity. Where groundwater is high, such as West Bozeman, infiltration can influence wastewater flows even during dry conditions. This is referred to as base groundwater infiltration (BI), which makes up a portion of the Dry Weather Flow (DWF), Wet Weather Flow (WWF), and Average Annual Flow (AAF) at the Bozeman WRF.

TM 5 recommended the following BI flows be allocated within the following model scenarios:

- ***1.5 MGD*** of BI for the base DWF scenario for existing conditions.
- ***5.7 MGD*** of BI for the base WWF scenario for existing conditions.
    -

The BI was allocated based on the size and length of gravity main using the following equation:

$$BI\ duty\ factor = \frac{BI}{\sum_{all\ gravity\ mains}(D\ x\ L)}$$

Where:

BI duty factor = groundwater infiltration rate gallons per day per inch-diameter-mile of pipe (gpd/idm)
BI = groundwater infiltration (gpd)
Diameter = pipe diameter (inches)
Length = pipe length (miles)

- BI for DWF: 672 gpd/idm (or 1.5 MGD)
- BI for WWF: 2,525 gpd/idm (or 5.7 MGD)

The BI was calculated for each conduit by multiplying the BI duty factor by the conduit length and by the conduit diameter. The resulting BI flow was then allocated to the manholes on each end of the conduit as a constant flow entering the manholes. The BI calculation was completed for DWF and WWF scenarios.

2.3.2 Rainfall Derived Inflow and Infiltration Loading

During and after rain events, flows within the collection system increase, which is referred to as rainfall derived inflow and infiltration (RDII). The RDII flow component is combined with BI and diurnal peak domestic flows to define the total wastewater flow conveyed by the wastewater collection system, which is ultimately routed and treated at the WRF. This peak WWF condition is considered and representative of the City's worst-case wastewater flow scenario and is subsequently used to evaluate a collection system's capacity.

The WWF scenario of the model update utilized a synthetic design storm event to allocate RDII. RDII model calibration and design storm results are discussed in ***Section 2.3.4*** and ***Chapter 4***, respectively.

2.3.3 Summary of System Loading

The following summary and ***Table 2-1*** provide an overview of loading allocated within the hydraulic model to establish the existing collection system scenarios. Refer to TM5 for a detailed analysis of the following parameters.

- **DWF Domestic Flow**: A total of 3.8 MGD was assigned as the base domestic flow rate for both DWF and WWF scenario based on the 2018 non-irrigation metered water use.
  - Flow metering conducted in support of the model update indicated minor irregularities from previously documented diurnal wastewater patterns in Bozeman, due to the Covid-19 pandemic.
  - Diurnal peaking factors for the DWF and WWF design scenarios utilize the diurnal patterns as calculated from data collected during the calibration period. The demand patterns were then allocated across each flow monitored area for the calibration period.
  - For the 2020 calibration, the total DWF was calculated as 6.0 MGD based on WRF inflow. The domestic flow allocation used April 2020 water metered data at 4.4 MGD. The metered flow was found to be too high, so it was scaled down evenly to 3.9 MGD to reflect flows experienced at the WRF. 3.9 MGD was applied to both the DWF and WWF calibration.
- **BI**: based on gpd/idm and findings within TM5 – Wastewater Flow Characterization.
  - The base existing conditions DWF scenario: A total 1.5 MGD BI was assigned as a representative DWF starting condition based on the 2018 DWF WRF inflow of 5.3 MGD.
    - Calibration period occurred during April through June of 2020: A total of 2.1 MGD BI was used for model calibration.
      - The BI for the DWF calibration was initially modeled as 1.5 MGD. However, this was found to be too low and was scaled evenly to 2.1 MGD to match flow monitoring locations and WRF inflow for April through June, 2020 flows at the WRF. 2.1 MGD was applied to both the DWF and WWF calibration.
  - The base existing conditions WWF scenario: A total of 5.7 MGD BI was assigned as a representative WWF starting condition.
    - The BI assigned for the WWF is based on the highest 30-day flow of BI occurred during April and May of 2018 as the WRF experience an average inflow of *9.5 MGD*. With the assumption

that the domestic flow was 3.8 MGD, the estimated BI flow at the WRF during the maximum 30-day flow is ***5.7 MGD.***

- **RDII**: flow and peaking as determined by modeling analysis.
  - (peaking factors vary by flow monitored area)
  - RDII is not considered in the DWF modeling scenarios.

Table 2-1: Summary of Base Loading for Existing Conditions Model Scenarios

Scenario	Domestic Flow (MGD)	Ground Water BI (MGD)	Total Base Loading (Domestic + Ground Water BI) (MGD)
DWF	3.8	1.5	5.3
WWF	3.8	5.7	9.5
DWF Calibration	3.9	2.1	6.0
WWF Calibration	3.9	2.1	6.0

2.3.4 Wastewater Flow Hydrograph

A wastewater flow hydrograph is a useful way to display the components of the wastewater flow over time. ***Figure 2-1*** shows a conceptual hydrograph of the dry weather and wet weather components of the City's wastewater collection system flows.

Dry weather flow components consist of the domestic flow and base groundwater infiltration as described above. Combined, these two flow components make up the average daily dry weather flow. The base groundwater infiltration is generally a constant flow rate but may vary based on the season and groundwater table elevation. Groundwater infiltration enters the system through defective pipes, pipe joints, and manhole structures. The domestic flow originates from indoor water use and varies throughout the day following a diurnal pattern that typically peaks in the morning and afternoon or evening.

Wet weather flow components consist of the domestic flow, base groundwater infiltration, and rainfall derived inflow and infiltration(RDII). Combined, these three flow components make up the wet weather flow. The rainfall derived inflow is water that enters the collections system through direct sources such as cross connection to storm sewers, private laterals, downspouts, manhole defects, or other connections. Rainfall derived infiltration is in the additional groundwater infiltration that occurs in the hours or days following the rainfall event due to higher groundwater. RDII is influenced by the during and intensity of the rainfall event and varies by each rainfall event. The wet weather peaking factor is the ratio of the peak wet weather flow to the average dry weather flow.

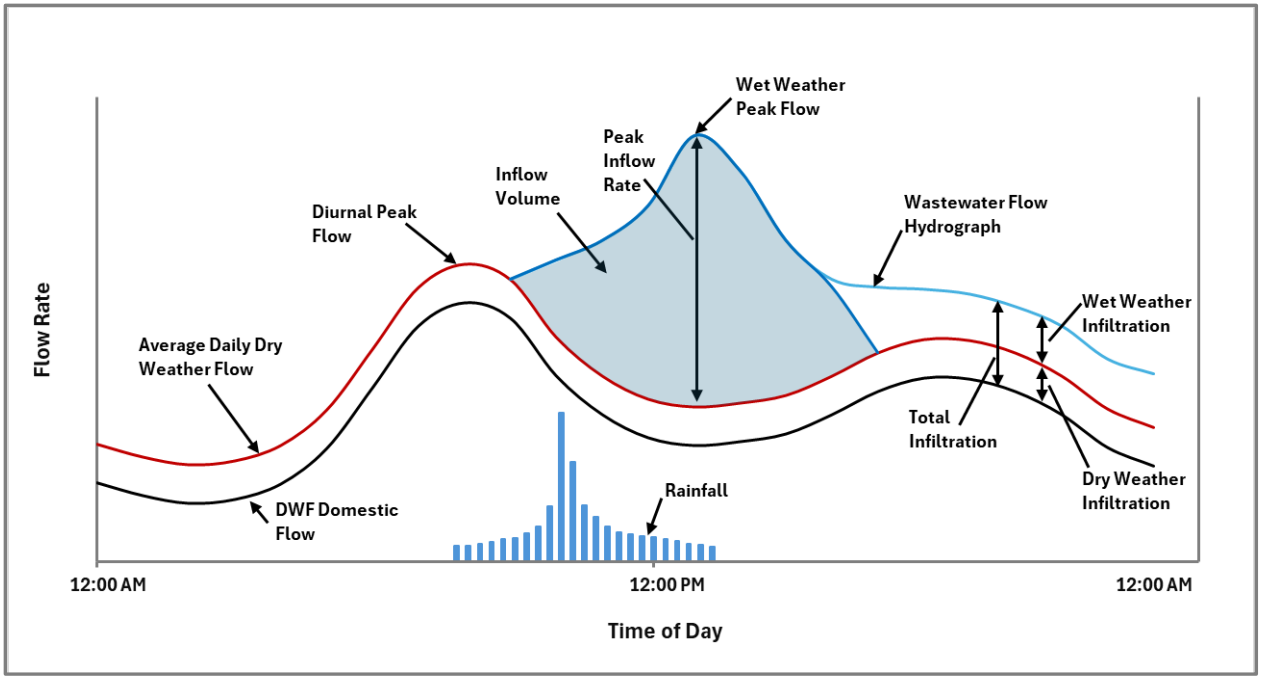


Figure 2-1: Components of a Sewer Flow Hydrograph

2.4 Model Calibration

Model calibration is a process used to improve model results to match real-world observations more closely. The model results can be adjusted by modifications to the physical attributes, to the flow allocation, or flow patterns. A model that is more closely calibrated to observed conditions generally improves the model's ability to predict wastewater flows and overall collection system performance. Examples of calibration adjustments include:

- Modifying pipe roughness coefficients;
- Varying flow diversion between wastewater sub-basins;
- Adjusting base flow volume;
- Changing base flow diurnal patterns; and
- Adjusting RDII contributing factors.

The calibration process ends when the model results are within a targeted range compared to observed conditions, or when no further benefit is realized from reasonable model adjustments. The following sections describe the DWF and WWF weather calibration processes and how calibration was performed for the model update.

A total of six (6) flow meters were placed in the western and central portion of the City's collection system between April and June of 2020. The resulting flow data along with metered flow data from the WRF (furthest downstream point in the collection system) was utilized to calibrate the model. In addition to the six (6) flow meters utilized the City had collected wastewater information for various past studies and new developments. These historical flow monitoring locations where used to augment the data set and in model refinement and calibration.

Figure 2-2 shows the six (6) 2020 flow monitoring locations, the upstream gravity main network that represents the six (6) locations, and the historical flow monitoring locations used in the analysis.

2.4.1 Dry Weather Calibration

The DWF is composed of BI and Domestic flow (*DWF = BI + Domestic*). DWF is the average flow that occurs on a day not influenced by rainfall. Selection of the DWF is important since it is the base flow that is carried into WWF calculations. DWF is identified using the following criteria:

- No rainfall occurred on that day or on the preceding days.
- Flow rates were within a specified range (not less than 85 percent of the average or more than 115 percent of the average)

The day of the week is also considered since significant changes in wastewater generation patterns can often be observed between weekdays and weekend days. Dry days for both

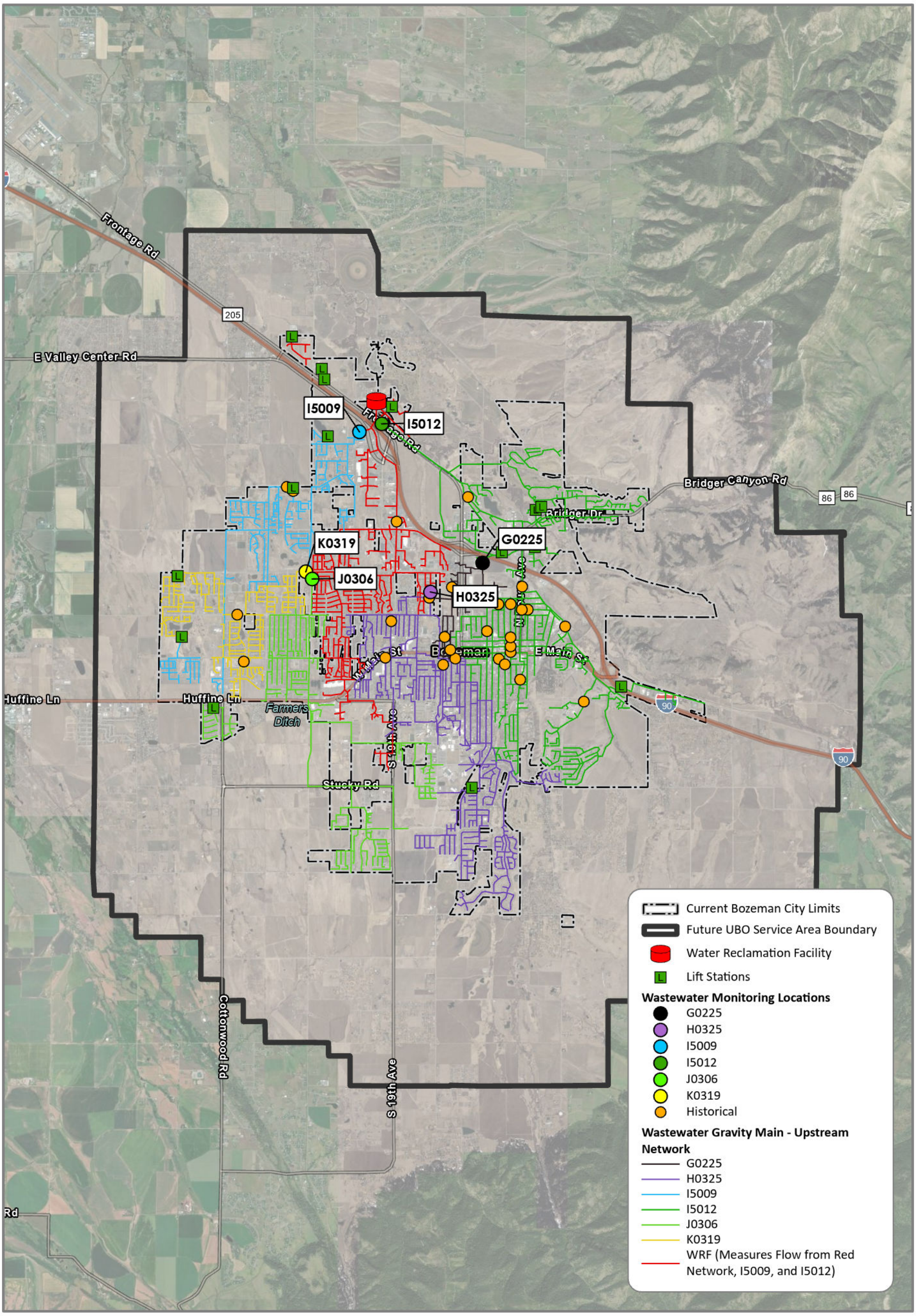
weekdays and weekends were identified, and the rate of flow and shape of the hydrograph was determined.

Sanitary sewer hydraulic model calibration standards have not been established at this time in the U.S. Therefore, goals for DWF calibration were taken from the United Kingdom's Wastewater Planning Users Group (WaPUG[1]) and consisted of the following:

- The shape of the modeled versus metered data curves should be similar.
- The timing of the peaks, troughs, and recessions of the modeled versus metered curves should be similar.
- Modeled total volume should be plus or minus 10 percent of measured total volume.
- Modeled peak flow rate should be plus or minus 10 percent of measured peak flow rate.
- Peak depth should be plus or minus 0.3 feet (3.6 inches)

During the calibration process, the DWF diurnal curves were adjusted within the model until they closely matched the metered data. Once the timing of the peak flows and low flows in the modeled diurnal curves visually matched the metered data, the hourly multipliers, BI, and domestic flows were further adjusted to meet the numerical calibration goals.

[1] WaPUG, Code of Practice for the hydraulic modelling of sewer systems, 3rd Edition WAPUG 2002 www.wapug.org.uk



Information depicted may include data unverified by AE2S. Any reliance upon such data is at the user's own risk. AE2S does not warrant this map or its features are either spatially or temporally accurate.

Coordinate System: NAD 1983 UTM Zone 12N | Edited by: DVoeller | C:\Data\Projects\WAFS\B\Bozeman\05097-2018-006\GIS\Bozeman Wastewater Collection Facility Plan - Mapping and Analysis.aprx | TM7 2-1 Meter Locations



Figure 2-2

FLOW MONITORING LOCATIONS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

Table 2-2 provides a numerical comparison between modeled results versus observed metered flow information at the six (6) 2020 monitoring locations as well as at the WRF. Specific flow attributes of both volume and peak flow were compared and analyzed for differences.

Figure 2-3 through ***Figure 2-8*** provides a visual comparison between the modeled results versus observed metered information.

The comparisons show that the DWF model calibration falls within the calibration goals. Therefore, considering the general shape similarity achieved for diurnal flow charts and diurnal peak matching, the model was considered calibrated for DWF. The bullet summary below provides a high-level summary of the results and variances from calibration goals:

- WRF, Meter I5012, and H0325 data fell within the calibration goals.
- Meter I5009 had lost data measurements during the DWF April metering period, could not be compared to the model, and was not calibrated for DWF scenario. Calibration results for Meter I5012 and the WRF, which are nearby and downstream, had acceptable levels of calibration. Therefore no further monitoring or calibration at site I5009 was deemed necessary as downstream results were found to be representative of field conditions and no change in the outcome of the model is expected.
- Meter G0225 had large variances in diurnal peak flow when compared to the model. These variances were brief high and low flows that could not be replicated in the model and are likely due to varied commercial flow.
- Meter K0319 had a large diurnal peak flow variance. It appears this is due to upstream pump station operation that could not be replicated within the model.

Table 2-2: Summary of Dry Weather Flow Calibration Results

Meter Location	Modeled vs Metered Volume ±10% of measured values	Modeled vs Metered Peak Flows ±10% of measured values
WRF	-0.1	-2.6
I5009	*	*
I5012	-0.1	-4.6
G0225	0.9	-21.4
H0325	1.3	-5.7
K0319	-4.6	-25.0
J0306	9.1	-11.7

*The flow meter at I5009 had errant measurements during the DWF flow monitoring time period.

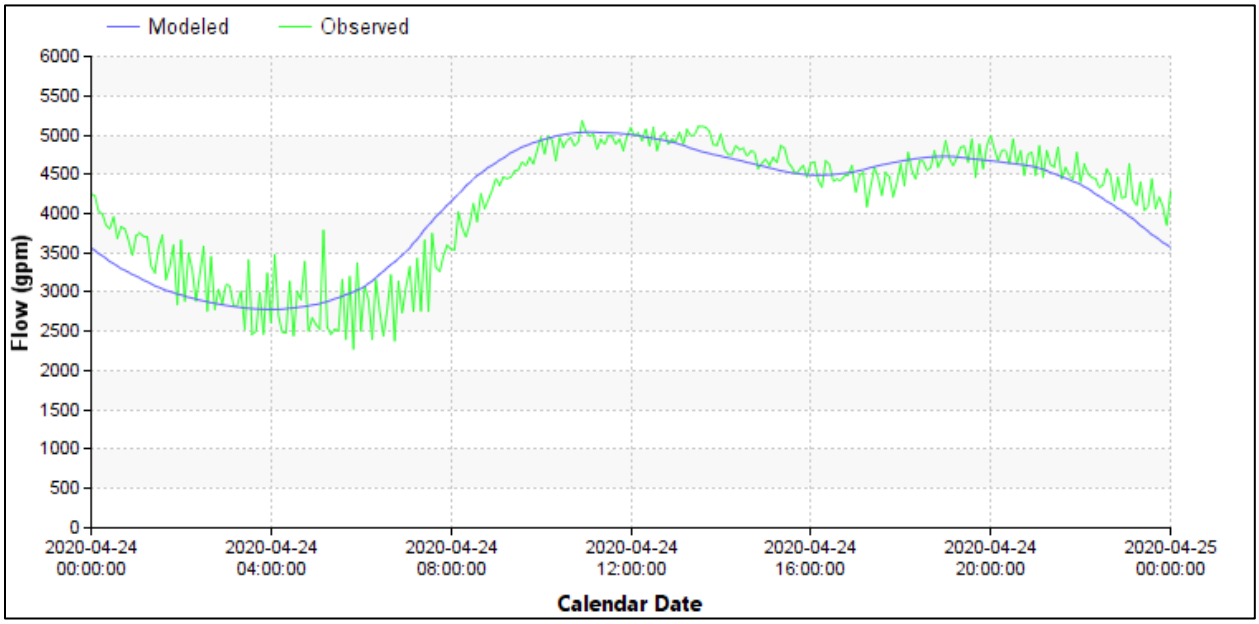


Figure 2-3: WRF Metered vs Modeled Dry Weather Flows

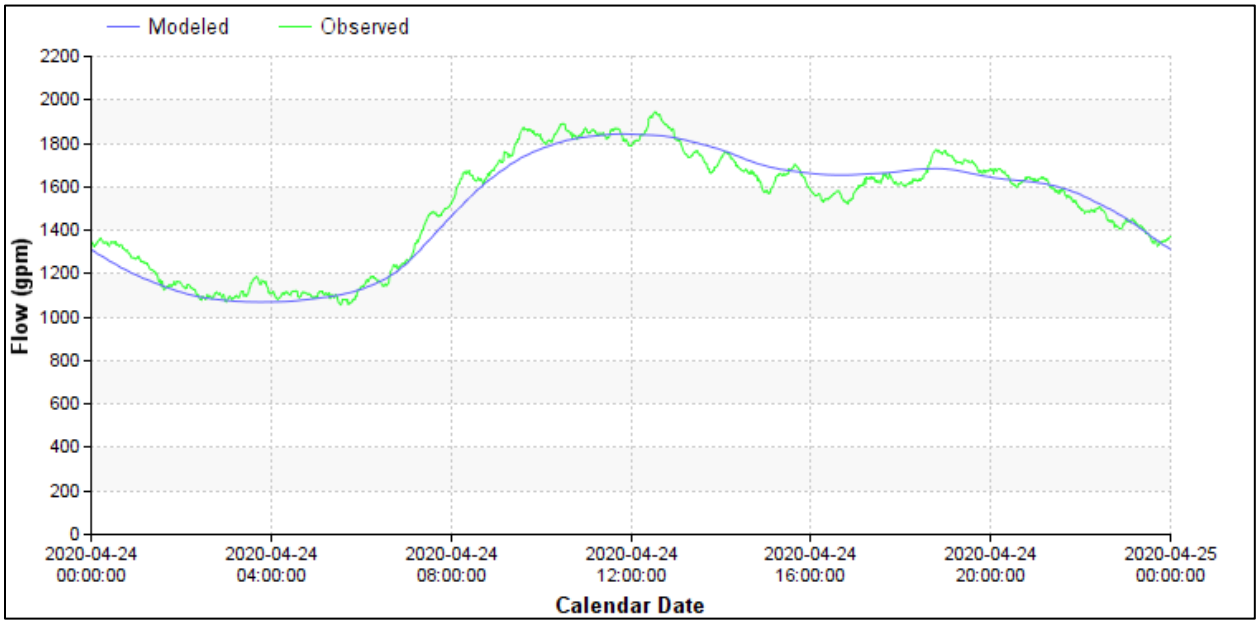


Figure 2-4: I5012 Metered vs Modeled Dry Weather Flows

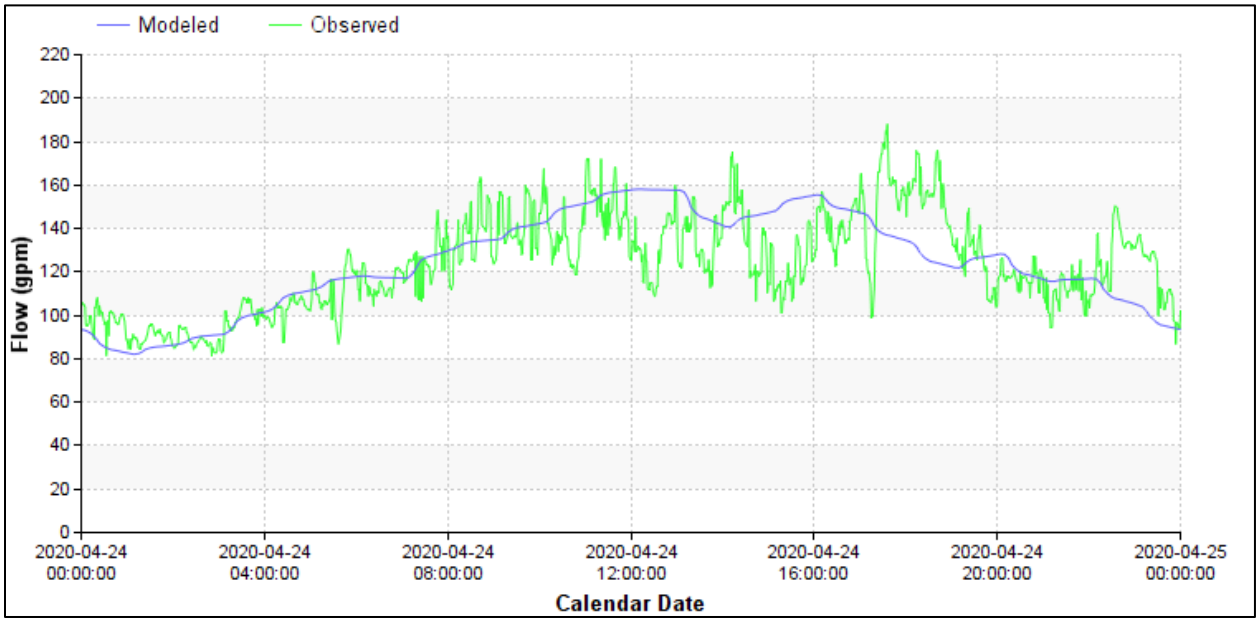


Figure 2-5: G0225 Metered vs Modeled Dry Weather Flows

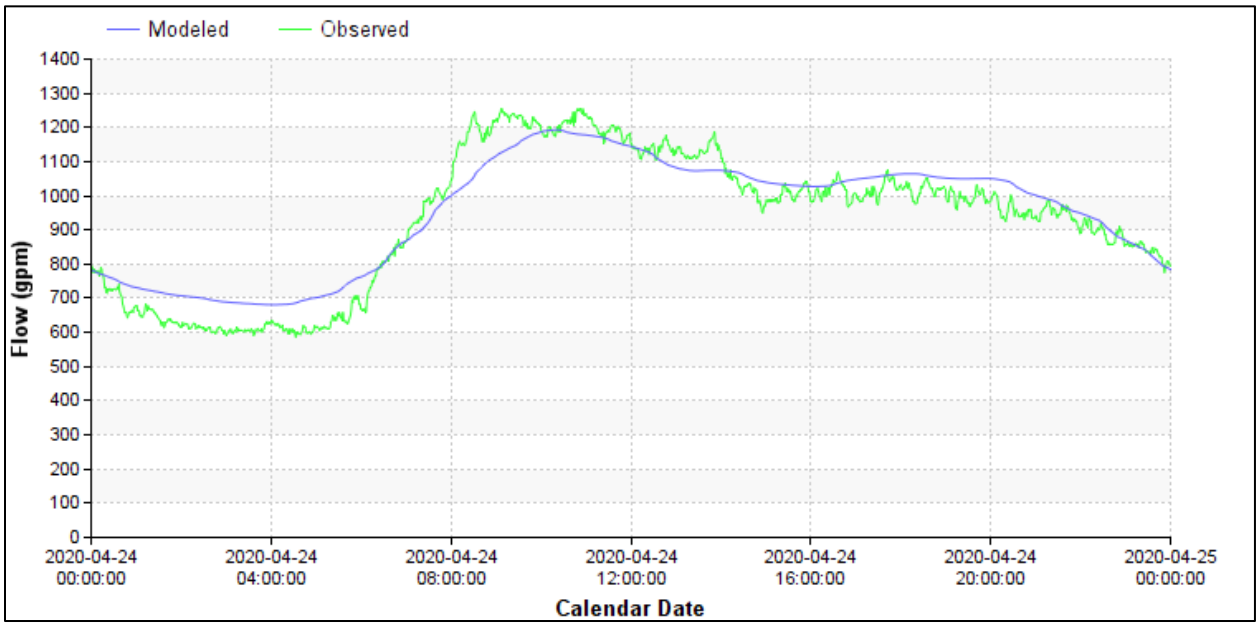


Figure 2-6: H0325 Metered vs Modeled Dry Weather Flows

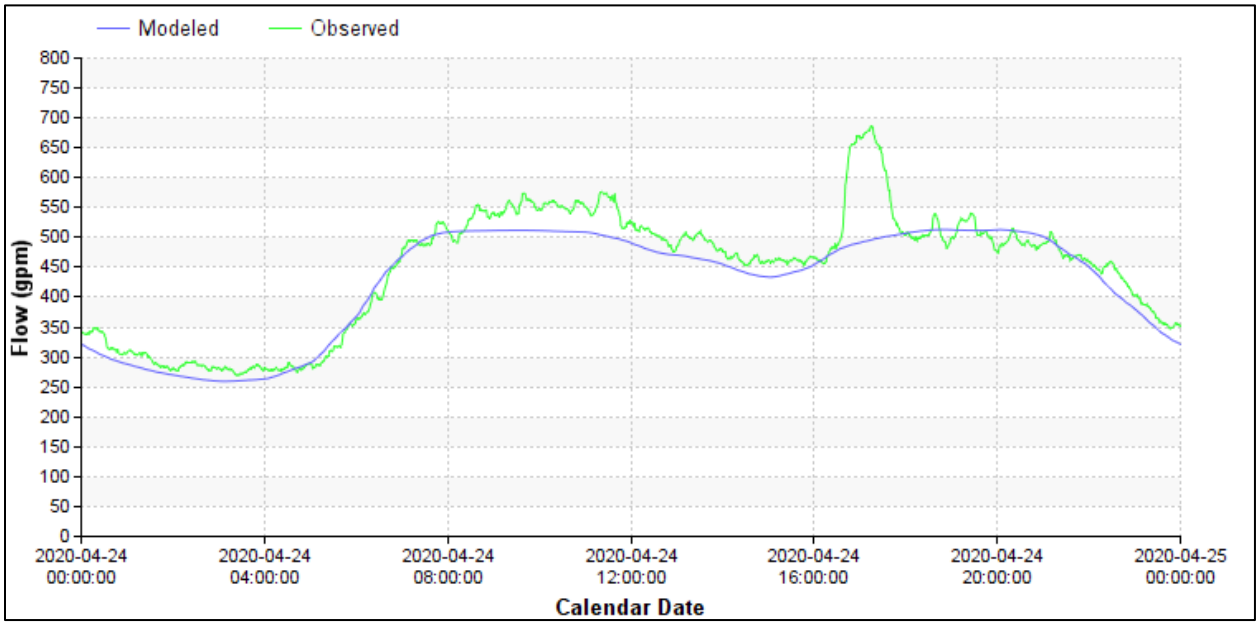


Figure 2-7: K0319 Metered vs Modeled Dry Weather Flows

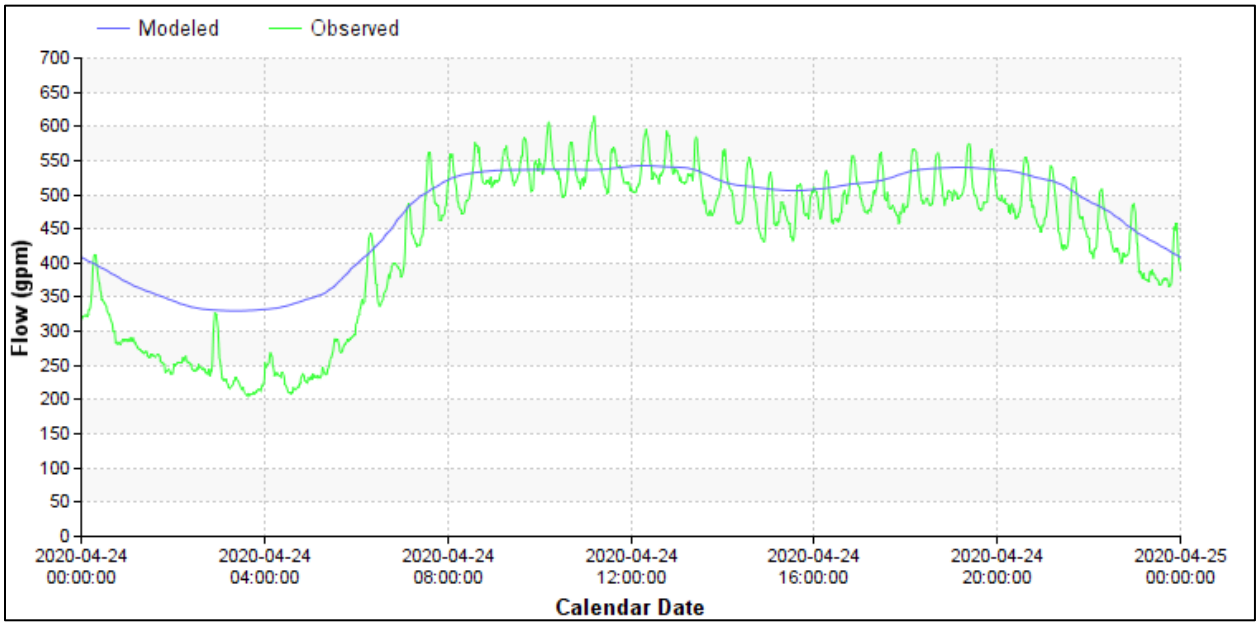


Figure 2-8: J0306 Metered vs Modeled Dry Weather Flows

2.4.2 Wet Weather Calibration

Following DWF calibration, the hydraulic model was calibrated for WWF. June 17, 2020 was chosen for calibrating the model for WWF because during this time period the City experienced a recognizable rainfall event, which totaled 0.69 inches over a 24-hour time period. ***Figure 2-9*** presents the observed rainfall distribution pattern utilized for the calibration. It should be noted that the City did not experience any significant rainfall in the week prior to the June 17th event, which allows the effects of this specific rainfall event to be evaluated without the influence of prior rainfall events.

The following steps were taken for performing the WWF calibration:

- Establish the contributing flow area for each individual calibration point. Utilizing the Thiessen polygon method, polygons were initially created for each manhole in model. Each representative contributing area was assigned to the nearest representative manhole in the model (i.e. rainfall that occurs within the model is routed to the assigned manhole). These polygons were checked against the City's current boundary area and considered representative areas that could contribute RDII during periods of WWF.
- The Thiessen Polygon method produced a few large contributing drainage areas that were determined unrealistic for a sanitary sewer system. To account for these unrealistic areas, all contributing drainage areas greater than 5 acres were reduced to 5 acres, which mirrored the previous 2015 wastewater facility plan, and considered representative for this WWF analysis.
- Observed rainfall depth versus time model inputs were created and input into the model.
- For each contributing flow area, specific input based RDII factors were input in the model. During calibration these RDII factors were manually adjusted until model results closely matched the observed meter data.

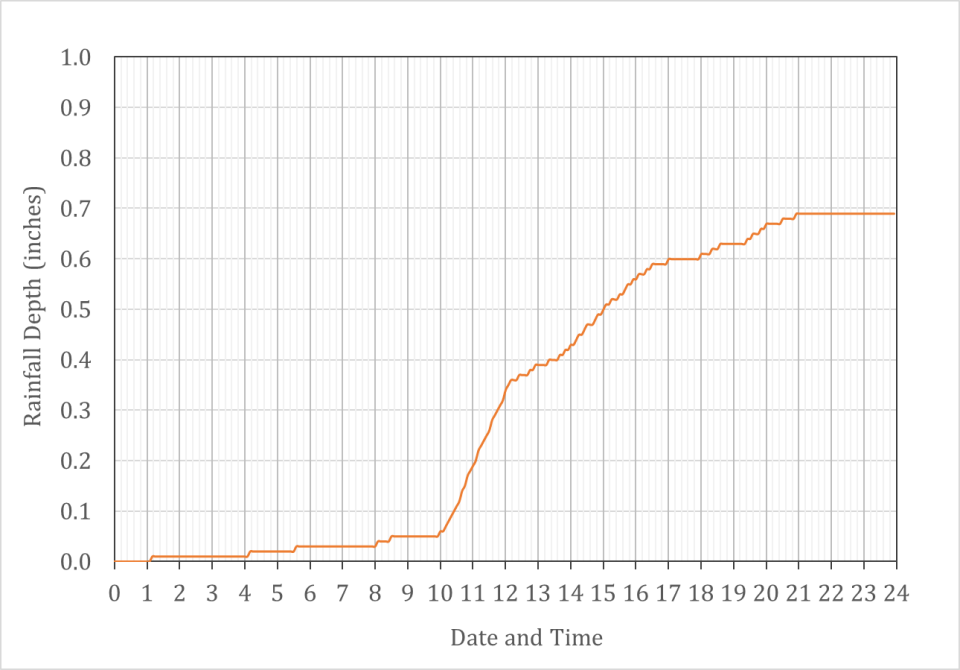


Figure 2-9: Calibration Storm Event: June 17, 2020 Rainfall Distribution

The WWF calibration was evaluated against the following goals from the WaPUG:

- The shape of the modeled versus the metered flow curves should be similar.
- The timing of the peaks, troughs, and recessions of the modeled versus metered curves should be similar.
- Modeled total volume should be within -10 percent and +20 percent of measured total volume.
- Modeled peak flow rate should be within -15 percent and +25 percent of measured peak flow rate.

WWF analysis is performed to determine how the collection system responds to rainfall events. Understanding how WWF events influence a collection system allows subsequent mitigation efforts (i.e. gravity main replacement, pipe lining, etc.) to be focused primarily in areas with the most significant WWF responses. Typically areas that exhibit high WWF responses indicate defects in the collection system, aging infrastructure, or infrastructure that has a direct conduit into the collection system, such as rooftop stormwater downspout connections to name a few.

Extreme WWF responses resulting from RDII can result in flows that exceed the capacity of the collection system, possibly leading to Sanitary Sewer Overflows (SSOs). SSOs can create serious issues for the public and environment. RDII is composed of:

- The inflow component of RDII from defects directly connected to the surface. It is water that enters the sewer system directly via depressed manhole lids and frames, connection of downspouts, sump pumps, and foundation drains; and cross-connections with storm sewers.
- The infiltration component of RDII originates from groundwater that infiltrates a sanitary sewer system through damaged pipe sections, leaky joints, or leaky manhole connections.

Of these two components, the inflow response most often dominates the peak flow of the RDII hydrograph.

The flow data and rainfall are broken down into distinct DWF and RDII components for input into the model. The DWF component was analyzed during the DWF calibration to construct a DWF pattern. The RDII component was analyzed to determine RDII events and to calibrate parameters of the RTK synthetic unit hydrograph (described below) to fit the RDII flow simulated by the RTK method to the RDII flow. The calibrated RTK parameters and DWF patterns are then used in the model to carry out detailed dynamic flow routing through the sewer system.

The RTK hydrograph is based on a set of parameters, which consist of the following:

- R (Percent) – the fraction of rainfall volume that enters the sewer system (areas with greater than five percent are typically problem areas)
- T (Hours) – the time from the onset of rainfall to the peak of the unit hydrograph

- K – the ratio of time to recession of the unit hydrograph to the time to peak

Each of the RTK parameters has a fast, medium, and slow response variable that is adjusted within the model to replicate the hydrograph created during a rainfall event. During the calibration process, RTK parameters were adjusted and reviewed graphically until the model results closely matched the metered data. The results were then checked to verify they met the calibration goals. If modeled output did not meet the goals, the RTK parameters were further adjusted within the model until the goals were met.

Table 2-3 provides a numerical comparison between modeled results versus overserved metered flow information at the six (6) 2020 monitoring locations as well as the WRF. Specific flow attributes of both volume and peak flow were compared and analyzed for differences.

Figure 2-10 through ***Figure 2-16*** *provides a visual comparison between modeled results versus observed flow metered information.*

The comparisons show that the WWF model calibration falls within the calibration goals. Considering these results and the general shape of the diurnal flow curves and peak flows, the model was considered calibrated for WWF.

Table 2-3: Summary of Wet Weather Calibration Results

Meter Location	Modeled vs Metered Total Volume within 10% of and +20% of measured values	Modeled vs Metered Peak Flow Rates within 15% of and +25% of measured values
WRF	-3.3	0.1
I5009	0.7	6.6
I5012	-1.0	0.4
G0225	-2.8	-3.7
H0325	5.3	0.3
K0319	-1.7	-1.6
J0306	-5.4	1.6

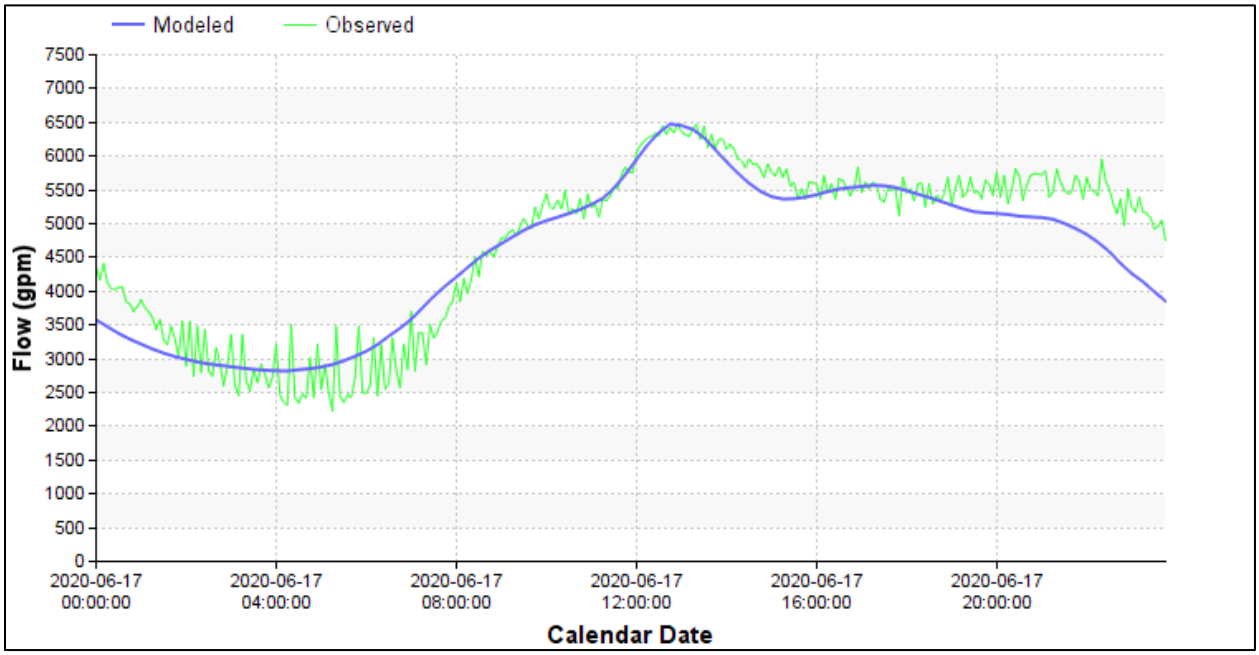


Figure 2-10: WRF Metered vs Modeled Wet Weather Flows

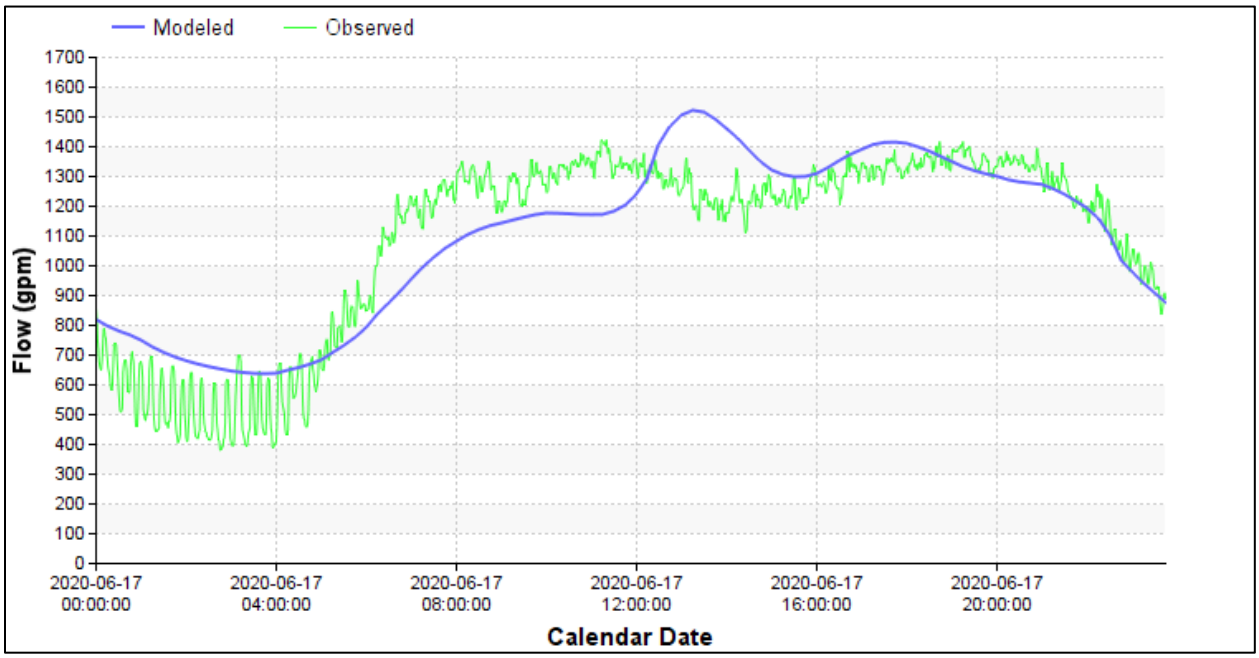


Figure 2-11: I5009 Metered vs Modeled Wet Weather Flows

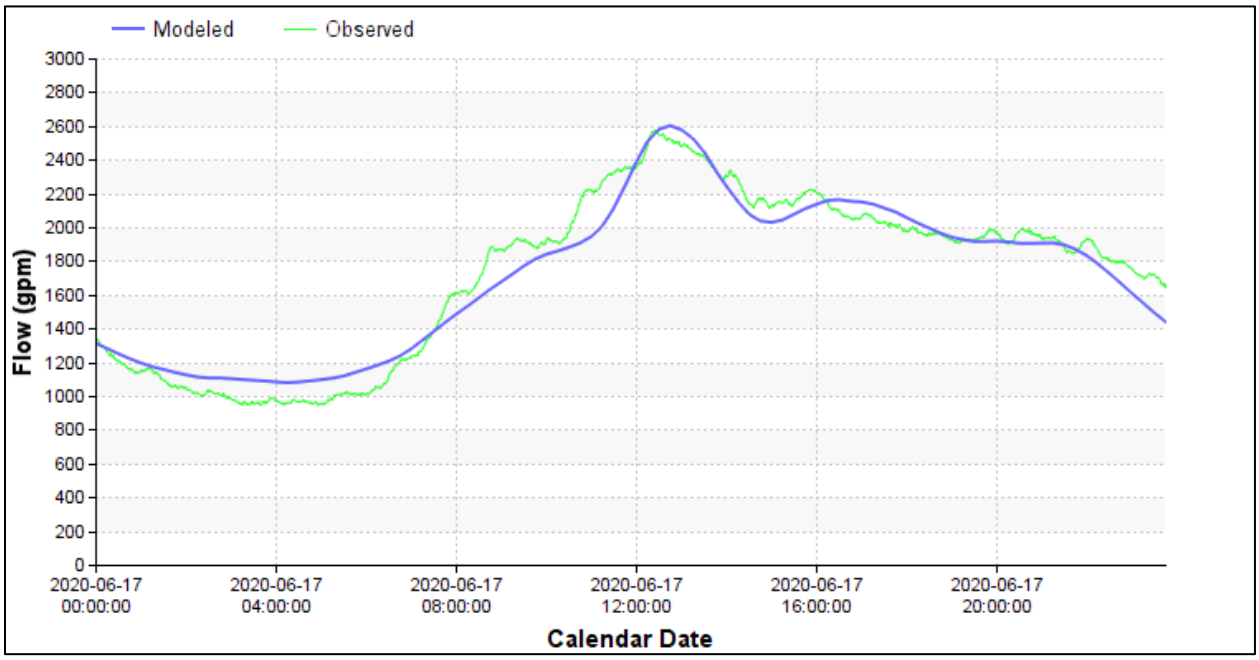


Figure 2-12: I5012 Metered vs Modeled Dry Weather Flows

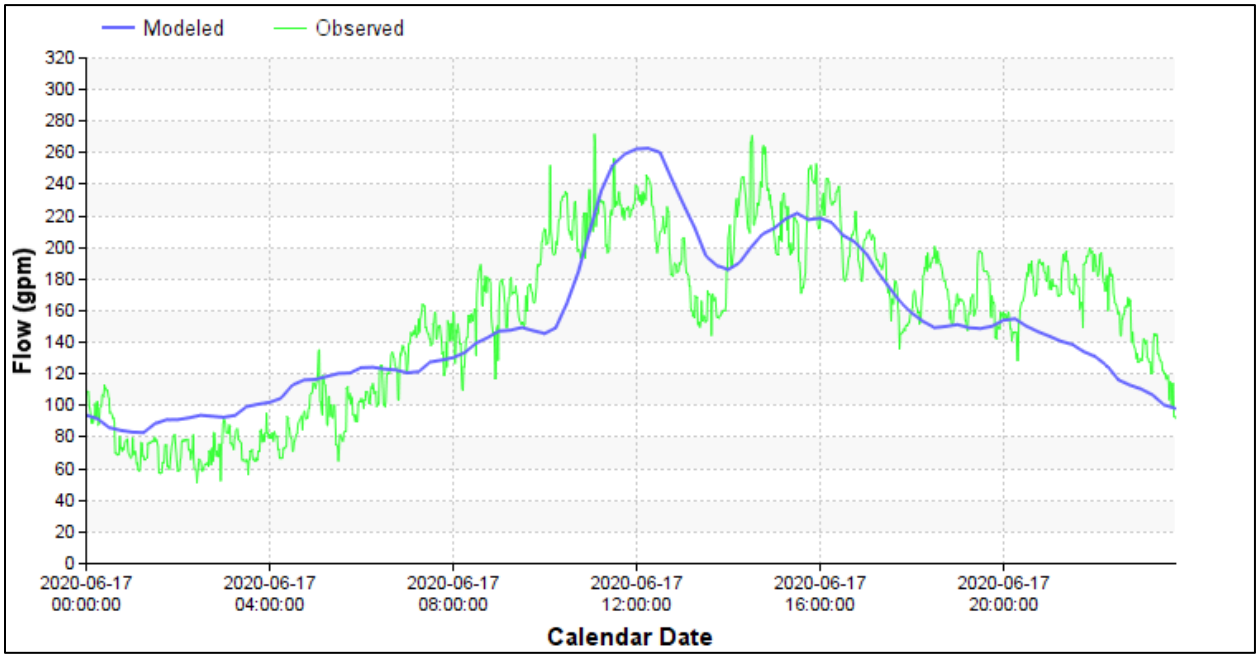


Figure 2-13: G0225 Metered vs Modeled Wet Weather Flows

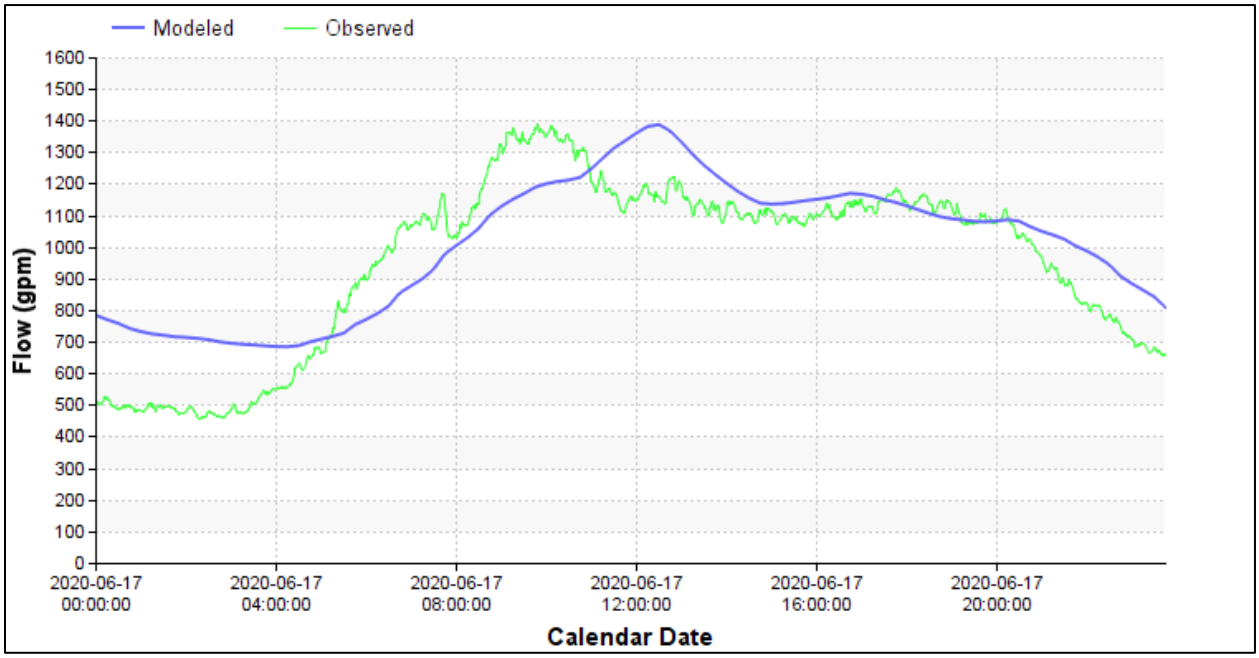


Figure 2-14: H0325 Metered vs Modeled Dry Weather Flows

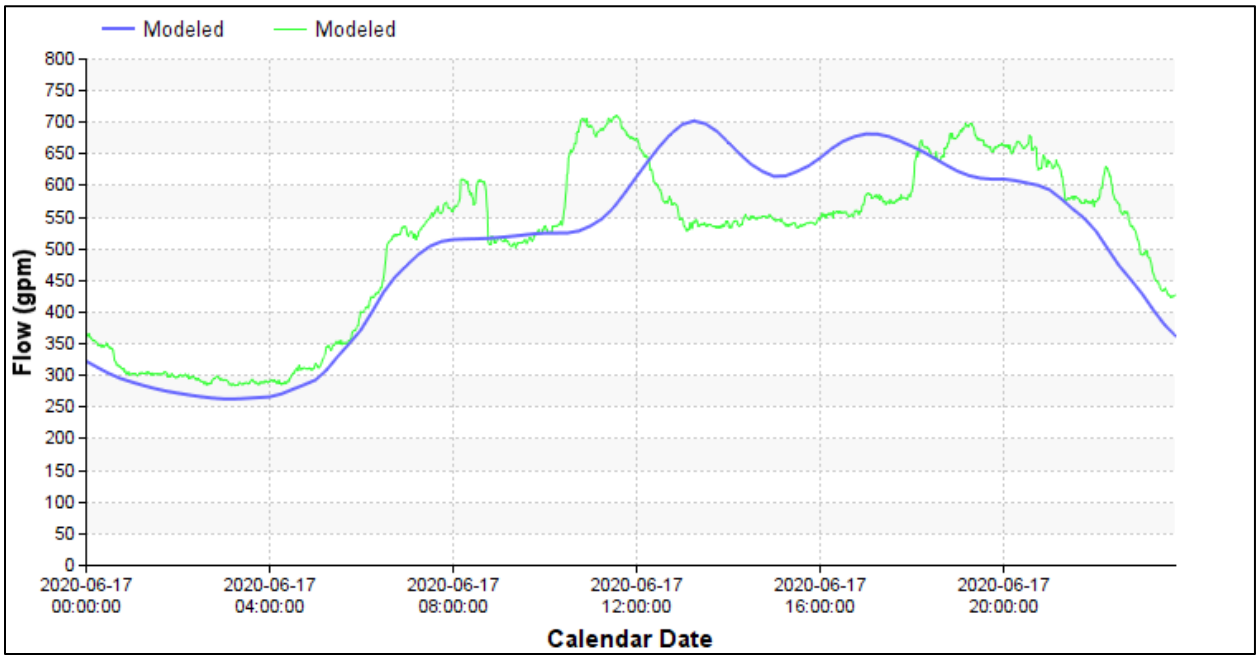


Figure 2-15: K0319 Metered vs Modeled Wet Weather Flows

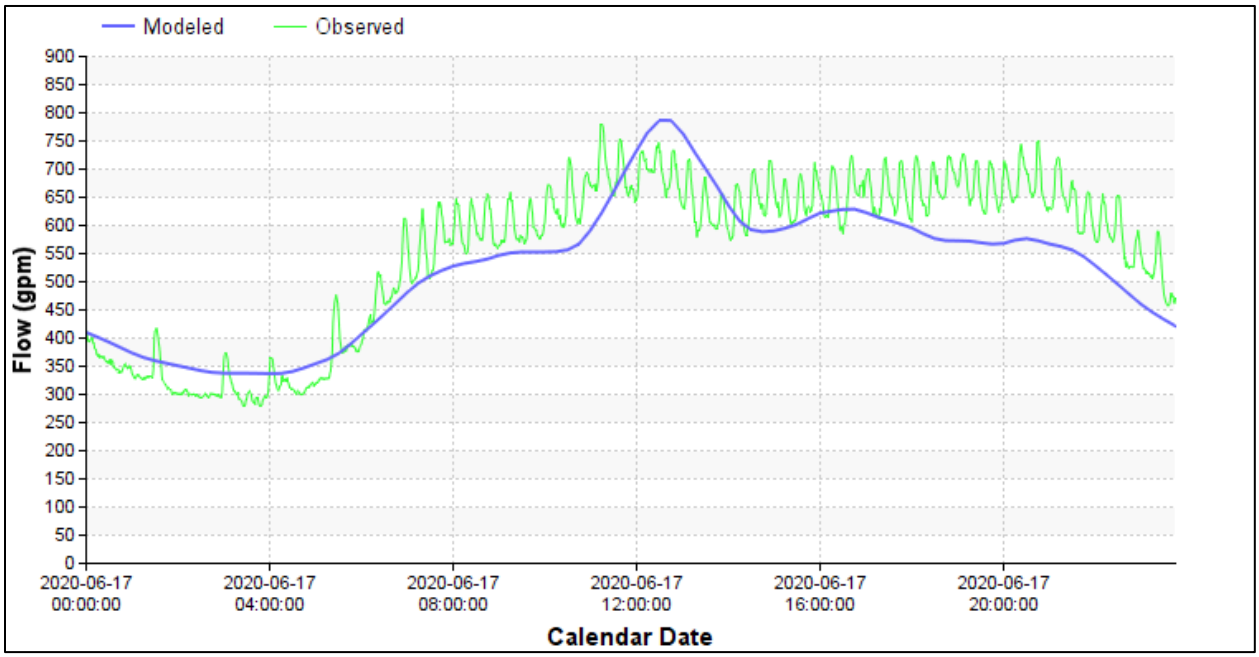


Figure 2-16: J0306 Metered vs Modeled Wet Weather Flows

2.4.3 Summary of RTK Factors from the 2020 Calibration

The RTK factors were adjusted until the difference between modeled and measured total volume and modeled and measured peak flow rates fell within the calibration goals. ***Figure 2-2*** provides an overview of the metered areas for which the RTK factors were calculated and adjusted. The RTK factors were applied within the model as summarized below:

<u>2020 System Calibration:</u>

- The network upstream of J0306 received the 2020 J0306 RTK factors.
- The network upstream of K0319 received the 2020 K0319 RTK factors.
- The network upstream of I5009 and downstream of J0306 and K0319 received the 2020 I5009 RTK factors.
- The network upstream of the WRF and downstream of H0325, J0306, and K0319 received the 2020 WRF RTK factors.
- The network upstream of H0325 and downstream of previously monitored areas received the 2020 H0325 RTK factors.
- The network upstream of I5012 and south of Interstate 90 kept the previously established RTK factors.
- The network upstream of I5012 and north of Interstate 90 received the 2020 I5012 RTK factors.

- The network upstream of G0225 primarily kept the previously established RTK factors.

2.4.4 2018 Midtown/Downtown Metering and Model Calibration

The Midtown/Downtown Sewer Capacity Analysis (Sanderson & Stewart, 2018) was used to further verify modeled peak flow rates. ***Figure 2-2*** also shows a number of different historical monitoring locations, which were utilized in the verification process. In general, a significant amount of these historical locations were located in the Midtown/Downtown region and monitored various flow conditions in 2018.

As with any significant monitoring effort, the Midtown/Downtown capacity analysis observed various rainfall events. In particular, the Midtown/Downtown monitoring effort captured the response from an approximately 1-inch storm event on June 29th, 2018. This precipitation hyetograph (intensity vs time) was incorporated into the model as a unique calibration event to verify peak flow rates observed at these historical locations. Initially, the simulated peak flows for the Midtown/Downtown region were lower than the actual measured flow rates. The initial discrepancy in peak flows was attributed to a change in the base groundwater allocation method, updated domestic flow allocation, and a change in split flows within the model due to updated invert data when compared to the City's previous InfoSWMM model. Subsequently, to account for these differences, the RTK factors within the Midtown/Downtown region were adjusted until the model produced peak flows similar to the observed measured peak flows. ***Table 2-4*** presents a summary of the measured versus adjusted RTK peak flows. It should be noted that this adjustment method is not considered a true model calibration, rather an adjustment and verification of peak flow conditions. This approach was deemed necessary to ensure the Midtown/Downtown peak flows accurately reflect observed conditions given the substantial update in invert information.

This approach was thoroughly discussed with City staffed and deemed necessary and appropriate given the historical information collected by the City in the region.

Table 2-4: Summary of 2018 Rain Event Downtown Calibrated Peak Flows

Sanderson & Stewart Flow Meter	City Manhole ID	June 29, 2018 Measured Peak Flow (gpm)	2020 Calibrated Model with Adjusted RTK Factors Simulated Peak Flow during 2018 Rainfall Event (gpm)
FM#1	G0225	842	960
FM#4B	F0312	394	390
FM#6A	F0307	574	568
FM#7	F0328	681	680
FM#9	F0431	229	237
FM#10	F0405	471	477
FM#11	F0332	2,400	2,653
FM#12	G0309	398	660

Chapter 3 Hydraulic Performance Standards

This chapter summarizes the current City and Montana Department of Environmental Quality (MDEQ) wastewater collection system standards, recommended design criteria, and hydraulic performance evaluation criteria utilized in the analysis.

Design criteria was used to evaluate the performance of the City's existing and future wastewater collection system. Specific system components such as gravity mains, forces mains, and pumping facilities were evaluated for conformance against the criteria. Components of the collection system that did not satisfy design criteria were identified and further investigated. If necessary, conceptual improvements were then evaluated, such as increasing the diameter of a gravity main or increasing the capacity of an existing pumping facility. An iterative based approach was employed until the upgrade satisfied design criteria. Lastly, improvements identified where then carried into the capital improvement plan portion of the analysis for further refinement and costing.

This approach is critical in order for the system to maintain existing reliability and accommodate future growth and development of the system.

The criteria were established based on industry standards, MDEQ regulations and standards, existing City codes and design standards, and professional engineering judgment. Design criteria utilized in the evaluation of the system are outlined below, but generally include parameters surrounding fluid dynamics and sizing (i.e. flow rate, flow depth compared to pipe diameter, velocity, slope, pipe size, roughness, etc.). Design criteria include the following:

- Gravity Main Design Criteria: velocity, maximum depth of flow, diameter, minimum slope, friction factor, and capacity;
- Force Main Design Criteria: velocity, diameter, and friction factor;
- Lift Station Design Criteria: firm capacity and peak hour flow;
- Peak Hour Design Factors;
- DWF Criteria; and
- WWF Event (Design Storm) Criteria.

Table 3-1 below summarize the performance standards and hydraulic design criteria pertinent to the model development and analysis.

3.1 Gravity Main Design Criteria

The collection system model uses Manning's Equation to calculate open channel pipe flow as follows:

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} \sqrt{S}$$

Where:

1.49 = Imperial unit conversion factor, ft^1/3/s

Q = Flow, cfs
n = Manning's roughness coefficient, unitless
A = Area, sq ft
R = Hydraulic radius, ft
S = Slope, ft/ft

Gravity mains must be designed to prevent deposition of solids within the main. MDEQ suggests a minimum velocity of 2.0 ft/s when flowing full based on Manning's formula "n" value of 0.013. Recommended Manning's n values are presented in ***Table 3-1***

The designed level of service for a gravity main is typically described in terms of a ratio between depth of flow to the diameter of the pipe or d/D. Bozeman's design standards has established a design criteria of 0.75 d/D meaning the depth within gravity sewers should be less than 75 % of the full diameter of the pipe.

Gravity mains can be categorized and defined by size and area served as follows:

- Lateral or Collector Sewer: These sewers are generally the smallest diameter sewer within the system at 8-inches or smaller. Laterals and collectors collect wastewater from small areas and typically have numerous service connections. Layout varies widely but generally follows streets of residential and commercial developments. There are over 166 miles of lateral and collector sewers which equates to 72 percent of the gravity mains within the system.
- Trunk Sewer: Trunk sewers are sized larger (generally between 10 and 15-inches) and collect wastewater from numerous collectors. Trunk sewers have little to no service connections, serve large, topographic areas, and convey wastewater between collectors and interceptors. There are over 34 miles of trunk sewers which equates to 15 percent of the gravity mains within the system.
- Interceptor Sewer: Interceptor sewers are the largest gravity conveyance sewers with diameters generally sized at 18-inch and larger. Several named interceptors include segments less than 18-inches in diameter but are included for continuity between larger segments or as critical conveyance corridors. Interceptors collect wastewater from numerous sewersheds and trunk sewers and convey wastewater across long distances typically along major traffic corridors. There are over 30 miles of interceptor sewers which equates to 13 percent of the gravity mains within the system.

For the purposes of this study, gravity main performance was evaluated at 0.75 d/D consistent with the previous Facility Plans and the 2024 COP Design and Construction Standards.

3.2 Force Main Design Criteria

Force mains are designed to carry wastewater from lift stations to the wastewater treatment facility or to other gravity mains or sewer interceptors. Undersized force mains can result in backpressures exceeding lift station design standards. Oversized force mains can result in low velocities and settling of solids.

MDEQ and other publications recommend a minimum velocity of 2 ft/s to keep solids suspended while pumping. When no wastewater is flowing through the force main solids may settle. A minimum velocity of 3 ft/s is recommended to resuspend settled solids.

MDEQ states that the maximum velocity shall not exceed 8 ft/s. Based on this criterion, it is recommended that existing force mains be upsized if the velocity routinely exceeds 8 ft/s. Velocities in excess of 8 ft/s can be acceptable for brief periods, as long as the upstream lift station and piping can handle the backpressure associated with higher friction losses.

Recommended force main velocities are presented in ***Table 3-1***.

3.3 Lift Station Design Criteria

Lift station capacity guidelines are based on firm capacity which is defined as the capacity of the station with the largest pump out of service. The City equips all new lift stations with an on-site backup power generator.

Lift station pumping capacity is sized to meet the meet hourly flow with firm capacity. Peak hourly flow is the largest volume of flow to be received during a one-hour period expressed in terms of flowrate such has gpm or MGD.

2024 COB Design and Construction Standards City standards do not have specific lift station design requirements and relies on MDEQ Circular 2 for lift station parameters. MEDQ recommends wet well filling time not to exceed 30 minutes and to follow pump manufacturer requirements for minimum cycle time. When only two pumps are provided for a lift station, industry practice suggests that they must be the same size, with firm capacity to handle peak hour flow. They should also be sized to maintain the minimum force main velocity and deliver uniform flow to minimum hydraulic surges.

3.4 Peak Hour Design Factors

2024 COB Design and Construction Standards City standards requires a peak hour factor be calculated for each pipe segment of new sewer infrastructure using the following formula (which matches MDEQ requirements):

$$\frac{Q_{max}}{Q_{ave}} = \frac{18 + \sqrt{P}}{4 + \sqrt{P}} \quad (P = Population/thousands)$$

The peaking formula based on population is a steady state calculation. As discussed in ***Section 2.3.4***, the dynamic wastewater collection system model uses the hydrograph method with RTK factors calculate peak flow which is different that the population based peaking formula. This RTK method is an acceptable approach for evaluating the collection system network and master planning efforts as the flow calculations represent wet weather conditions coupled with diurnal peaking factors and are a result of a well-calibrated model.

3.5 Dry Weather Criteria

The existing system will be analyzed using the calibrated InfoSWMM model as discussed in Section 2.3.4. The following DWF parameters will be used for analysis of the existing system:

- DWF equal to the average annual flow: 5.3 MGD.
- Diurnal patterns: as established during the flow monitoring period and calibration efforts.

3.6 Wet Weather Flow Event (Design Storm) Criteria

The modeled design storm is an important part for determining the performance and capacity of the collection system during periods of WWF. The 2019 Climate Vulnerability Assessment and Resiliency Strategy indicates the City will likely experience more frequent and higher-intensity storms compared to historic events. City staff and the design team reviewed the previously modeled storm utilized in the 2015 wastewater facility plan and concluded that the SCS Type I distribution is an appropriate design storm for planning purposes. High groundwater is expected to continue to contribute a substantial amount of baseload infiltration into the system. The 25-year, 24-hour rain event for the City has a rainfall depth of 1.99 inches. The design storm coupled with base groundwater infiltration for the WWF scenario could be considered conservative. However, City staff and the design team recognized that a slightly conservative design event would reasonably provide flexibility within the collection system to account for changes. These changes include climate change, varying localized groundwater

conditions found throughout the City, aging public infrastructure, and development patterns (i.e. higher density growth). Based on the aforementioned considerations the design storm was deemed appropriate for future planning.

It should be noted that timing and final sizing of system improvements could change depending on updated local flow monitoring and survey information.

The existing system was analyzed during a design WWF scenario utilizing the distribution was utilized with 0.1-hour increments. ***Figure 3-1*** shows the 25-year, 24-hour rainfall SCS Type I distribution storm pattern utilized in the WWF scenarios.

The WWF event was applied to the system with a total base loading of 9.5 MGD distributed as follows:

- Domestic Loading: 3.8 MGD
- BI: 5.9 MGD
- Total Base Scenario Loading: 9.5 MGD

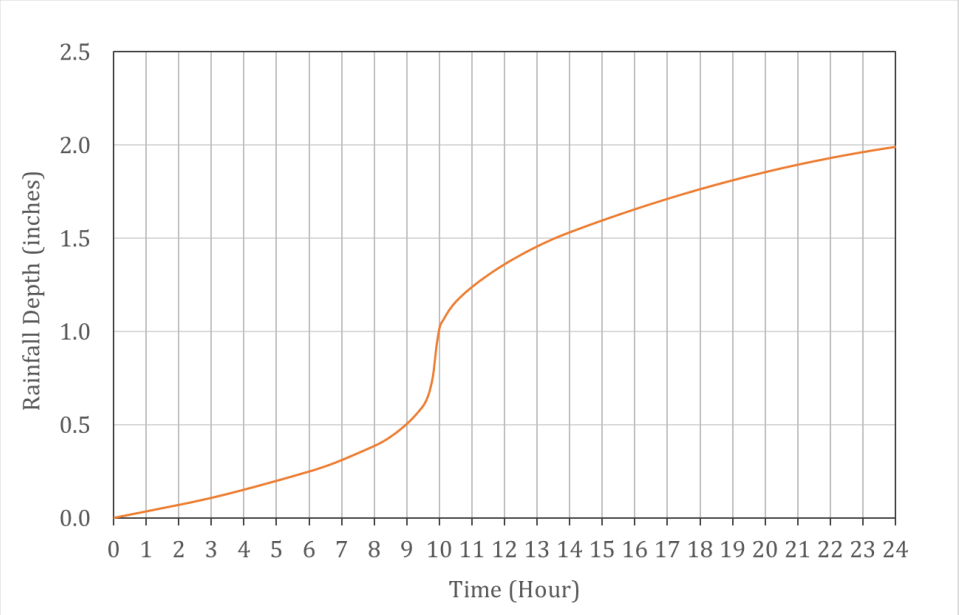


Figure 3-1: Design Storm Rainfall Distribution

Table 3-1: Summary of Hydraulic Parameters and Design Criteria

System Component	Recommended Standard/Criteria	Source
Gravity Mains		
Gravity Main Minimum Velocity (at full flow)	2 ft/s	MDEQ Circular 2
Gravity Main Maximum Velocity (at full flow)	15 ft/s	MDEQ Circular 2
Gravity Main Manning's Roughness Factor	0.011 – plastic 0.013 – all other pipe material	City of Bozeman Design Request – FME output
Target Design Depth (d/D)	0.75	City of Bozeman Design and
Force Mains		
Force Main Minimum Velocity[1]	3 ft/s	City of Bozeman Design Request
Force Main Maximum Velocity[1]	8 ft/s	MDEQ Circular 2
Hazen-Williams Coefficient C-Factor	120	MDEQ Circular 2 2015 Wastewater Facility Plan
Exit Loss Coefficient	0.2	-
Entrance Loss Coefficient	0.1	-
Lift Stations		
Minimum Number of Pumps	2	MDEQ Circular 2
Firm Capacity	Sized so one pump handles peak hourly flow.	MDEQ Circular 2
Considerations for Emergency Operations	Emergency backup power and bypass connection.	-
Wet Well Size	Fill time not to exceed 30 minutes based on average flow.	MDEQ Circular 2
Existing System Dry Weather		
Average Annual Flow (includes base flow and normal ground water)	5.3 MGD (existing)	-
Diurnal Peaking Factors	Based on hourly pattern. (varies by area, developed during calibration)	-
Existing System Wet Weather		
WWF (includes base flow and high ground water)	9.5 MGD (existing)	-
Peaking Factor	RTK factors (as determined during calibration)	-
WWF Analysis Design Storm	25-Year, 24-Hour Event Depth = 1.99" SCS Type I Distribution	City of Bozeman

[1] 2015 Wastewater Facility Plan update assumes force main design velocity= 5 fps

Chapter 4 Existing System Evaluation

This chapter presents the evaluation of the City's existing wastewater collection system and its ability to accommodate peak flows and meet performance criteria under various existing flow conditions. Evaluations, findings, and recommendations for addressing any deficiencies identified in the City's existing wastewater collection system are summarized in this chapter. The existing wastewater collection system was evaluated under both DWF and WWF loading conditions as described in ***Section 2.3*** using the performance standards summarized in ***Chapter 3***.

Table 4-1 provides a general overview of the existing lift stations within the City's collection system. The lift station summary includes the name, ownership, force main size, firm capacity, standby power, receiving drainage area, and installation year. An overview of the locations of the interceptors is presented in ***Figure 4-1***.

Firm pumping capacity was evaluated to determine if the lift station has firm capacity issues during the DWF and WWF assessment.

Table 4-2 provides an overview of the interceptor capacities based on pipe size and slope. In general, the slopes for the interceptors are based off of field collected survey information. The interceptor capacities were analyzed to identify existing capacity issues during the DWF and WWF assessment and were used to assess the future system. An overview of the locations of the interceptors is presented in ***Figure 4-1***.

Invert elevations were assigned to model nodes as described in ***Section 2.2*** and were used to calculate gravity main slope. A review of the pipe slopes showed several existing gravity mains having a slope that does not satisfy the current recommended MDEQ minimum slope standards. In these cases, the sewers show flat to slightly adverse slope. However, no hydraulic issues were found during review and model analysis.

Table 4-1: Summary of Existing Lift Stations

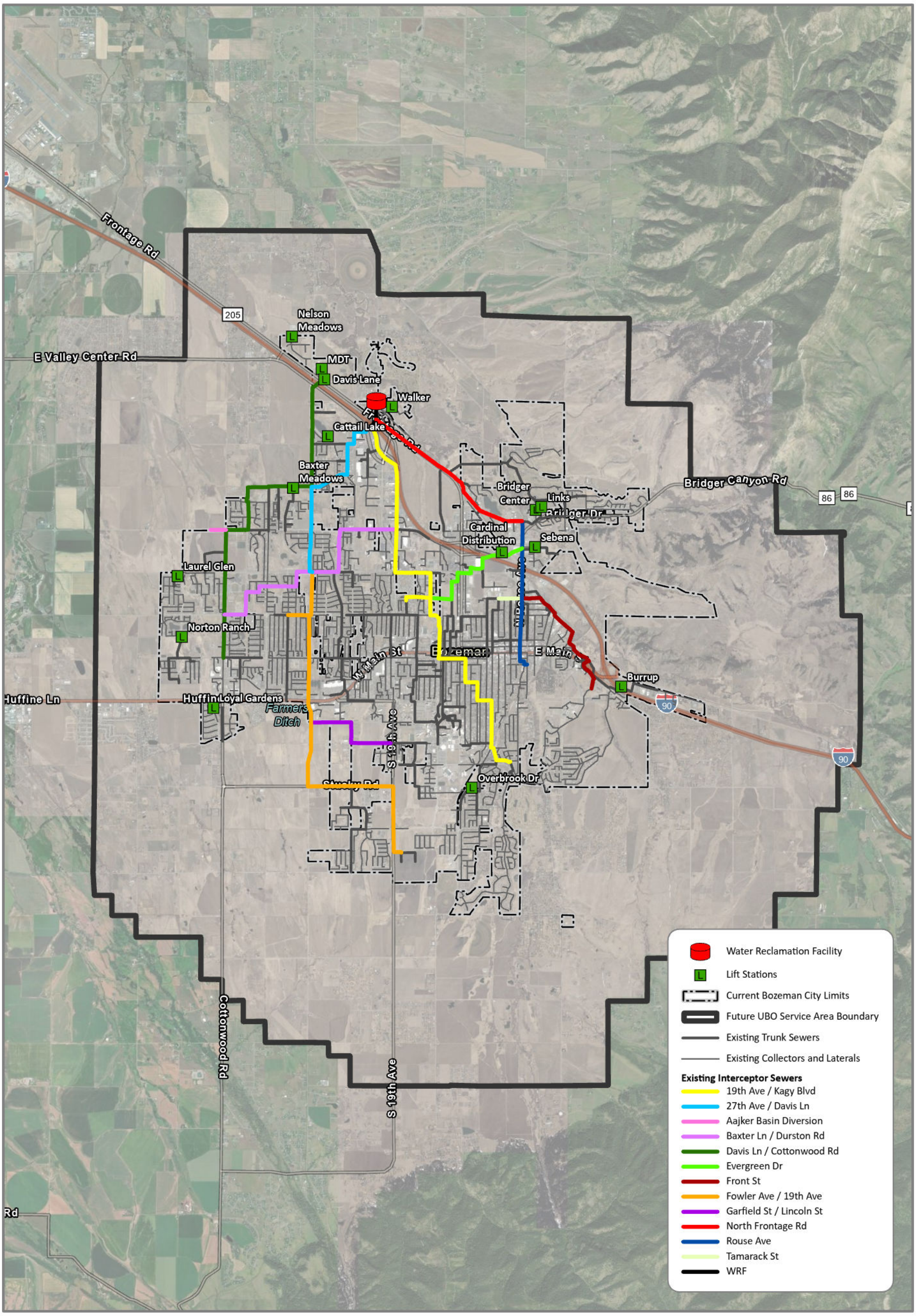
Lift Station	Ownership	Force Main Size (inches)	Approximate Firm Pump Capacity (gpm)	Standby Power	Interceptor Drainage	Year Installed
Baxter Meadows	City	12	690	yes	Cattail Interceptor	2002
Bridger Center	City	4	100	no	Rouse Interceptor	2004
Burrup	City	6	450	yes	Rouse Interceptor	1984
Cattail Lake	City	6	225	yes	Cattail Interceptor	2007
Davis Lane	City	18/18	5,000+	yes	Cottonwood-Davis Interceptor	2020
Laurel Glen	City	8	450	yes	Valley West Interceptor	2003
Loyal Gardens	City	6	364	yes	Davis-Fowler Interceptor	2007
Norton Ranch	City	4/6	121	yes	Valley West Interceptor	2010
Cardinal Distribution[1]	Private	4	unk	unk	N. Frontage Interceptor	unk
Links	Private	4	160	yes	N. Frontage Interceptor	2008
MDT	Private	2	unk	unk	WRF Interceptor	unk
Nelson Meadows	Private	6	190	yes	Cottonwood-Davis Interceptor	2019
Overbrook	Private	4	unk	unk		unk
Sebena[1]	Private	8	none	n/a	Rouse Interceptor	unk
Walker	Private	8	unk	no	WRF Interceptor	1992

[1] The Cardinal lift station was not modeled due to lack of information and the Sebena lift station is not in service.
+ Davis Lane firm capacity is based on the Davis Lane Lift Station & Norton East Ranch Outfall Sewer Project, Issued for Bid Plan set – 2 wetwell duty pumps and 1 wetwell jockey pump (HDR, March 2020).

Table 4-2: Summary of Existing Interceptors

Interceptor	Size (inch)	Full Flow Capacity[1] (MGD)	Year Installed	Drainage
19th Ave / Kagy Blvd	12	0.9 – 1.4	1972	Central
	14	2.3 – 6.0	1963, 1969	
	18	1.5 – 7.6	1969, 1998	
	20	4.2 – 6.0	1969	
	24	5.1 – 26.9	1969	
27th Ave / Davis Ln	21	6.7 – 22.7	2006	Western
	24	10.5 – 29.3	2002, 2006	
	27	10.9 – 56.7	2002	
Aajker Basin Diversion	21	3.8 – 9.7	2024	Western
Baxter Ln / Durston Rd	18	2.6 – 6.6	2007	Western
	20	2.8 – 10.6	1980, 2000, 2006	
	21	3.4 – 9.7	2005, 2007	
	24	2.6 – 10.3	1980	
Davis Ln / Cottonwood Rd	18	4.8 – 9.8	2019	Western
	21	5.4 – 25.6	2015	
	27	8.9 – 36.3	2021	
	30	9.3 – 24.8	2021	
Evergreen Dr	15	2.9 – 6.8	1952	Eastern, Northern
	18	1.5 – 14.9	1947, 1952, 1963 1994, 2004	
	21	2.4 – 9.0	1951	
Fowler Ave / 19th Ave	18	2.5 – 13.4	1980, 2022	Western
	21	5.7 – 27.1	2005, 2007, 2016	
	24	14.1 – 30.2	2007	
	27	10.1 – 11.3	2007	
Front St	18	5.5 – 20.1	2020	Eastern
	21	6.0 – 9.6	2020	
	24	1.7 – 31.3	2020	
Garfield St / Lincoln St	18	2.8 – 8.6	2016	Southern
North Frontage Rd	Parallel 20 and Parallel 36	1.0 – 11.7 (20-inch) 20.0 (36-inch)	1969, 1974, 1980 2020	Eastern, Northern
	Single 20	5.3 – 12.6	1969	
	Single 30	6.3 – 38.4	1992	
	Parallel 20	2.6 – 13.8	1969, 1980	
	Single 20	8.0 – 9.0	1969	
Rouse Ave	21	3.8 – 5.2	2017	Eastern
	24	14.3 – 29.2	2004	
	30	15.1 – 42.2	2004	
Tamarack St	18	4.3 – 7.9	1917	Eastern
WRF	30	17.6 – 20.5	1969	All

[1]Range based on full flow, Manning's n, and surveyed inverts (slope). Capacity varies throughout interceptor due to varying slopes of each segment of gravity main.
[2]North Frontage Road interceptors listed in order of upstream to downstream (east to west).



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Coordinate System: NAD 1983 UTM Zone 12N | Edited by: DVoeller | C:\Data\Projects\WAFS\B\Bozeman\05097-2018-006\GIS\Bozeman Wastewater Collection Facility Plan - Mapping and Analysis.aprx | TM7 4-1 Existing Interceptors

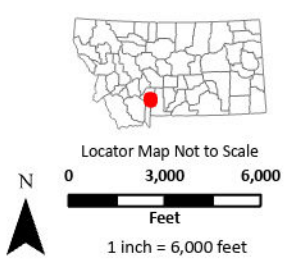


Figure 4-1

EXISTING COLLECTION SYSTEM INTERCEPTORS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

4.1 Existing Dry Weather Modeling Analysis

Gravity main velocity, depth, and flow were evaluated during the DWF analysis. The minimum gravity main velocity (2 ft/s) is not being met for most of the sewer system during DWF conditions. The standard minimum velocity is intended to ensure adequate velocities are maintained during full flow conditions so settled solids will be scoured downstream. Full flow does not occur during DWF conditions and therefore minimum velocities are not met. No gravity mains showed velocities greater than the maximum allowed.

Depths of flow in the gravity mains and at the manholes were also evaluated. DWF modeling results showed no locations that surcharged indicating no issues within the collection system under DWF conditions.

City owned lift stations and force mains were evaluated based on the velocity criteria presented in ***Chapter 3***. The DWF analysis results showed the lift stations have adequate capacity to handle peak flows. All but three force mains satisfy the minimum velocities required by the City (operating at 3 ft/s or above). The Baxter Meadows, Bridger Center, and Cattail Lake force mains meet the minimum velocity recommended by MDEQ (2 ft/s or greater) at the firm pumping capacity. Although these three force mains are not meeting minimum velocity required by the City, it is not considered a major concern. Given these flow parameters, these particular force mains could be more susceptible to solids deposition. Therefore, it is recommended that the City's operations and maintenance staff conduct more frequent monitoring and cleaning of these assets.

Lift station pump curves were provided for the analysis and are stored within the model; however, to improve model stability and reduce model runtimes, the model is set up to run peak flow directly through the lift station using an ideal pump (inflow = outflow). Firm pumping capacities provided by the City were used for analysis of force main capacity.

4.2 Existing Wet Weather Modeling Analysis

The InfoSWMM model was utilized to simulate a WWF scenario which utilizes a design storm. The WWF event is defined as a 25-yr rainfall event totaling 1.99 inches with a SCS Type I rainfall distribution pattern was selected to evaluate the systems response during periods of WWF, which can untimely stress system capacities.

4.2.0 Wet Weather Lift Station Analysis

Lift stations and force mains were evaluated under the design rainfall event. For the purposes of this analysis and based on the best information available, all lift stations were assumed to operate at the firm capacity provided by the City. As a result, velocities in the force mains remained the same during both WWF and DWF evaluations. As expected, inflows into the lift stations increased significantly under the WWF analysis. A summary of the lift station capacities and the modeled peak flows under existing conditions during the WWF rainfall event are presented in ***Table 4-3***.

Model results indicate that firm capacity of the lift station exceeds the peak hourly flows for all lift stations excluding the Laurel Glen lift station. The peak flow entering the Laurel Glen lift station is shown to exceed the lift station firm capacity by approximately 17 percent. For instance, the DWF flow peaked at 140 gpm while the WWF peaked at 507 gm. At this point, it is recommended that the City continues to further monitor the Laurel Glen lift station during periods of seasonal high groundwater and large rain events to determine how localized RDII affects the upstream sewershed and before making any lift station improvements.

Table 4-3: Capacity Summary of Existing Lift Stations

City Lift Station	Approximate Firm Capacity (gpm)	Modeled Peak Inflow (gpm)
Baxter Meadows	690	270
Bridger Center	100	30
Burrup	450	102
Cattail Lake	225	16
Davis Lane	5,000+	365
Laurel Glen	450	507
Loyal Gardens	364	177
Norton Ranch	121	70
Cardinal Distribution[1]	unk	-
Links	160	8
MDT	unk	16
Nelson Meadows	190	75
Overbrook	unk	32
Sebena[1]	none	-
Walker	unk	34

[1] The Cardinal lift station is not modeled and the Sebena lift station is not in service.
[+] Davis Lane firm capacity based on Davis Lane Lift Station & Norton East Ranch Outfall Sewer Project, Issued for Bid Plan set – 2 wetwell duty pumps and 1 wetwell jockey pump (HDR, March 2020)

4.2.1 WWF Interceptor and Gravity Main Analysis

Both Interceptors and gravity mains were evaluated under the design rainfall event which included velocities, depths of flow in the gravity mains, and capacities of the interceptors. No interceptors or gravity mains were identified with velocities that exceeded the maximum recommended rates allowed.

Wet Weather Gravity Main Summary

Figure 4-2 presents the d/D as a ratio of the maximum modeled flow depth during WWF in relation to the diameter of the gravity main conduit being evaluated. This analysis was completed for the entire gravity main network of the City. The WWF modeling analysis shows that a majority of the City's collection system has sufficient capacity to adequately handle additional inflow resulting from increased seasonal groundwater coupled with a design storm. However, it should be noted that there are several segments that reach model capacity. These segments include specific individual manholes that show minimal surcharging during the design storm. Surcharging of a sewer is the situation in which the sewer entrance and exit are submerged and the pipe is flowing full under pressure. A surcharge is different than a node overflowing. If a node is overflowing the hydraulic grade of the incoming flow is greater than the rim elevation of the manhole (or ground elevation of lid), which indicates flow is no longer contained in the conveyance system and is overflowing out of the system through the nodes.

Below is a list of manholes, which correlate to nodes within the model, that showed a surcharge during the design storm. No overflows were shown in the modeling results during WWF. ***Figure 4-2*** shows the City's existing collection system in relation to modeled d/D results for WWF. The results are broken down into four flow classifications (<.5 Blue), (0.5-0.75 Yellow), (0.75-0.99 Orange) and (1.0 full flow Red). Segments >.75 d/D where further evaluated to determine if mitigation is necessary or flagged for further monitoring and evaluation as the City continues to grow.

The following is a list of manholes in which the hydraulic model indicated surcharge at the node. The representative street intersection was listed for simplicity versus the specific model node ID.

- **Intersection of Westridge Dr and Wagon Wheel Road:** The 10-inch sewer experiences a grade change at this intersection which results in a surcharge of less than 0.5 ft.

- **Intersection of S Black Avenue and Hoffman Dr:** The 10-inch sewer is at capacity at this intersection which results in a surcharge of less than 0.25 ft.

- **S Willson Avenue between W Mason Street and W Hayes St:** The 14-inch sewer is modeled to flow at capacity in this area with a surcharge of less than 1 ft.

- **Intersection of E College Street and S Grand Ave:** The 14-inch sewer along College Street is at capacity and surcharges less than 0.25 ft.

- **S Black Ave:** 6-inch sewer between E Olive Street and E Babcock Street is at capacity and modeled with a surcharge between 1 and 1.6 ft.

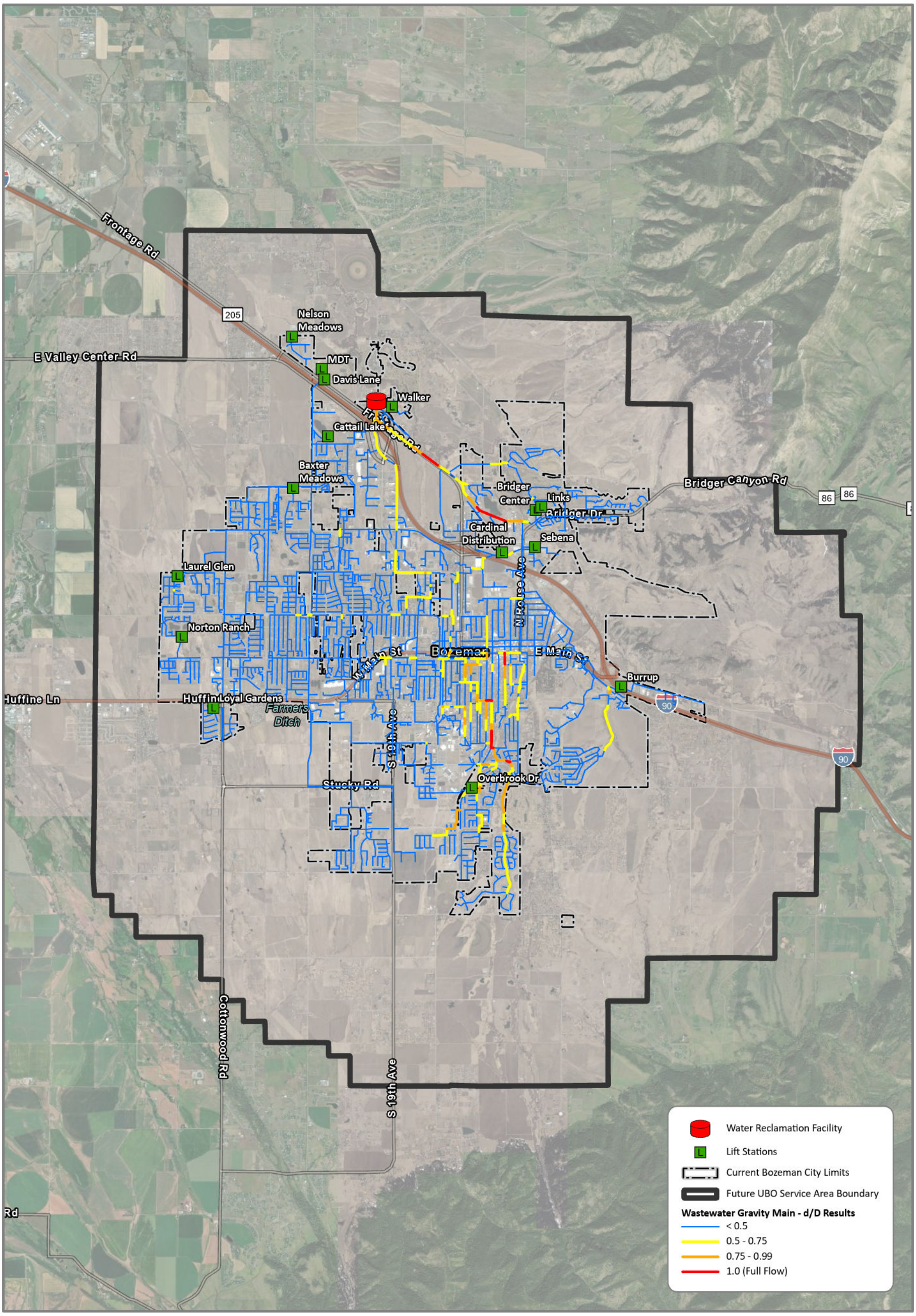
- **Intersection of S 6th Avenue and W Curtiss St:** The 18-inch sewer shows a dip in this location causing the pipe to flow at capacity and a surcharge of less than 0.75 ft.

- **Intersection of S 5th Avenue and W Olive St:** The 6-inch sewer is modeled to flow at capacity in this area with a surcharge of less than 1 ft.

- **Manley Road: Parallel 20-inch Section:** The north section of 20-inch parallel interceptor between Manholes F0114 and G0132 is modeled to flow at capacity with a surcharge of less than 1 ft.

- **Manley Road: Single 20-inch Section:** The single 20-inch interceptor between Manholes G0132 and G0133 is modeled to flow at capacity with a surcharge of less than 1 ft.

- **Frontage Road: Parallel 20 inch Section:** The north section of the 20-inch parallel interceptor between model manhole IDs H0012 and H0005 flows at capacity with a surcharge of 0.5 ft.



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Coordinate System: NAD 1983 UTM Zone 12N | Edited by: DVoeller | C:\Data\Projects\WAFS\B\Bozeman\05097-2018-006\GIS\Bozeman Wastewater Collection Facility Plan - Mapping and Analysis.aprx | TM7 4-2 d_D Results

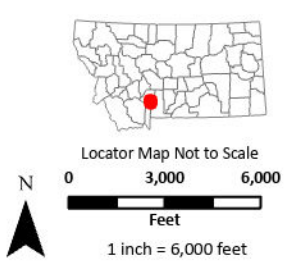


Figure 4-2

EXISTING SYSTEM WET WEATHER d/D CAPACITY ANALYSIS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

Wet Weather Existing System Interceptor Summary

Understanding the capacity of the collection system interceptors is discussed in the following paragraphs. ***Figure 4-1*** provides an overview of the locations of the existing interceptors.

Table 4-4 presents a summary of the existing system interceptor capacity, modeled peak flow, and remaining capacity. ***Figure 4-3*** highlights the existing d/D analysis for the interceptor sewers segments. The existing system inceptor capacity analysis is summarized below.

- **19th Avenue / Kagy Boulevard:** The 19th Avenue / Kagy Boulevard interceptor has varying levels of remaining capacity in the WWF scenario with the depth to diameter ratio ranging from 0.25 to surcharging. The larger diameter downstream sections (20 to 24- inch) can support additional loading from growth or infill. However, the smaller diameter upstream sections (12 to 18-inch between Kagy Boulevard and Babcock Street) need to be upsized to support additional loading from growth or infill. The average depth to diameter ratio during peak flows for the 12 to 18-inch sewer is 0.72 while the ratio is much lower at 0.51 for the 20 to 24-inch sewers.

- **27th Avenue / Davis Lane:** The 27th Avenue / Davis Lane interceptor has sufficient capacity in the WWF scenario with the depth to diameter ratio ranging from 0.25 to 0.5. The average depth to diameter ratio during peak flows is 0.33 indicating the 27th Avenue / Davis Lane interceptor can support additional loading from growth or infill.

- **Aajker Basin Diversion:** The Aajker Basin Diversion is a new interceptor under construction along Baxter Lane with little loading. The interceptor is under construction and will server western growth areas when complete.

- **Baxter Lane / Durston Road:** The Baxter interceptor has sufficient capacity in the WWF scenario with the depth to diameter ratio ranging from 0.25 to 0.5. The average depth to diameter ratio during peak flows is 0.32 indicating the Baxter Lane / Durston Road interceptor can support additional loading from growth or infill.

- **Davis Lane / Cottonwood Road:** The newly constructed Davis Lane / Cottonwood Road interceptor in the WWF shows a depth to diameter ratio less than 0.25. The average depth to diameter ration during peak flows is 0.1

indicating the Davis Lane / Cottonwood Road interceptor can support additional loading from growth or infill.

- **Evergreen Drive:** The Evergreen Drive interceptor has sufficient capacity in the WWF scenario with depth to diameter ratio ranging from 0.25 to 0.75. The average depth to diameter ratio during peak flows is 0.38 indicating the Evergreen Drive interceptor can support additional loading from growth or infill.

- **Fowler Avenue / 19th Avenue:** The Fowler Avenue / 19th Avenue interceptor has sufficient in the WWF scenario with depth to diameter ratio ranging from 0.1 to 0.6. The 18-inch portion of the interceptor has sections with less capacity compared to the larger diameter sections. The average depth to diameter ratio during peak flows is 0.21 indicating the Fowler Avenue / 19th Avenue interceptor can support additional loading from growth or infill.

- **Front Street:** The Front Street interceptor has sufficient capacity in the WWF scenario with depth to diameter ratios less than 0.25. It should be noted that the Front Street interceptor was recently upsized by the City and incorporated into the existing conditions model. The project included approximately 7,600 linear feet of new gravity main, with pipe segments that ranged from 18- to 24-inchs. The purpose of the project was to accommodate new development along East Main Street, Haggerty Lane, and potential future expansions of Bozeman Deaconess Hospital. The average depth to diameter ratio during peak flows is 0.21 indicating the interceptor can support additional loading from growth or infill.

- **Garfield Street / Lincoln Street:** The Garfield Street / Lincoln Street interceptor has sufficient capacity in the WWF scenario with depth to diameter ratio ranging from 0.2 to 0.3. The average depth to diameter ratio during peak flows is 0.27 indicating the Garfield Street / Lincoln Street interceptor can support additional loading from growth or infill.

- **North Frontage Road:** The North Frontage Road interceptor has various segments that reach full flow capacity in the WWF scenario with the depth to diameter ratio ranging from 0.25 to 1.00, meaning some sections have underutilized capacity while others have no remaining capacity in the WWF model scenario. Based on the modeling results additional large-scale development or significant infill growth will further increase surcharging through these sections. These results are generally in line with the previous facility plan, in

which the North Frontage Road was flagged for future mitigation. As of recent, the City upgraded a section of the interceptor with their Manely Road upgrade. However, the remaining segments of the Frontage Road have been incorporated into the City's short-term CIP program and discussed in further detail in the capital improvement TM. Two sections within the hydraulic model that indicate surcharging during the WWF scenario include:

  - Area 1: Located along Manley Road, both upstream and downstream of the transition from a parallel 20-inch and 36-inch section into the single 20-inch sewer at manhole ID G0132. The 20-inch sewer upstream of the manhole and the 20-inch downstream of the manhole is surcharging during the design storm.

  - Area 2: Located northwest of transition from a single 30-inch sewer to parallel 20-inch sewer at Manhole H0016. The model indicates the north 20-inch sewer is surcharging.

- **Rouse Avenue:** The Rouse Avenue interceptor has sufficient capacity during WWF with the depth to diameter ratio ranging from 0.1 to 0.50, meaning the interceptor flows less than half full. The average depth to diameter ratio during peak flows is 0.24 indicating the Rouse Avenue interceptor can support additional loading from growth or infill.

- **Tamarack Street:** The Tamarack Street interceptor has sufficient capacity during WWF with the depth to diameter ratio ranging from 0.4 to 0.50, meaning the interceptor flows slightly less than half full. The average depth to diameter ratio during peak flows is 0.47 indicating the Tamarack Street interceptor can support additional loading from growth or infill.

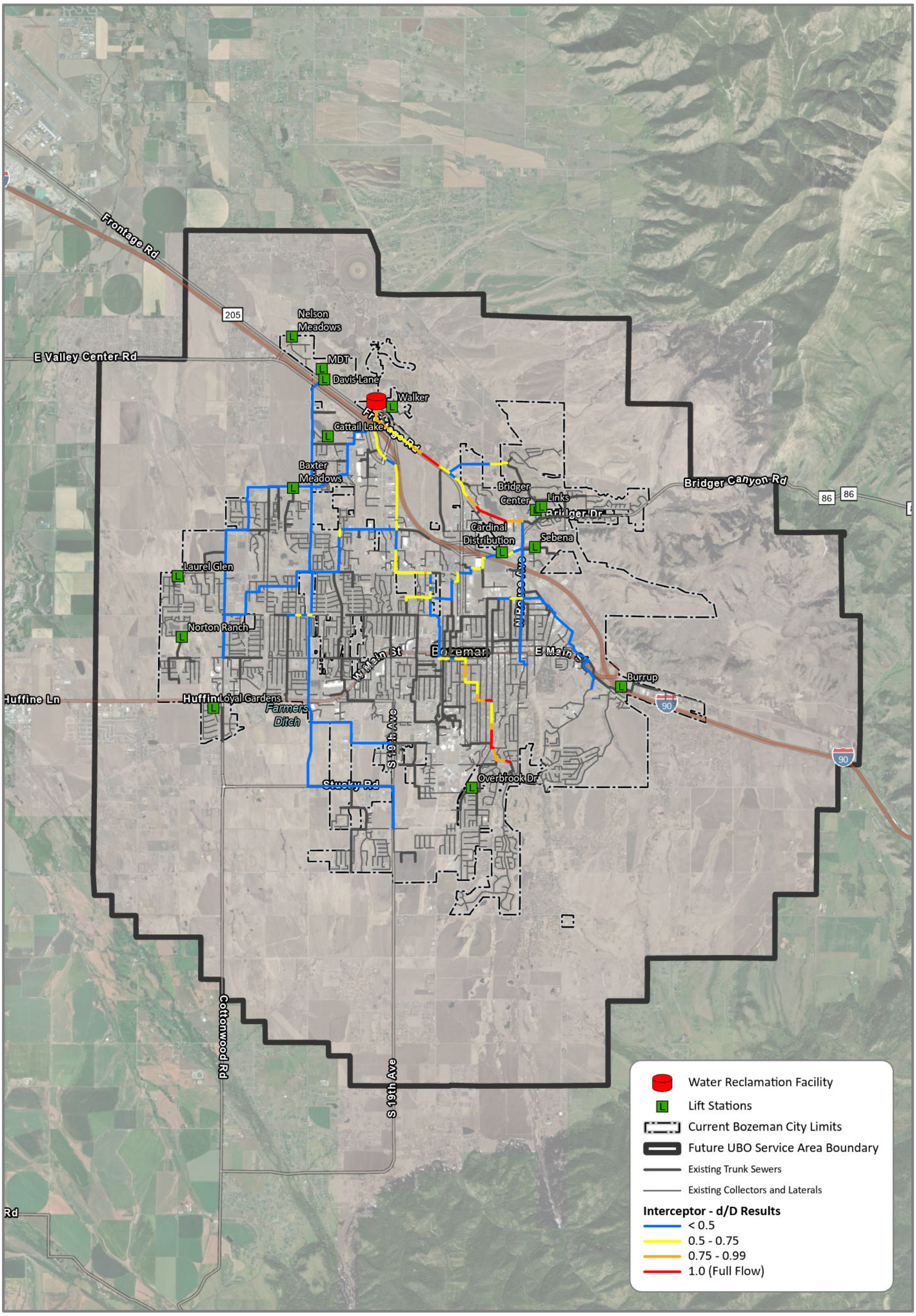
  WRF: The WRF interceptor shows segments with the WWF scenario that that nearly reach full flow capacity. Model results for this particular segment show the segment near capacity with the depth to diameter ratio exceeding 0.75. However, no significant surcharging was noted during peak flows in the analysis. The WRF interceptor does not have any service connections and can support additional loading from growth or infill before surcharging. These results are generally in line with the previous facility plan, in which the WRF interceptor was flagged for future mitigation. As such, the WRF interceptor has been incorporated into the City's short-term CIP program and discussed in further detail in the capital improvement TM.

Table 4-4: Capacity Summary of Existing Interceptors

Interceptor	Size (inch)	Full Flow Capacity[1] (MGD)	Design Capacity[2] (MGD)	Modeled Peak Flow (MGD)	Percent Capacity Remaining
19th Ave / Kagy Blvd	12	0.9 – 1.4	0.7 – 1.1	1.2	0 to 20% (At Capacity)
	14	2.3 – 6.0	1.7 – 4.5	2.6 – 3.2	0 to 50% (At Capacity)
	18	1.5 – 7.6	1.1 – 5.7	1.5 – 3.5	0 to 60% (At Capacity)
	20	4.2 – 6.0	3.2 – 4.5	2.8 – 4.5	30%
	24	5.1 – 26.9	3.8 – 20.2	4.5 – 8.8	25 to 75%
27th Ave / Davis Ln	21	6.7 – 22.7	5.0 – 17.0	2.9	50 to 75%
	24	10.5 – 29.3	7.9 – 22.0	2.9 – 3.2	50 to 75%
	27	10.9 – 56.7	8.2 – 42.5	3.3	50 to 75%
Aajker Basin Diversion	21	3.8 – 9.7	2.9 – 7.3	2.4 at buildout	< 50%
Baxter Ln / Durston Rd	18	2.6 – 6.6	2.0 – 5.0	0.5 – 0.8	50 to 75%
	20	2.8 – 10.6	2.1 – 8.0	0.5 – 1.8	50 to 75%
	21	3.4 – 9.7	2.6 – 7.3	0.8 – 1.2	50 to 75%
	24	2.6 – 10.3	2.0 – 7.7	1.8 – 1.9	50 to 75%
Davis Ln / Cottonwood Rd	18	4.8 – 9.8	3.6 – 7.4	0.1	>75%
	21	5.4 – 25.6	4.1 – 19.2	0.3	>75%
	27	8.9 – 36.3	6.7 – 27.2	0.3	>75%
	30	9.3 – 24.8	7.0 – 18.6	0.3	>75%
Evergreen Dr	15	2.9 – 6.8	2.2 – 5.1	1.4 – 1.7	25 to 75%
	18	1.5 – 14.9	1.1 – 11.2	2	25 to 75%
	21	2.4 – 9.0	1.8 – 6.8	2	50 to 75%
Fowler Ave / 19th Ave	18	2.5 – 13.4	1.9 – 10.1	2.2	25 to 75%
	21	5.7 – 27.1	4.3 – 20.3	1.6	>75%
	24	14.1 – 30.2	10.6 – 22.7	1.6	50 to 75%
	27	10.1 – 11.3	7.6 – 8.5	0.8	>75%
Front St	18	5.5 – 20.1	4.1 – 15.1	0.3 – 0.9	>75%
	21	6.0 – 9.6	4.5 – 7.2	0.9	>75%
	24	1.7 – 31.3	1.3 – 23.5	0.9 – 1.0	>75%
Garfield St / Lincoln St	18	2.8 – 8.6	2.1 – 6.5	0.5 – 0.6	>75%
North Frontage Rd	Parallel 20 and Parallel 36	1.0 – 11.7 (20-inch) 20.0 (36-inch)	0.8 – 8.8 15.0	2.7 – 4.8 2.9 – 3.2	0 to 50% (Segments at Capacity) >75%
	Single 20	5.3 – 12.6	4.0 – 9.5	6.5 – 6.6	0 to 50% (Segments at Capacity)
	Single 30	6.3 – 38.4	4.7 – 28.8	5.6 – 7.5	25 to 75%
	Parallel 20	2.6 – 13.8	2.0 – 10.4	3.7 – 7.6	0 to 50% (Segments at Capacity)
	Single 20	8.0 – 9.0	6.0 – 6.8	7.6	<25%
Rouse Ave	21	3.8 – 5.2	2.9 – 3.9	0.1 – 0.6	>75%
	24	14.3 – 29.2	10.7 – 21.9	0.6 – 1.4	>75%
	30	15.1 – 42.2	11.3 – 31.7	4.7 – 7.8	50 to 75%
Tamarack St	18	4.3 – 7.9	3.2 – 5.9	1.9 – 2.4	>50%
WRF	30	17.6 – 20.5	13.2 – 15.4	11.8 – 19.2	0 to 50% (Segments at Capacity)

[1]Range based on full flow, Manning's n, and surveyed inverts (slope). Capacity varies throughout interceptor due to varying slopes of each segment of gravity main.
[2]Calculated as 75% of full flow capacity.
[3]North Frontage Road interceptors listed in order of upstream to downstream (east to west).

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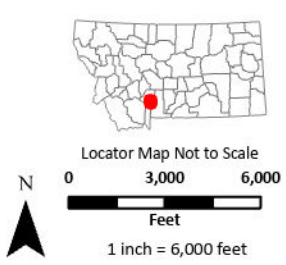


Figure 4-3

EXISTING SYSTEM WET WEATHER INTERCEPTOR d/D CAPACITY ANALYSIS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

Chapter 5 Existing System Recommendations

None of the current system deficiencies identified in the DWF and WWF analyses require immediate attention.

Major recent interceptor improvements (Front Street, North Frontage Road, Davis Lane / Cottonwood Road, and Garfield Street / Lincoln Street, and south end of the Fowler Avenue / 19th Avenue interceptors) have addressed some of the short-term improvement and growth needs identified in the previous 2015 Collection System Facility Plan.

Identified deficiencies in the existing conditions analysis will be further evaluated in conjunction with system risk and future system expansion. Surcharging exhibited in the existing WWF scenario identified in ***Section 4.2.1*** could likely be alleviated by upsizing specific segments of gravity sewer. However, developing detailed improvement recommendations without considering loading associated with future growth could result in underdeveloped CIP mitigation recommendations.

Therefore, any system improvements will be developed in conjunction with the existing system risk assessment results and future conditions analysis build-out analysis.

Chapter 6 Future Conditions Model Development

As described in the City's 2020 Community Plan, growth in Bozeman and Gallatin County has been rapid and steady over the past several decades and will likely continue. The City must plan its utilities and services to accommodate the growth. Development is occurring within the City limits as well as expansion to the west and south – this growth will impact the collection system facilities. To understand and evaluate these impacts, future condition scenarios based on the City's growth planning boundary were included in the hydraulic model. This chapter describes the future conditions modeling and results. Future wastewater flow is described in detail in the Wastewater Flow Characterization Technical Memorandum (TM 5).

6.1 Model Network Expansion

To serve the future development within the City limits and UBO planning area, extensions of gravity mains and force mains were laid out. The following summarizes the approach used to build the framework for the Future Conditions Wastewater Collection System Model Network.

- The topography within the growth area boundary was reviewed to verify and adjust the 2015 drainage basins.
- The topography within the growth area boundary was reviewed to verify and adjust the 2015 drainage basins. Drainage basin boundaries were analyzed to better reflect anticipated development patterns and existing terrain. Subsequently, sewer infrastructure sizing was planned for the service areas identified in this plan. Going forward, the City should review detailed drainage basin boundaries in future Facility Plan updates, with regional lift station planning and design, or with major trunk or interceptor sewer design. The collection system gravity mains were extended to serve the entire growth area by adding gravity mains to the existing system model network. The network was established to approximately run at quarter sections where feasible, along major drainage corridors within basins, and/or along arterial roads as identified in the COB 2017 Transportation Master Plan.
- Manholes were generally placed at quarter- to half-mile intervals along the proposed gravity main network.
- A 2018 digital elevation model (DEM) was used to extract manhole rim elevations for the proposed future network. Manhole inverts were initially assumed to be 8-ft below grade and slopes were set to match ground topography between manholes. Where slopes did not meet minimum grade standards, manhole depths, and thereby slopes, were increased to achieve the minimum standard slope for the respective main size. When manhole inverts were manually adjusted to achieve require slopes and collecting system routing a maximum depth of 15 feet was used per City standards.

- Gravity sewer mains were sized to handle modeled flows without exceeding 0.75 d/D during peak flows of the wet-weather UBO scenario.
- Where required, lift stations and force mains were added to pump wastewater from a low-lying areas to the near-by trunk sewers. No new proposed lift stations were added beyond those identified in the 2015 Facility Plan. Additional information about the proposed lift stations is provided in ***Section 7.3.3***.

6.2 Scenarios

Four scenarios were developed in collaboration with City Engineering staff to evaluate future growth and collection system infrastructure:

- **Infill Scenario:** The Infill scenario includes additional flow loading from the following growth categories within City limits.
  - Vacant Areas: Additional loading is added to the sanitary network using wastewater duty factors established for existing land uses based on each land use type as identified in TM 5.
  - Zoned Areas: All zoned properties within City limits are added to the sanitary network using wastewater duty factors established for existing zoning uses based on each zone type as identified in TM 5.
  - Redeveloped Areas: Urban renewal districts (URD) and tax increment finance (TIF) areas modeled to have increased domestic loading as identified in TM 5.
- **Ultimate Buildout (UBO)**
  - The UBO scenario includes all areas outside City limits and within the growth area boundary added to the sanitary network using wastewater duty factors established for land uses based on each land use type as identified in TM 5.
- **Ultimate Buildout West (UBO West)**
  - The UBO West scenario includes the same loading as the UBO scenario but includes wastewater flow diversion to a regional wastewater treatment facility assumed to be located northwest of City limits and the growth area boundary.
- **Increased Density**
  - The Increased Density scenario included additional domestic loading for residential classification as identified in TM5. The increased density scenario was only analyzed under WWF conditions.
    - Existing residential areas with R1 zoning experience increased domestic loading by 25%.
    - Future residential growth areas with zoning of R2 or R3 experience increased domestic loading to R4 zoning.

6.3 Future Wastewater Allocation

Wastewater flow and loading analysis was completed using the wastewater duty factors developed in TM 5. TM 5 describes the wastewater characterization methodology and analyses in detail. This section summarizes the key results and describes the model flow allocation methodology.

- Manhole Loading:
    - Manholes were added to the growth network as described above in ***Section 6.1***
    - Thiessen polygons were automatically generated to determine the area of influence for covering the growth area.
    - Wastewater duty factors based on land use were applied to each manhole based on the Thiessen polygon area of influence for each manhole.
    - For RDII, the area of influence for future manholes was limited to 5 acres to maintain realistic representations and consistency with the previous Facility Plan.
    - RTK factors for calculating RDII in growth areas were assumed consistent with the existing factors established during model calibration.
- ***Domestic Flow***: The portion of wastewater flow that originates from residential, commercial, and industrial sources. This flow is relatively steady throughout the year and can be estimated from non-irrigation (winter, or indoor) metered water use.
- ***Base Infiltration (BI)***: The portion of wastewater flow that originates from groundwater and can vary by depth of the groundwater table.
- ***Rainfall Derived Inflow and Infiltration (RDII):*** The portion of wastewater flow that originates from rainfall events as inflow and infiltration into the collection system.

6.3.1 Domestic Flow Allocation

Wastewater duty factors were applied for each of the main growth scenarios including Infill, UBO, UBO West, and Increased Density scenarios using factors established in TM5.

6.3.2 Groundwater Baseflow

The BI was calculated for each future manhole the ground water duty factors based on acreage. The area of influence for future manholes was limited to 5 acres to have realistic representations for area of influence and be consistent with previous master planning efforts. The resulting BI flow was then assigned to the future manholes as constant inflow.

- BI for DWF: 150 gpad
- BI for WWF: 550 gpad

6.3.3 Rainfall Derived Inflow and Infiltration Loading

The 2020 Model Update utilized a synthetic design storm event to allocate RDII, but also included calibration to a WWF event that was captured with metering in 2020. RDII model calibration and design storm results are discussed in ***Section 2.3.4*** and ***Chapter 4***, respectively. For RDII, the area of influence for future manholes was limited to 5 acres to have realistic representations for area of influence and be consistent with previous master planning efforts.

6.3.4 Summary of Future System Loading

The bulleted summary below, ***Table 6-1***, and ***Table 6-2*** provide an overview of loading allocated within the model to establish the future collection system scenarios.

- **DWF Domestic Flow**:
  - Existing: 3.8 MGD
  - Infill Increase: 5.1 MGD
  - UBO Increase: 30.2 MGD
  - Increased Density: 2.2 MGD
  - Diurnal peaking factors for the DWF and WWF design scenarios utilize established diurnal peaking factors, which were allocated upstream of the existing system network.
- **BI for DWF**:
  - Existing: 1.5 MGD
    - Based on established 672 gpd/idm
  - Infill Increase: 0.1 MGD
    - Based on established 150 gpad
  - UBO Increase: 4.0 MGD
    - Based on established 150 gpad
  - Increased Density: no change
- **BI for WWF**: based on gpd/idm
  - Existing: 5.7 MGD
    - Based on established 2,525 gpd/idm
  - Infill Increase: 1.3 MGD
    - Based on established 550 gpad
  - UBO Increase: 15.2
    - Based on established 550 gpad
  - Increased Density: no change.

Table 6-1: Summary of Loading for Dry Weather Model Scenarios

Scenario	Domestic Flow (MGD)	Ground Water BI (MGD)	Total Loading (MGD)
Existing	3.8	1.5	5.3
Infill (existing + infill)	8.9	1.6	10.5
UBO (and UBO West) (existing + infill + UBO)	39.1	5.6	44.7
Increased Density	2.2	-	-

Table 6-2: Summary of Loading for Wet Weather Model Scenarios

Scenario	Domestic Flow (MGD)	Ground Water BI (MGD)	Total Loading (MGD)
Existing	3.8	5.7	9.5
Infill (existing + infill)	8.9	8.5	16.0
UBO (and UBO West) (existing + infill + UBO)	39.1	22.2	63.3
Increased Density	2.2	-	-

Chapter 7 Future System Evaluation and Recommendations

This chapter presents the evaluation of the City's future wastewater collection system and its ability to accommodate peak flows and meet performance criteria under various future growth conditions. Evaluations, findings, and recommendations for addressing deficiencies identified in the City's existing wastewater collection system along with additional loading from infill and future growth and development are summarized in this chapter.

7.1 Future Conditions Modeling Scenarios

The future wastewater collection system was evaluated under four future growth conditions including Infill, Ultimate Buildout (UBO), Ultimate Buildout with regional wastewater treatment to the west (UBO West), and Increased Density. Recommended improvements under each of the future scenarios are described in this Section; cost estimates and additional detail on the improvements are provided in TM 9 (**CIP Technical Memorandum)**.

7.1.1 Dry Weather Model Conditions

Gravity main velocity, depth, and flow were evaluated during the DWF analysis for the Infill, UBO, and UBO West scenarios. The design standard minimum gravity main velocity is 2 ft/s to minimize solids settling and reduce maintenance requirements. This minimum velocity standard is not met under DWF conditions but is acceptable because it is achieved under WWF.

DWF depths in the gravity mains and at the manholes were also evaluated under the four future growth condition scenarios. DWF modeling results show no locations that surcharge.

City owned lift stations and force mains were evaluated based on the velocity criteria discussed in ***Chapter 3***. Pump curves were provided for existing lift stations and are stored within the model; however, to improve model stability and reduce model runtimes, the model is set up to run peak flow directly through the lift station using an ideal pump (inflow = outflow). This pump approach also provides a conservative estimate for capacity evaluations. Firm pumping capacities provided by the City were used for analysis of force main capacity. Future lift stations were modeled to run the peak flow directly through the lift stations using ideal pumps. The DWF analysis results showed the lift stations have adequate capacity to receive peak flows.

7.1.2 Wet Weather Model Conditions

The InfoSWMM model was utilized to simulate the WWF event with additional loading as described in ***Section 6.3*** Gravity main velocity, depth, and flow were evaluated during four WWF loading scenarios. The gravity main, force main, and lift stations analysis is summarized in the following sections.

7.2 Infill Evaluation and Improvements Summary

The collection system under the Infill scenario was sized to accommodate WWF peak flows for the UBO and Infill loadings.

7.2.1 Modeling Results of Gravity Main and Interceptors for Infill Conditions

Figure 7-1 presents the depth to diameter (d/D) ratio of maximum depth to full depth for the infill loading on the existing gravity main network. A majority of the network shows sufficient capacity to meet the design storm and support additional growth from infill. However there are a number of locations that will require improvements to support infill growth. The main corridors that show d/D that are shown to result in full pipe flow (d/D = 1.0) include the following:

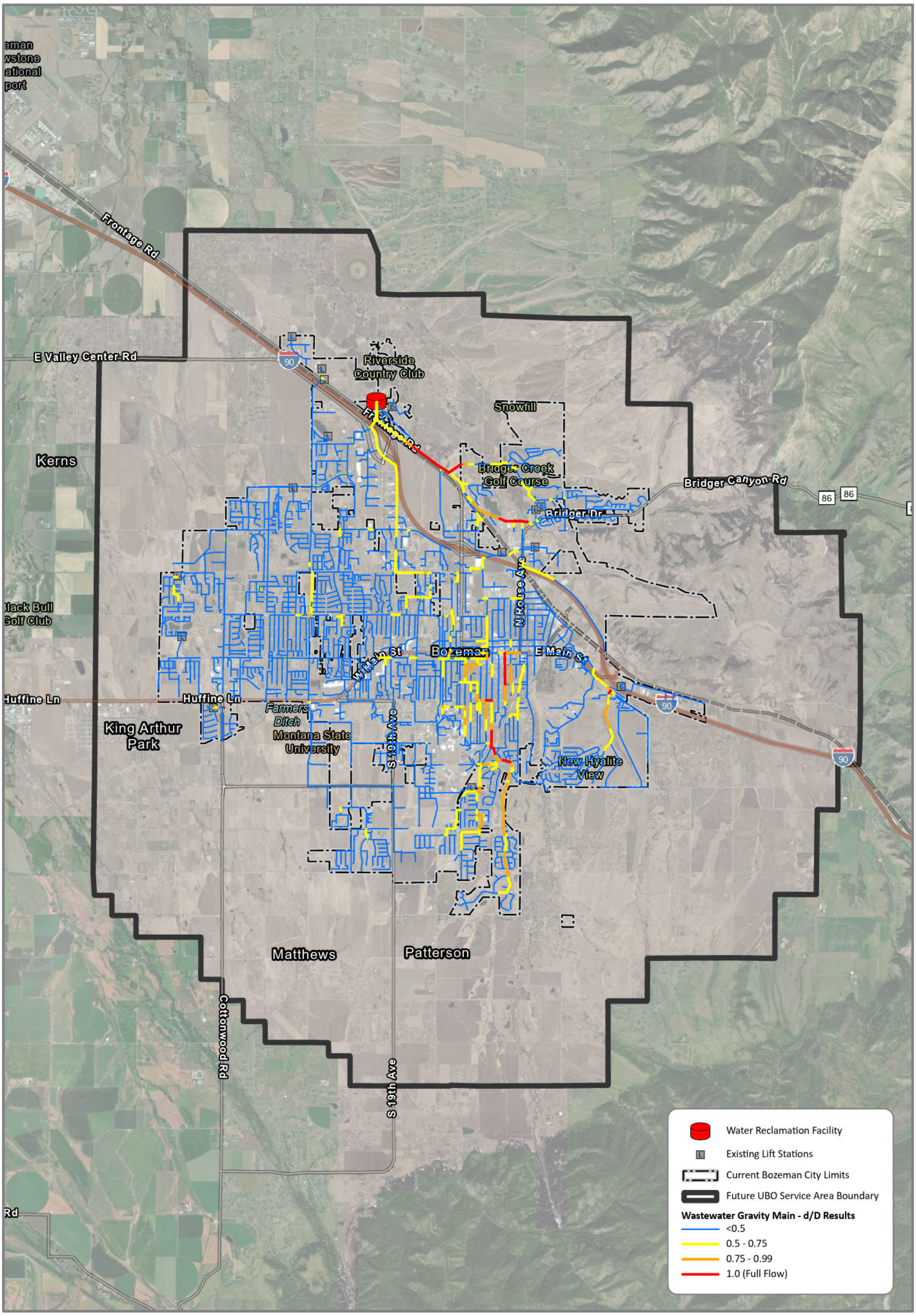
- Sections of the North Frontage Road Interceptor
- Sections of the 19th Avenue / Kagy Boulevard Interceptor between Kagy Boulevard and Babcock Street.
- Black Avenue sewer between College Street and Main Street.

A detailed list of improvements required to correct these sewers for infill conditions is presented in ***Section 7.2.2***. In addition, ***Section 7.2.2*** addresses improvements required to correct sewers that are modeled to have a d/D between 0.75 and 1.0.

There are two gravity main sections that exceed the City's design d/D criteria under Infill Conditions after the identified improvements are completed. These two sections are described in more detail below.

- North Frontage Road Interceptor: The primary recommended improvements include paralleling the North Frontage Road in areas where there is currently a single interceptor from N Rouse to Springhill Road and upsizing where surcharging occurs under existing conditions. There are segments where old smaller sections still show a peak d/D exceeding 0.75; however, these segments are considered acceptable for the Infill scenario until the old, smaller trunk main is replaced for UBO conditions.
- Fairway Dr: Fairway Dr shows capacity exceeding 0.75 d/D for Infill conditions. Discussions with City staff indicate that there are no known issues or concerns with sewer capacity in this sewer. Therefore it is recommended that the City monitor the flow rate from this basin and complete further model calibration for the subbasin before making a decision on upsizing sewer in this corridor.

- S 3rd Ave: Short sections of sewer along S 3rd Ave between Westridge Dr and W Graf St show capacity exceeding 0.75 d/D for Infill conditions. Discussions with City staff indicate that there are no known issues or concerns with sewer capacity in this sewer. Therefore it is recommended that the City monitor the flow rate from this basin and complete further model calibration for the subbasin before making a decision on upsizing sewer in this corridor.



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Coordinate System: NAD 1983 UTM Zone 12N | Edited by: DVoeller | C:\Data\Projects\WAFS\B\Bozeman\05097-2018-006\GIS\Bozeman Wastewater Collection Facility Plan - Mapping and Analysis.aprx | TM7 7-1 Infill d_D Results

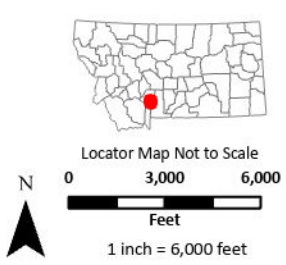


Figure 7-1

INFILL SYSTEM WET WEATHER d/D CAPACITY ANALYSIS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

7.2.2 Infill Interceptor and Gravity Main Improvements

Figure 7-2 provides an overview of the required improvements to meet infill loading. The projects described below include recommended improvements required for upsizing existing gravity main as well as extensions required to serve future growth areas within the overall City limit boundary.

7.2.2.1 Infill Upsizing Improvements:

Figure 7-1 highlights the existing sewer with modeled capacity issues when additional loading is added for the Infill scenario. The projects described below address Infill capacity issues but are sized to account for the UBO WWF. These projects and their estimated costs are discussed in more detail in the CIP Technical Memorandum (TM 9). The list below notes with which CIP Project # each of these segments is associated.

- **North Frontage Road Interceptor:**
  - It is recommended to complete parallel segments along the entire Frontage Road interceptor in places where there is currently a single interceptor segment. Recommended parallel segments include:
    - 27-inch parallel segment along North Frontage Road between Reeves Road and Springhilll Road.
    - 30-inch and 27-inch parallel segment from Manley Road westward along North Frontage Road.
  - It is recommended to upsize one of the existing parallel 20-inch segments between North Rouse Avenue and Manley Road to a 36-inch Interceptor. It should be noted that a 36-inch interceptor segment was completed west of Manley Rd with the Manley Road Improvement project.
  - This project was a previously identified City CIP: WWIF20
- **WRF Interceptor:**
  - It is recommended to complete a 42-inch diameter parallel segment along Springhill Road from North Frontage Road to the WRF.
  - This project was a previously identified City CIP Project: WWIF44
- **19th Avenue / Kagy Boulevard Interceptor (South Wilson Avenue Kagy Boulevard to Olive Street Sewer Improvements):**
  - Improvements to address both capacity and condition concerns needed. It is recommend to upsize and replace various pipe segments from 10- to 18-inch.
  - CIP Project: Project 1
- **Front Street Interceptor and Highland Glen Sewer Main:**
  - The existing gravity main should be upsized from 8-inch to 12-inch and 18-inch starting at Cherry Drive, through the Highland Glen open space, along Haggerty Lane, and ending at intersection of South Main and Haggerty.

  - CIP Project: Project 11
- **4th Avenue, Babcock Street and Grand Avenue Sewer Main Replacement:**
  - The section of pipe between along W Babcock St and S 3rd Ave is recommended to be upsized to a 10-inch main. Remaining sewer along 4th Ave is recommended to be upsized to 8-inch main. In total, 1,300 feet of pipe will be replaced in this project.
  - CIP Project: Project 6
- **South Black Avenue between E Story Street and W Main St:**
  - The existing gravity main should be upsized from 6-inch to 8-inch.
  - CIP Project: Small-Pipe Project 1
- **Olive Street between S 4th Avenue and S 6th Ave:**
  - The existing gravity main should be upsized from 6-inch to 8-inch.
  - CIP Project: Small-Pipe Project 4
- **Main Street between Tracy and S Rouse Ave to E Babcock St:**
  - The existing gravity main should be upsized from 6-onch and 8-inch to be 8-inch and 10-inch. The new 10-inch sewer is on Main St between Black Ave and S Rouse Ave.
  - CIP Project: Small-Pipe Project 7
- **S Bozeman Ave, E Story St, and Dell Pl Sewer Main Replacement:**
  - The existing gravity main should be upsized from 6-onch and 8-inch to be 8-inch
  - CIP Project: Small-Pipe Project 8

7.2.2.2 Infill Interceptor Extensions

The dashed colored lines in ***Figure 7-2*** show future collector, trunk, and interceptor sewer extensions that are required to extend to serve the infill area. The proposed sewer size includes capacity for the UBO scenario. The projects described below are limited to trunk and interceptor sewers for planning purposes. The sizing and layout of these projects should be more carefully considered as the need for them approaches.

- **Bohart Lane Interceptor:**
  - This interceptor ranges in size from 21 to 24-inches and runs along the north side of the interstate starting at the railroad crossing near mile post 309. This interceptor extension would connect into the existing 30-inch Rouse Avenue Interceptor.
- **South Church Avenue Interceptor**
  - This interceptor ranges from 21 to 24-inch between Kagy Blvd and Olive Street and ending at S Rouse Ave.
- **Aajker Basin Diversion**
  - The 21-inch interceptor that will serve as the Aajker Basin Diversion will be extended to serve growth. The interceptor opens up a significant portion of the Aajker Creek sewershed basin south of Baxter Lane. The Diversion will take flow

from the Aajker Creek basin and convey wastewater to the Davis Lane / Cottonwood Road interceptor.

- **Painted Hills Road Trunk Sewer:**
  - A12-inch sewer is required to serve the growth area southeast of Cherry Dr. The trunk sewer is generally located within the Highland Glen open space, which is the topographical low area of the drainage and follows the west side of the creek between Kagy Road and Haggerty Lane. For infill conditions 12-inch sewer is required between Painted Hills Road and the existing 8-inch sewer serving Cherry Dr. UBO will require larger 18-inch main northward along Haggerty Lane.
- **Farmhouse Lane Trunk Sewer**
  - A 12-inch sewer is required to serve the growth area south of the Haggerty Lane and east of the Highland Glen drainage. The trunk sewer is generally located within the Highland Glen open space, which is the topographical low area of the drainage and follows the east side of the creek between Kagy Road and Haggerty Lane.

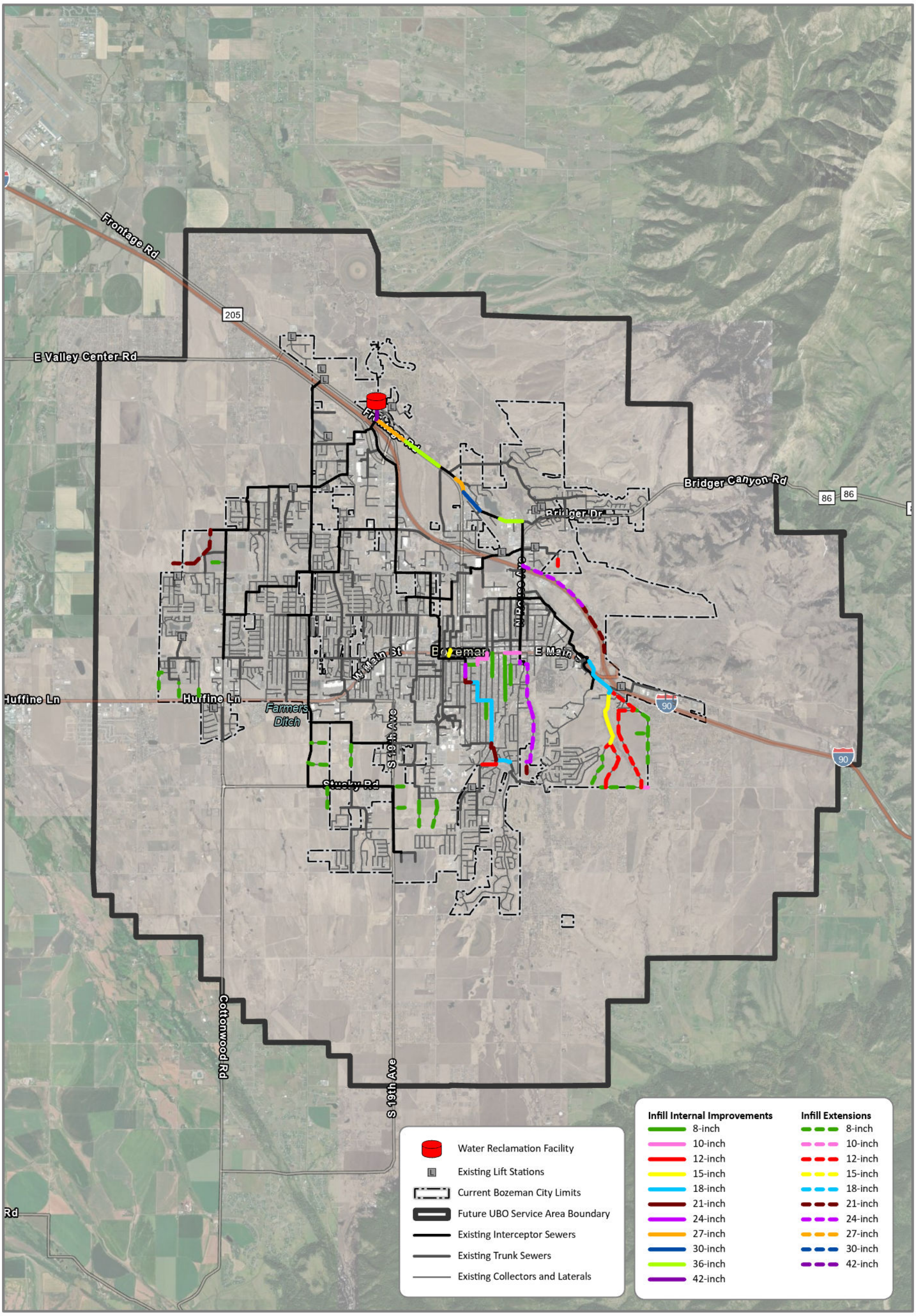
7.2.3 Infill Lift Station Summary

No lift stations or lift station upgrades are required to meet the Infill loading scenario. However, based on recent growth and development adjacent to the City's existing service boundary, a new lift station is required to support growth and development to the west. The identified lift station necessary to meet expected near-term growth has been identified as the Valley Center Lift Station (VCLS). The VCLS will reside within the Baxter Creek Drainage Basin, located on the south side of East Valley Center Road, east of Stubbs Lane near the East Valley Center Spur Road intersection.

The 2015 Facility Plan originally planned to serve the Baxter Creek Drainage Basin with the Hidden Valley Regional Lift Station, which is northwest of the proposed VCLS. However, development pressure within the Baxter Creek Drainage area requested the City to evaluate and ultimately consider the possibility of splitting the Hidden Valley Regional Lift Station into two separate lift stations. Based on feasibility criteria, modeling results, and input from City Staff, AE2S recommended two smaller lift stations to service the Baxter Creek Drainage Basin and the construction of the VCLS lift station in the near-term to help support anticipated future development west of Davis Lane. The analysis also provided the City with long-term options for a second lift station or regional alternative to service the Baxter Creek Drainage Basin as the City continues to grow and develop to the west.

The detailed analysis of the Baxter Creek Drainage Basin and lift station alternatives was completed in 2022 (Baxter Creek Drainage Basin Analysis Technical Memorandum (AE2S, 2022). The recommendations were formally adopted by the City commission January 24, 2023. Thus, amending the City's adopted 2015 wastewater facility plan. These findings and recommendations have been incorporated into the facility plan update and will be utilized as the basis of planning for the Baxter Creek Drainage Basin.

Currently, the City is in preliminary design phase for VCLS, with an anticipated construction starting early 2025. Under the UBO loading, the City will need an additional lift station to serve areas further west and north of the Valley Center Lift Station. ***Section 7.5*** provides details about the UBO scenario lift station analysis and recommendations.



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Coordinate System: NAD 1983 UTM Zone 12N | Edited by: DVoeller | C:\Data\Projects\WAFS\B\Bozeman\05097-2018-006\GIS\Bozeman Wastewater Collection Facility Plan - Mapping and Analysis.aprx | TM7 7-2 Infill Improvements

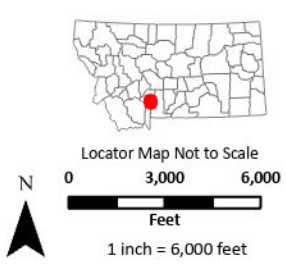


Figure 7-2

INFILL SYSTEM IMPROVEMENTS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/13/2024

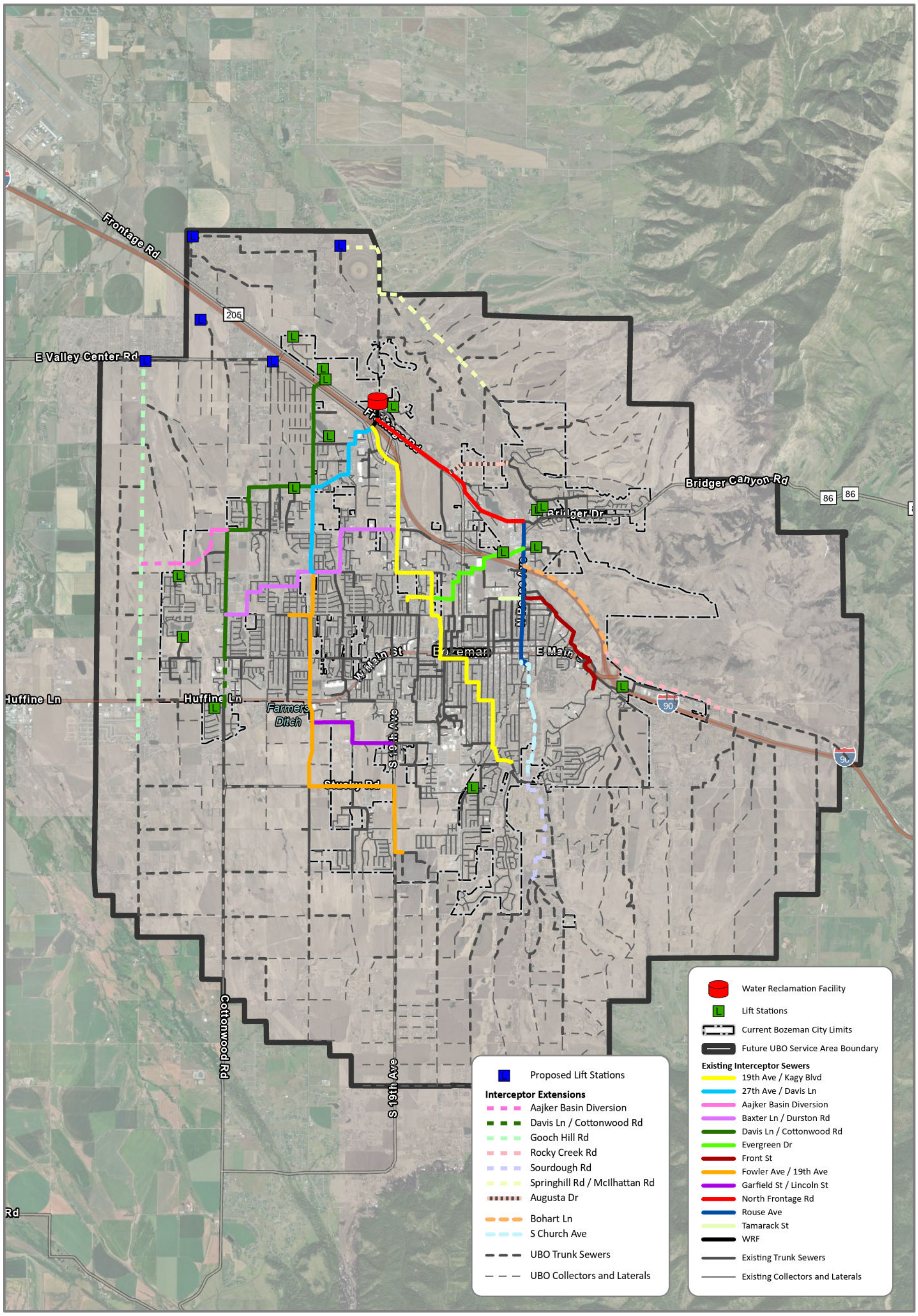
7.3 UBO Improvements Summary

7.3.1 Modeling Results of Gravity Main and Interceptors for UBO Conditions

Figure 7-3 presents an overview of the interceptor system at UBO. Outlined in the figure are existing and proposed interceptors by name along with highlights of proposed and future trunk sewers. Figure 7-4 presents an overview of the interceptor system at UBO overlaid with the sewershed basins for reference. Interceptor improvement projects are discussed in more detail in the following sections.

Figure 7-5 presents the d/D as a ratio of maximum depth to full depth for the buildout gravity main network. ***Figure 7-6*** presents the infrastructure improvements by diameter required to achieve the design criteria d/D. A majority of the network shows sufficient capacity to meet the design storm and support additional growth from UBO conditions while meeting design criteria. There are minor areas in which the City design criteria for d/D (0.75) is not met; these are described in more detail below.

- There are a number of short segments scattered throughout the system that exceed the design evaluation criteria. While they exceed the criteria, they do not necessarily warrant upsizing as there is no manhole surcharging within the system and the pipe segment d/D marginally exceeds 0.75. It is recommended that the City continue to monitor growth and review modeling results to determine if any of these areas begin to experience surcharging and require improvements. Some of the areas include the following:
    - Existing 21-inch on Fowler Ave just north of Main St.
    - Existing 21-inch on Davis Lane just north of W Oak St.
    - Existing 24-inch on Simmental Way just north of Baxter Ln
    - Existing 15-inch to N 7th Ave between W Birch St and W Oak St.
    - Existing 6-inch on S 6th Ave between Harrison St and Garfield St.
    - Existing 8 and 10-inch sewer on S 3d Ave between Graf St and Kagy Blvd.
    - Existing 18-inch in Blackwood Groves east of S 19th Ave.
- Davis Lane / Cottonwood Road Interceptor: There are three short segments of this interceptor that marginally exceed 0.75 d/D at UBO conditions. However, replacing or paralleling these sewers is not recommended at this time because of the long duration for when buildout flows are realized in this corridor These locations include the following segments on Cottonwood Road: (1) 15-inch sewer just south of Alpha Drive, (2) 18-inch interceptor just north of Babcock Street, and (3) existing 18-inch interceptor on Cottonwood Road just south of Babcock St.



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Locator Map Not to Scale

N

0 3,000 6,000

Feet

1 inch = 6,000 feet

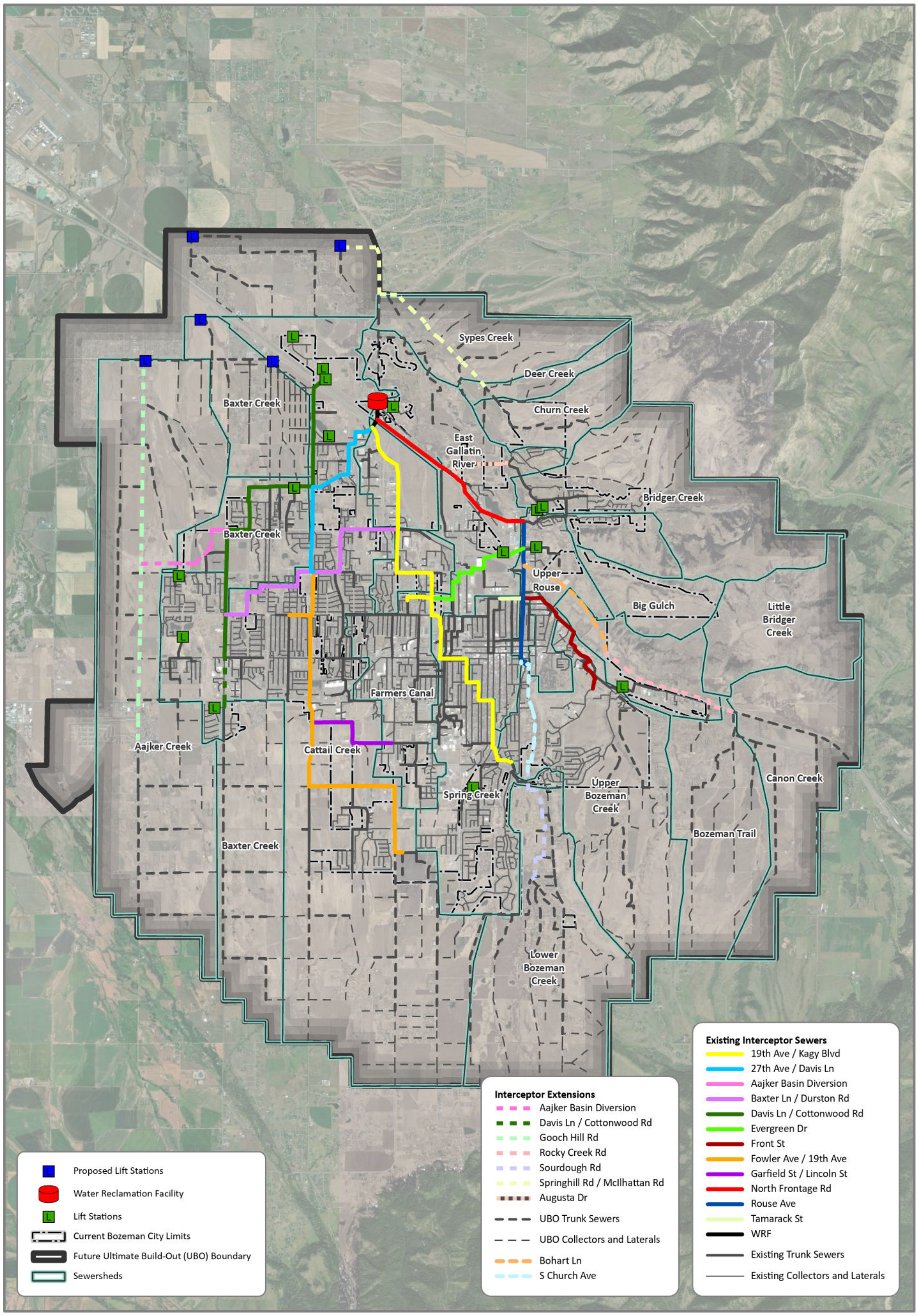
Figure 7-3

UBO INTERCEPTOR SYSTEM

WASTEWATER COLLECTION FACILITY PLAN

City of Bozeman | Gallatin County, MT

Date: 9/11/2024



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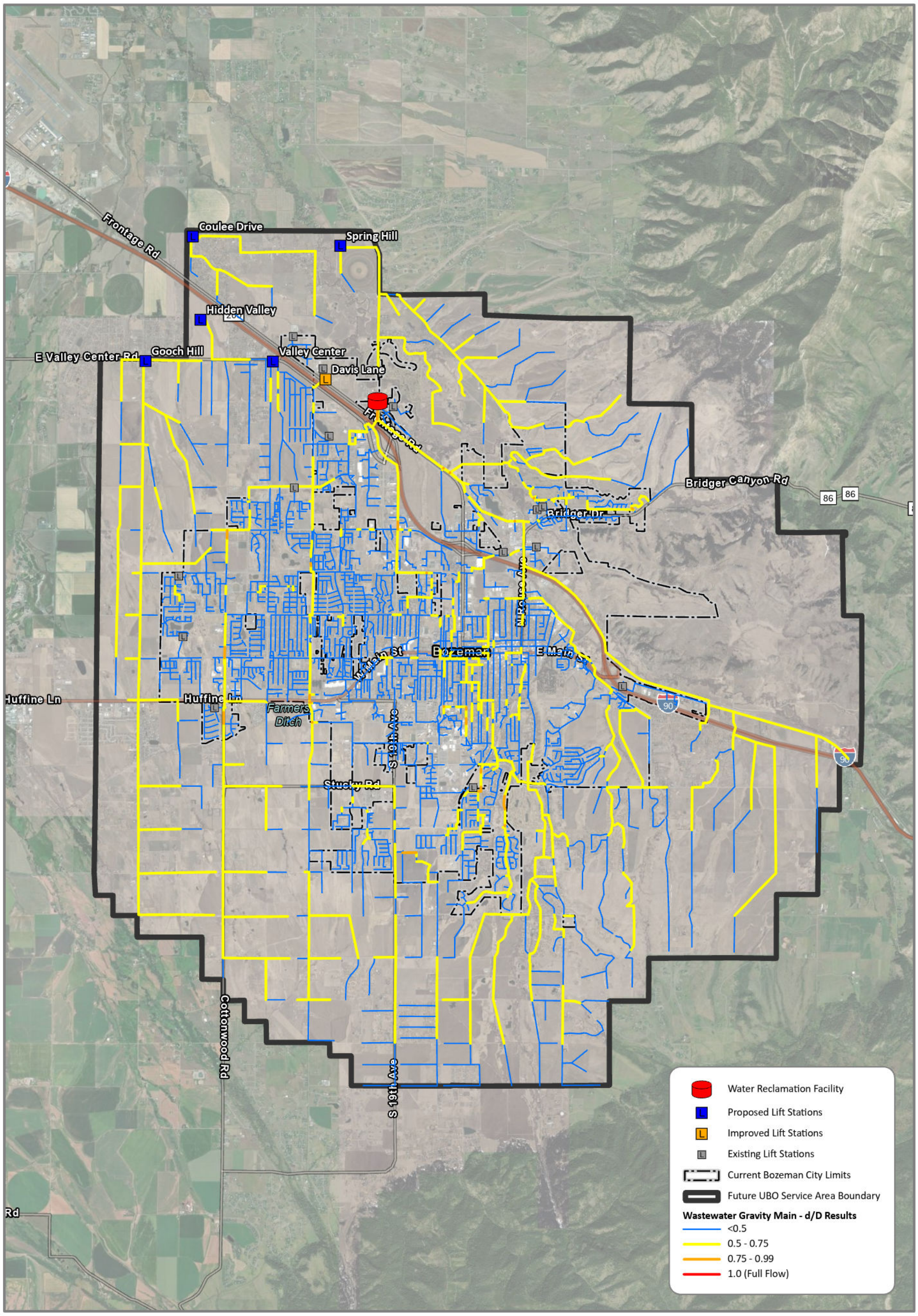
Figure 7-4

UBO INTERCEPTORS and SEWERSHED BASINS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/10/2024

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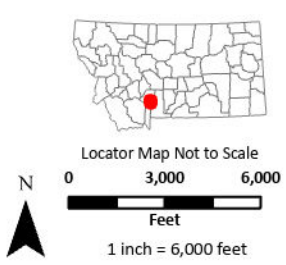


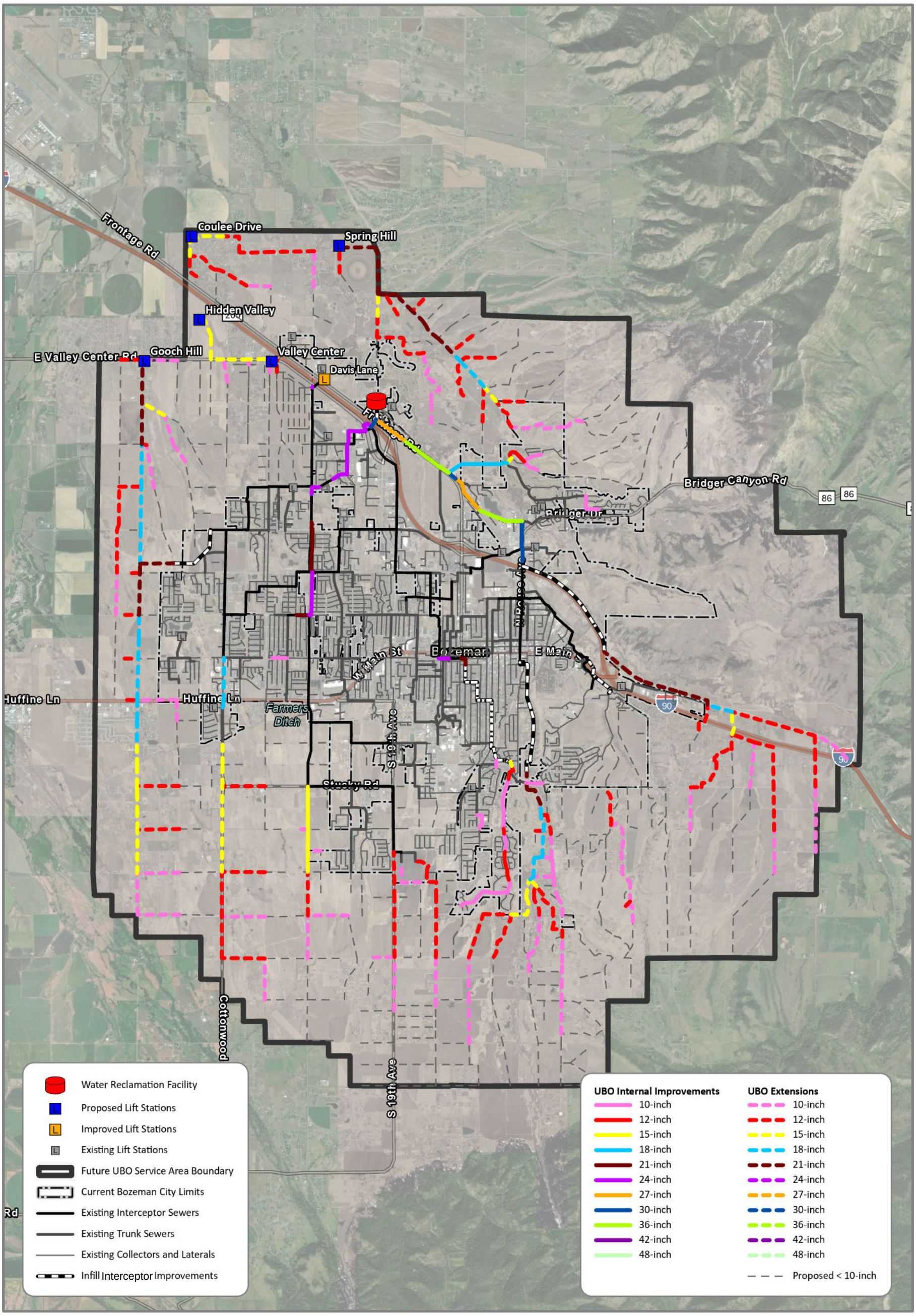
Figure 7-5

UBO SYSTEM WET WEATHER d/D CAPACITY ANALYSIS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

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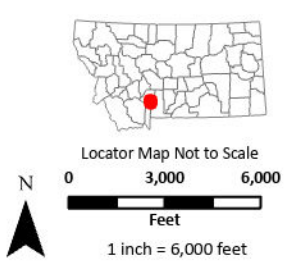


Figure 7-6

UBO
SYSTEM IMPROVEMENTS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

7.3.2 UBO Interceptor and Gravity Main Improvements

Figure 7-6 provides an overview of the required improvements to meet UBO loading. The improvements described below are required for the system to expand from the infill scenario to the UBO scenario. These improvements are in addition to those listed in ***Section 7.1*** .

7.3.2.1 UBO Upsizing and Interceptor Improvements

The solid-colored lines in ***Figure 7-6*** show existing sewer with modeled capacity issues when additional loading is added for the UBO scenario and include:

- **North Frontage Road Interceptor:**
  - It is recommended to upsize the remaining interceptor sections along the North Frontage that were not upsized under the Infill scenario.
  - This improvement consists of 27- and 36-inch interceptors between North Rouse Avenue and Springhill Road.
  - Parallel segments are recommended east of the Cherry River fishing access, which is located off of North Frontage Road.
- **27th Avenue / Davis Lane Interceptor:**
  - The 27th Avenue / Davis Lane Interceptor will require parallel segments at the following locations:
    - 24-inch between Davis Lane / Cattail Street intersection and the interstate crossing near Honor Lane.
    - A secondary 30-inch interstate crossing parallel to the existing 30-inch crossing.
    - Parallel the existing 21-inch along the Davis Lane / Fowler corridor with a new 21-inch from Oak Street to north of Baxter Lane.
- **Fowler Avenue / 19th Avenue Interceptor:**
  - The Fowler Avenue / 19th Avenue Interceptor will require a number of improved segments for UBO conditions as follows:
    - Upsize existing sewer within Durston Road from 18-inch to 21-inch between Meagher Avenue and Fowler Avenue.
    - Upsize existing sewer along the Davis Lane / Fowler corridor from 18-inch to 24-inch between Durston Road and Oak Street.
- **Davis Lane / Cottonwood Road Interceptor:**
  - The existing 8-inch sewer along Cottonwood Road between Huffine Lane and Babcock Street is not sufficient to support future growth. The existing line can continue to serve as a local collector in the near-term, however the existing interceptor segment along this corridor will need to be extended to the south.
  - It is recommended to install an 18-inch Interceptor within Cottonwood Road between Huffine Lane to Babcock Street. A boring will be necessary as part of this project to connect the upstream 15-inch section, which is located just south of Huffine Lane in Cottonwood Road. Currently the existing 15-inch interceptor

south of Huffine Lane within Cottonwood Road drains into the Loyal Garden Lift station. This extension would allow the flow to gravity drain north into the new 18-inch interceptor and into the Cottonwood-Davis Interceptor network.
    - Additionally, this connection will allow additional development to occur to the south of Huffine lane, specifically along the Cottonwood Road corridor, which will continue helping the City realize it's recent investment in the Cottonwood-Davis Interceptor.
- **North Rouse Interceptor:**
    - The North Rouse Interceptor between the interstate and North Frontage Road interceptor will require a parallel 30-inch interceptor under full buildout conditions.
- **Augusta Drive Interceptor (Bridger Creek Golf Course Area):**
    - The existing 12-inch trunk sewer along Augusta Drive westward toward the Cherry Creek fishing access will need to be upsized to an 18-inch interceptor.
- **19th Avenue / Kagy Boulevard Interceptor (Babcock St Area):**
    - Buildout conditions modeled to be upsized to 21 and 24 under buildout conditions. 21-inch sewer is modeled block upstream and one block downstream of the intersection of Babcock St and S 6th Ave. 24-inch sewer is modeled between S 9th Ave and S 11th Ave. It is recommended that the City continue to monitor flows within this subbasin for future growth contributions which may warrant upsizing this sewer.
- **Fairway Drive Trunk Sewer:**
    - The existing 8-inch sewer along Fairway Drive (between Little Horse Dr and Kagy Blvd) is modeled to be upsized to 10 and 12-inch trunk sewer under buildout conditions. It is recommended that the City continue to monitor flows within this subbasin for future growth contributions which may warrant upsizing this sewer.

7.3.2.2 UBO Interceptor Extensions

The dashed colored lines in ***Figure 7-6*** show future collector, trunk, and interceptor sewer extensions that are required to serve the UBO growth area. The projects described below are limited to trunk and interceptor sewers for planning purposes. As development pressure continues in these areas, the recommended sewer projects should be reevaluated and refined to better reflect proposed conditions and ensure adequate capacity.

- **Gooch Hill Interceptor:**
    - The Gooch Hill interceptor ranges in size from 18 to 21 inches and will serve the far west extents of the growth area. The interceptor begins near Farmers Canal and extends north along Gooch Hill Road, eventually meeting Harper Puckett Road. The interceptor ends at East Valley Center Road at the proposed Gooch Hill Lift station. The Gooch Hill lift station and force main will pump flow east to the Davis Lane Lift Station. A planning study should be completed to determine

the connection point whether it will convey water to the Davis Lane Lift station to be repumped, or if it will convey wastewater directly to the WRF.
        - There is a planned flow split between Oak Street and Baxter Lane to divert some of the wastewater to the Davis Lane / Cottonwood Road Interceptor. The diversion is planned to maximize the capacity within the Cottonwood Davis Interceptor and minimize lifting the same wastewater volume twice between Gooch Hill and Davis Lane Lift Stations.
    - Additional trunk sewer sized at 15-inch and smaller will extend farther south along Gooch Hill Road to serve further growth in the southern reaches of the basin.
- **McIlhattan Road Interceptor:**
    - The McIlhattan Road interceptor will serve the far northeast reaches of the growth area and ranges in size from 18 to 21 inches. The Interceptor begins near the intersection of Manley Road and McIlhattan Road. The Interceptor will follow McIlhattan Road to Springhill Road where it will deliver wastewater to the proposed Springhill Lift Station which pumps to the WRF.
- **Sourdough Road Interceptor:**
    - As discussed under the Infill improvements, the Sourdough Road Interceptor will need to be extended from Kagy Blvd southward to Gardner Park Drive generally along the Sourdough Road corridor. Overall, the Sourdough Road Interceptor ranges in size from 18 to 24 inches and will stretch from Garner Park Drive to Olive Street.
- **Bohart Lane Interceptor:**
    - As discussed under the Infill improvements, the Bohart Lane Interceptor will need to be extended from the interstate east along Rocky Creek Road to Fort Ellis Road. Overall, the Bohart Lane Interceptor ranges in size from 18 to 24 inches and will stretch from Fort Ellis Road to N Rouse Avenue.
- **South End Trunk Sewers:**
    - The southern portion of the future network will require a number of south-to-north trunk sewers ranging in size from 10 to 15 inches. ***Figure 7-6*** shows the locations of trunk sewers. Trunk sewers in this area generally follow major planned transportation corridors.
- **North End Trunk Sewers:**
    - Trunk sewer extensions ranging from 10 to 15 inches are also required to serve the northern extents of the growth area and are shown in in ***Figure 7-6***.

7.3.3 UBO Lift Station Summary

Four primary regional lift stations are required to serve the UBO system:

- Coulee Drive Lift Station;
- Gooch Hill Lift Station;
- Hidden Valley Lift Station; and

- Spring Hill Lift Station.

Detailed lift station summaries for each are provided in ***Section 7.5*** .

7.4 UBO West Improvements Summary

The natural topography of the City and surrounding area generally slopes downhill north and west. Much of the western and northern growth areas lie at elevations below the WRF which is why regional lift stations have been identified and required to pump wastewater to the treatment facility. Large regional lift stations are generally expensive to build, operate, and maintain so the City is exploring long-term future scenarios that would allow for gravity service for the western and north growth areas of the City. As part of this evaluation, the "UBO West" scenario was developed to analyze collection system infrastructure needs assuming wastewater would be conveyed northwest under gravity flow conditions. ***Figure 7-7*** shows the approximate drainage split between what will continue to flow to the existing WRF and what will be able to flow west to a new treatment facility under the UBO West scenario. The drainage boundary is not exact because there would be flow splits and bypasses that allow some areas to drain both directions. In this alternative scenario, wastewater would be treated at a different facility. This scenario may be conducive for partnering with neighboring communities west of Bozeman to increase feasibility.

The UBO West scenario includes the same loading as the UBO scenario but conveys wastewater northwest of City limits and the growth area boundary along the Interstate 90 corridor to a hypothetical treatment facility.

Figure 7-7 provides an overview of the proposed improvements under the UBO West scenario. The Figure also highlights the existing lift stations that would be "decommissioned" to rely on gravity flow. The proposed improvements include varying configurations of future interceptors as well as diverting flows from existing lift stations in order to reduce overall system operation and maintenance costs. The projects described below include recommended improvements and conveyance infrastructure upsizing beyond those proposed under the base UBO scenario.

7.4.1 UBO West Interceptor Improvements

The primary changes for interceptors between the UBO and UBO West scenarios would occur in the northwest corner of the study area west of Davis Lane and along Interstate 90. These interceptor changes are shown in ***Figure 7-7*** and include:

- **Frontage Road Regional Interceptor:**
    - A new interceptor would start at the intersection of Springhill Road and the North Frontage Road and tie into the existing Frontage Road interceptor allowing wastewater to continue gravity flowing northwest. The interceptor is sized at 42 inches. The existing WRF maximum capacity is 14.6 MGD. Flows through the Frontage Road interceptor beyond the 14.6 MGD would be diverted by this new

interceptor extension. The modeled peak flow in the UBO West scenario has approximately 14 MGD heading the WRF and approximate 41 MGD heading northwest to a hypothetical future treatment facility.

- **Gooch Hill Road Interceptor:**
  - The Gooch Hill Road interceptor would require upsizing for the UBO West conditions as compared to the base UBO conditions. This is due to higher flows experienced by diverting flow from western lift stations allowing more wastewater to flow through the primary interceptor through the Aajker Creek Drainage Basin.
    - The Gooch Hill Interceptor will need to be increased as follows:
      - Increases from 18 to 21 inches between the Aajker Diversion and one mile south of Valley Center Road.
      - Increase from 21 to 24 inches from one mile south of Valley Center Road to Valley Center Road.
- **Valley Center Road Trunk Sewer:**
  - It is recommended that the 15-inch trunk sewer be installed under either the UBO and UBO West conditions to allow the City flexibility for future decommissioning of the Valley Center Lift Station whether the flow is conveyed to a future regional Hidden Valley Lift Station or the flow goes westward for regional treatment.
- **Consideration of Additional Flow Diversion:**
  - It is possible to add additional flow diversions from the southwestern growth area to be diverted towards the Gooch Hill Interceptor rather than sending the flow northward through existing and planned improvements within City limits. Additional flow diversions could come from/connect to:
    - Cottonwood Road south of Huffine Lane.
    - Fowler Lane South of Stucky Road.
      Analysis of these alternative flow diversions were excluded from this study.

7.4.2 UBO West Lift Station Summary

Two regional lift stations are required to serve the UBO West system; Coulee Drive and Spring Hill lift stations. A detailed lift station summary is provided in ***Section 7.5*** .

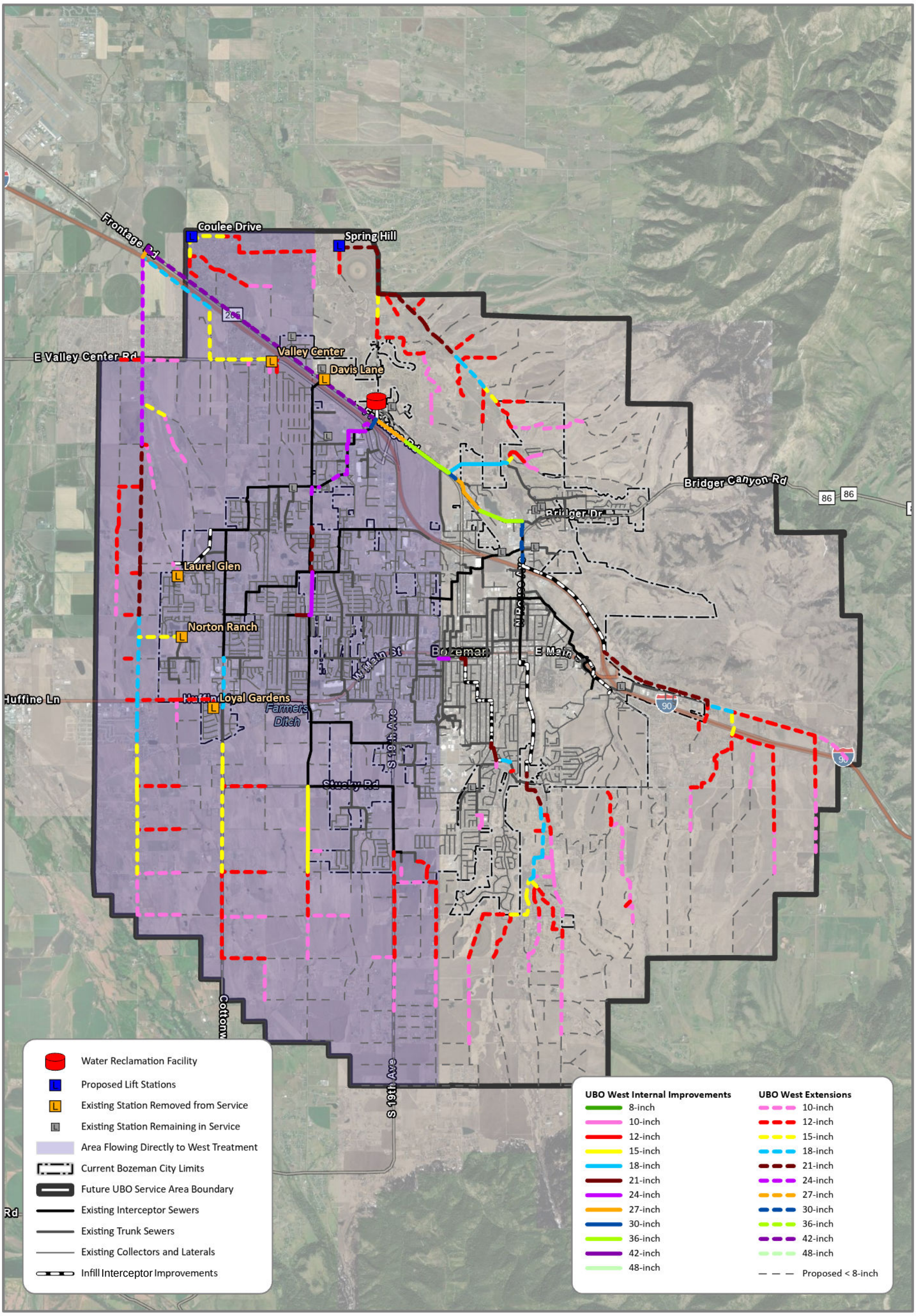
- **Coulee Drive Lift Station:**
  - This station is required under both the base UBO and UBO West scenario. For the UBO West scenario, this station will convey wastewater to the new Frontage Road Regional Interceptor extension.
- **Spring Hill Lift Station:**
  - This station is required under both the base UBO and UBO West scenario. For the UBO West scenario, this station can convey wastewater to the WRF or to the new Frontage Road Regional Interceptor.

Four existing lift stations can be removed from service and replaced by gravity trunk sewers conveying wastewater northwestward under the UBO West system. Additionally, the Valley Center Lift Station, which is in the final design phase at the time of this analysis, can be removed from service. A detailed lift station summary is provided in ***Section 7.5*** . Existing lift stations removed under the UBO West scenario:

- Laurel Glen Lift Station
- North Ranch Lift Station
- Loyal Garden Lift Station
- Davis Lane Lift Station
- Valley Center Lift Station (under design)

7.4.3 Modeling Results of Gravity Main and Interceptors for UBO West Conditions

Figure 7-8 presents the d/D as a ratio of maximum depth to full depth for the UBO West gravity main network. No manhole surcharging occurs under the UBO West scenario. A detailed list of improvements specifically required for UBO West conditions is presented in ***Section 7.4*** .



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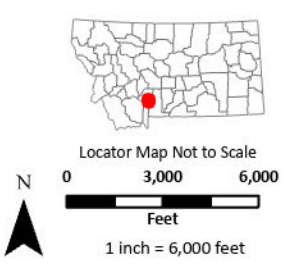


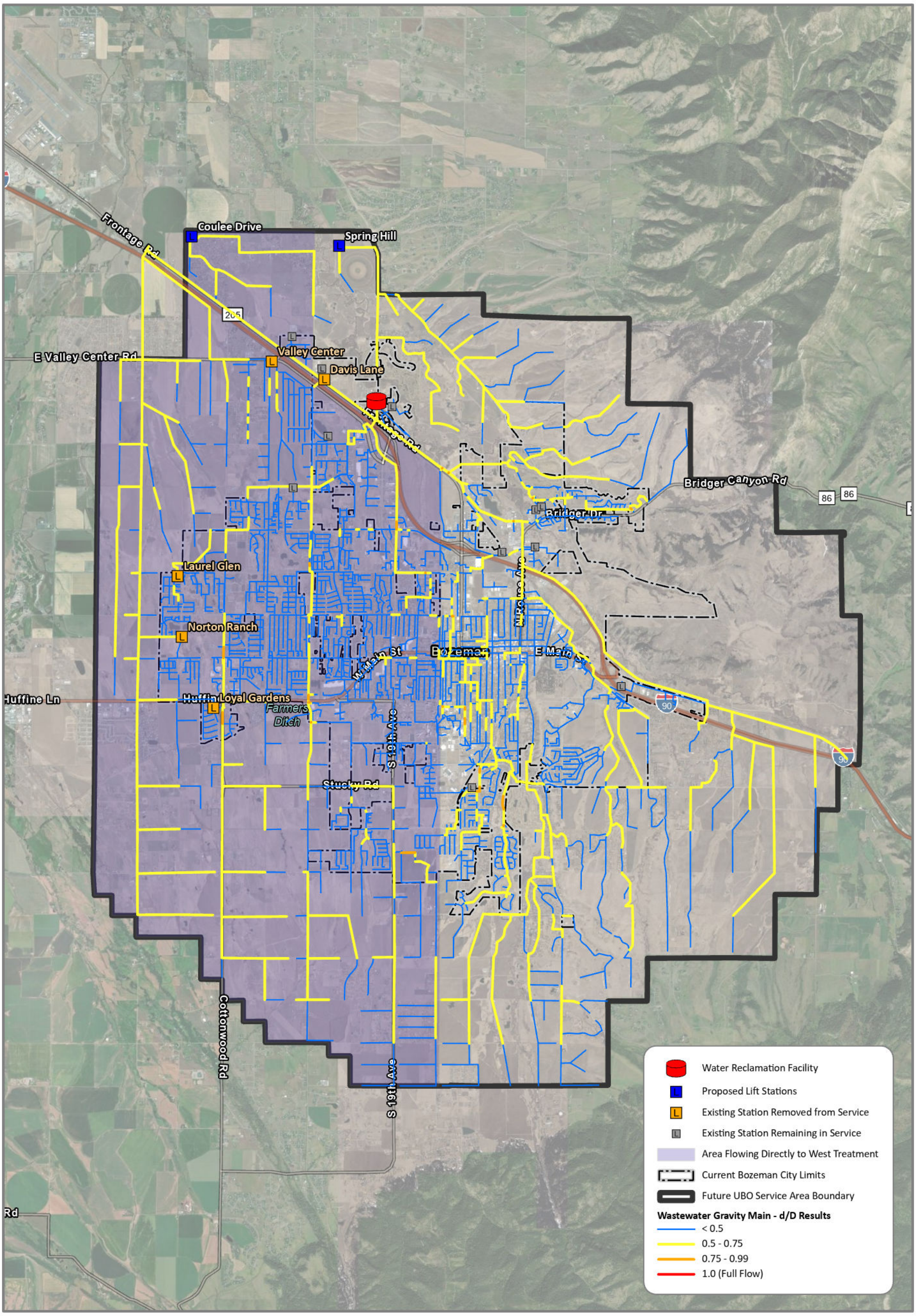
Figure 7-7

UBO WEST SYSTEM IMPROVEMENTS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

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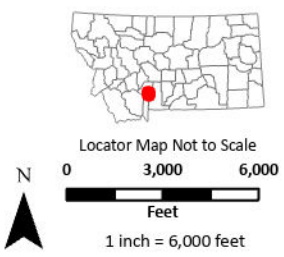


Figure 7-8

UBO WEST SYSTEM WET WEATHER d/D CAPACITY ANALYSIS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

7.5 Summary of Lift Stations and Force Main Improvements

Lift station capacity was set to equal the modeled peak flow and force main sizing was determined based on the velocity criteria discussed in ***Chapter 3***. Proposed lift station locations are the same as the 2015 Facility Plan with the exception of the Baxter Creek Drainage Basin modifications and addition of the Valley Center Lift Station. Table 7-1 provides an overview of lift station capacity analysis and improvements required for Infill, UBO, UBO West, and Increased Density scenarios.

Table 7-2 summarizes the proposed of force main improvements. The following summarizes the lift station improvements:

- **Infill Lift Station Projects:**
  - No new lift station projects are identified to meet infill loading.
  - Valley Center Lift Station: This lift station is currently under design by the City to meet immediate growth needs adjacent to City limits and is included in the Infill Scenario because it is expected to be online soon. This station is modeled with a peak flow of 2,015 gpm. A 14-inch force main will convey wastewater along Valley Center Road to the Davis Lane Interceptor.
- **Improvements to Existing Lift Stations Required for UBO:** The following lift station improvements are required to meet UBO loading:
  - Loyal Garden lift station would reach maximum capacity at UBO conditions with a modeled peak flow to the lift station of 370 gpm. It is recommended that the City continue to monitor growth within the basin and evaluate required capacity when lift station maintenance or improvements projects are implemented.
  - Davis Lane lift station would reach maximum capacity under the UBO conditions. The peak flow is modeled to be in excess of 14,000 gpm which is nearly three times the capacity of the existing station – the lift station was designed to be phased with expansions allowing up to 10,400 gpm while operating 4 duty pumps. In order to achieve 14,000 gpm at UBO, pump and wet well expansions will be required. A third 18-inch force main (parallel to the existing two force mains) is required to convey the UBO peak flow to the WRF.
- **New Lift Stations Required for UBO:** The following is a summary of proposed lift stations to serve the UBO scenario. All of these proposed lift stations, with the exception of the Coulee Drive station, are also recommended in the previous Facility Plan.
  - Coulee Drive lift station is in the far northwest corner of the growth area and will have a peak flow of 2,270 gpm under the UBO scenario. This lift station was not identified in the 2015 Facility Plan because its service area was not within the City's growth boundary. This lift station will require a 14-inch force main conveying wastewater directly to the WRF.

        - Under the UBO-West condition, this lift station will convey wastewater south toward the proposed Frontage Road interceptor rather than the Davis Lane lift station.
    - Spring Hill lift station is in the far north-center area of the collection system and is modeled to have a UBO peak flow of 5,480 gpm. This lift station will require a 21-inch force main conveying wastewater directly to the WRF.
        - Under the UBO-West condition, this lift station could convey wastewater to either the WRF or west to a future gravity main.
    - Gooch Hill lift station in the northwest corner of the growth area and is modeled to have a UBO peak flow of 6,770 gpm. This lift station will require a 24-inch force main conveying wastewater to the Davis Lane lift station.
        - Under the UBO-West condition, this lift station will not be necessary as wastewater can be conveyed northwest via gravity.
    - Hidden Valley lift station is in the northwest corner of the growth area and is modeled to have a UBO peak flow of 2,230 gpm. This lift station will require a 14-inch force main conveying wastewater to the Davis Lane lift station.
        - Under the UBO-West condition, this lift station will not be necessary as wastewater can be conveyed northwest via gravity.
- **UBO West Lift Station Decommissioning:** The following existing lift stations could potentially be decommissioned under the UBO West scenario:
    - Valley Center Lift Station
        - Wastewater flow can be directed westward along Valley Center Road with a 15-inch gravity main.
    - Laurel Glen Lift Station
        - Wastewater flow can be directed northward with a 12-inch gravity main towards the Baxter Lane interceptor.
    - Norton Ranch
        - Wastewater flow can be directed westward with a 15-inch gravity main to the Gooch Hill interceptor.
    - Loyal Garden
        - Wastewater flow can be directed north and westward along Huffine Lane with a 12-inch gravity main to the Gooch Hill interceptor.

Table 7-1: Lift Station Capacity Summary

City Lift Station	Current Firm Capacity (gpm)	Existing Peak Inflow (WWF) (gpm)	Infill Peak Flow (gpm)	UBO Peak Flow (gpm)	UBO West Peak Flow (gpm)	Improvement Type
Baxter Meadows	690	270	450	520	520	
Bridger Center	100	30	20	20	20	
Burrup	450	110	100	140	140	
Cattail Lake	225	20	50	50	50	
Davis Lane	3,000	310	620	**14,040**	Removed	Increase Pump and Wetwell Capacity for Growth
Laurel Glen	450	360	400	400	Removed	
Loyal Gardens	364	180	270	**370**	Removed	Monitor, Rehab for Growth if Needed
Norton Ranch	450	70	**450**	**450**	Removed	Monitor, Rehab for Growth if Needed
Cardinal Distribution[1]	unk	-	-	-	0	
Links	160	30	30	40	40	
MDT	unk	20	20	50	50	
Nelson Meadows	190	80	100	**190**	**190**	
Overbrook	unk	40	40	40	40	
Sebena[1]	none	-	-	-	-	
Walker	unk	40	40	80	80	
Coulee Drive				**2,270**	**2,270**	New for Growth
Spring Hill				**5,480**	**5,480**	New for Growth
Gooch Hill				**6,770**		New for Growth
Hidden Valley				**2,230**		New for Growth
Valley Center (Shallow)[2] (Reduce Hidden Valley by amount)				**1,620**	**-**	New for Growth
Valley Center (Deep)[2] (reduce Hidden Valley by amount)				**2,015**	**2,015**	New for Growth

[1] The Cardinal lift station is not modeled due to lack of information and the Sebena lift station is not in service.
[2] Valley Center Lift Station under preliminary design at the time of this report

Table 7-2: Capacity Force Main

City Lift Station	Existing Force Main (inch)	Velocity at Firm Capacity (ft/s)	Velocity at UBO Flow (ft/s)	Force Main Improvement
Baxter Meadows	12.00	1.96	1.48	
Bridger Center	4.00	2.55		
Burrup	6.00	5.11		
Cattail Lake	6.00	2.55		
Davis Lane	18.00	6.53	**5.90**	Install third parallel 18-inch. (3,700 ft) o
Laurel Glen	8.00	2.87	3.45	
Loyal Gardens	6.00	4.13	6.01	
Norton Ranch	4.00	3.09	3.06	Use existing parallel 6-inch.
Cardinal Distribution[1]				
Links	4.00	4.09		
MDT				
Nelson Meadows	6.00	2.16		
Overbrook				
Sebena[1]				
Walker				
Coulee Drive	14.00		**4.73**	Install 14-inch force main. (17,200 ft)
Spring Hill	21.00		**5.08**	Install 21-inch force main. (12,050 ft)
Gooch Hill	24.00		**4.80**	Install 24-inch force main. (11,200 ft)
Hidden Valley	14.00		**4.65**	Install 14-inch force main. (9,900 ft)
Valley Center (Shallow)[2] (Reduce Hidden Valley by amount)	14.00		**3.38**	Install 14-inch force main. (3,200 ft)
Valley Center (Deep)[2] (reduce Hidden Valley by amount)	14.00		**4.20**	Install 14-inch force main. (3,200 ft)

[1] The Cardinal lift station is not modeled due to lack of information and the Sebena lift station is not in service.
[2] Valley Center Lift Station under preliminary design at the time of this report

7.6 Increased Density Improvements Summary

Figure 7-9 shows areas that experience increased domestic loading based on increased density. Flow increases under this scenario are described in detail in TM 5 and generally follow:

- Existing residential areas with R1 zoning experience increased domestic loading by 25%.
- Future residential growth areas with (Zoned R1, R2, or R3) experience increased domestic loading to the R4 zoning duty factor (20 dwelling units per acre).
- Infill B2-M and REMU zoning was increased to R5 density and its respective duty factor.
- Select areas of varying Zoning and Future Land Use types as identified by the City where increased density development is likely to occur.
- Any future land use within City Limits as identified in the 2020 Community Plan was assigned the duty factor for Urban Neighborhood (~12 dwelling units per acre).

Figure 7-9 presents the d/D as a ratio of maximum depth to full depth for the UBO gravity main network under the increased density modeling scenario. A majority of the network continues to show sufficient capacity to meet the design storm and support the additional density. No manhole surcharging within manholes is modeled within the increased density system with the assumption that the planned UBO recommended improvements are implemented. Figure 7-10 shows the gravity main d/D increase from the UBO scenario to the increased density scenario. Generally, the d/D ratio increases by 0.1 or less for most of the system. The City recognizes that densities beyond those modeled in this scenario may be proposed by developers in the future and should be carefully evaluated on a case-by-case basis using the system-wide model.

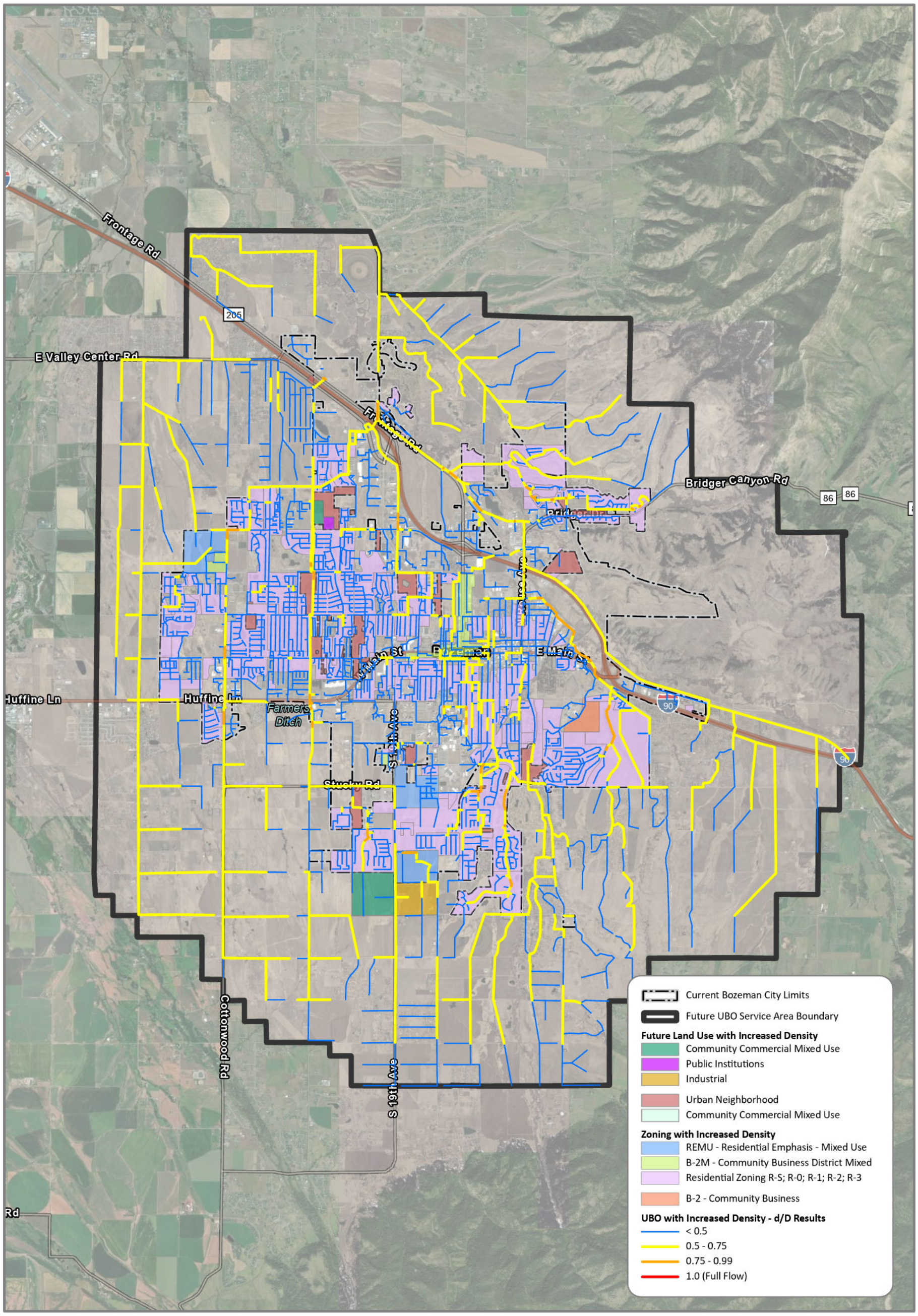
There are three gravity main sections (shown in Figure 7-9) that experience enough increased flow to marginally exceed the City's design d/D of 0.75:

- **Davis Lane / Cottonwood Road Interceptor:** The existing 15-inch trunk sewer on Cottonwood Road just south of Alpha Drive and the existing 18-inch interceptor on Cottonwood Road just north of Babcock Street remain below 0.9 d/D in the UBO conditions. Note that these sewers are new (2019-2020).
- **Front Street Interceptor:** The Front Street Interceptor between the Bozeman Softball Complex through Tamarack Street would experience increased d/D but remain below 0.90 d/D. Note that the portion of the interceptor north of the Haggerty and Main intersection is new (2020) and is an 18 and 21-inch sewer.

- **Highland Glen Sewer Main**: The sewer through the Highland Glen open space between Cherry Drive and Ellis Street is modeled to experience increase d/D but remain below 0.90. This sewer is currently 8 inches, proposed to be upsized to 12- to 15-inch in UBO, and would need to be further upsized under the Increased Density loading to meet the d/D City standards.

While these corridors are shown to have increased flow, the recommendations under the base UBO scenario are believed to be adequate currently. It is recommended that the City continue to monitor these corridors to observe potential increases due to increased density.

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Coordinate System: NAD 1983 UTM Zone 12N | Edited by: DVoeller | C:\Data\Projects\WAFS\B\Bozeman\05097-2018-006\GIS\Bozeman Wastewater Collection Facility Plan - Mapping and Analysis.aprx | TM7 7-9 Increased Density d_D Results

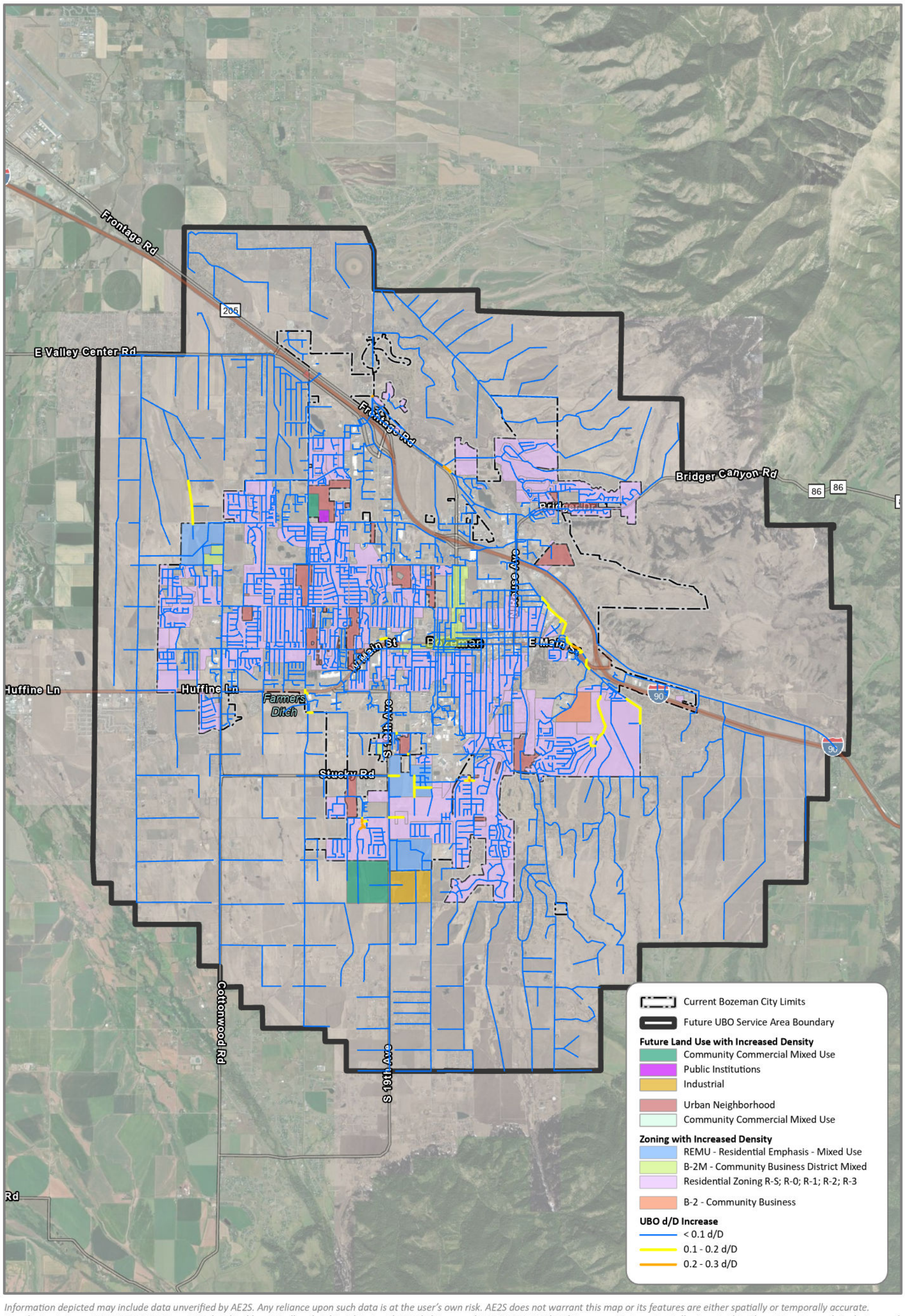


Figure 7-9

INCREASED DENSITY
WET WEATHER d/D CAPACITY ANALYSIS

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024



Information depicted may include data unverified by AE2S. Any reliance upon such data is at the user's own risk. AE2S does not warrant this map or its features are either spatially or temporally accurate.

Coordinate System: NAD 1983 UTM Zone 12N | Edited by: DVoeller | C:\Data\Projects\WAFS\B\Bozeman\05097-2018-006\GIS\Bozeman Wastewater Collection Facility Plan - Mapping and Analysis.aprx | TM7 7-10 d_D Change from UBO to Increased Density

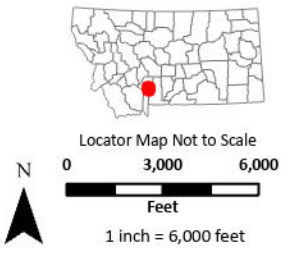


Figure 7-10

INCREASED d/D FROM UBO TO INCREASED DENSITY

WASTEWATER COLLECTION FACILITY PLAN
City of Bozeman | Gallatin County, MT

Date: 9/11/2024

8.0

Risk Assessment Technical Memorandum

Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

Table of Contents

Chapter 1 Risk Assessment Overview 4

1.1 Risk Assessment Framework 4
1.2 Risk Matrix 6
1.3 Likelihood of Failure Criteria and Weighting Factors 7

1.3.1 Pipe Material 7
1.3.2 Hydraulic Model Output – Flow Depth-to-Diameter Ratio (d/D) 8
1.3.3 NASSCO Pipe Ratings 8
1.3.4 Sewer Stoppage 10
1.3.5 Pipe Remaining Useful Life 10
1.3.6 LOF Weighting Factors 11

1.4 Consequence of Failure Criteria and Weighting Factors 11

1.4.2 Pipe Flow 12
1.4.3 COF Weighting Factors 13

Chapter 2 Sewer Main Risk Results 14

2.2 Renewal & Replacement Planning 15

Chapter 3 Sewer Main Capital Replacement Projects 16

3.1 8-inch and Larger Sewer Main Replacement Projects 16

3.1.1 Project 1: 19th Ave / Kagy Blvd Interceptor Improvement (between Kagy and Olive) 17
3.1.2 Project 2: Durston Road and 17th Avenue Sewer Main Replacement 21
3.1.3 Project 3: 7th Avenue to Oak Street Sewer Main Replacement 22
3.1.4 Project 4: North 11th Avenue Sewer Main Replacement 23
3.1.5 Project 5: Plum Avenue Sewer Main Replacement 24
3.1.6 Project 6: 4th Ave., Babcock Street and Grand Avenue Sewer Main Replacement 25
3.1.7 Project 7: North 9th Avenue, West Villard Street, and South 9th Avenue Sewer Main Replacement 27
3.1.8 Project 8: Harrison and 10th Avenue Sewer Main Replacement 29
3.1.9 Project WWIF20: North Frontage Rd Interceptor 30

3.2 6-inch Sewer Main Replacement Projects 31

3.2.1 Likelihood of Failure Criteria and Weighting Factors 31
3.2.2 Consequence of Failure Criteria and Weighting Factors 31
3.2.3 Small Pipe Risk Results 32

3.3 Small Pipe Capital Replacement Projects 33

3.3.1 Small Pipe Project 1: South Black Avenue 6-inch Sewer Main 34

3.3.2 Small Pipe Project 2: South Willson Avenue 6-inch Sewer Main 35
3.3.3 Small Pipe Project 3: South Grand Avenue 6-inch Sewer Main 36
3.3.4 Small Pipe Project 4: West Olive Street 6-inch Sewer Main 37
3.3.5 Small Pipe Project 5: South 4th Avenue 6-inch Sewer Main 38
3.3.6 Small Pipe Project 6: South 3rd Avenue 6-inch Sewer Main 39

Chapter 4 Future Risk Model Updates 41

4.1 GIS Updates 41
4.2 CCTV Updates 43
4.3 Work Order (Sewer Stoppage) Updates 43
4.4 Risk Model Re-Run 43
4.5 Conclusion 44

List of Tables

Table 1-1: Criteria Weighting Factors 6
Table 1-2: Risk Matrix 6
Table 1-3: Risk Category and Response 7
Table 1-4: Pipe Material LOF Scores 7
Table 1-5: d/D LOF Scores 8
Table 1-6: NASSCO LOF Scores 9
Table 1-7: Sewer Stoppage LOF 10
Table 1-8: Pipe Lifespan by Material 11
Table 1-9: RUL LOF Scores 11
Table 1-10: LOF Weighting Factors 11
Table 1-11: Pipe Flow COF Score 13
Table 1-12: COF Weighting Factors 13
Table 2-1: Risk Results by Pipe Diameter 14
Table 2-2: Risk Results by Pipe Material 15
Table 3-1: LOF Criteria Weighting 31
Table 3-2: Small Pipe Risk Results 32

List of Figures

Figure 1-1: Simplified Equation for calculating Asset Risk 4
Figure 3-1: Project 1 Extents (checkered line) 17
Figure 3-2: Project 1 Upsized Pipe Diameters 20
Figure 3-3: Project 2 Extents (checkered line) 21

Figure 3-4: Project 3 Extents (checkered line) 22
Figure 3-5: Project 4 Extents (checkered line) 23
Figure 3-6: Project 5 Extents (checkered line) 24
Figure 3-7: Project 6 Extents (checkered line) 25
Figure 3-8: Project 6 Upsized Pipe Diameters (checkered line) 26
Figure 3-9: Project 7 Extents (checkered line) 27
Figure 3-10: Project 7 Upsized Pipe Diameters (checkered line) 28
Figure 3-11: Project 8 Extents (checkered line) 29
Figure 3-12: Small Pipe Project 1 Extents (checkered line) 34
Figure 3-13: Small Pipe Project 2 Extents (checkered line) 35
Figure 3-14: Small Pipe Project 3 Extents (checkered line) 36
Figure 3-15: Small Pipe Project 4 Extents (checkered line) 37
Figure 3-16: Small Pipe Project 5 Extents (checkered line) 38
Figure 3-17: Small Pipe Project 6 Extents (checkered line) 39
Figure 4-1: Field Mapping for Sanitary Sewer Mains 42

Chapter 1 Risk Assessment Overview

The purpose of this memorandum is to explain the risk assessment performed for the City's sanitary sewer collection system (pipes). Following a methodical risk assessment process results in a documented and consistent method for assessing risk associated with potential sewer system failures. This process is not intended to be a one-time, static approach for assessing sewer system failure risks. It is intended to be updated and refined over time as improvements are conducted and additional data is continually collected.

The sewer system risk assessment includes data made available from the City's GIS geodatabase, hydraulic model results, the City's sewer stoppage history, and CCTV records. InfoAsset Planner® (Version 2023) software is used for development of the risk assessment model. InfoAsset Planner® is a fully GIS integrated water and wastewater infrastructure assessment software application. The risk assessment framework utilized for this project incorporates consequence of failure (COF) and likelihood of failure (LOF) criteria for each asset type to fully understand the components that contribute to asset risk.

1.1 Risk Assessment Framework

The first step of the risk assessment is to select the criteria to be included in the assessment. The risk criteria are grouped into two categories – Consequence of Failure (COF) and Likelihood of Failure (LOF). These two categories form the basis of risk and are important to fully understand how asset risk levels are determined.

Figure 1-1 shows a simplified equation for how risk is calculated for each asset type. It is simplified because it does not show all the specific COF and LOF criteria included when calculating risk. The 'union' symbol between COF and LOF represents the combination of the data sets in both categories; COF and LOF can be multiplied or added together when calculating risk within InfoAsset Planner®. For this assessment, COF and LOF were multiplied together to calculate risk.



Figure 1-1: Simplified Equation for calculating Asset Risk

Consequence of Failure (COF) Criteria

COF is defined as the consequence or impact a system would experience during a negative event (most commonly an infrastructure failure). While all sewer system components are important, some are more critical than others based on a variety of factors including but not limited to customers served, critical facilities, physical location, etc. For example, a 24" interceptor, that provides service to 50% of the customer base is more critical than an 8" collector that only provides service to a few homes. Both sewer system components are important, but the consequence of losing the 24" interceptor versus the 8" collector is much greater. For these reasons, COF criteria were developed in order to understand the consequence magnitude for all sewer system components. For each COF criteria evaluated, a score of 1 to 10 was assigned to each asset with 1 being the lowest consequence of failure, and 10 being the highest consequence of failure.

Likelihood of Failure (LOF) Criteria

LOF is defined as the likelihood or probability that a negative event (most commonly an infrastructure failure; could be either a structural or performance failure) will occur. All sewer system components will eventually experience issues as time progresses. The LOF side of the risk equation provides an understanding of which sewer system assets are most likely to fail and why. By evaluating multiple relevant LOF criteria sets, the approach to determining which assets are most likely to fail is practical and defendable. For each LOF criteria evaluated, a score of 1 to 10 is assigned to each asset with 1 being the lowest likelihood of failure, and 10 being the highest likelihood of failure.

Weighting Factors

Not all criteria for this assessment are considered equal; like sewer system components, some of the COF and LOF criteria developed are more important than others. A workshop was conducted with City staff to determine appropriate weighting factors for the COF and LOF criteria. Weighting factors are applied as multipliers to the criteria score assigned to the asset. For example, if a large diameter sewer pipe received a COF score of 10 for the criteria of pipe diameter, and the criteria weight selected by the City for pipe diameter was 3, the resultant COF score would be 30 (10 x 3 = 30). Weighting factors selected by the City are shown in ***Table 1-1***.

Table 1-1: Criteria Weighting Factors

Criteria Weight	Description
3	Criteria Extremely Critical
2	Criteria with Elevated Criticality
1	Criteria with Normal Criticality

Each of the COF criteria are individually evaluated for all pipes, scores of 1 to 10 are assigned, and weighting factors are applied. The sum of the weighted COF scores is calculated for each pipe. The same procedure is followed for the LOF criteria.

1.2 Risk Matrix

Bi-directional risk grading or a risk matrix is used to segregate assets into brackets of risk based on the City's defined risk parameters. In the bi-directional risk grading approach, the total COF and total LOF scores are considered separately and independently. The brackets are simply divided into thirds based on the distribution of COF and LOF scores. For example, if a sewer pipe was ranked in the top third of all pipes based on COF scores, but only in the middle third of all pipes based on LOF scores, it would land in the medium risk grade following the matrix in ***Table 1-2***. This ensures that an asset does not get flagged for risk driven replacement based on a total risk score alone. To be classified as extreme risk, the pipe must be classified as both a high likelihood and high consequence of failure.

Table 1-2: Risk Matrix

	LOF Low	LOF Medium	LOF High
COF High	Medium	High	Extreme
COF Medium	Low	Medium	High
COF Low	Negligible	Low	Medium

The observant reader will quickly note that the consequence of failure is always going to be high for many pipes, and always going to be low for others based on their location and customers served. This observation is correct. The thought behind the risk grading process is not that every pipe will eventually cycle through the extreme risk grade and be replaced, but rather the extreme risk grade will flag all pipes that the City cannot afford to let fail. It does not mean that other pipes will not age, begin to deteriorate, and need replacement over time. As the highest priority projects are addressed and the City begins to gain a comfort level with their acceptable risk level, the bracket levels in the risk matrix can be adjusted so that projects are more driven by

likelihood of failure, or more driven by consequence of failure depending on the City's risk appetite.

A description of the risk categories and an appropriate risk response is included in ***Table 1-3***.

Table 1-3: Risk Category and Response

Risk Category	Risk Response
Extreme	Include in 5 Year CIP
High	Prioritize for additional inspection. Budget replacement for 20 Year CIP.
Medium	Schedule inspection in <2 years
Low	No Action Required
Negligible	No Action Required

1.3 Likelihood of Failure Criteria and Weighting Factors

The following tables summarize how the pipe LOF criteria are evaluated for the collection system which include:

- Pipe Material
- Hydraulic Model Output – Flow Depth-to-Diameter Ratio (d/D)
- NASSCO Pipe Rating from CCTV
- Pipe Main Repair History
- Pipe Remaining Useful Life

1.3.1 Pipe Material

A common LOF indicator is the material of the pipe. Over the last century, a number of materials have been used to create pipes for use in a sewer system including vitrified clay pipe (VCP), ductile iron (DI), and more recently polyvinyl chloride (PVC). Due to age, fragility, and corrosivity, certain materials last longer than others and are thus given LOF scores that reflect the material's longevity. ***Table 1-4*** details the scores assigned to each pipe material found in the City's sewer system. In the event of a pipe with unknown material, a score of 10 was given to help the City prioritize identifying assets with missing information.

Table 1-4: Pipe Material LOF Scores

Pipe Material	LOF Score
Vitrified Clay Pipe	10
Ductile Iron Pipe	6
Asbestos Cement Pipe	5
PVC Pipe	3
Unknown	10

1.3.2 Hydraulic Model Output – Flow Depth-to-Diameter Ratio (d/D)

This factor uses the maximum flow depth to pipe diameter ratio (d/D) during a 25-year rainfall event under existing flow conditions as produced by the hydraulic model to assess the capacity of the mains to manage base loads and inflow and infiltration (I/I) from a frequent storm event. Risk factors are distinguished by the fullness of a pipe as a percentage modeled under the design event. The highest factor (10) represents a flow condition in a circular conduit where the volumetric efficiency of the conduit to convey flow begins to diminish with increasing depth of flow. This decreased efficiency occurs as water depth in a circular conduit exceeds approximately 85 percent of the pipe diameter. Conservatively, the acceptable d/D ratio before upsizing is recommend for the City is 75 percent of the pipe diameter. Lower risk factors (1-6) represent flow conditions modeled for the design event where the depth of flow is a smaller percentage of total conduit diameter, and hence, has a lower likelihood of having problems conveying the design flow event. ***Table 1-5*** provides the risk categories and scoring based on performance criteria.

Table 1-5: d/D LOF Scores

Hydraulic Model Output Flow Depth to Diameter Ratio (d/D)	LOF Score
>0.75	10
0.5 – 0.75	6
0.3 – 0.49	4
0.1 – 0.29	2
<0.1	1

1.3.3 NASSCO Pipe Ratings

CCTV data along with pipe defect ratings from the National Association of Sewer Service Companies (NASSCO) are used to gauge the current condition of the sewer system. Defects are ranked on a scale of 1 to 5 with 5 being worst-case defects. Two metrics are used two estimate the severity of the pipe conditions, the Pipe Rating Score (PRS) and the Pipe Rating Index (PRI). The PRS is the sum of the structural defect rating component and O&M defect rating component for a given pipe segment. A rating is the sum of the defect occurrences multiplied by the grade of each occurrence. The PRI is the average defect grade of a pipe segment. This is accomplished by dividing the PRS by the total number of defect occurrences in the given pipe segment. Using both metrics of defect analysis allows us to confidently rank potential pipe replacement plans based on severity of occurrence and severity of defect simultaneously.

To ensure pipes with a high PRI are always given priority over pipes with a low PRI and high PRS regardless of PRS, a secondary scoring system is applied that combines the LOFs for both the

PRI and PRS. The resulting "Effective LOFs" assigned to each pipe segment are shown in ***Table 1-6***.

Table 1-6: NASSCO LOF Scores

PRI	PRS	LOF Score
5	> 200	10
	50 - 200	9
	< 50	8
4-5	> 200	8
	50 - 200	7
	< 50	6
3-4	> 200	6
	50 - 200	5
	< 50	4
2-3	> 200	4
	50 – 200	3
	< 50	2
1-2	> 200	2

	50 - 200	1
	< 50	0
< 1	0	0

1.3.4 Sewer Stoppage

Work orders are used to identify which pipe segments caused sewer stoppages over the last 15 years. The more stoppages occurring on a single segment of pipe indicates higher chances that repairs may be required. Thus, the more stoppages along a pipe segment equals a higher LOF score and vice versa. The LOF Scores for Sewer Main repairs can be found in ***Table 1-7***.

Table 1-7: Sewer Stoppage LOF

Sewer Stoppage Count	LOF Score
>4	10
4	8
3	6
2	4
1	2

1.3.5 Pipe Remaining Useful Life

The lifecycle of a pipe is the number of years the pipe can be in operation before recommended replacement. Pipe lifecycles are determined from the material composition of the pipe. The remaining useful life (RUL) of a pipe is calculated by subtracting the age of the pipe (current year minus install year) from the pipe's designated lifecycle.

$$RUL = Lifecycle - (Current\ Year - Install\ year)$$

LOF scores were assigned based on the RUL of each pipe in the sewer system. Pipes with a RUL of less than or equal to zero were given the highest scores to indicate the immediate need of replacement. ***Table 1-8*** provides the lifecycle associated to each pipe material found in the sewer system while ***Table 1-9*** details the LOF score ranges. The lifespan of a pipe is subject to

numerous variables, and no estimate is perfect. Standard estimates provided by the EPA are used for the purposes of this risk assessment.

Table 1-8: Pipe Lifespan by Material

Pipe Material	Lifespan (Years)
Vitrified Clay Pipe	70
Ductile Iron Pipe	100
Asbestos Cement Pipe	70
PVC Pipe	100

Table 1-9: RUL LOF Scores

RUL	LOF Score
0	10
1-10	8
11-20	6
21-30	4
31-50	2
51-100	0

1.3.6 LOF Weighting Factors

LOF criteria and their respective weighting factors for the sewer system are summarized in ***Table 1-10***. The weighting factor is a multiplier for the LOF score of each asset within the respective category. For example, if a pipe received a LOF score of 5 for the pipe material, the multiplier of 4 would be applied and the overall LOF contribution of material for that pipe would be 20 (5 x 4 = 20).

Table 1-10: LOF Weighting Factors

LOF Criteria	Weighting Factor
Pipe Material	1
d/D	3
NASSCO Rating	3
Sewer Stoppage	2
RUL	2

1.4 Consequence of Failure Criteria and Weighting Factors

Initially, the risk model included multiple COF criteria including pipe diameter, proximity to critical facilities, road type, stream crossing, and expansion growth areas. After the first review of the risk results and the sensitivity analysis, it became apparent that the analysis was too heavily dependent on COF criteria and after a workgroup meeting with the City it was decided that

reducing the COF criteria to focus on the core fundamental of pipe flow rates would eliminate the "criteria dilution" previously experienced.

With the COF criteria limited to pipe flow, the analysis currently focuses on pipes with a high likelihood of failure, that also experience elevated flow rates.

1.4.2 Pipe Flow

Results from the hydraulic model are used to assign COF scores based on the maximum flow rate expected under a wet weather flow event. These scores are shown in ***Table 1-11*** where pipes with higher flow rates receive a higher COF score.

Table 1-11: Pipe Flow COF Score

Pipe Flow (gpm)	COF Score
>700	10
500 – 699	9
400 – 499	8
300 – 399	7
200 – 299	6
100 – 199	5
50 – 99	4
<50	3

1.4.3 COF Weighting Factors

Each of the sewer system COF criteria previously explained are assigned a weighting factor, as summarized in ***Table 1-12***. The weighting factor is a multiplier for the COF score of each asset within the respective category. For example, if a pipe received a COF score of 5 for the maximum flow rate, the multiplier of 1 would be applied and the overall COF contribution of flow rate for that pipe would be 5 (5 x 1 = 5).

Table 1-12: COF Weighting Factors

Consequence of Failure Criteria	Weighting Factor
Pipe Flow	1

Chapter 2 Sewer Main Risk Results

The pipe risk results shown by size and risk category are shown in ***Table 2-1***. Additionally, risk results shown by material and risk category are shown in ***Table 2-2***. Overall, approximately 3% of the system pipes fall in the "Extreme" risk category.

Table 2-1: Risk Results by Pipe Diameter

Pipe Diameter (in)	Risk Category by Diameter (Length in Feet)					Total Length (ft)	Percent of System
	Negligible	Low	Medium	High	Extreme		
<=6	20,396	22,917	35,224	13,569	870	92,975	7%
8	630,187	133,350	36,009	20,814	4,316	824,676	66%
10	26,556	26,175	13,212	13,501	3,429	82,872	7%
12	12,408	14,368	19,713	7,812	5,576	59,877	5%
14				5,527	2,212	7,739	1%
15	14,674	4,333	10,204	5,305	3,244	37,760	3%
16	172					172	0.01%
18	5,805	5,200	6,990	14,568	3,075	35,637	3%
20		853	1,133	8,324	10,091	20,401	2%
21	1,708	4,679	18,294		2,532	27,213	2%
24	292	10	19,800	18,056	964	39,122	3%
27	7,340	1,001	4,357			12,698	1%
30	6,892		5,198	1,403	1,724	15,217	1%
Total Length (ft)	**726,430**	**212,885**	**170,132**	**108,879**	**38,033**	**1,256,360**	
Total Length (mi)	**138**	**40**	**32**	**21**	**7**	**238**	
% Of System	**58%**	**17%**	**14%**	**9%**	**3%**		

Table 2-2: Risk Results by Pipe Material

Pipe Diameter (in)	Risk Category by Diameter (Length in Feet)					Total Length (ft)	Percent of System
	Negligible	Low	Medium	High	Extreme		
AC	1,123	4,852	3,111	40,678	18,156	67,920	5%
CMP	385	1,908		1,783	450	4,526	0.4%
DI	4,889		309	230		5,428	0.4%
PVC	719,483	112,390	92,542	19,956	1,380	945,750	75%
VCP	550	93,478	74,171	46,232	18,047	232,479	19%
Total Length (ft)	**726,430**	**212,885**	**170,132**	**108,879**	**38,033**	**1,256,360**	
Total Length (mi)	**138**	**40**	**32**	**21**	**7**	**238**	
% Of System	**58%**	**17%**	**14%**	**9%**	**3%**		

The risk categories should not be viewed as definitive brackets of projects to be addressed in different target years. Everything in the risk analysis needs to be viewed through the lens of "prioritization based on the best available data at the time." As the City continues to complete CCTV inspection, better data will become available and should be used to re-prioritize. The power of InfoAsset Planner is the ability to quickly assimilate new data and update risk analyses and compare and evaluate changes in priorities for future years.

2.2 Renewal & Replacement Planning

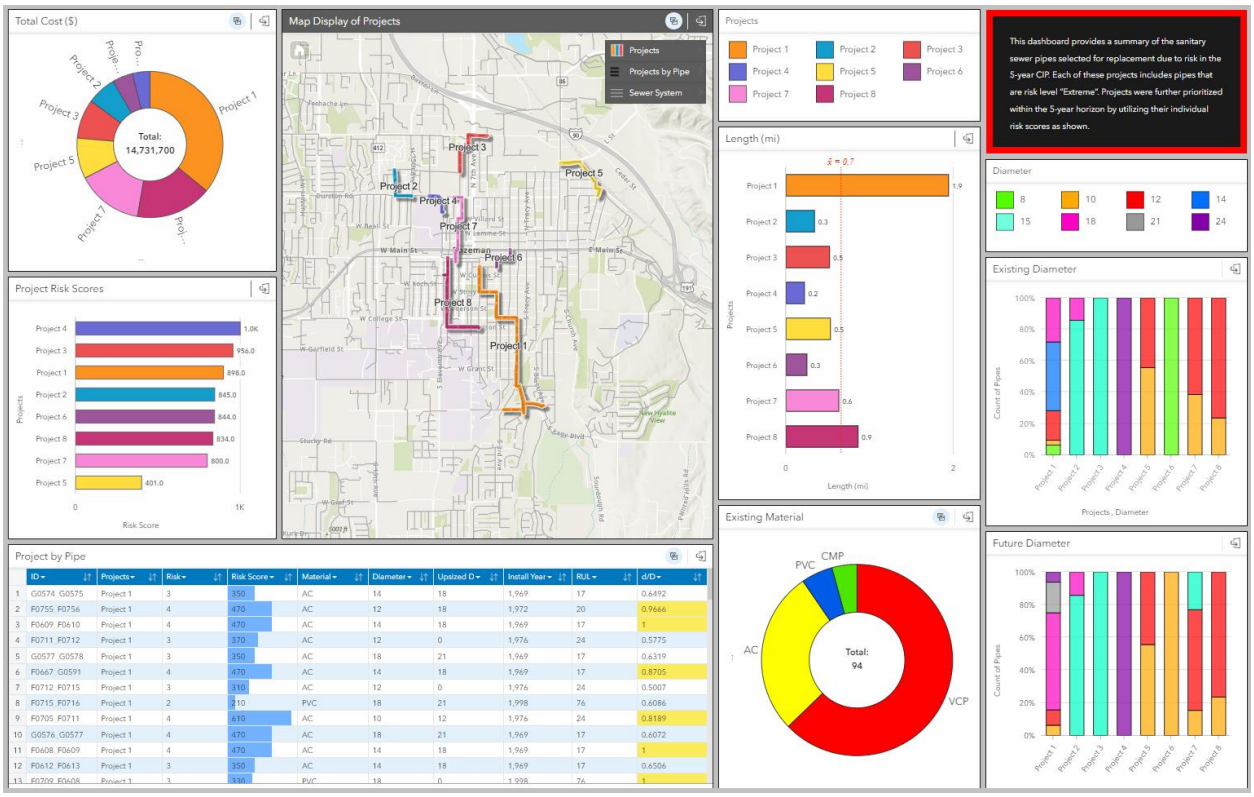
A workshop was held with the City to review the preliminary asset renewal plan, or decision tree. This decision tree provides a way to automate renewal and replacement decisions based on predefined asset condition criteria. Throughout the course of this workshop the City expressed that their experience with pipe rehabilitation activities such as slip lining have not been positive, and at this time the City of Bozeman will only consider full replacement of sewer pipes. This approach eliminates the need for a decision tree to help delineate projects into rehab vs. replacement categories. If at a future date the City decides to consider rehabilitation activities for sewer pipe, the decision tree functionality should be utilized within InfoAsset Planner to help streamline these pipe renewal decisions.

Chapter 3 Sewer Main Capital Replacement Projects

3.1 8-inch and Larger Sewer Main Replacement Projects

With the direction that all pipes needing rehabilitation should be budgeted for full replacement, the pipes with the most extreme risk were assembled into logical project extents and reviewed with City staff. The City's sewer main replacement needs are much more extensive than what can be funded under the current $1 million dollars per year allocated. The City has approved a resolution to increase this budget up to $2.5 million dollars per year. The 5-year sewer pipe replacement program outlined in this memo is based on a budget of $2.5 million dollars per year. An interactive online dashboard detailing the extents, costs, and combined risk scores of these projects can be found at the link below:

ArcGIS Insights CIP Dashboard



The following sections describe the extents of the replacement projects, as well as the factors that caused these projects to be ranked as extreme risk in the analysis.

3.1.1 Project 1: 19th Ave / Kagy Blvd Interceptor Improvement (between Kagy and Olive)

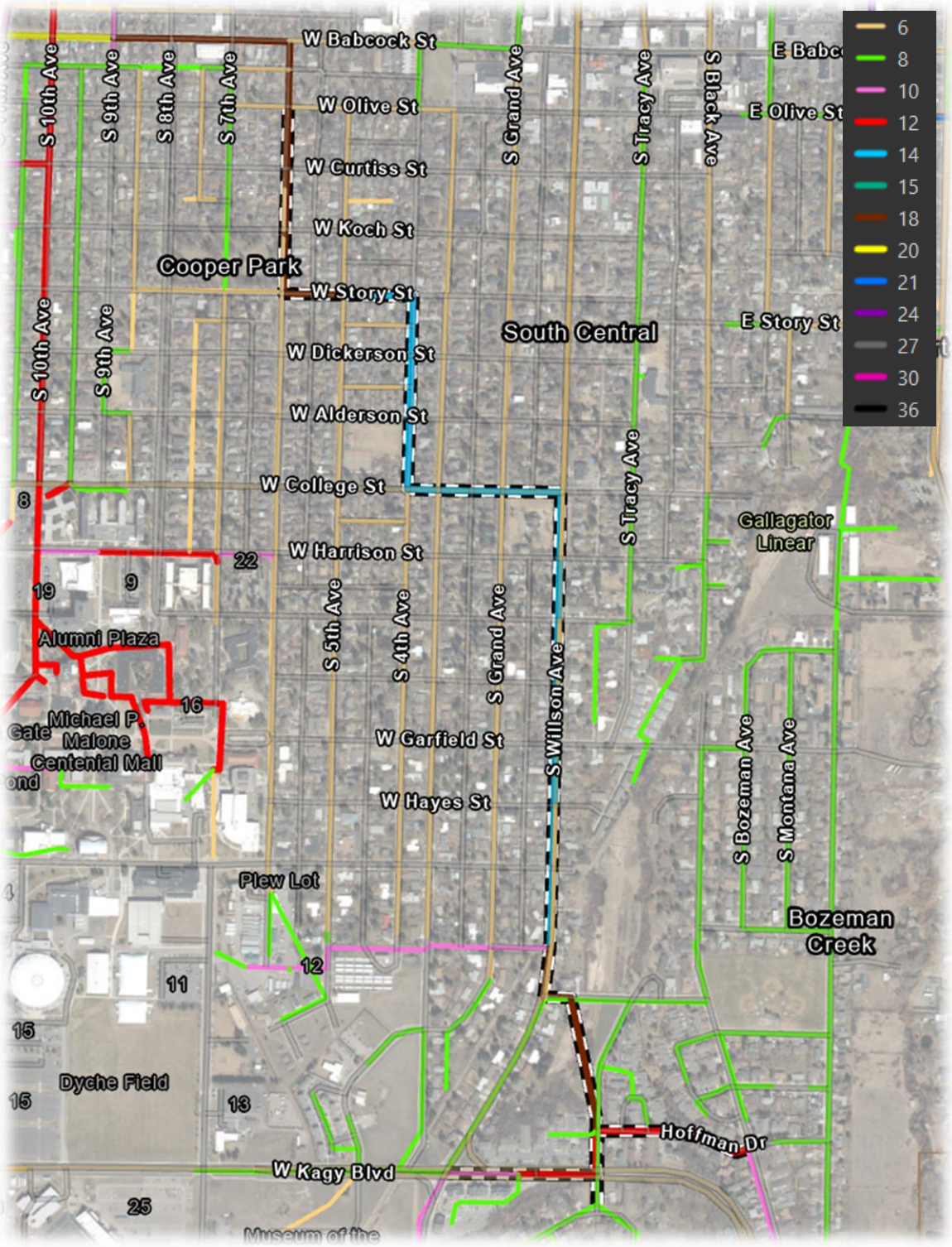


Figure 3-1: Project 1 Extents (checkered line)

A critical section of sewer main begins on Kagy Blvd and Hoffman Drive as a 10-inch diameter AC line, and runs north through the park to Mason Street, and continues north on Wilson Ave., west on College Street, north on 4th Ave., west on Story Street, and finally north on 6th Ave. By the time this sewer main reaches Olive Street it is an 18-inch diameter pipe. This is shown with a checkered line in ***Figure 3-1***.

This project is recommended for replacement (and upsizing) due to the following risk factors:

- d/D criteria of 75% is exceeded for much of the pipe in this critical sewer main, indicating additional flow capacity is needed.
- The majority of this pipe was installed in the late 60's and early 70's. AC pipe typically has a lifespan of around 70 years, but CCTV data indicates the condition of portions of this pipe are not in great condition. There are also portions of PVC installed in the late 90's running through the park. This section of pipe is included in the project due to the additional needed flow capacity.
- As a critical sewer main, the flow in these pipes exceeds 2,400 gpm under wet weather conditions.

The recommended pipe diameters to be installed for this project are shown in

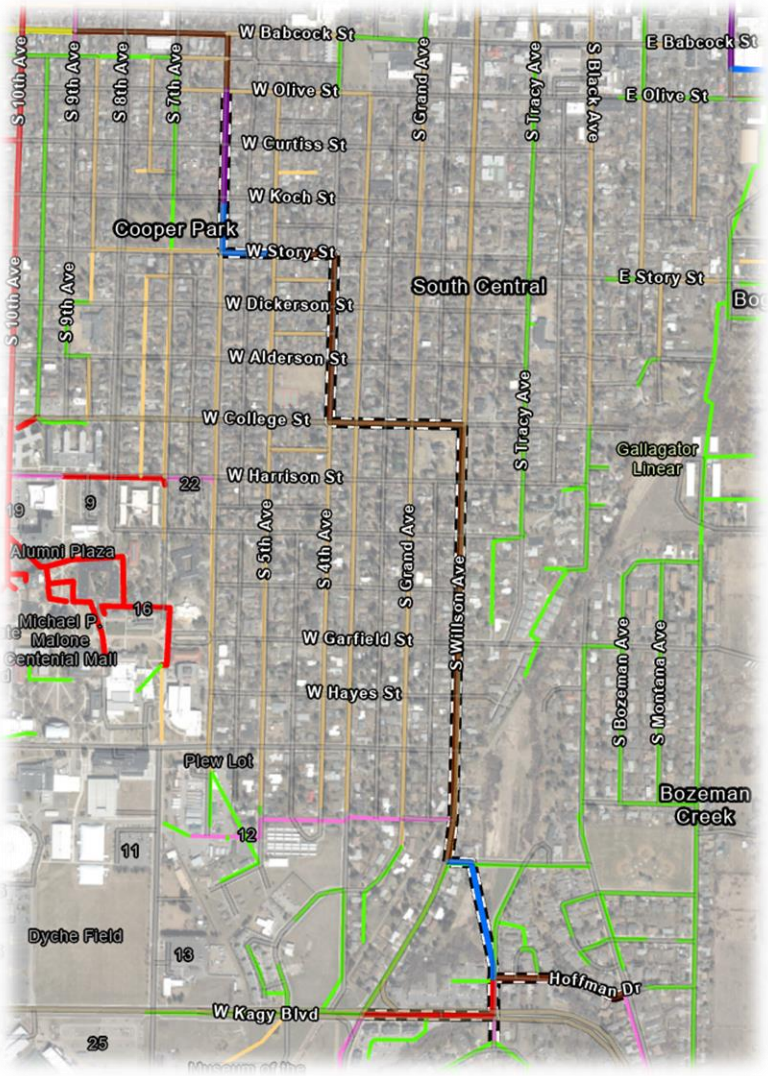


Figure 3-2.

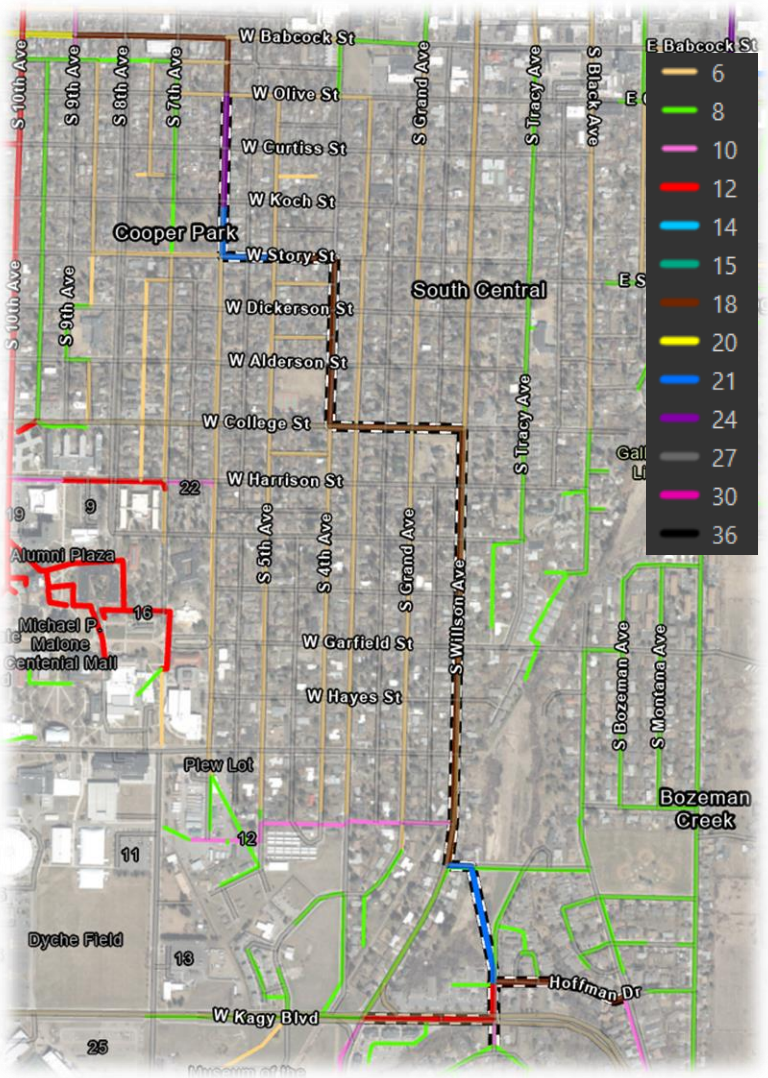


Figure 3-2: Project 1 Upsized Pipe Diameters

3.1.2 Project 2: Durston Road and 17th Avenue Sewer Main Replacement

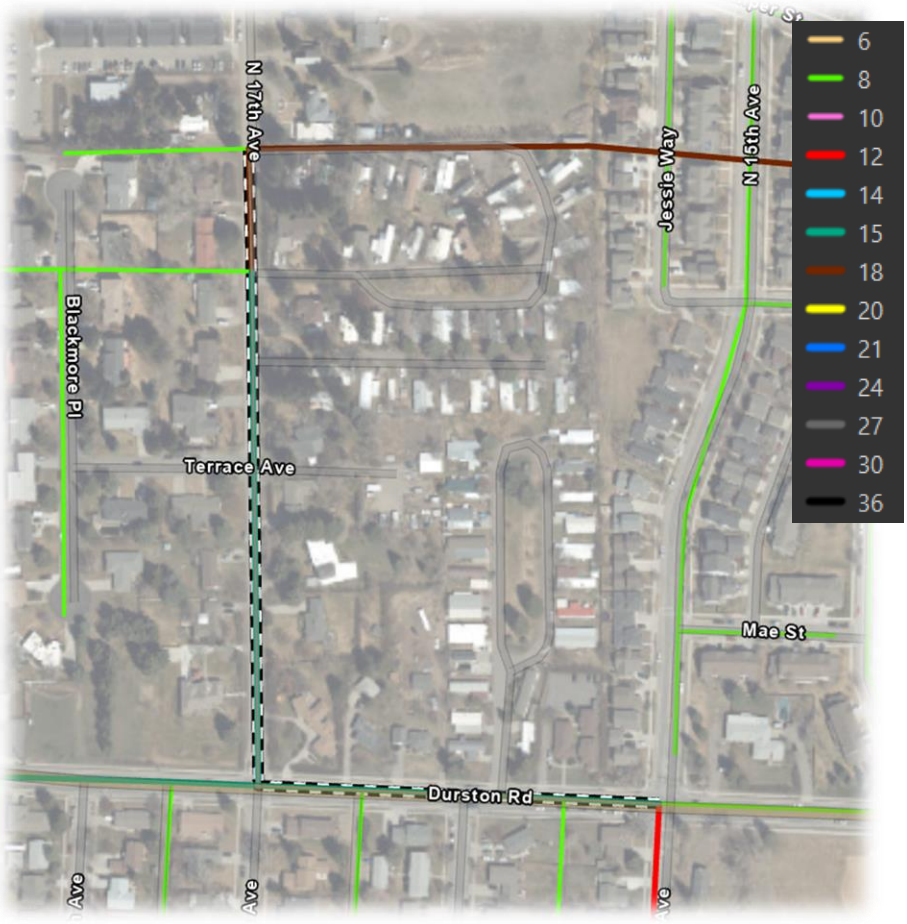


Figure 3-3: Project 2 Extents (checkered line)

A 15-inch sewer main running west along Durston Road, turns north on 17th Ave. and becomes an 18-inch sewer main. This project is recommended for replacement due to the following risk factors:

- These VCP pipes were installed in the early 60's and are near the end of their useful life.
- CCTV data indicates significant pipe defects in portions of this corridor.
- As a critical sewer main, the flow in these pipes exceeds 1,000 gpm under wet weather conditions.

3.1.3 Project 3: 7th Avenue to Oak Street Sewer Main Replacement

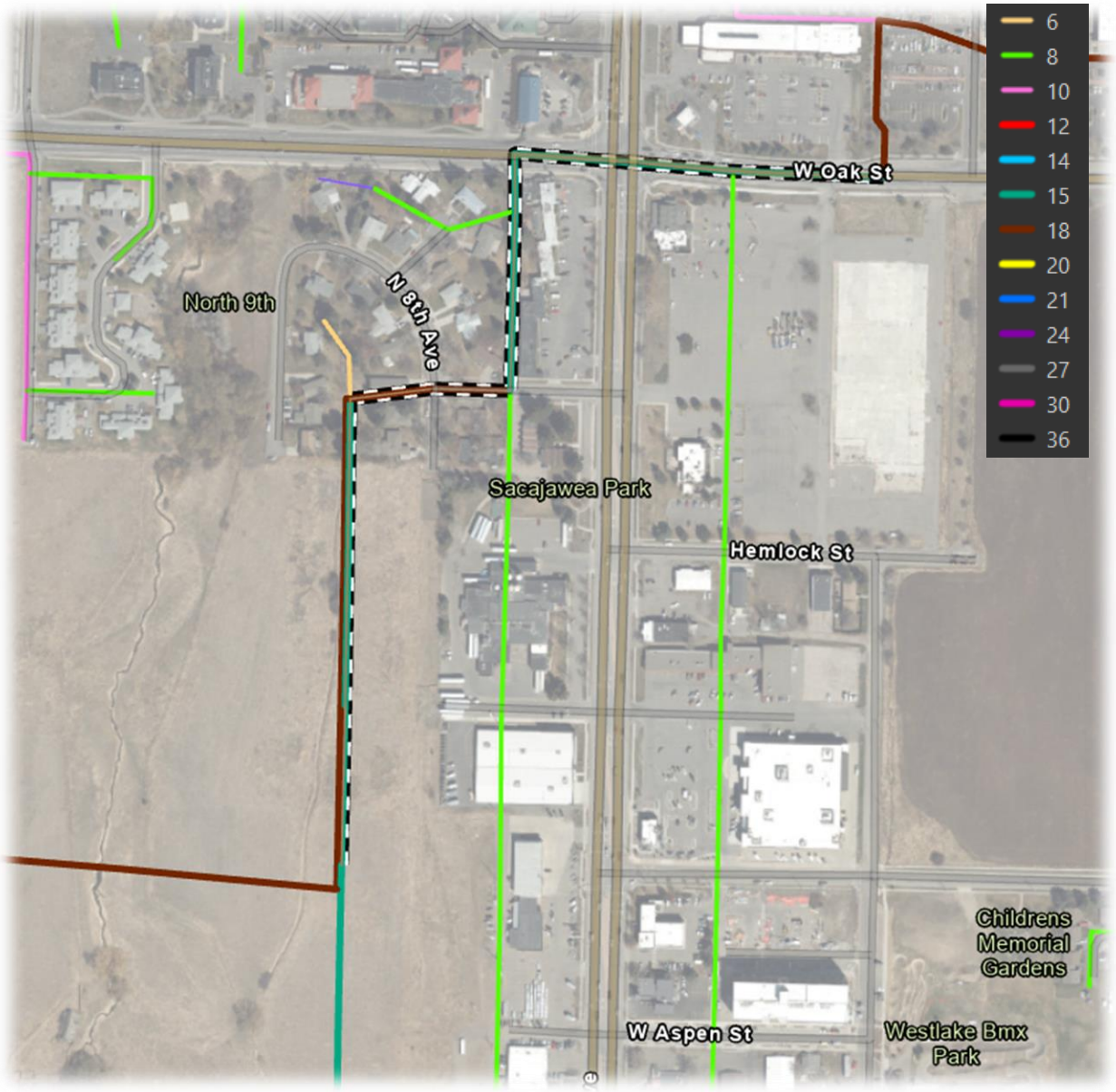


Figure 3-4: Project 3 Extents (checkered line)

A 15-inch sewer main running north in the fields west of 7th Avenue turns east on Birch Street and becomes an 18-inch main. Just before reaching 7th Avenue, the 18-inch main turns north until it intersects Oak Street. This project continues along Oak Street until approximately 5th Avenue.

This project is recommended for replacement due to the following risk factors:

- These VCP pipes were installed in the early 50's and have reached the end of their useful life.

- CCTV data indicates several pipe defects throughout portions of this corridor.
- As a critical sewer main, the flow in these pipes exceeds 1,100 gpm under wet weather conditions.

3.1.4 Project 4: North 11th Avenue Sewer Main Replacement

On the west side of 11th Avenue immediately north of the High School, a 24-inch sewer main wraps around the corner of Durston Road to the west until approximately Oaks Park Drive.

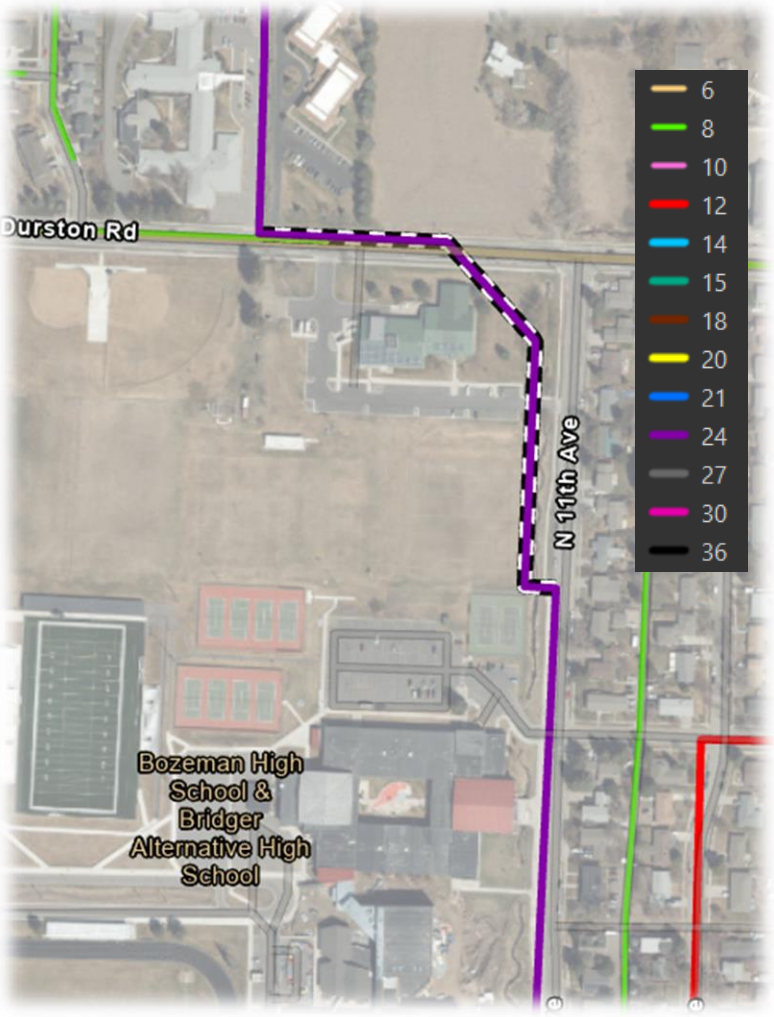


Figure 3-5: Project 4 Extents (checkered line)

This project is recommended for replacement due to the following risk factors:

- These VCP pipes were installed in the late 60's and are nearing the end of their useful life.
- CCTV data indicates severe pipe defects throughout portions of this corridor, particularly in front of the High School.
- As a critical sewer main, the flow in these pipes exceeds 3,100 gpm under wet weather conditions.

3.1.5 Project 5: Plum Avenue Sewer Main Replacement

This project begins at the intersection of Plum Avenue and Peach Street with a 10-inch main running north along Plum Avenue. The main continues up Plum Avenue and becomes a 12-inch diameter at the intersection of Tamarack Street. The project extends along Juniper Street to the intersection of Rouse Avenue.

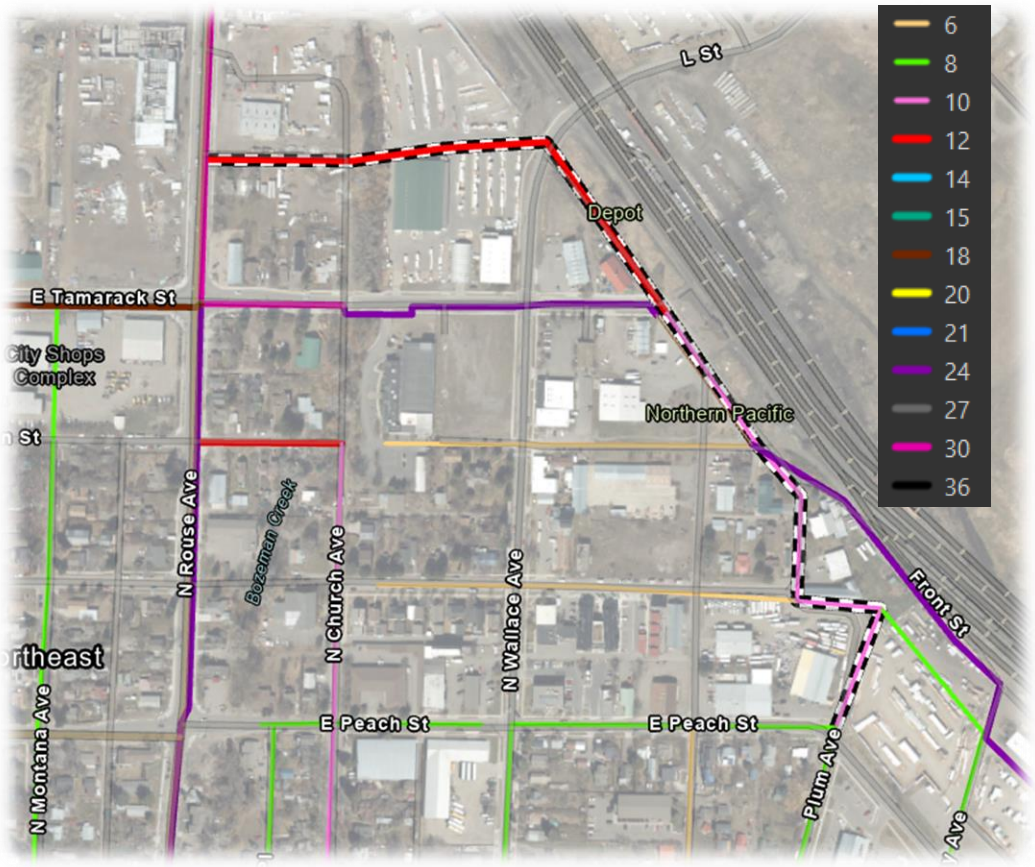


Figure 3-6: Project 5 Extents (checkered line)

This project is recommended for replacement due to the following risk factors:

- These VCP pipes were installed in the late 1930's, making these pipes overdue for replacement based on their expected useful life.
- CCTV data indicates several pipe defects throughout portions of this corridor.
- This project is less of a critical sewer main than most of the recommended projects in this assessment, however the wet weather flow still exceeds 200 gpm.

3.1.6 Project 6: 4th Ave., Babcock Street and Grand Avenue Sewer Main Replacement

This project includes the replacement and upsizing of the 8-inch main which starts at the corner of Olive Street and 4th Avenue, extends north along 4th Avenue to Babcock Street, follows Babcock Street to Grand Avenue, and wraps up to Main Street (see ***Figure 3-7***).



Figure 3-7: Project 6 Extents (checkered line)

This project is recommended for replacement due to the following risk factors:

- These VCP mains were installed in 1903, making them well past their expected lifespan and overdue for replacement.
- d/D criteria of 75% is exceeded for much of the pipe in this main, indicating additional flow capacity is needed.
- CCTV data indicates several pipe defects throughout portions of this corridor.
- This project is less of a critical sewer main than most of the recommended projects in this assessment, however the wet weather flow still exceeds 500 gpm.

The recommended pipe diameters to be installed for this project are shown in ***Figure 3-8***.

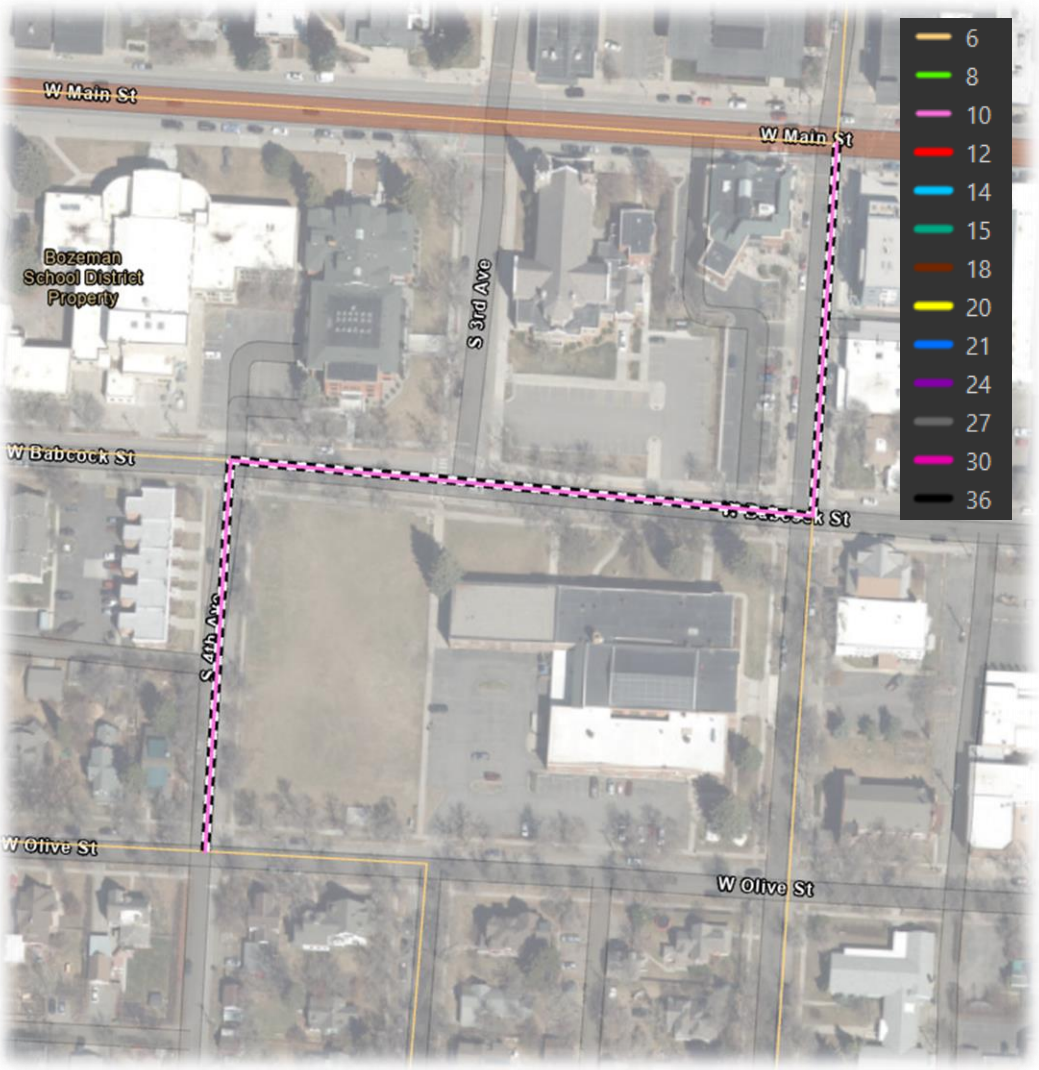


Figure 3-8: Project 6 Upsized Pipe Diameters (checkered line)

3.1.7 Project 7: North 9th Avenue, West Villard Street, and South 9th Avenue Sewer Main Replacement

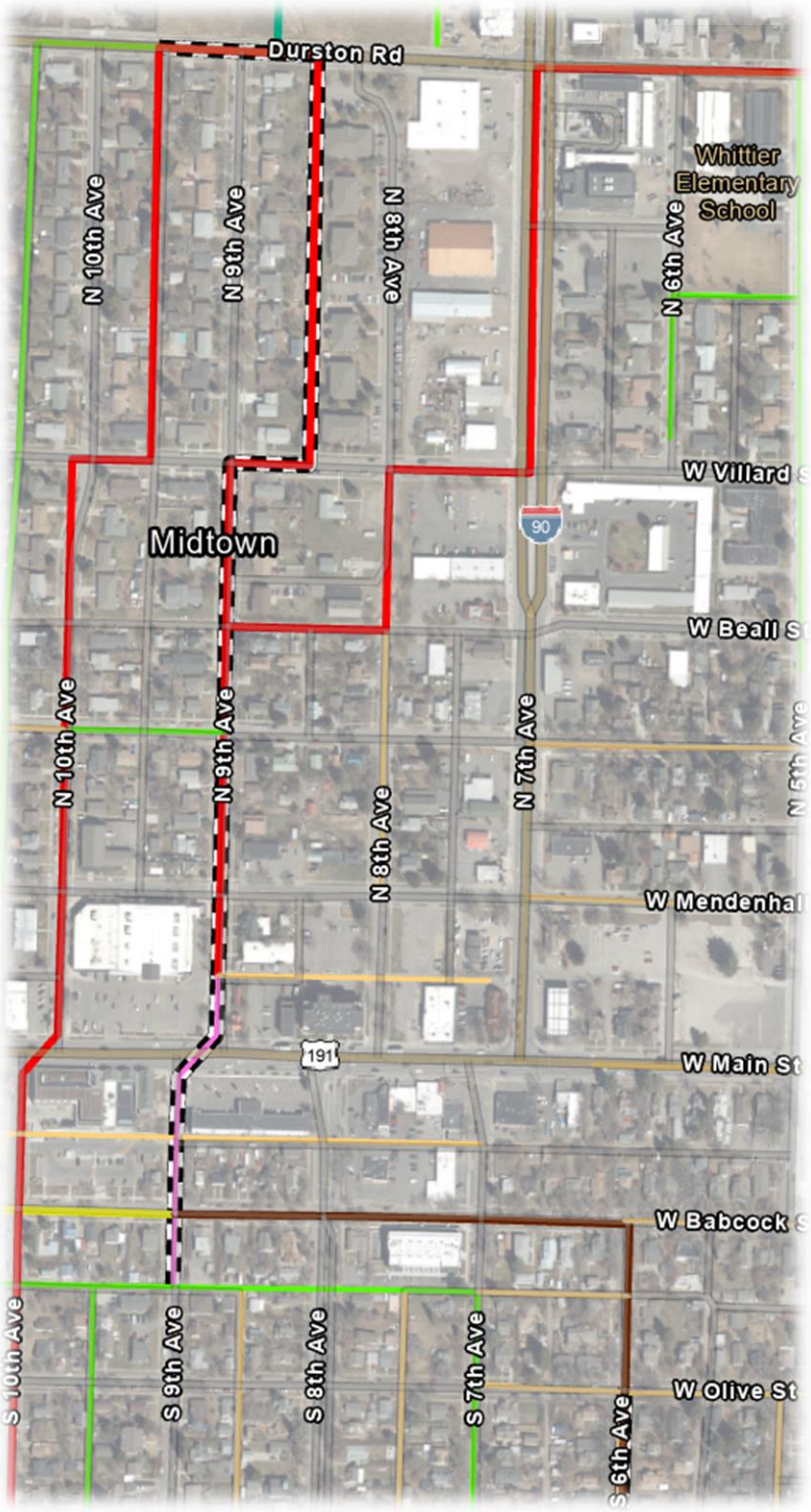


Figure 3-9: Project 7 Extents (checkered line)

This project includes the replacement of the 10-inch main that starts on South 9th Avenue just south of Babcock Street. It continues to Willard Street, where it jogs east then north through the alley where it continues to Durston Road. 370 feet of the 10-inch needs to be upsized to a 15-inch main. Further north, the slope increases and the pipe can be replaced with a 12-inch diameter for the remainder of the project. This project is recommended for replacement due to the following risk factors:

- These VCP mains were installed in between 1917 and 1952, making them well past their expected lifespan and overdue for replacement.
- d/D criteria of 75% is exceeded for a small portion of the pipe in this main, indicating additional flow capacity is needed.
- CCTV data indicates several pipe defects throughout portions of this corridor.
- This project is less of a critical sewer main than most of the recommended projects in this assessment, however the wet weather flow still exceeds 600 gpm.

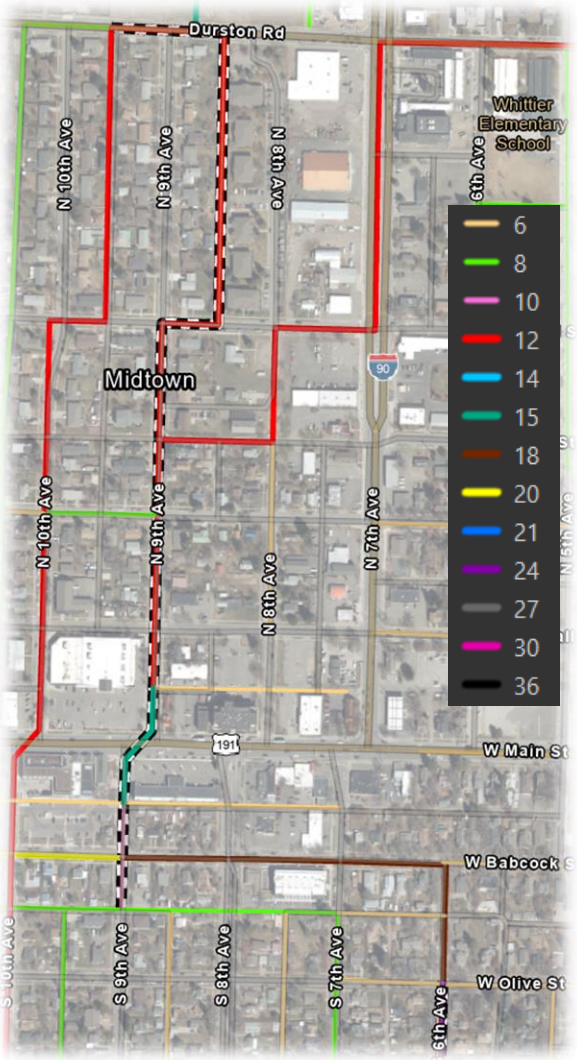


Figure 3-10: Project 7 Upsized Pipe Diameters (checkered line)

3.1.8 Project 8: Harrison and 10th Avenue Sewer Main Replacement

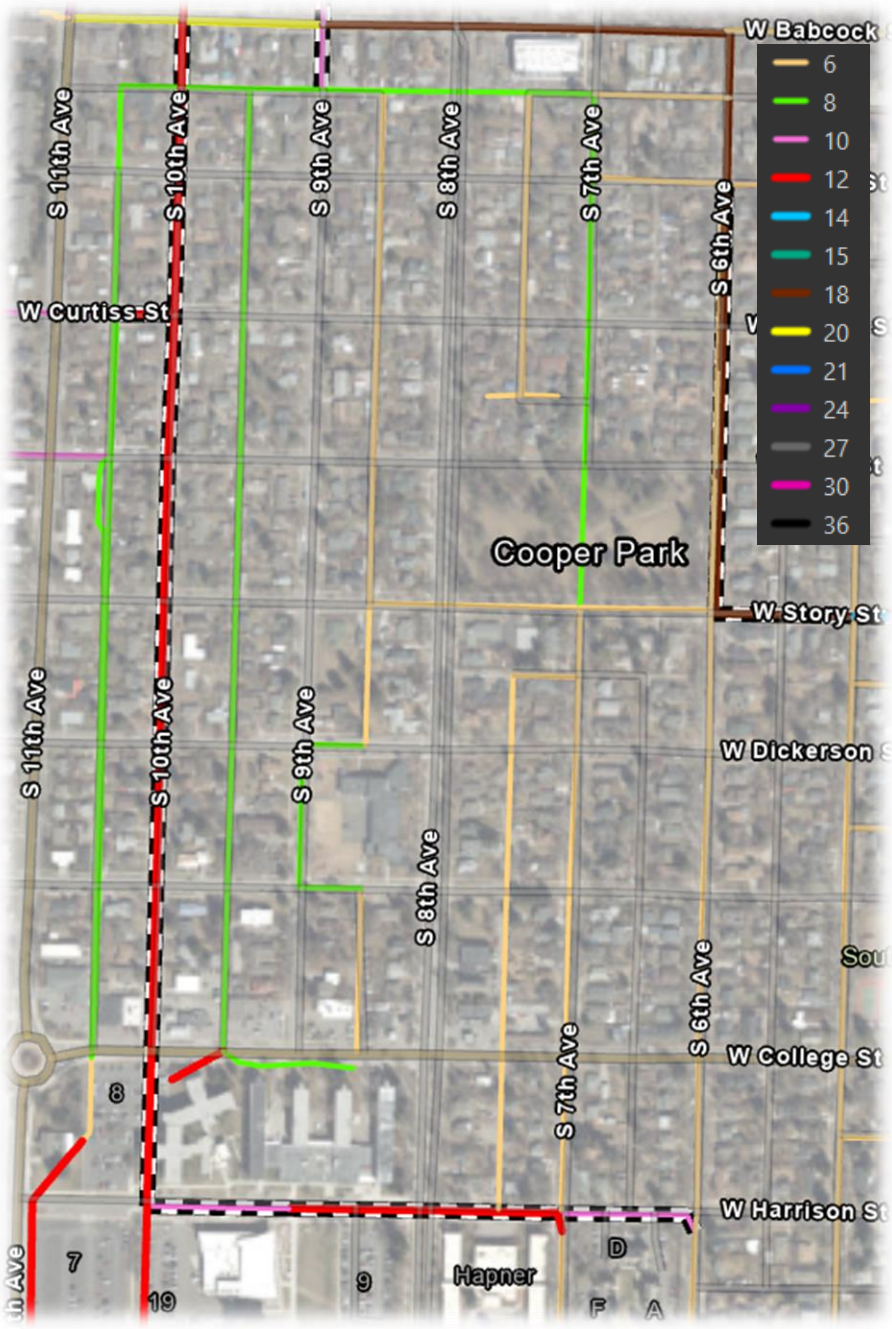


Figure 3-11: Project 8 Extents (checkered line)

This project includes the replacement of the 10-inch main that starts at the corner of Harrison Street and 6th Avenue and runs west to 10th Avenue. Roughly half of this stretch is 12-inch diameter and should be replaced with 12-inch. From there the project extends north to Babcock Street replacing the 12-inch main. A small segment of 12-inch main on Curtis Street is also included. This project is recommended for replacement due to the following risk factors:

- These VCP mains were installed in 1954, placing them at the end of their expected lifespan and due for replacement.
- CCTV data indicates several pipe defects throughout portions of this corridor.
- This project is less of a critical sewer main than most of the recommended projects in this assessment, however the wet weather flow still exceeds 1,300 gpm.

3.1.9 Project WWIF20: North Frontage Rd Interceptor

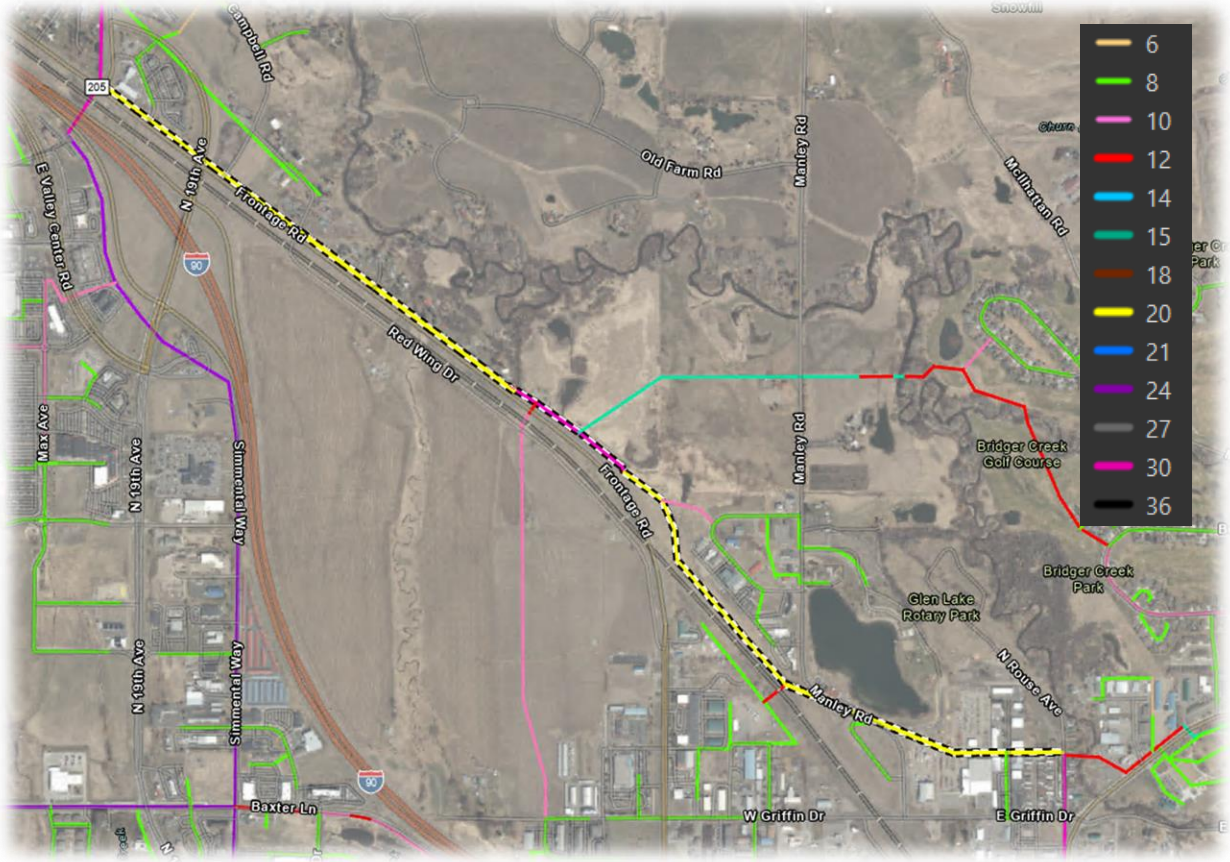


Figure 3-11: Project WWIF20 North Frontage Rd Interceptor (checkered line)

- As a critical sewer main, the flow in several of the pipes exceeds 3,100 gpm under wet weather conditions.
- d/D criteria of 75% is exceeded for much of the pipe in this critical sewer main, indicating additional flow capacity is needed.
- Average RUL of the pipes is around 15 years as of the date of this report.

3.2 6-inch Sewer Main Replacement Projects

In addition to the risk assessment performed over the entire wastewater system, a secondary risk assessment was performed on pipe segments that were 6-inches or less in diameter whose material is VCP. These pipes, designated as Small Pipes in this document, were identified and analyzed for their risk to the City. The second assessment was needed due to the grading system used in the wastewater system risk assessment. In the wastewater system risk assessment, priority is given to pipes of higher flows, which results in smaller sized pipes receiving less severe risk grading regardless of their LOF factors. Performing a separate risk assessment on smaller diameter pipes ensures all necessary projects and improvements are captured.

3.2.1 Likelihood of Failure Criteria and Weighting Factors

LOF criteria for the Small Pipe Risk Analysis are adopted from the Wastewater System Risk Analysis, excluding LOF for pipe material. No changes were made to the scoring systems for the LOF criteria, however, the weighting factors for the LOF Criteria were adjusted to provide higher accuracy.

Table 3-1: LOF Criteria Weighting

Likelihood of Failure Criteria	Weighting Factor
RUL	2
Wet-Weather Depth-to-Diameter Ratio	1
NASSCO Pipe Ratings	3
Pipe Main Repair	2

3.2.2 Consequence of Failure Criteria and Weighting Factors

COF criteria for the Small Pipe Risk Analysis were also adopted from the Wastewater System Risk Analysis. The COF Criteria of Pipe Flow was given a weighting factor of **1**. No changes were made to the scoring system for the Pipe Flow criteria.

3.2.3 Small Pipe Risk Results

The pipe risk results shown by size and risk category are shown in ***Table 3-2.***

Table 3-2: Small Pipe Risk Results

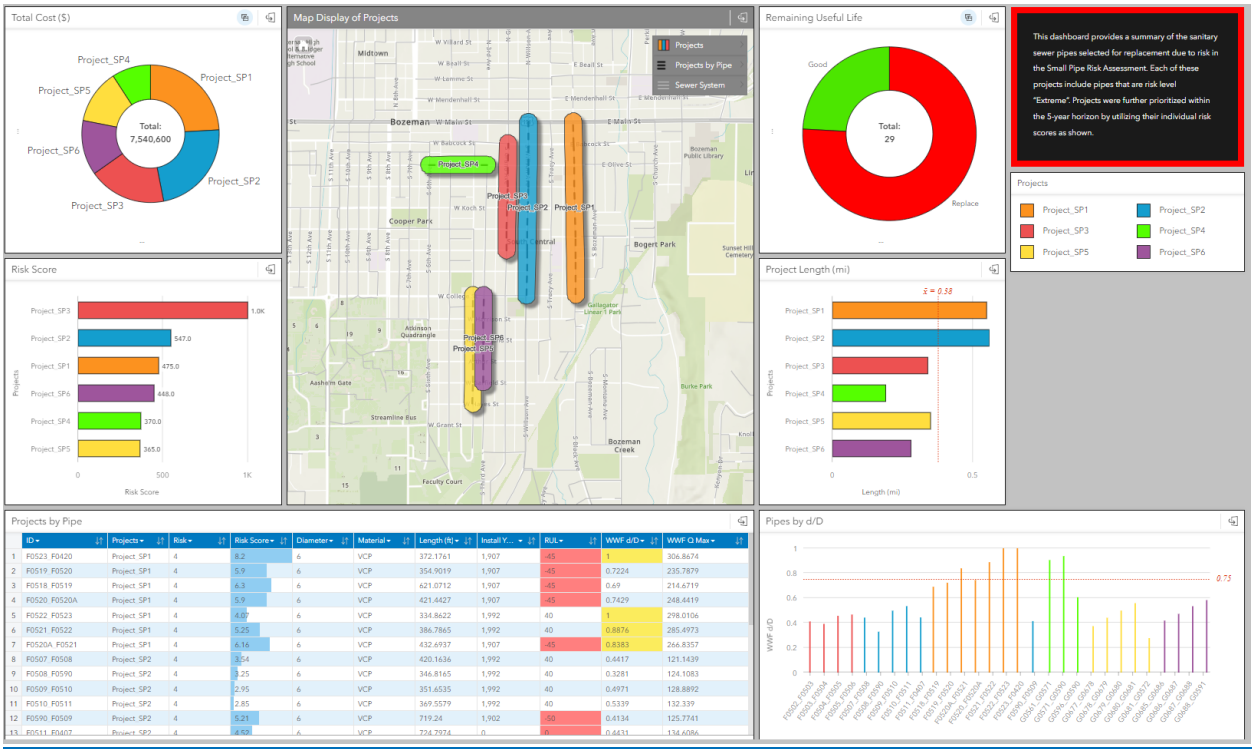
Pipe Diameter (in)	Risk Category by Diameter (Length in Feet)					Total Length (ft)
	Negligible	Low	Medium	High	Extreme	
<=6	2,665	4,925	36,116	10,977	15,940	70,623

3.3 Small Pipe Capital Replacement Projects

The results of the small pipe risk assessment are used to identify key projects to replace small, old VCP pipes within the system. Pipes that fell within the "Extreme" and "High" risk category rankings were deemed eligible for projects.

Once projects were identified, a process of elimination began that took into consideration City budgetary constraints and removed projects that overlapped with preexisting projects. After the process of elimination, six small pipe projects were identified. For a comprehensive breakdown of each project, visit the interactive dashboard found here:

ArcGIS Insights Small Pipe Dashboard



The following sections describe the extents of the small pipe replacement projects, as well as the factors that caused these projects to be flagged as extreme risk in the analysis.

3.3.1 Small Pipe Project 1: South Black Avenue 6-inch Sewer Main

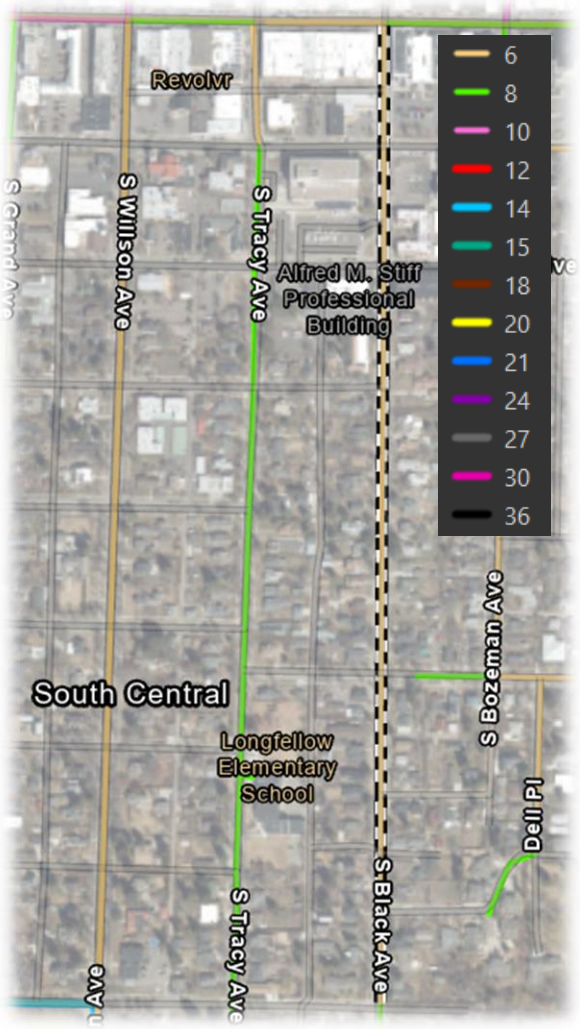


Figure 3-12: Small Pipe Project 1 Extents (checkered line)

This project includes the replacement of the 6-inch main on South Black Avenue with an 8-inch PVC pipe from W Main St to E College St. This pipe is recommended for replacement due to the following risk factors:

- This section of VCP main was installed in 1907, placing it at the end of its expected lifespan and due for replacement.
- d/D criteria of 75% is exceeded for a portion of the pipe in this main, indicating additional flow capacity is needed.
- This project is less of a critical sewer main than most of the recommended projects in this assessment, however the wet weather flow still exceeds 300 gpm.
- These combined risk factors make this a segment of pipe the City should prioritize for replacement.

3.3.2 Small Pipe Project 2: South Willson Avenue 6-inch Sewer Main

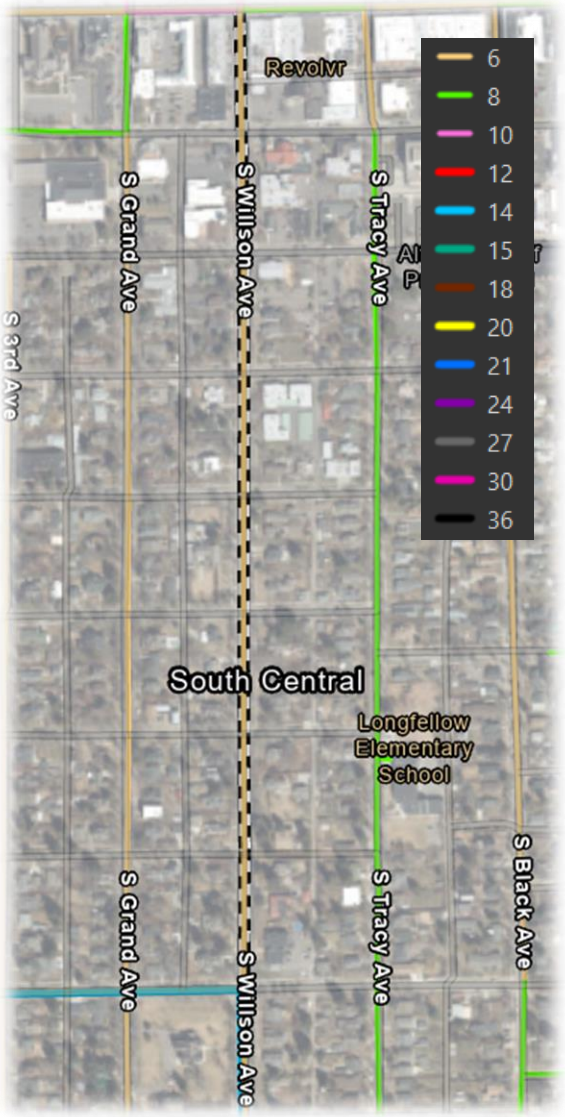


Figure 3-13: Small Pipe Project 2 Extents (checkered line)

This project includes the replacement of the 6-inch main on South Willson Avenue with an 8-inch PVC pipe from W Main St to W College St. This pipe is recommended for replacement due to the following risk factors:

- This section of VCP main was installed in 1902, placing it at the end of its expected lifespan and due for replacement.
- CCTV data indicates several pipe defects throughout portions of this corridor.
- These combined risk factors make this a segment of pipe the City should prioritize for replacement.

3.3.3 Small Pipe Project 3: South Grand Avenue 6-inch Sewer Main

This project includes the replacement of the 6-inch main on South Grand Avenue with an 8-inch PVC pipe from W Babcock St to W Dickerson St. This pipe is recommended for replacement due to the following risk factors:

- This section of VCP main was installed in 1902, placing it at the end of its expected lifespan and due for replacement.
- CCTV data indicates several pipe defects throughout portions of this corridor.
- These combined risk factors make this a segment of pipe the City should prioritize for replacement.

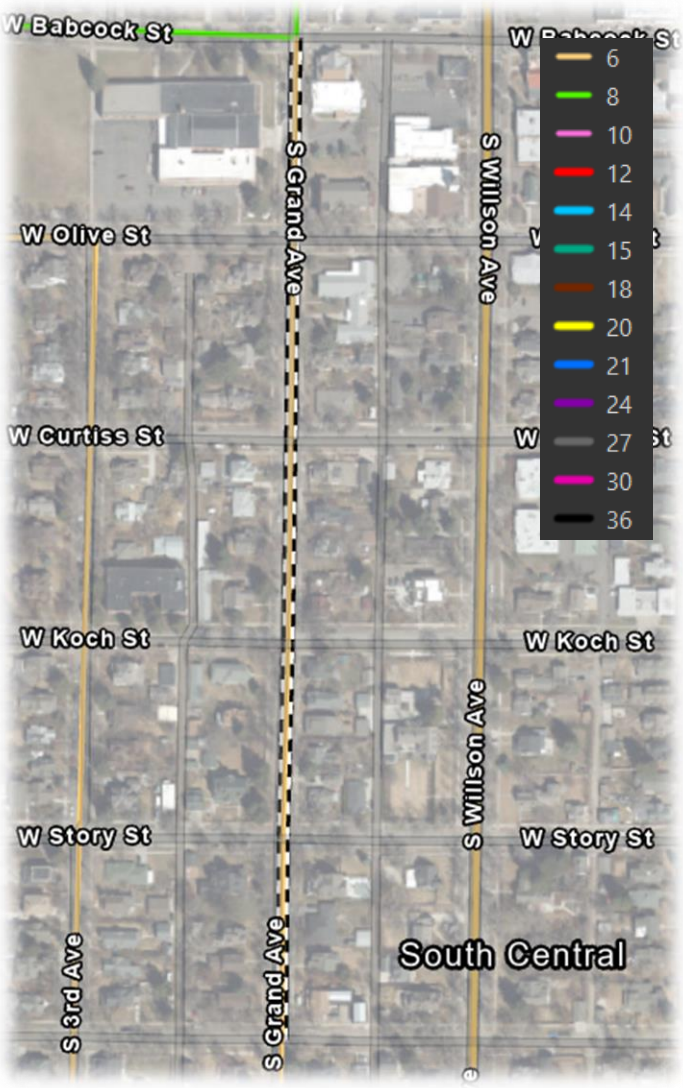


Figure 3-14: Small Pipe Project 3 Extents (checkered line)

3.3.4 Small Pipe Project 4: West Olive Street 6-inch Sewer Main



Figure 3-15: Small Pipe Project 4 Extents (checkered line)

This project includes the replacement of the 6-inch main on South Grand Avenue with an 8-inch PVC pipe along S 6th Ave and Olive Street to S 3rd Ave. This pipe is recommended for replacement due to the following risk factors:

- This section of VCP main was installed in 1917, placing it at the end of its expected lifespan and due for replacement.
- d/D criteria of 75% is exceeded for a portion of the pipe in this main, indicating additional flow capacity is needed.
- This project is less of a critical sewer main than most of the recommended projects in this assessment, however the wet weather flow still exceeds 250 gpm.
- These combined risk factors make this a segment of pipe the City should prioritize for replacement.

3.3.5 Small Pipe Project 5: South 4th Avenue 6-inch Sewer Main

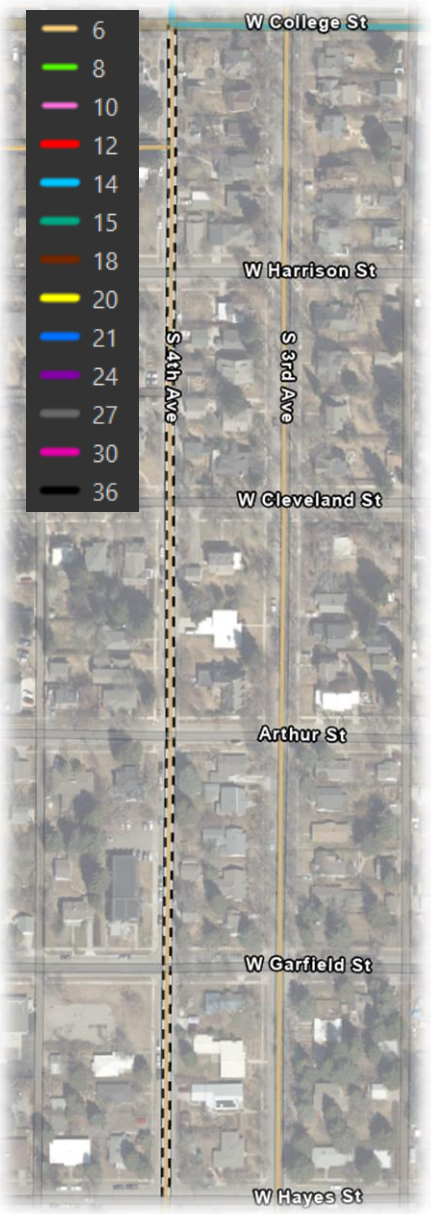


Figure 3-16: Small Pipe Project 5 Extents (checkered line)

This project includes the replacement of the 6-inch main on South 4th Ave with an 8-inch PVC pipe from W College St to W Hayes St. This pipe is recommended for replacement due to the following risk factors:

- This section of VCP main was installed in 1927, placing it at the end of its expected lifespan and due for replacement.
- This pipe has had multiple sewer stoppage reports recorded throughout its life.

- CCTV data indicates several pipe defects throughout portions of this corridor.
- These combined risk factors make this a segment of pipe the City should prioritize for replacement.

3.3.6 Small Pipe Project 6: South 3rd Avenue 6-inch Sewer Main

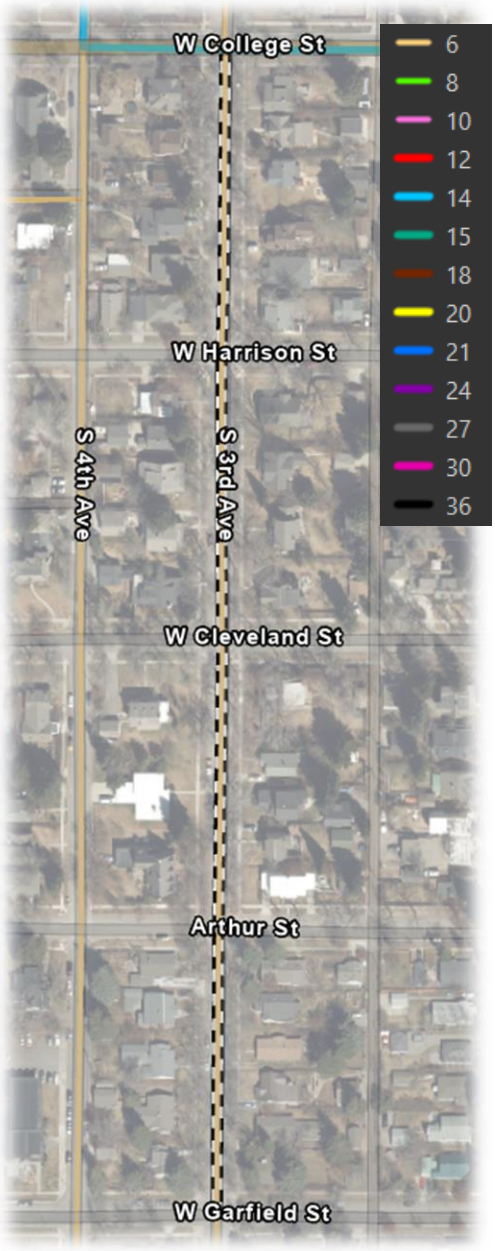


Figure 3-17: Small Pipe Project 6 Extents (checkered line)

This project includes the replacement of the 6-inch main on South 3rd Ave with an 8-inch PVC pipe from W College St to W Garfield St. This pipe is recommended for replacement due to the following risk factors:

- This section of VCP main was installed in 1907, placing it at the end of its expected lifespan and due for replacement.
- d/D criteria of 75% is exceeded for a portion of the pipe in this main, indicating additional flow capacity is needed.
- This project is less of a critical sewer main than most of the recommended projects in this assessment, however the wet weather flow still exceeds 110 gpm.
- These combined risk factors make this a segment of pipe the City should prioritize for replacement.

Chapter 4 Future Risk Model Updates

As mentioned previously in this report, the risk analysis results must be viewed as prioritization based on the best available data at the time. To get the most value out of the risk model, as the City continues to complete CCTV inspections, routine maintenance, and updates of GIS records, the risk model should be updated. There is not a prescribed frequency for incorporating these updates into the risk model, but a good practice would be to complete these updates on an annual basis. This helps ensure that valuable data does not get overlooked and omitted from the risk analysis.

If data collection standards are maintained and followed, updating the risk model is a very simple and straightforward process. The following paragraphs summarize the steps to be taken to update the risk model annually.

4.1 GIS Updates

The risk model is built 1:1 with the City's GIS database. This means that the element locations and ID's in the risk model are identical to the export the City provided for the development of the risk model. As the City adds more elements and improves the accuracy of the information within GIS, those files simply need to be swapped out in InfoAsset Planner. When the new GIS layer is referenced in InfoAsset Planner, the user will need to re-map the system fields with the client fields, as shown in ***Figure 4-1.***

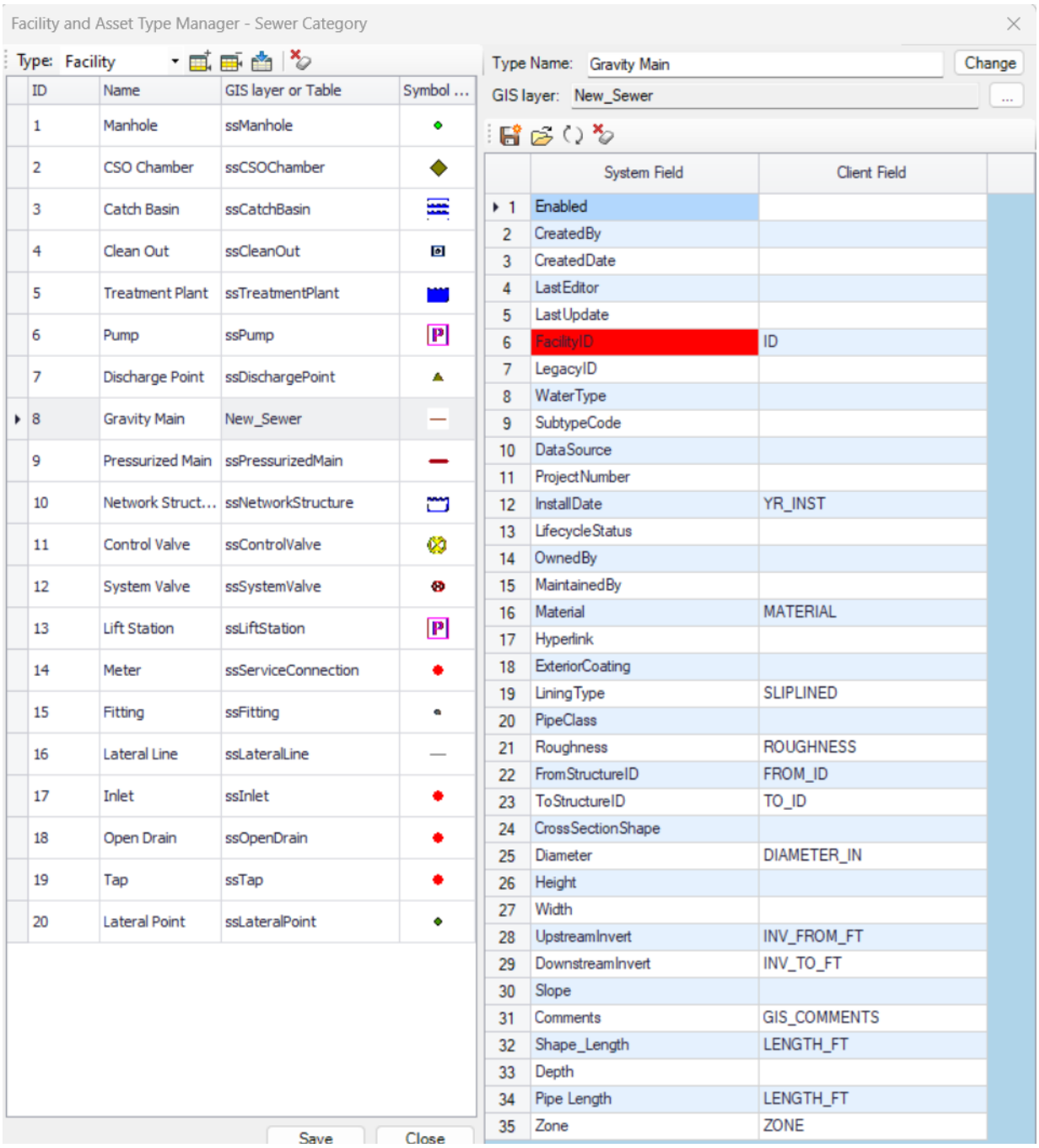


Figure 4-1: Field Mapping for Sanitary Sewer Mains

The same re-mapping process is followed for the shapefile containing the sewer manholes.

4.2 CCTV Updates

For incorporation of CCTV updates, the City should follow the following steps:

1. Export coded CCTV results from GraniteNET to a csv file
2. Follow the CCTV LOF scoring process outlined in section 1.3.3, where the PRS and PRI correspond to the Total_PR and Total_PRI columns from the GraniteNET query results.
3. The facility IDs in GraniteNET correspond to the facility IDs in the risk model, making the updates as simple as a join based on facility ID in GIS.

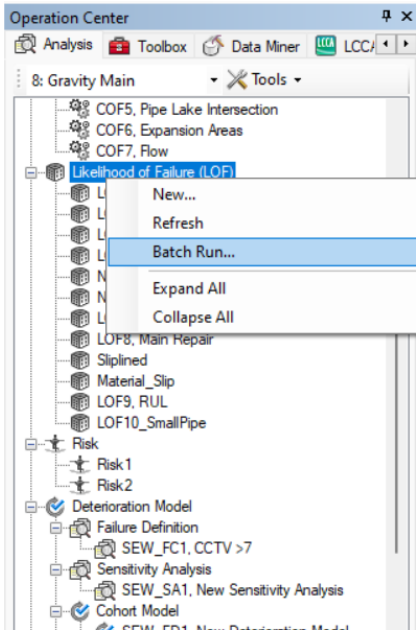
4.3 Work Order (Sewer Stoppage) Updates

Future work order incorporation can be accomplished in a number of ways depending on how the City tracks sewer stoppage going forward. For the initial development of the risk model, the City's sewer stoppage report was exported to a csv file and used to determine the number of stoppages reported for each sewer main. The facility ID in the stoppage report aligns with the facility ID in the risk model, making the updates as simple as a join based on facility ID in GIS. Alternatively, if the City decides to start tracking sewer stoppage utilizing a geodatabase or shapefile in GIS to record locations of stoppages with the corresponding facility ID, this shapefile could simply be uploaded to the risk model to update the corresponding LOF criteria.

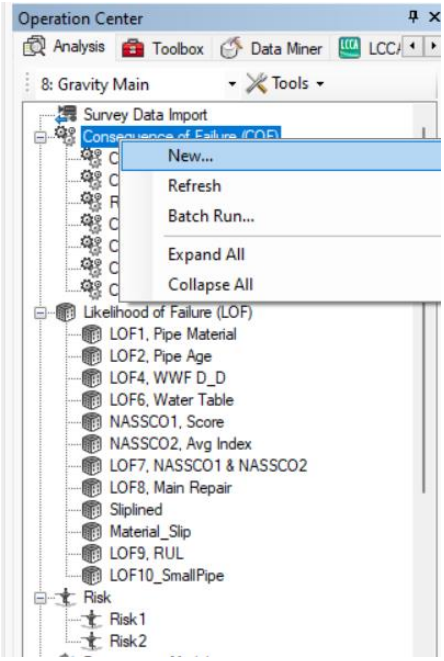
4.4 Risk Model Re-Run

Once any data updates are complete, re-running the risk model is completed in three simple steps.

1. Within the "Operation Center," the user should right click on the heading "Consequence of Failure COF" and select "Batch Run". Each of the COF factors should be re-run.
2. The same process is followed with "Likelihood of Failure" factors, and a "Batch Run" should be completed to update each of the factors.
3. Finally, the calculations are completed in a similar fashion by right clicking on "Risk" within the "Operation Center" and running a batch run of each of the desired risk scenarios.



Over time the City will likely develop multiple risk scenarios with additional criteria or weighting factors to analyze model sensitivity. These updates can be simply incorporated by right clicking on the respective field to be modified in the "Operation Center" and selecting "New". This will allow the City to add new COF criteria, new LOF criteria, or an additional risk scenario with modified weighting factors.



4.5 Conclusion

Detailed cost estimates for the pipe replacement projects outlined in the risk assessment are included in the subsequent Capital Improvement Project memo.

Following the risk assessment procedures outlined in this memo will allow the City to maintain a transparent and defensible method for prioritizing sewer main replacements.

9.0

Capital Improvement Plan Technical Memorandum

Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

Table of Contents

Chapter 1 Introduction 6

1.1 Opinions of Probable Project Cost 6
1.2 Estimate Classification 7
1.3 Estimate Exclusions 7

Chapter 2 Total Estimated Project Cost 8

2.1 Hard Costs 8
2.2 Component Unit Costs 8
2.3 Paved Gravity Sewer Mains 8
2.4 Other Sewer Main Items 9
2.5 Sewer Lift Station Facilities 10
2.6 Hard Cost Markups 11
2.7 Soft Costs 11
2.8 Property Acquisition Costs 12
2.9 Contingency 12
2.10 Inflation 12
2.11 Summary of Estimate Markups 13

Chapter 3 Recommended Improvements 14

3.1 Risk Assessment Improvements 14
3.2 Growth and Development Improvements 14
3.3 Lift Station Improvements 15

Chapter 4 Near-Term (5-Year) Capital Improvement Plan 16

4.1 8-inch and Larger Sewer Main Replacement Projects 18

4.1.1 Project 1: 19th Ave / Kagy Blvd Interceptor Improvements 18
4.1.2 Project 2: Durston Road and 17th Avenue Sewer Main Replacement 22
4.1.3 Project 3: 7th Avenue to Oak Street Sewer Main Replacement 23
4.1.4 Project 4: North 11th Avenue Sewer Main Replacement 24
4.1.5 Project 5: Plum Avenue Sewer Main Replacement 25
4.1.6 Project 6: 4th Avenue, Babcock Street and Grand Avenue Sewer Main Replacement 26
4.1.7 Project 7: North 9th Avenue, West Villard Street, and South 9th Avenue Sewer Main Replacement 28
4.1.8 Project 8: West Harrison Street, 10th Avenue, and West Curtiss Street Sewer Main Replacement 30

4.2 6-inch and Smaller Sewer Main Replacement Projects 31

4.2.1 Small Pipe Project 1: South Black Avenue 6-inch Sewer Main 32
4.2.2 Small Pipe Project 2: South Willson Avenue 6-inch Sewer Main 33

4.2.3 Small Pipe Project 3: South Grand Avenue 6-inch Sewer Main 34
4.2.4 Small Pipe Project 4: West Olive Street 6-inch Sewer Main 35
4.2.5 Small Pipe Project 5: South 4th Avenue 6-inch Sewer Main 36
4.2.6 Small Pipe Project 6: South 3rd Avenue 6-inch Sewer Main 37
4.3 Lift Station Improvement Projects 38
4.3.1 Lift Station Project 1: Valley Center Lift Station 38
4.4 Summary of Near-Term (5-Year) Capital Improvement Projects 38
Chapter 5 Long-Term (6-20-Year) Capital Improvement Plan 40
5.1 8-inch and Larger Sewer Main Replacement Project 41
5.1.1 Project 9: N Grand Ave Sewer Replacement 41
5.1.2 Project 10: N 20th Ave Sewer Replacement 42
5.1.3 Project 11: Upper Front Street Interceptor and Highland Glen Sewer Main Replacement 43
5.1.4 Project 12: S Grand Ave Sewer Replacement 44
5.1.5 Project 13: N 19th Ave Sewer Replacement 45
5.1.6 Project 14: W Oak St Sewer Replacement 46
5.1.7 Project 15: E Lamme St Sewer Replacement 46
5.1.8 Project 16: Plum Ave Sewer Replacement 47
5.2 6-inch and Smaller Sewer Main Replacement Projects 48
5.2.1 Small Pipe Project 7: Main Street Sewer Main Replacement 48
5.2.2 Small Pipe Project 8: S Bozeman Ave, E Story St, and Dell Pl Sewer Main Replacement 49
5.2.3 Small Pipe Project 9: S 5th Ave and Alleys Sewer Main Replacement 50
5.2.4 Small Pipe Project 10: S 6th Ave Sewer Main Replacement 51
5.2.5 Small Pipe Project 11: W Lamme St Sewer Main Replacement 52
5.2.6 Small Pipe Project 12: S 4th Ave and S 3rd Ave Sewer Main Replacement 53
5.2.7 Small Pipe Project 13: S 7th Ave Sewer Main Replacement 54
5.2.8 Small Pipe Project 14: S 3rd Ave Sewer Main Replacement 55
5.2.9 Small Pipe Project 15: N Black Ave, E Cottonwood St, and N Tracy Ave Sewer Replacement 56
5.2.10 Small Pipe Project 16: Ida Ave and Fridley St Sewer Replacement 57
5.2.11 Small Pipe Project 17: E Cottonwood St Sewer Replacement 58
5.2.12 Small Pipe Project 18: E Aspen St Sewer Replacement 58
5.2.13 Small Pipe Project 19: N 3rd Ave Sewer Replacement 59
5.2.14 Small Pipe Project 20: N 8th Ave Sewer Replacement 60
5.2.15 Small Pipe Project 21: W Lamme St Sewer Replacement 61
5.2.16 Small Pipe Project 22: W Mendenhall St 61
5.2.17 Small Pipe Project 23: W Main St and W Babcock St Alley Sewer Replacement 62
5.2.18 Small Pipe Project 24: W Main St Sewer Replacement 62
5.2.19 Small Pipe Project 25: S 5th Ave Sewer Replacement 63

5.2.20 Small Pipe Project 26: W Story St and S 6th Ave Sewer Replacement 64
5.2.21 Small Pipe Project 27: S 9th Ave and S 8th Ave Alley Sewer Replacement 65
5.2.22 Small Pipe Project 28: S 8th Ave and S 7th Ave Sewer Main Replacement 66
5.2.23 Small Pipe Project 29: S Wallace Ave Sewer Replacement 67
5.2.24 Small Pipe Project 30: E Main St Sewer Replacement 68
5.2.25 Small Pipe Project 31: E Mendenhall St Sewer Replacement 68
5.2.26 Small Pipe Project 32: S Church Ave Sewer Replacement 69
5.2.27 Small Pipe Project 33: W Babcock St Sewer Replacement 70
5.2.28 Small Pipe Project 34: S 6th Ave Sewer Replacement 70
5.2.29 Small Pipe Project 35: W Babcock Ave, W Olive St, and S 7th Ave Sewer Main Replacement 71
5.2.30 Small Pipe Project 36: W Main St, S Tracy Ave, and E Babcock St Sewer Main Replacement 71

5.3 Lift Station Improvement Projects 72

5.3.1 Lift Station Project 2: Coulee Drive 72
5.3.2 Lift Station Project 3: Spring Hill 73
5.3.3 Lift Station Project 4: Gooch Hill 74
5.3.4 Lift Station Project 5: Hidden Valley 75
5.3.5 Lift Station Project 6: Davis Lane 76
5.3.6 Lift Station Project 7: Laurel Glen 77
5.3.7 Lift Station Project 8: Loyal Gardens 78

5.4 Summary of Long-Term Capital Improvement Projects 79

Chapter 6 Relevancy of Previously Recommended Yet to be Constructed CIP's 81

Chapter 7 Conclusion 86

List of Tables

Table 2-1: Paved Gravity Main Cost per Linear Foot 9
Table 2-2: Sewer Main Connection Costs 10
Table 2-3: Sewer Main Crossing Costs 10
Table 2-4: Total Estimate Project Markup Summary 13
Table 3-1: Lift Station Existing and Needed Capacity Summary 15
Table 4-1: Summary of Near Term (5-year) Capital Improvement Projects 38
Table 5-1: Summary of Long-Term Capital Improvement Projects 79

List of Figures

Figure 4-1: Project 1 Extents (checkered line) 19
Figure 4-2: Project 1 Upsized Pipe Diameters 20
Figure 4-3: Project 2 Extents (checkered line) 22
Figure 4-4: Project 3 Extents (checkered line) 23
Figure 4-5: Project 4 Extents (checkered line) 24
Figure 4-6: Project 5 Extents (checkered line) 25
Figure 4-7: Project 6 Extents (checkered line) 26
Figure 4-8: Project 6 Upsized Pipe Diameters (checkered line) 27
Figure 4-9: Project 7 Extents (checkered line) 28
Figure 4-10: Project 7 Upsized Pipe Diameters (checkered line) 29
Figure 4-11: Project 8 Extents (checkered line) 30
Figure 4-12: Small Pipe Project 1 Extents (checkered line) 32
Figure 4-13: Small Pipe Project 2 Extents (checkered line) 33
Figure 4-14: Small Pipe Project 3 Extents (checkered line) 34
Figure 4-15: Small Pipe Project 4 Extents (checkered line) 35
Figure 4-16: Small Pipe Project 5 Extents (checkered line) 36
Figure 4-17: Small Pipe Project 6 Extents (checkered line) 37
Figure 4-18: Valley Center Lift Station 38
Figure 5-1: Project 9 Extents (checkered line) 41
Figure 5-2: Project 10 Extents (checkered line) 42
Figure 5-3: Project 11 Extents (checkered line) 43
Figure 5-4: Project 12 extents (checkered line) 44
Figure 5-5: Project 13 Extents (checkered line) 45
Figure 5-6: Project 14 Extents (checkered line) 46
Figure 5-7: Project 15 Extents (checkered line) 46
Figure 5-8: Project 16 Extents (checkered line) 47
Figure 5-9: Small Pipe Project 7 Extents (checkered line) 48
Figure 5-10: Small Pipe Project 8 Extents (checkered line) 49
Figure 5-11: Small Pipes Project 9 Extents (checkered line) 50
Figure 5-12: Small Pipe Project 10 Extents (checkered line) 51
Figure 5-13: Small Pipe Project 11 Extents (checkered line) 52
Figure 5-14: Small Pipe Project 12 Extents (checkered line) 53
Figure 5-15: Small Pipe Project 13 Extents (checkered line) 54
Figure 5-16: Small Pipe Project 14 Extents (checkered line) 55
Figure 5-17: Small Pipe Project 15 Extents (checkered line) 56
Figure 5-18: Small Pipe Project 16 Extents (checkered line) 57
Figure 5-19: Small Pipe Project 17 Extents (checkered line) 58
Figure 5-20: Small Pipe Project 18 Extents (checkered line) 58

Figure 5-21: Small Pipe Project 19 Extents (checkered line) 59
Figure 5-22: Small Pipe Project 20 Extents (checkered line) 60
Figure 5-23: Small Pipe Project 21 Extents (checkered line) 61
Figure 5-24: Small Pipe Project 22 Extents (checkered line) 61
Figure 5-25: Small Pipe Project 23 Extents (checkered line) 62
Figure 5-26: Small Pipe Project 24 Extents (checkered line) 62
Figure 5-27: Small Pipe Project 25 Extents (checkered line) 63
Figure 5-28: Small Pipe Project 26 Extents (checkered line) 64
Figure 5-29: Small Pipe Project 27 Extents (checkered line) 65
Figure 5-30: Small Pipe Project 28 Extents (checkered line) 66
Figure 5-31: Small Pipe Project 29 Extents (checkered line) 67
Figure 5-32: Small Pipe Project 30 Extents (checkered line) 68
Figure 5-33: Small Pipe Project 31 Extents (checkered line) 68
Figure 5-34: Small Pipe Project 32 Extents (checkered line) 69
Figure 5-35: Small Pipe Project 33 Extents (checkered line) 70
Figure 5-36: Small Pipe Project 34 Extents (checkered line) 70
Figure 5-37: Small Pipe Project 35 Extents (checkered line) 71
Figure 5-38: Small Pipe Project 36 Extents (checkered line) 71
Figure 5-39: Coulee Drive LS 72
Figure 5-40: Spring Hill Lift Station 73
Figure 5-41: Gooch Hill Lift Station 74
Figure 5-42: Hidden Valley Lift Station 75
Figure 5-43: Davis Lane Lift Station 76
Figure 5-44: Laurel Glen LS 77
Figure 5-45: Loyal Gardens LS 78
Figure 6-1: North Frontage Road Interceptor 81
Figure 6-2: Davis-Fowler Interceptor 82
Figure 6-3: WRF Interceptor 83
Figure 6-4: Cottonwood Rd Capacity 84

Chapter 1 Introduction

This Technical Memorandum presents recommended capital improvement projects identified while evaluating hydraulic performance of the existing and future wastewater collection system. This Capital Improvement Plan (CIP) includes recommended projects to address near-term (5 year) and long-term (6-20 year) needs. The recommended wastewater collection system improvement projects are based on the results of:

1. The existing and future system evaluations - Hydraulic Model Development and Results Technical Memorandum (TM 7).
2. The risk-based system assessment- Risk Assessment Technical Memorandum (TM 8); and
3. Multiple meetings with City staff.

An all-inclusive list of identified improvement projects was compiled for a comprehensive CIP evaluation. Cost estimates were generated for each project and the projects were placed into their respective planning periods to facilitate spending capital dollars in the most cost-effective manner possible.

This memorandum includes descriptions of the CIP project categories, cost estimate methodology, implementation considerations, and a summary of each recommended improvement.

1.1 Opinions of Probable Project Cost

The opinion of probable project cost (OPPC) values are based on the total capital investment necessary to complete a project from engineering design through construction. All estimates are based on engineering experience and judgment, recent bid tabulations for projects of similar scope, and input from area contractors and material suppliers. All costs are presented in 2022 dollars and inflated for each CIP project based on the estimated year it will be bid or constructed.

Total estimated project costs were divided into five main components, as follows:

- Hard Costs – The actual physical construction of the project (i.e., excavation, materials, labor, restoration).
- Soft Costs – Fees not directly related to labor and building materials (i.e., architecture and engineering fees, permitting/environmental, contract administration, legal).
- Property Acquisition Costs – The cost to obtain property, right-of-way, and easements.
- Contingency – Amount added to the estimated cost to cover both identified and unidentified risk events that occur on the project.

- Inflation – The application of the average annual inflation rate anticipated between the time an estimate is prepared and when the project is bid or projected for construction.

The sum of these five components is the total OPPC. The OPPC values are based on the preliminary concepts and layouts of the wastewater system components developed as a result of the hydraulic modeling of the system and corresponding recommendations. The estimate is to be an indication of fair market value and is not necessarily a reflection of the lowest bid. Fair market value is assumed to be mid-range tender considering four or more competitive bids.

1.2 Estimate Classification

The Association for the Advancement of Cost Engineering (AACE) provides guidelines for applying the general principles of estimate classification to project cost estimates (i.e., cost estimates that are used to evaluate, approve, and/or fund projects). The purpose for following a classification process is to align the level of estimating with the use of the information. The estimates provided in the CIP are classified in accordance with the criteria established by AACE cost estimating classification system referred to as Standard Practice 18R-97.

In accordance with AACE criteria, the OPPC values are representative of Class 4 estimates. A Class 4 estimate is defined as a study or feasibility estimate. Typically, the engineering effort is from 1 to 15 percent complete. Class 4 estimates are used to prepare planning-level effort cost scopes or complete an evaluation of alternative schemes, technical feasibility, and preliminary budget approval or approval to proceed to the next stage of implementation.

Expected accuracy for Class 4 estimates typically range from -30 to +50 percent, depending on the technical complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.

1.3 Estimate Exclusions

Unless specifically identified, the following estimating exclusions were assumed in the development of the cost estimates:

- Environmental mitigation of hazardous materials and/or disposal.
- O&M costs for the project components.

Chapter 2 Total Estimated Project Cost

The following sections provide a breakdown of the different items included in each cost component associated with developing the total OPPC for each project.

2.1 Hard Costs

Hard costs, sometimes referred to as contractor construction costs, represent the actual physical construction of a project. This section was divided into component unit costs and hard cost markups. The following sources of information were used to compile the hard cost estimates:

- Review of previous construction bid tabs for similar projects;
- Review of historical bid prices for the City;
- Vendor, supplier, and contractor estimates for specific equipment and materials.

2.2 Component Unit Costs

All estimates are based on engineering experience and judgment, recent bid tabulations for projects of similar scope, cost indexing, and input from area contractors and material suppliers.

For specific equipment and materials, information was requested from vendors and suppliers and the costs were increased by applying a multiplication factor to include the related costs and expenses (such as labor, connections, and miscellaneous materials) required to complete the installation.

2.3 Paved Gravity Sewer Mains

The pipe material assumed for new gravity sewer mains located within paved public right-of-way was ASTM D3034 SDR35 PVC for pipes ranging from 8-inches to 16-inches in diameter, while pipe sizes between 18-inches and 42-inches were assumed to be ASTM F679 PS46 PVC. ***Table 2-1*** presents the paved gravity main construction costs. The costs are based on the following assumptions:

- Pipe Size with full depth import backfill (8’ to 12’ depth)
- Manhole every 200 ft plus extra vertical depth
- Pavement sawcut and removal
- 4” asphalt paving at 14 sq ft per foot
- Number of laterals replaced, assuming a 45-foot lateral length per connection.

Table 2-1: Paved Gravity Main Cost per Linear Foot

Pipe Diameter (inches)	PVC Pipe ($/linear foot)
8	$210
10	$215
12	$222
14	$228
15	$231
16	$234
18	$240
20	$246
21	$248
24	$258
27	$267
30	$276
36	$306
42	$318

Please note that the costs of curb and gutter or sidewalk removal and replacement are not included in the unit costs presented in ***Table 2-1.***

2.4 Other Sewer Main Items

Additional items included in the sewer main cost estimates are presented below:

- Sewer Main Connections of proposed mains to other mains in the system (***Table 2-2***);
- Sewer Main Crossings (
- ***Table*** 2-3).

Table 2-2: Sewer Main Connection Costs

Connecting Pipe Diameter (inches)	
Existing Sewer Service Connection (including 45 feet of lateral replacement)	$5,500
Existing Sewer Main Connection	$5,400
Lift Station Connection	$5,400
10'H x 10'L x 5'W Specialty Manifold Structure	$15,400

Table 2-3: Sewer Main Crossing Costs

Pipe Diameter (inches)	Crossing Type	Cost ($/linear foot)
18 - 24	Highway Bore with Space Constraints	$770
27 - 36	Highway Bore with Space Constraints	$1,030
8 - 18	Road Crossing/Bore	$410

2.5 Sewer Lift Station Facilities

Project costs for proposed lift station facilities were prepared for several different sizes. Costs were based on information obtained from package lift station vendors, previous construction experience, and recently bid projects for similar lift station projects. The cost is based on the following assumptions:

- Wet well structures vary depending on associated capacity requirements;
- Includes major components (i.e., pumps, fittings, valves, electrical, emergency generator, odor control, and communications).

Project cost estimates for construction of sewer lift stations were based on planning level costs depending on overall capacity and whether it was for a retrofit of an existing lift station or construction of a new lift station facility. Costs assigned to lift stations were general in definition and items such as vault assemblies associated with force mains were not included but would likely be covered as part of project contingencies if needed.

2.6 Hard Cost Markups

Hard costs markups are applied to the hard costs and construction costs to calculate total construction costs. The hard cost markups are reflected in the individual capital improvement project cost estimates. Markups vary depending on the size and type of the project.

- Mobilization/demobilization/insurance/permits/bonds – 6 percent
    - Mobilization costs include the administrative costs and expenses to mobilize materials, equipment, and labor to the jobsite and demobilize upon project completion. Costs associated with contractor insurance, permits, and bonding are also included.
- Traffic Control – 2 percent
    - Traffic control was assigned to projects that occur in the public right-of-way, primarily gravity main replacement or force main projects.
- Erosion Control – 1 percent
    - Erosion control is required for all construction projects to ensure compliance with Storm Water Pollution Prevention Plans.
- Testing and Construction Surveying – 3 percent
    - Costs associated with materials testing during construction in addition to construction surveying and staking.
- Existing Utility Adjustments – 10 percent
    - This hard cost markup was only applied to gravity sewer main installation projects within urban areas where utility conflicts and associated re-routing are anticipated.

2.7 Soft Costs

To adequately complete the planning, design, and construction of projects listed in this CIP, there are significant soft costs that will be required. Soft costs are non-construction labor costs consisting of architecture and engineering fees, permitting and environmental compliance, contract administration, legal fees, etc. Soft costs are applied to the hard costs plus the hard cost markups. A breakdown and summary of the soft costs that were included in the cost estimates are provided below.

- Engineering Design – 10 percent
    - Costs include preliminary engineering through final design, which involves the development of final project plans and specifications that will be stamped by a

professional consulting engineer. Engineering costs include disciplines such as process, civil, electrical, mechanical, architectural, and structural. Costs also include surveying, testing, investigations, and inspections during the design phase. Examples include surveys of pipeline alignments and facility parcels, security and safety inspections, material and geological testing, and inspection services.

- Construction Administration and Management – 8 percent
    - Costs include services to provide quality control, quality assurance, and construction management during the construction phase and services associated with the initial operation including training of operational, maintenance, and supervisory staff.
- Legal and Administrative – 5 percent
    - Costs associated with the local and State project approval process, and any legal costs, are included in this category. Responsible tasks may include road crossing permits, construction permits, county building permits, inter-disciplinary team meetings, NEPA compliance, expenses incurred by the City, etc.

2.8 Property Acquisition Costs

Property acquisition costs are associated with purchasing property and acquiring right-of-way or easements for the project. Costs normally consist of payments to landowners. Costs for purchasing property associated with a new lift station or lift station upgrades were generated based on average 2022 real estate values of vacant lots with utilities within Bozeman urban areas. Costs for acquiring right-of-way or easements were based on average 2022 real estate values of City easements for rural land in Bozeman with generally no utilities. This was appropriate for most of the identified CIP projects anticipated to be built outside of right-of-way.

2.9 Contingency

A contingency is an amount added to the base cost to cover both identified and unidentified risk events that occur on the project. The contingency value used was 30 percent. The contingency values were added to the overall project base cost (i.e., hard and soft costs) in anticipation of uncertainties inherent to the planning-level analysis completed for the BWWCS.

2.10 Inflation

Projects intended for construction several years in the future include a factor for inflationary impacts to address the general trend of cost indices, which accounts for future labor, material, and equipment cost increases beyond values at the time the estimate is prepared. For this planning-level analysis, the 2022 project costs were inflated to the construction year anticipated

for each CIP project. An annual average inflation rate was generated based on historic inflation data to estimate inflation trends into the future.

2.11 Summary of Estimate Markups

Table 2-4 provides a summary of suggested hard costs markups, soft costs, and contingency rate percentages.

Table 2-4: Total Estimate Project Markup Summary

Item	
Hard Cost Markups	
Mobilization/Demobilization/Insurance/Permits/Bonds	6%
Traffic Control	2%
Erosion Control	1%
Testing and Construction Surveying	3%
Existing Utility Adjustments (as applicable)	10%
Soft Costs	
Engineering Design	10%
Construction Administration and Management	8%
Legal and Administrative	5%
Other	
Property Acquisition	Varies per acre
Contingency	30%
Estimated Annual Inflation	5%

Chapter 3 Recommended Improvements

3.1 Risk Assessment Improvements

Projects identified through the collection system risk assessment target the replacement of aging and failing infrastructure, which present a significant risk to the City. Failure can imply infrastructure deterioration, or failure to meet the needed level of service such as flow capacity limitations. It is important to note that all recommended pipe replacement projects in this memo are sized for ultimate build out (UBO) conditions.

3.2 Growth and Development Improvements

The timing for growth and development projects can be difficult to predict. For this reason, the City treats this class as its own separate category, and the prioritization of improvements is evaluated as growth occurs. For the future system evaluation, needed improvements are broken into four main categories:

1. Infill Internal Improvements
2. Infill Extensions
3. UBO Internal Improvements
4. UBO Extensions

Infill internal improvements include pipes that must be upsized when the undeveloped portions of land within the existing City limits are developed as currently zoned. Infill extensions are similar and include the new pipes needed to serve infill growth within the existing City limits.

UBO internal improvements include pipes within existing City limits that will need to be upsized to serve the City at buildout conditions. UBO extensions are similar but include the pipe extensions (not replacements) that will be needed to serve the City at buildout.

These pipe sizes and locations are discussed in detail in the Hydraulic Model Development and Results Technical Memorandum (TM 7). For the purposes of the CIP, the majority of the "Infill Internal Improvements" are addressed with the risk driven projects based on their age and insufficient capacity (d/D between 0.5 and 0.75) and are included in the 5-year CIP. There are two "Infill Internal Improvement" projects that are postponed to the 6–20-year CIP. Several "UBO Internal Improvement" projects also overlap with the risk driven projects. All recommended pipe replacement projects are sized to serve the City at buildout conditions.

Timing for the remainder of the growth projects should be driven based on the timing and location of growth within the City. The Hydraulic Model Development and Results Technical Memorandum (TM 7) includes details on the recommended pipe sizing for infill and UBO pipe extensions and internal improvements.

3.3 Lift Station Improvements

Lift station projects consist of existing lift stations that are anticipated to be under capacity prior to full buildout and new lift stations that will serve future growth areas. ***Table 3-1*** summarizes the capacity of the three lift stations that must be upsized under infill and buildout conditions as well as the new lift stations to be constructed for buildout conditions. This information is provided to help understand the potential timing and priority of these projects which are driven primarily by growth. The red text in the table indicates the time/growth period at which inflow is anticipated to exceed existing firm capacity.

Table 3-1: Lift Station Existing and Needed Capacity Summary

Lift Station Name	Existing Firm Capacity (gpm)	Originally Planned Buildout Capacity (gpm)	Existing Peak Flow (gpm)	Infill Peak Flow (gpm)	UBO Modeled Peak Flow (gpm)
Davis Lane	5,000	10,400	310	620	**14,040**
Laurel Glen	450	600	360	400	400
Loyal Gardens	364	N/A	270	270	**370**
Valley Center[2,3]	-		-	-	1,620
Hidden Valley[2]	-		-	-	2,230
Coulee Drive	-		-	-	2,270
Spring Hill	-		-	-	5,480
Gooch Hill	-		-	-	6,770

[2] The Valley Center lift station is being designed as of July 2024 to meet immediate growth needs adjacent to City limits and will break the Baxter Creek Drainage Basin into two distinct sewersheds and allow for a smaller Hidden Valley lift station than was presented in the 2015 Facility Plan.
[3] The Valley Center lift station cost and capacity assumes the "shallow" alternative, as described in more detail in the Baxter Creek Drainage Basin Analysis Technical Memorandum (AE2S, 2022).

Chapter 4 Near-Term (5-Year) Capital Improvement Plan

In coordination with City staff, the near-term (5-year) recommendations marked a departure from previous strategies by utilizing both hydraulic models and risk assessment models to prioritize capital planning needs. This dual approach provided a comprehensive view, identifying high-risk areas, assets that have exceeded their useful service life, and specific infrastructure or facilities needed to support future growth.

The comprehensive analysis revealed that the City's current replacement funding for FY23, approximately $1 million per year, is insufficient to meet long-term needs. It should be increased to maintain existing and future levels of service. Based on discussions with City staff and current budgetary considerations, a $1.5 million per year increase to the City's wastewater replacement fund was recommended. The proposed list of projects for the near term is approximately $12.5 million ($2.5 million per year). Depending on the project type, funding for the annual wastewater pipe replacement is sourced either from utility rates or a combination of rates and impact fees.

Additionally, there are around 19 miles of existing 6-inch collection pipes (typically VCP) that have reached the end of their useful life and require replacement and upsizing. These smaller assets, typically serving single-family homes or smaller facilities, generally do not rank high in the risk-based model when evaluating larger system assets (8-inch pipes and above). Moreover, most of these pipes are located in existing service areas, which may not trigger growth-related project upsizing.

Despite their lower risk ranking, City staff consider the replacement of these 6-inch pipes a priority due to their age, material type, and service history. A separate risk assessment specifically for the 6-inch pipes was completed and documented in TM8. Following discussions with City staff, the establishment of a dedicated fund for the 6-inch replacement program was recommended.

The 6-inch wastewater replacement program aims to replace approximately 19 miles of undersized, aging collection pipes over a 25-year period. These pipes are not identified as high risk for immediate replacement or rehabilitation under the City's annual wastewater pipe replacement program. All 6-inch pipes will be upgraded to a minimum of 8-inch per city standards or resized based on the City's Wastewater Facility Plan and hydraulic model. Prioritization for the 6-inch replacement projects will generally align with the City's street reconstruction program, new developments, and system risk compared to other 6-inch pipes. Remaining funds will be used to update pipe condition data to better inform future capital planning and project prioritization.

The estimated cost for completing near-term projects involving 6-inch and smaller sewer replacements is approximately $7.5 million. A fund of $1 million was recommended based on discussions with City staff and the current budgetary framework.

Overall, considering the City's infrastructure needs, existing assets, and recommended replacement cycles, the City should plan to spend approximately $4 million per year over the next two decades to address existing replacement needs. Once the replacement of the 6-inch assets is complete, the City may choose to roll this funding into the annual wastewater replacement fund, depending on future needs. Additionally, if development partners collaborate with the City on the 6-inch replacement, additional funding may become available sooner to offset other emerging project needs.

A proactive approach will help maintain stable rates and consistent levels of service. The City should periodically update these recommendations to reflect evolving needs and circumstances.

The near-term improvements presented include:

1. 8-inch and Larger Sewer Main Replacement
2. 6-inch and Smaller Sewer Main Replacement
3. Lift Station Improvements

Even if the identified projects take slightly longer than five years to complete at the current funding level, the prioritization of these projects is suitable for addressing the challenge of aging infrastructure. As each project is completed, the risk model should be updated, and the next project should be identified and incorporated into the Capital Improvement Plan (CIP).

An interactive GIS dashboard showing the project extents and other pertinent details can be accessed using the link below:

ArcGIS Insights CIP Dashboard

Additionally, the City's complete capital improvement plan is included in an AE2S developed web tool known as OptX. In addition to tracking capital improvement project timing and costs, OptX can be used to track fund balances, revenue streams (utility rates, taxes, etc.), tie capital projects to specific funds, evaluate revenue adequacy, and much more.

4.1 8-inch and Larger Sewer Main Replacement Projects

4.1.1 Project 1: 19th Ave / Kagy Blvd Interceptor Improvements

The 19th Ave / Kagy Blvd Interceptor was flagged as lacking sufficient capacity under existing and infill conditions at some locations, particularly in the upper sections between Kagy and West Babcock Street. Additionally, this pipe is very old asbestos concrete and noted as high risk in the risk analysis. Project 1 proposes to improve this interceptor from Kagy through the intersection of South 9th Avenue and West Babcock Street. Project 1 is shown with a checkered line in ***Figure 4-1***.

The total amount of pipe replaced in Project 1 is over 10,000 feet. It should be noted that some portions of the existing 18-inch sewer at the downstream end of this project along South 6th Avenue and West Babcock Street, may need to be upsized to a 21-inch under the UBO loading in order for every segment to meet d/D standards.

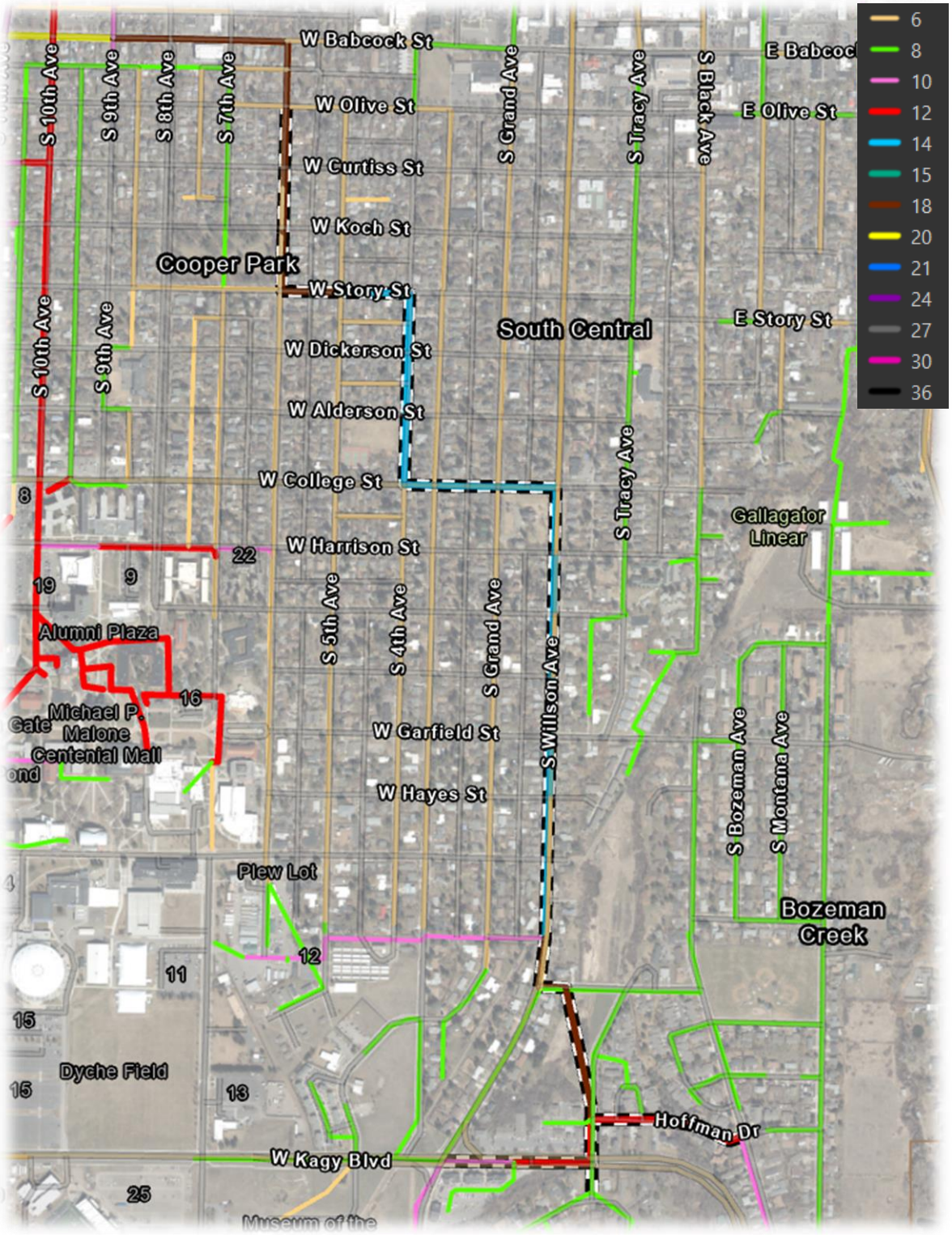


Figure 4-1: Project 1 Extents (checkered line)

The recommended pipe diameters to be installed for this project are shown in ***Figure 4-2***.

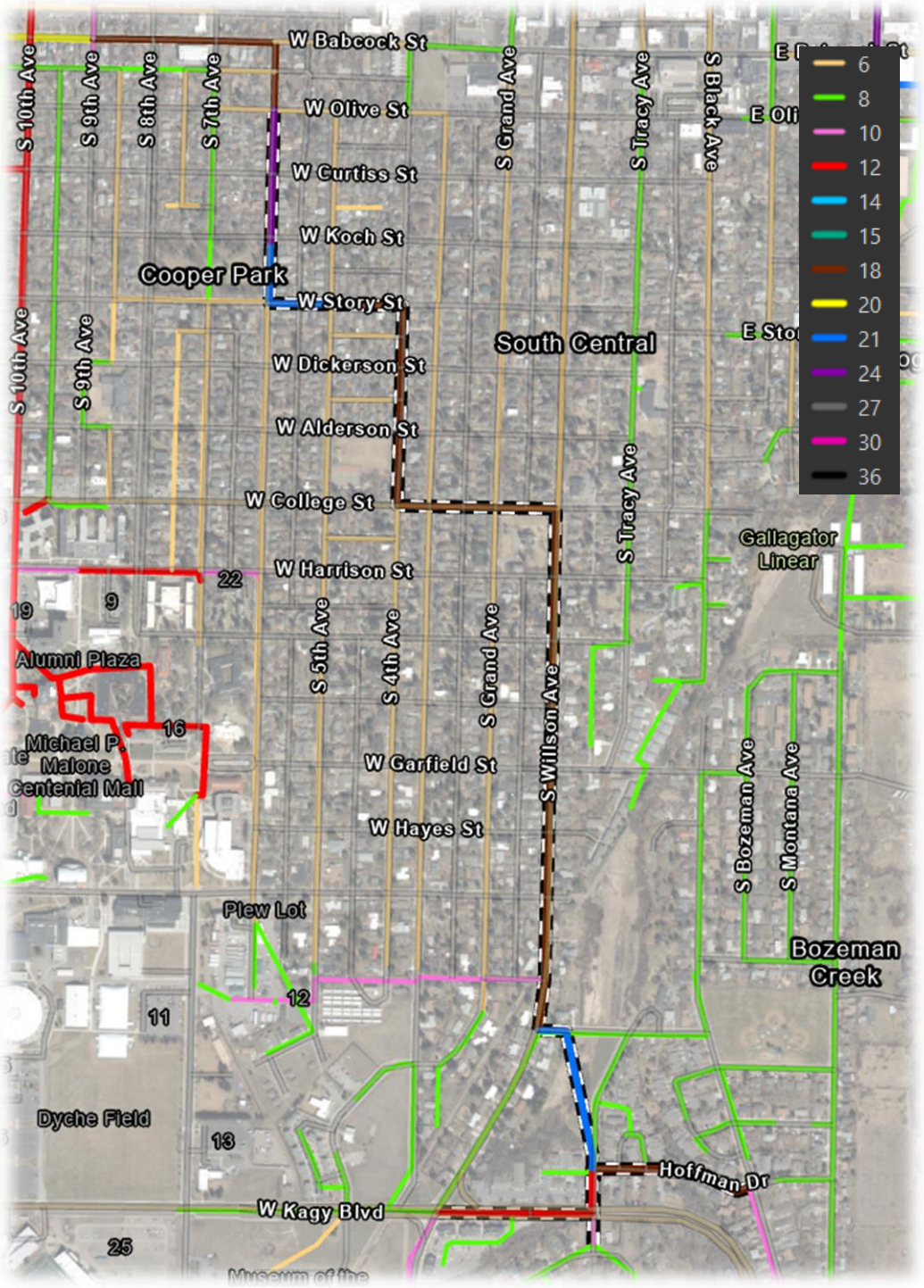


Figure 4-2: Project 1 Upsized Pipe Diameters

Project 1 is needed to renew critical aging infrastructure identified in the risk analysis and addresses infill capacity concerns. The recommended pipe sizes are set to provide sufficient capacity for the UBO scenario.

4.1.2 Project 2: Durston Road and 17th Avenue Sewer Main Replacement

This project includes the 15-inch sewer main running west along Durston Road, which turns north on 17th Ave. and becomes an 18-inch sewer main extending to Nelson Trailer Park. This pipe should be replaced with the same diameter PVC pipe. The checkered line in ***Figure 4-3*** below shows the project extents, and colored lines represent the current diameters of the pipe. This project requires the replacement of 1,800 feet of pipe.

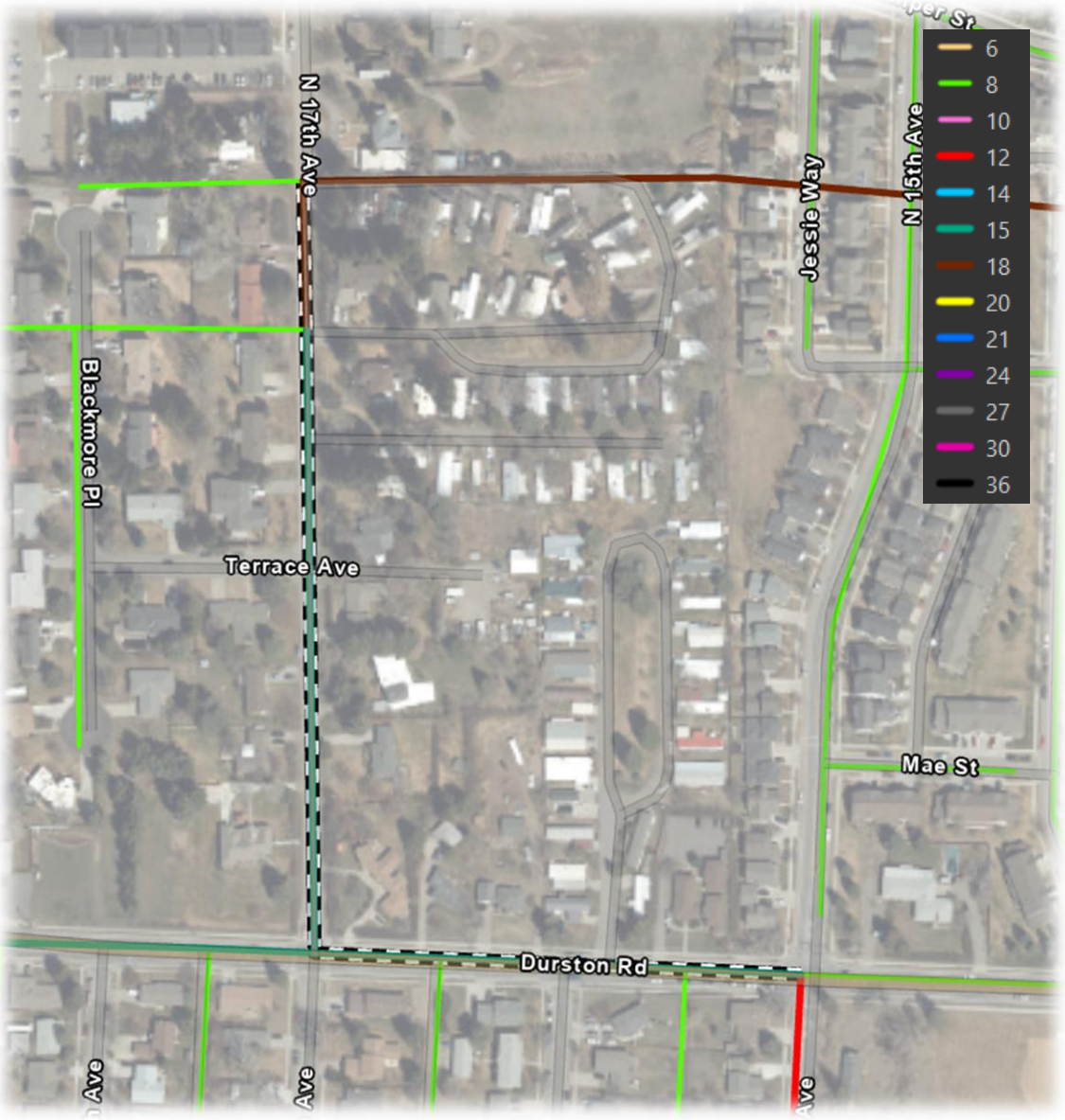


Figure 4-3: Project 2 Extents (checkered line)

Project 2 is needed to renew critical aging infrastructure identified in the risk analysis.

4.1.3 Project 3: 7th Avenue to Oak Street Sewer Main Replacement

A 15-inch sewer main running north in the fields west of 7th Avenue turns east on Birch Street and becomes an 18-inch main. Just before reaching 7th Avenue, the 18-inch main turns north until it intersects Oak Street. This project continues along Oak Street until approximately 5th Avenue. The total amount of pipe replaced in this project is 2,700 feet, which will match the existing pipe diameters. The extents of the project can be seen below in ***Figure 4-4***.

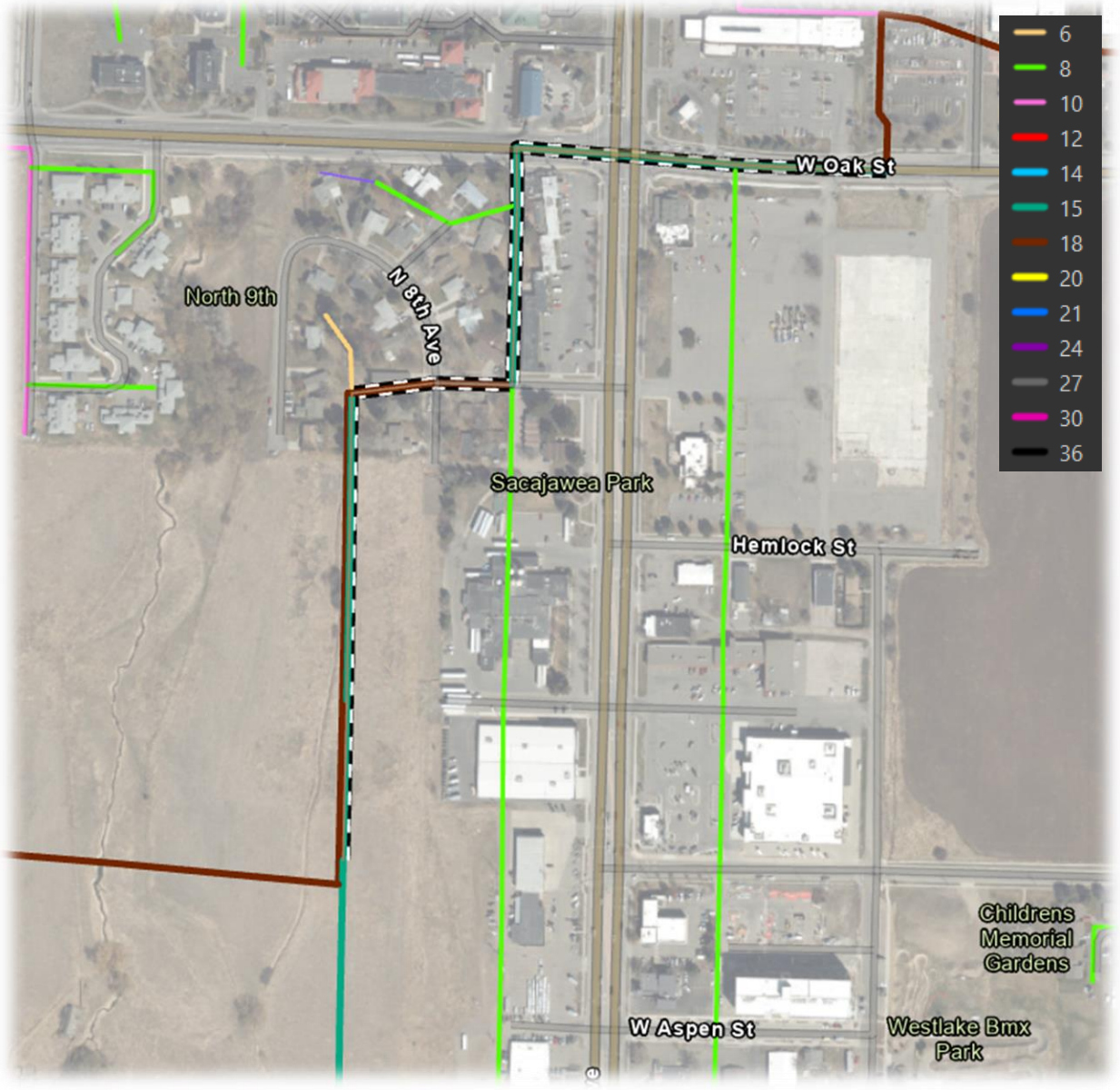


Figure 4-4: Project 3 Extents (checkered line)

Project 3 is needed to renew critical aging infrastructure identified in the risk analysis.

4.1.4 Project 4: North 11th Avenue Sewer Main Replacement

On the west side of 11th Avenue immediately north of the High School, a 24-inch sewer main wraps around the corner of Durston Road to the west until approximately Oak Park Drive. The 1,100 feet of pipe replaced in this project will be replaced with the same diameter pipe.

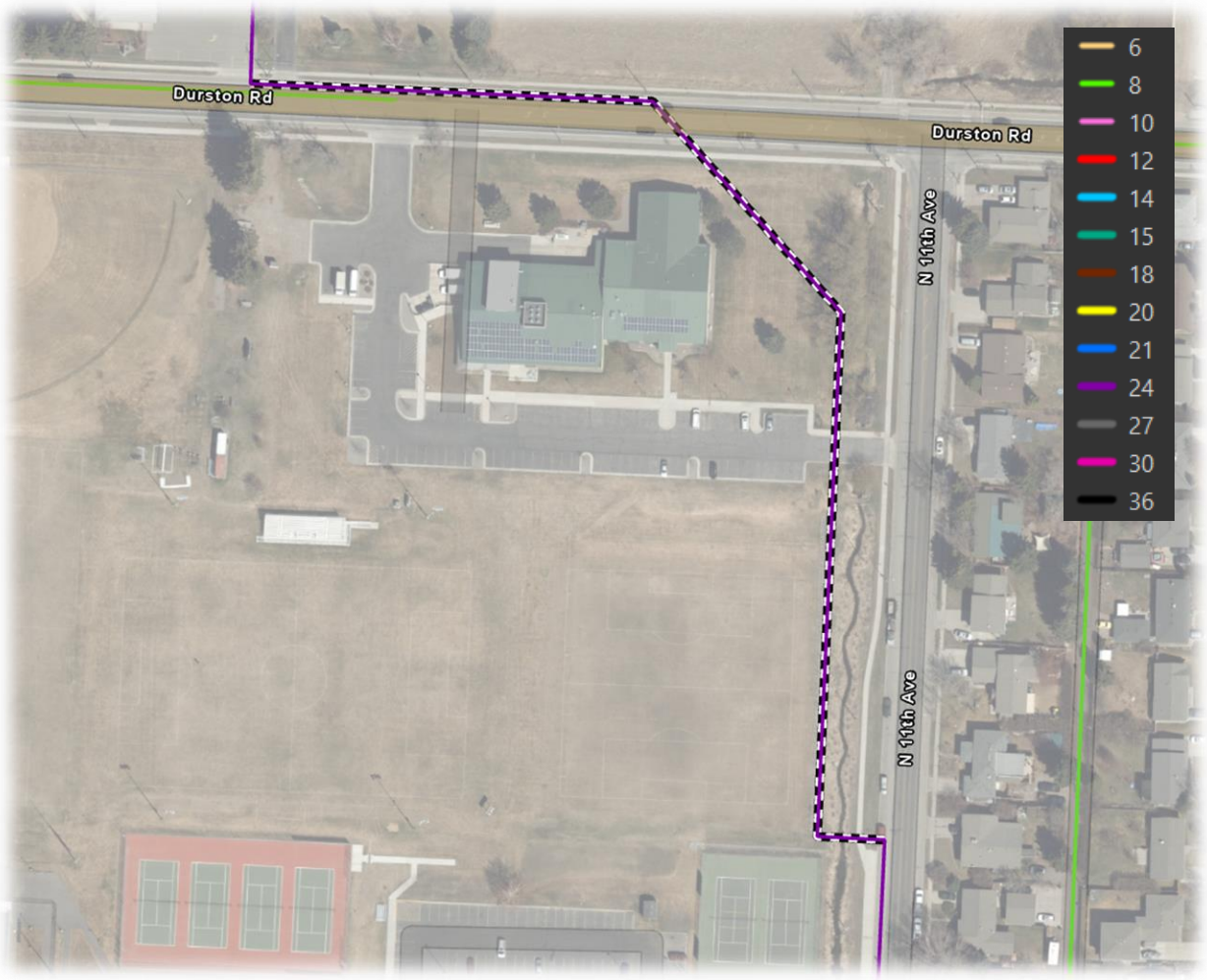


Figure 4-5: Project 4 Extents (checkered line)

Project 4 is needed to renew critical aging infrastructure identified in the risk analysis.

4.1.5 Project 5: Plum Avenue Sewer Main Replacement

This project begins at the intersection of Plum Avenue and Peach Street with a 10-inch main running north along Plum Avenue. The main continues up Plum Avenue and becomes a 12-inch diameter at the intersection of Tamarack Street. The project extents continue along Juniper Street to the intersection of Rouse Avenue. These pipes will be replaced with the same diameter, with a total of 2,800 feet of pipe replaced between the 10-inch and 12-inch mains. The extents of the project can be seen below in ***Figure 4-6***.



Figure 4-6: Project 5 Extents (checkered line)

Project 5 is needed to renew critical aging infrastructure identified in the risk analysis.

4.1.6 Project 6: 4th Avenue, Babcock Street and Grand Avenue Sewer Main Replacement

This project includes the replacement and upsizing of the 10-inch main which starts at the corner of Olive Street and 4th Avenue, extends north along 4th Avenue to Babcock Street, follows Babcock Street to Grand Avenue, and wraps up to Main Street. The project extents can be seen in ***Figure 4-7***.

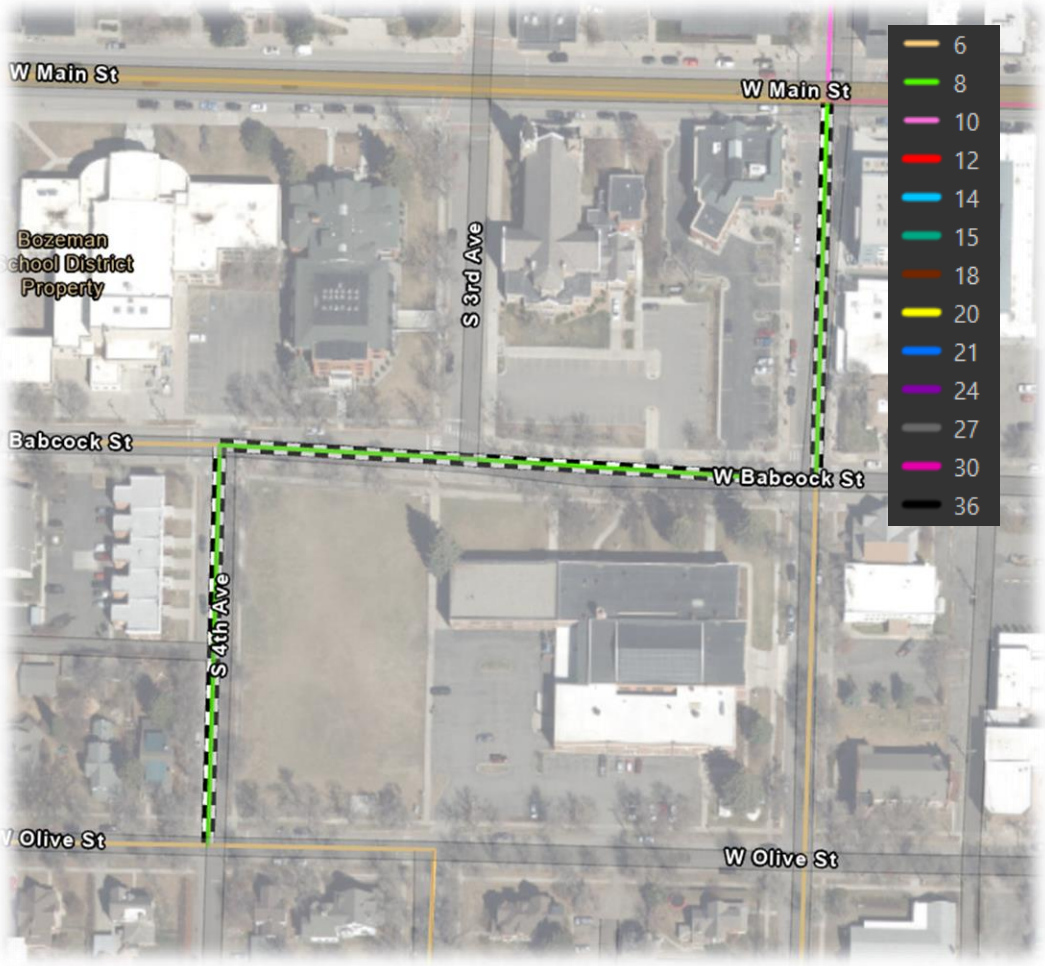


Figure 4-7: Project 6 Extents (checkered line)

The recommended pipe diameters to be installed for this project are shown in ***Figure 4-8***. The section of pipe between along W Babcock St and S 3rd Ave is recommended to be upsized to a 10-inch main. In total, 1,300 feet of pipe will be replaced in this project.

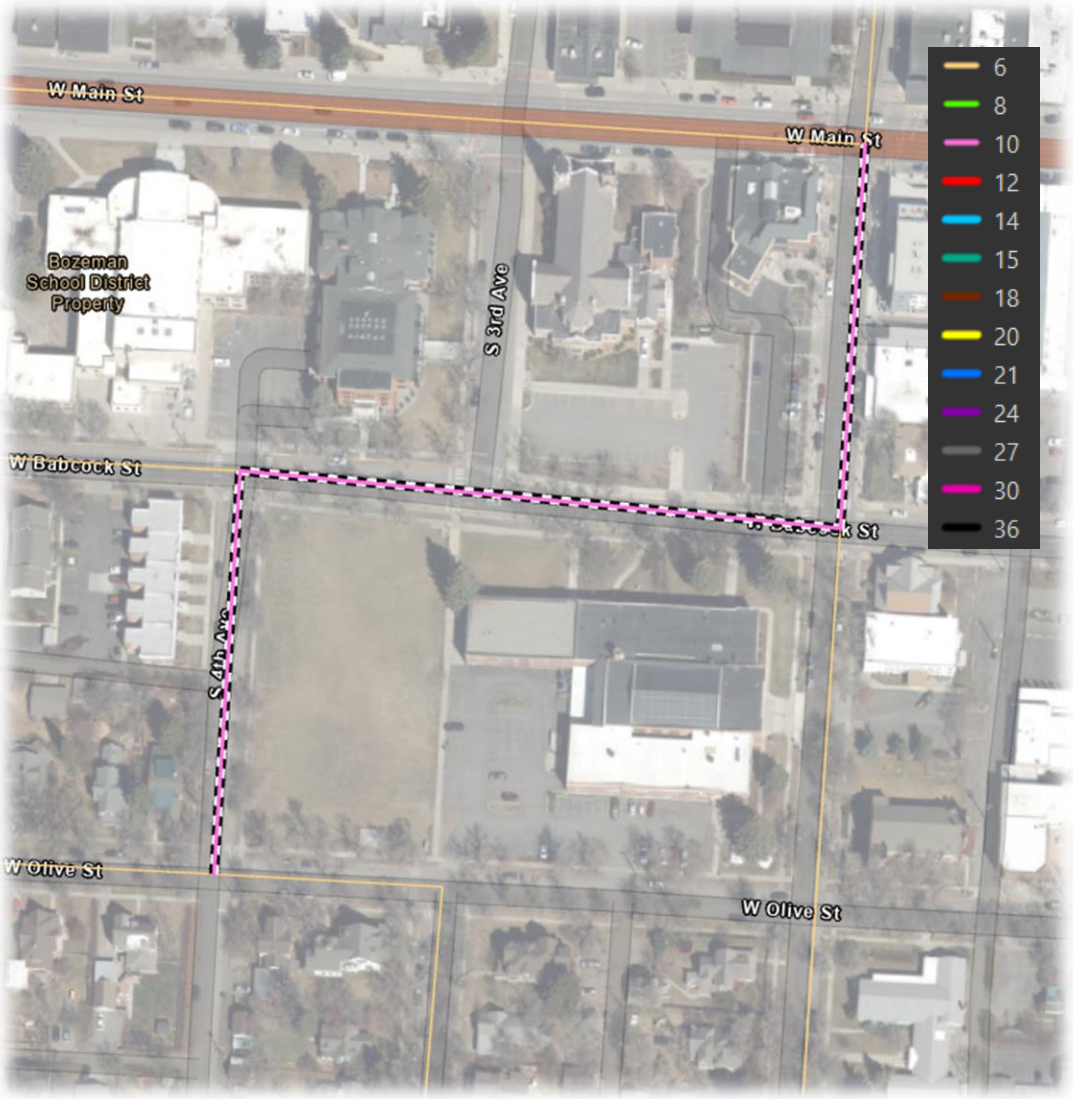


Figure 4-8: Project 6 Upsized Pipe Diameters (checkered line)

Project 6 is needed to renew critical aging infrastructure identified in the risk analysis, but also includes upsizing that is needed to alleviate existing capacity limitations.

4.1.7 Project 7: North 9th Avenue, West Villard Street, and South 9th Avenue Sewer Main Replacement

This project includes the replacement of the 10-inch main that starts on South 9th Avenue just south of Babcock Street. It continues to Willard Street, where it jogs east then north through the alley where it continues to Durston Road. 370 feet of the 10-inch needs to be upsized to a 15-inch main as shown in ***Figure 4-9***. Further north, the slope increases, and the pipe can be replaced with a 12-inch diameter for the remainder of the project.

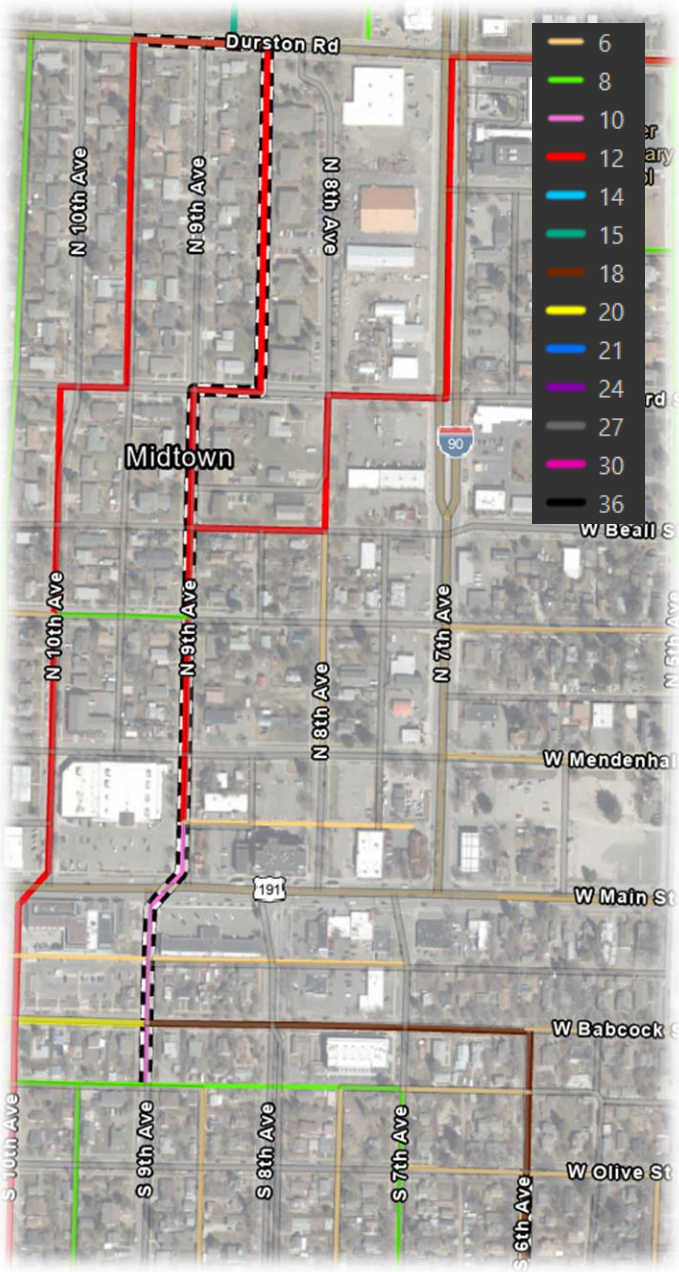


Figure 4-9: Project 7 Extents (checkered line)

Figure 4-10 shows the pipe configuration with all the needed pipes upsized. In total, 3,000 feet of pipe will be replaced and/or upgraded.

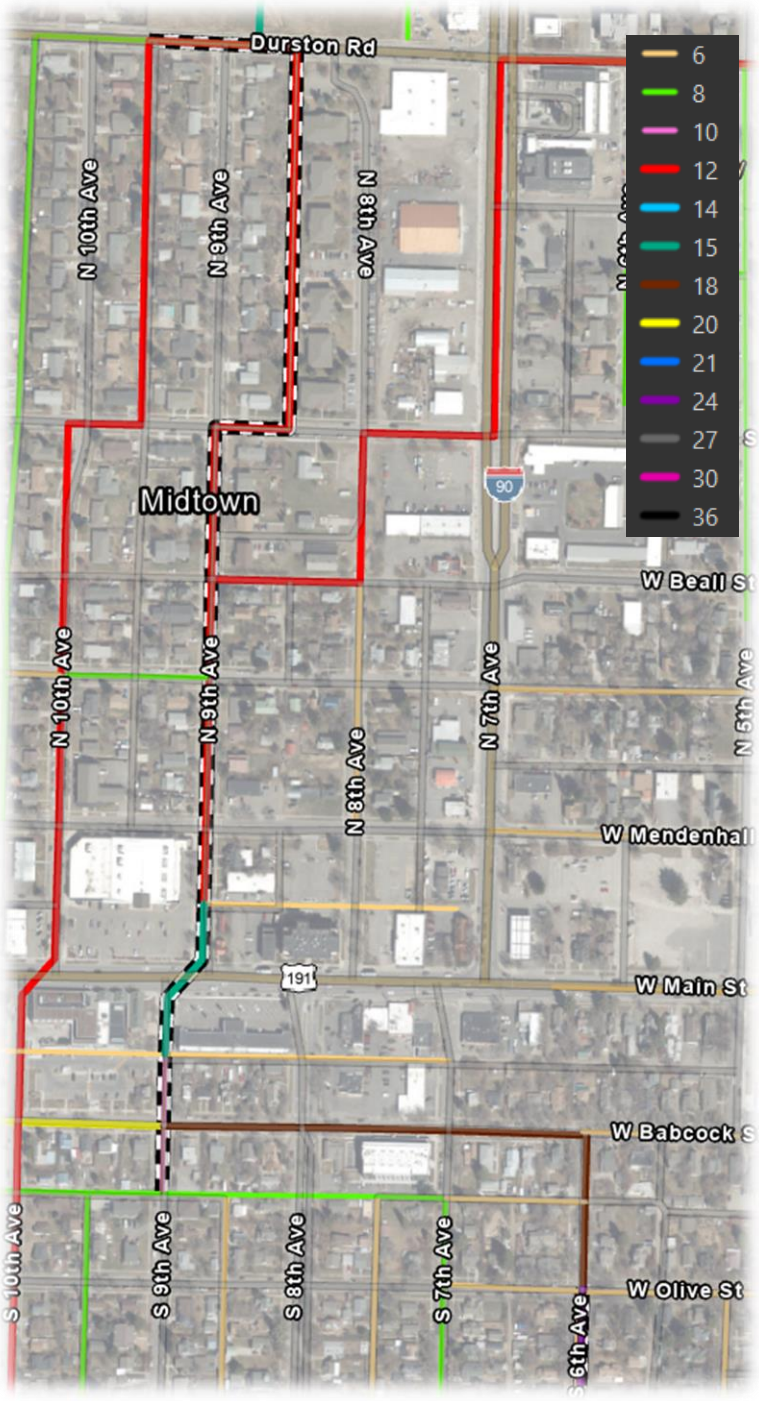


Figure 4-10: Project 7 Upsized Pipe Diameters (checkered line)

Project 7 is needed to renew critical aging infrastructure identified in the risk analysis.

4.1.8 Project 8: West Harrison Street, 10th Avenue, and West Curtiss Street Sewer Main Replacement

This project includes the replacement of the 10-inch main that starts at the corner of Harrison Street and 6th Avenue and runs west to 10th Avenue. Roughly half of this stretch is 10-inch diameter and should be replaced with 12-inch. From there the project extends north to Babcock Street replacing the 12-inch main. A small segment of 12-inch main on W Curtiss Street is also included. In total, 4,600 feet of pipe will be replaced. These pipes can be seen in ***Figure 4-11***.

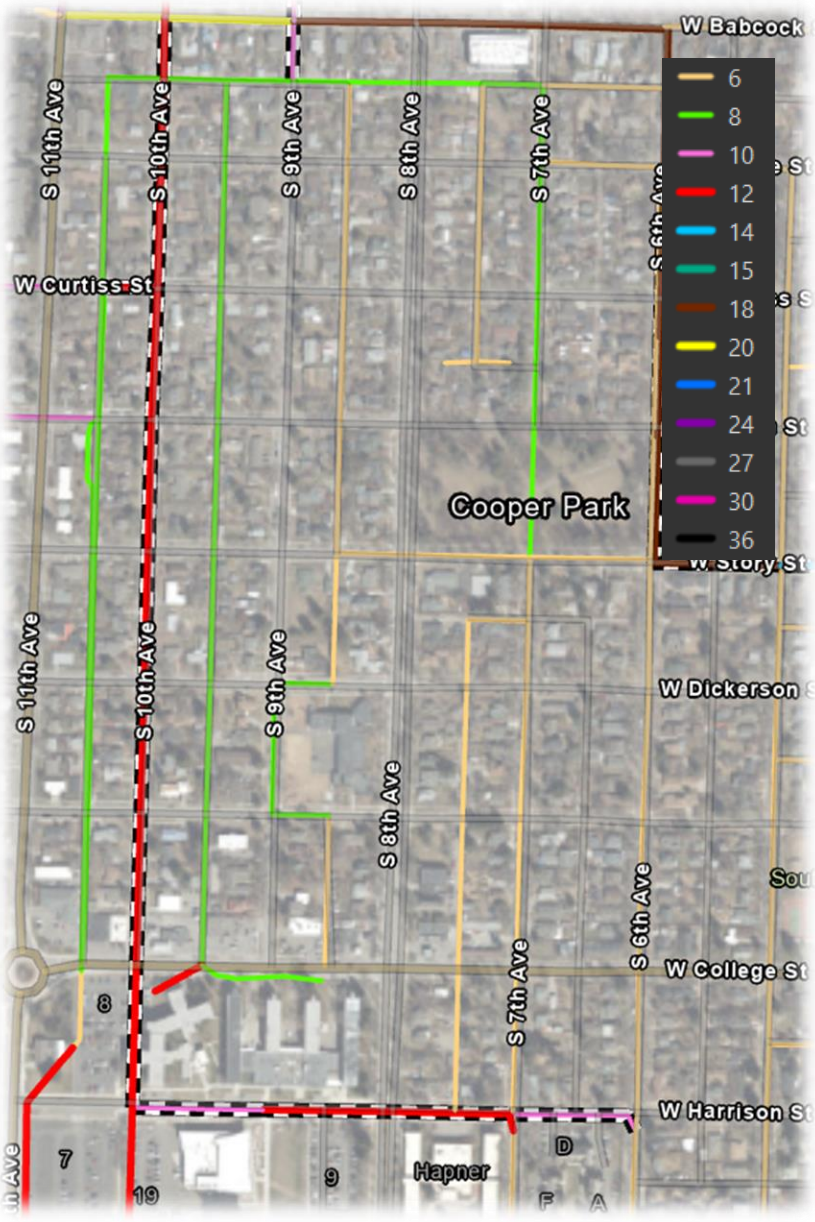


Figure 4-11: Project 8 Extents (checkered line)

Project 8 is needed to renew critical aging infrastructure identified in the risk analysis.

4.2 6-inch and Smaller Sewer Main Replacement Projects

The projects included in this section are focused on replacing the old 6-inch VCP throughout the sewer collection system. An interactive GIS dashboard showing the project extents and other pertinent details can be accessed using the link below: ArcGIS Insights Small Pipe Dashboard

4.2.1 Small Pipe Project 1: South Black Avenue 6-inch Sewer Main

This project includes the replacement of 3,000 feet of pipe along S Black Avenue. This pipe will be upgraded to 8-inch PVC pipe as part of the replacement project. The extents of this project are outlined with the checkered line in ***Figure 4-12***.

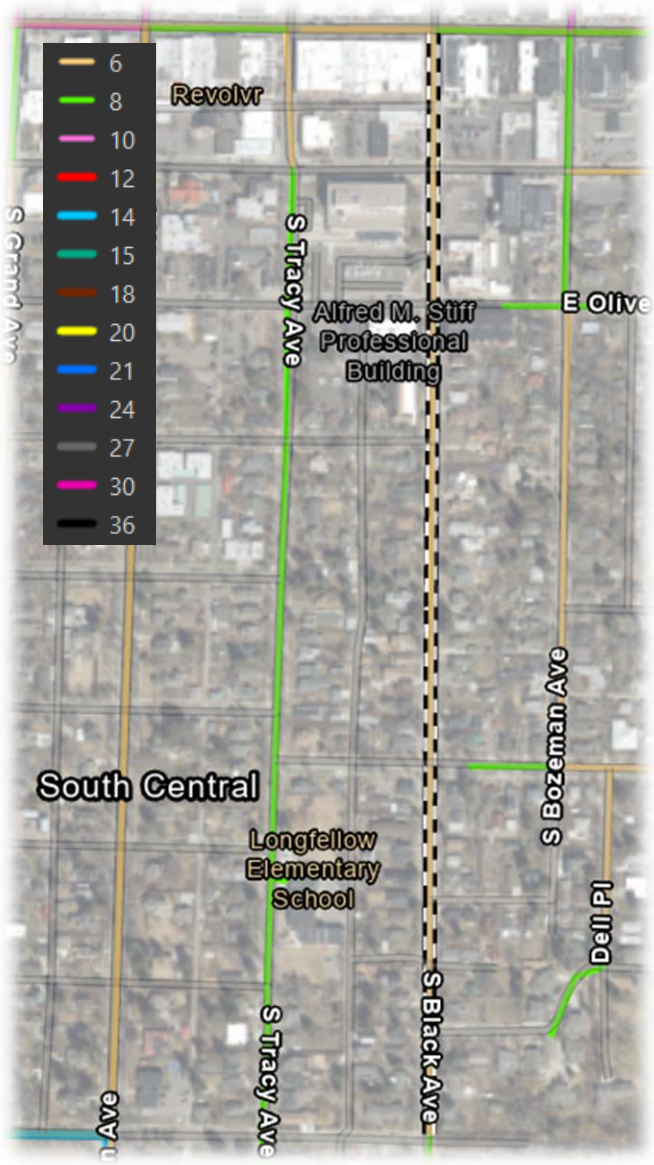


Figure 4-12: Small Pipe Project 1 Extents (checkered line)

4.2.2 Small Pipe Project 2: South Willson Avenue 6-inch Sewer Main

Project 2 involves the replacement of 3,000 feet of pipe along S Willson Ave. This pipe will be upgraded from a 6-inch to an 8-inch diameter pipe as part of this project. The extents of this project are outlined in ***Figure 4-13*** with the checkered line.

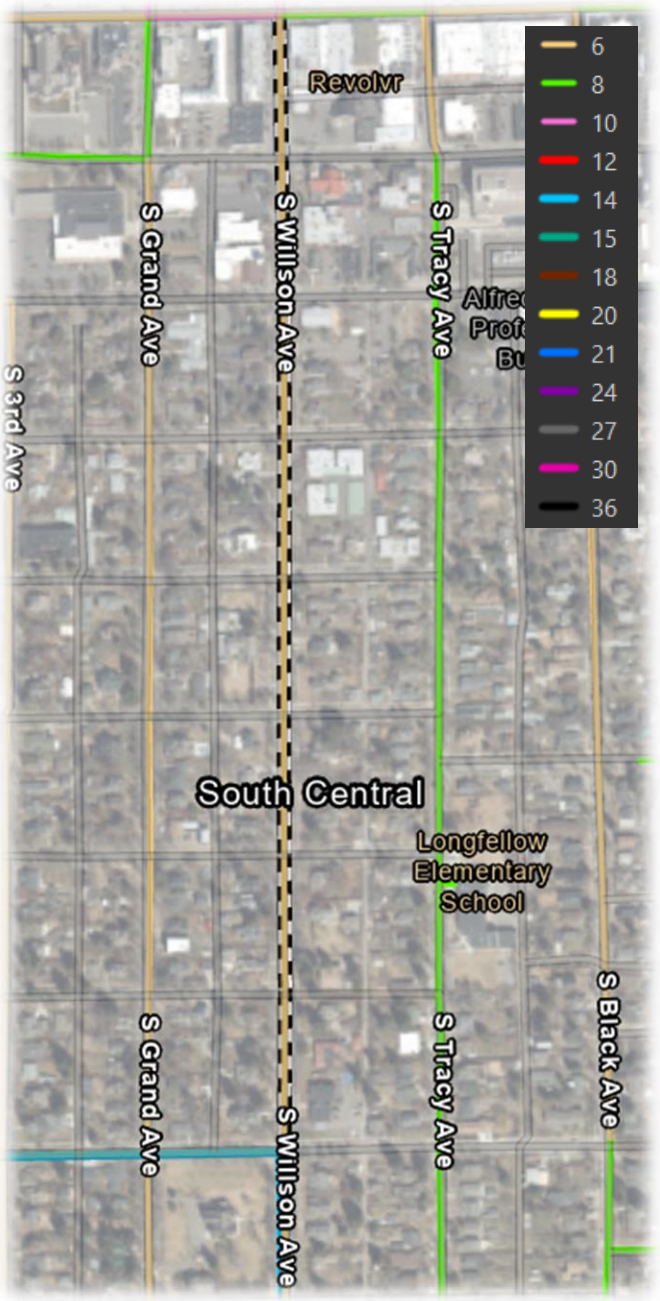


Figure 4-13: Small Pipe Project 2 Extents (checkered line)

4.2.3 Small Pipe Project 3: South Grand Avenue 6-inch Sewer Main

Project 3 involves the replacement of 2,500 feet of pipe along S Grand Ave. This pipe will be upgraded from a 6-inch to an 8-inch diameter pipe as part of this project. The extents of this project are outlined in ***Figure 4-14*** with the checkered line.

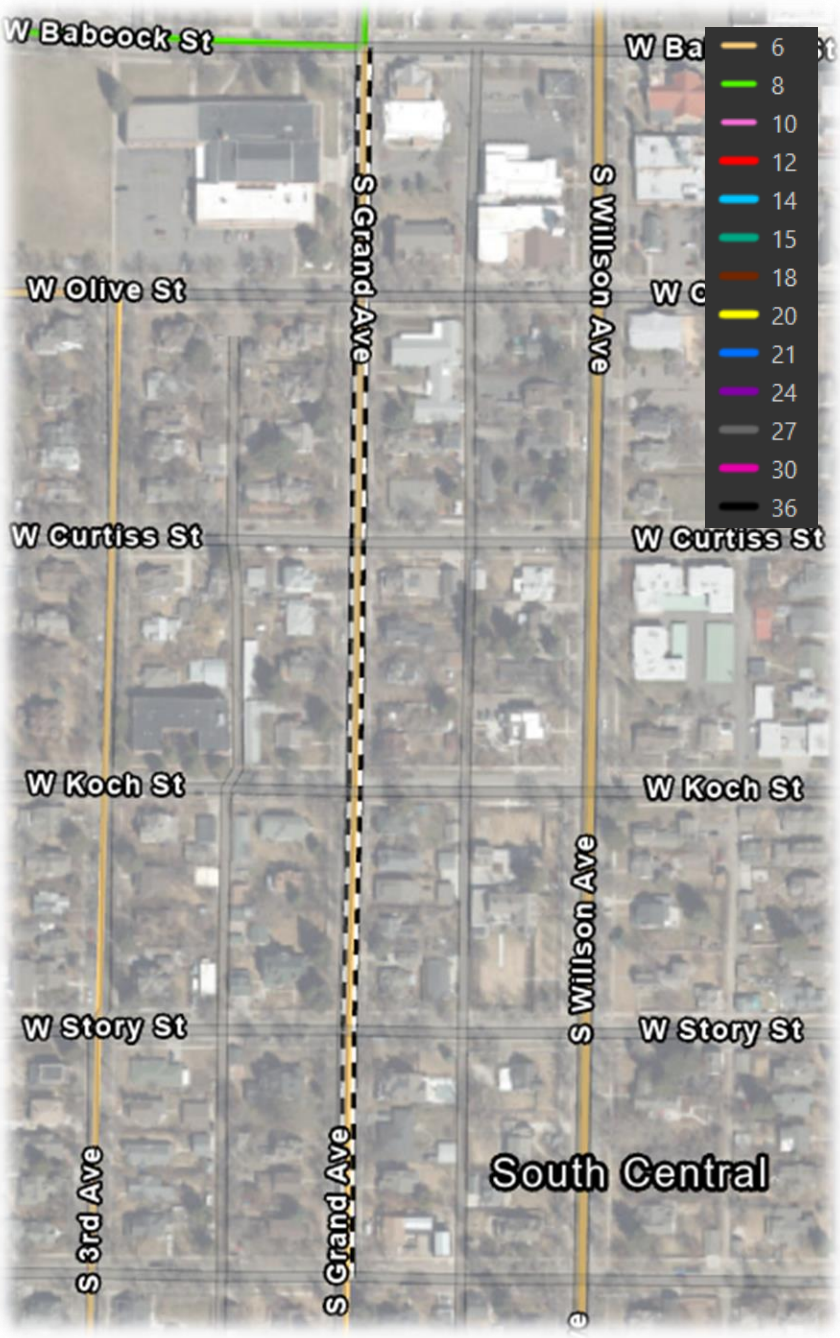


Figure 4-14: Small Pipe Project 3 Extents (checkered line)

4.2.4 Small Pipe Project 4: West Olive Street 6-inch Sewer Main

Project 4 involves the replacement of 1,000 feet of pipe along West Olive Street and South 6th Avenue. This pipe will be upgraded from a 6-inch to an 8-inch diameter pipe as part of this project. The extents of this project are outlined in ***Figure 4-15*** with the checkered line.



Figure 4-15: Small Pipe Project 4 Extents (checkered line)

4.2.5 Small Pipe Project 5: South 4th Avenue 6-inch Sewer Main

This project includes the replacement of 1,800 feet of pipe along S 4th Avenue. This pipe will be upgraded to 8-inch pipe as part of the replacement project. The extents of this project are outlined with the checkered line in ***Figure 4-16***.

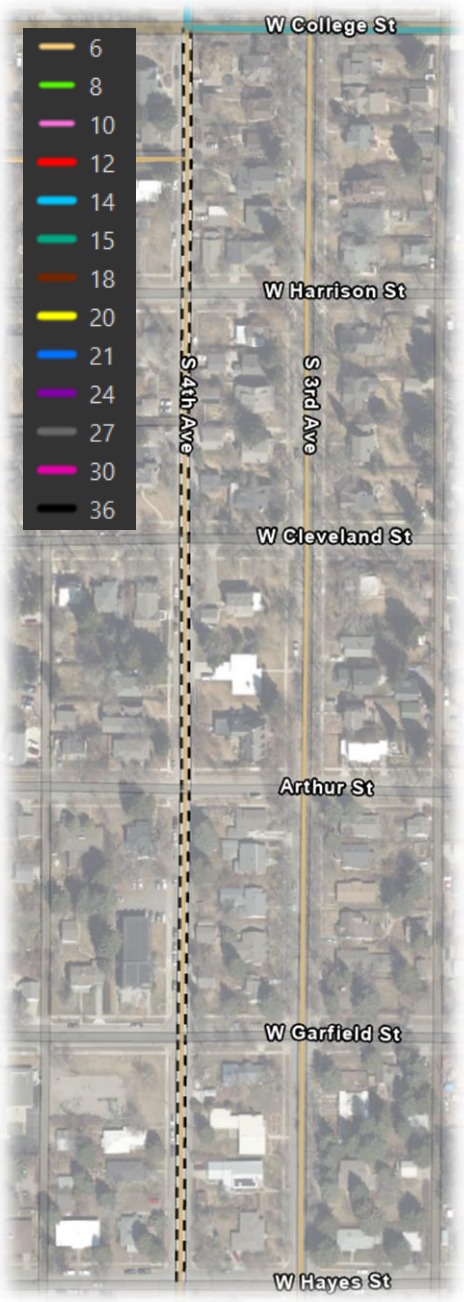


Figure 4-16: Small Pipe Project 5 Extents (checkered line)

4.2.6 Small Pipe Project 6: South 3rd Avenue 6-inch Sewer Main

Project 6 involves the replacement of 1,500 feet of pipe along S 3rd Ave. This pipe will be upgraded from a 6-inch to an 8-inch diameter pipe as part of this project. The extents of this project are outlined in ***Figure 4-17*** with the checkered line.



Figure 4-17: Small Pipe Project 6 Extents (checkered line)

4.3 Lift Station Improvement Projects

Additional lift station capacity is needed under the Infill and UBO future condition scenarios. The proposed lift stations and the existing lift station capacity expansions presented in this section are sized to meet the UBO growth conditions. In the near-term improvements (5-year), only one lift station project is recommended. The remainder of the projects are included in the long-term improvements and will be driven by the timing of new growth.

4.3.1 Lift Station Project 1: Valley Center Lift Station

The Valley Center Lift Station (shown in ***Figure 4-18***) is needed to support immediate growth within the City. This 2.33 MGD lift station project includes 3,200 feet of new 12-inch diameter force main.

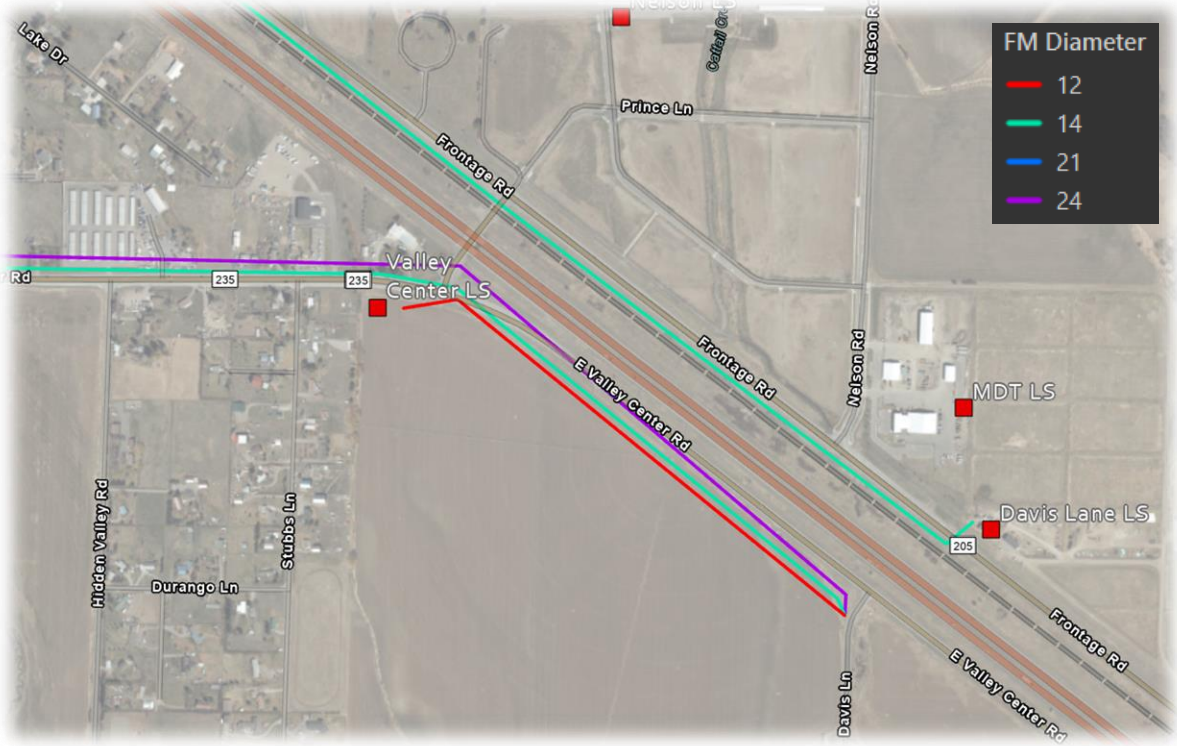


Figure 4-18: Valley Center Lift Station

4.4 Summary of Near-Term (5-Year) Capital Improvement Projects

A summary of the costs associated with the near-term capital improvement projects is included in ***Table 4-1***.

Table 4-1: Summary of Near Term (5-year) Capital Improvement Projects

Improvement ID	Location of Improvement	Opinion of Probable Cost (2024 $)
Project 1	19th Ave / Kagy Blvd Interceptor Improvements	$5,291,600
Project 2	Durston Road and 17th Avenue Sewer Main Replacement	$959,900
Project 3	7th Avenue to Oak Street Sewer Main Replacement	$1,276,400
Project 4	North 11th Avenue Sewer Main Replacement	$574,400
Project 5	Plum Avenue Sewer Main Replacement	$1,326,500
Project 6	4th Avenue, Babcock Street and Grand Avenue Sewer Main Replacement	$665,000
Project 7	North 9th Avenue, West Villard Street, and South 9th Avenue Sewer Main Replacement	$2,159,300
Project 8	West Harrison Street, 10th Avenue, and Curtiss Street Sewer Main Replacement	$2,478,600
Subtotal for 8-inch and Larger Sewer Main Replacement Projects		***$14,731,700***
Lift Station Project 1	Valley Center Lift Station	$5,962,700
Small Pipe Project 1	South Black Ave 6-inch Sewer Main Replacement	$1,817,000
Small Pipe Project 2	South Willson Ave 6-inch Sewer Main Replacement	$1,721,700
Small Pipe Project 3	South Grand Ave 6-inch Sewer Main Replacement	$1,377,600
Small Pipe Project 4	West Olive St 6-inch Sewer Main Replacement	$691,400
Small Pipe Project 5	South 4th Ave 6-inch Sewer Main Replacement	$961,100
Small Pipe Project 6	South 3rd Ave 6-inch Sewer Main Replacement	$971,800
Subtotal for 6-inch and Smaller Sewer Main Replacement Projects		***$7,540,600***
	Total 5-Year Project Costs	***$28,235,000***

Chapter 5 Long-Term (6-20-Year) Capital Improvement Plan

The most pressing infrastructure replacement needs are prioritized in the 5-year horizon. However, additional needs exist beyond what can be funded in the next 5 years. These projects are recommended for completion in the 6 to 20-year horizon. It should be noted that the risk assessment completed to prioritize project needs is based on the best available information at the time. As the City continues to complete CCTV inspections, new data should be incorporated into the risk assessment. Although core elements driving project prioritization such as pipe material, age, and diameter are unlikely to need revisions, CCTV inspections will help the City have a clear understanding of the current condition of the infrastructure and adjustments to project extents or timing can easily be completed.

5.1 8-inch and Larger Sewer Main Replacement Project

5.1.1 Project 9: N Grand Ave Sewer Replacement

A section of 10-inch diameter sewer main begins at W Main St and travels along N Grand Ave. Once the pipe reaches W Peach St, it transitions to a 15-inch diameter main. This is shown with a checkered line in ***Figure 5-1***. The total amount of pipe replaced in Project 9 totals 3,400 ft.

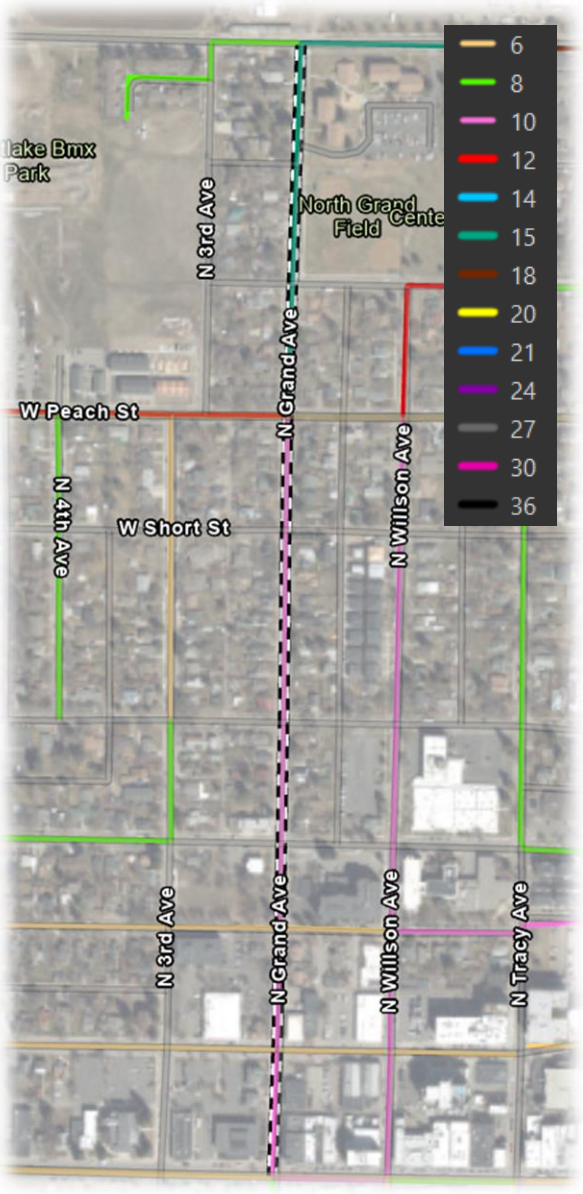


Figure 5-1: Project 9 Extents (checkered line)

5.1.2 Project 10: N 20th Ave Sewer Replacement

A section of sewer begins at W Babcock St and travels under industrial lots and joins N 20th Ave just before W Beall St. The main continues along N 20th Ave to Durston Rd. The entirety of this section is 10-inch diameter pipe. The total pipe replaced in this project is 2,700 ft. The checkered line in ***Figure 5-2*** below shows the extents of the project.

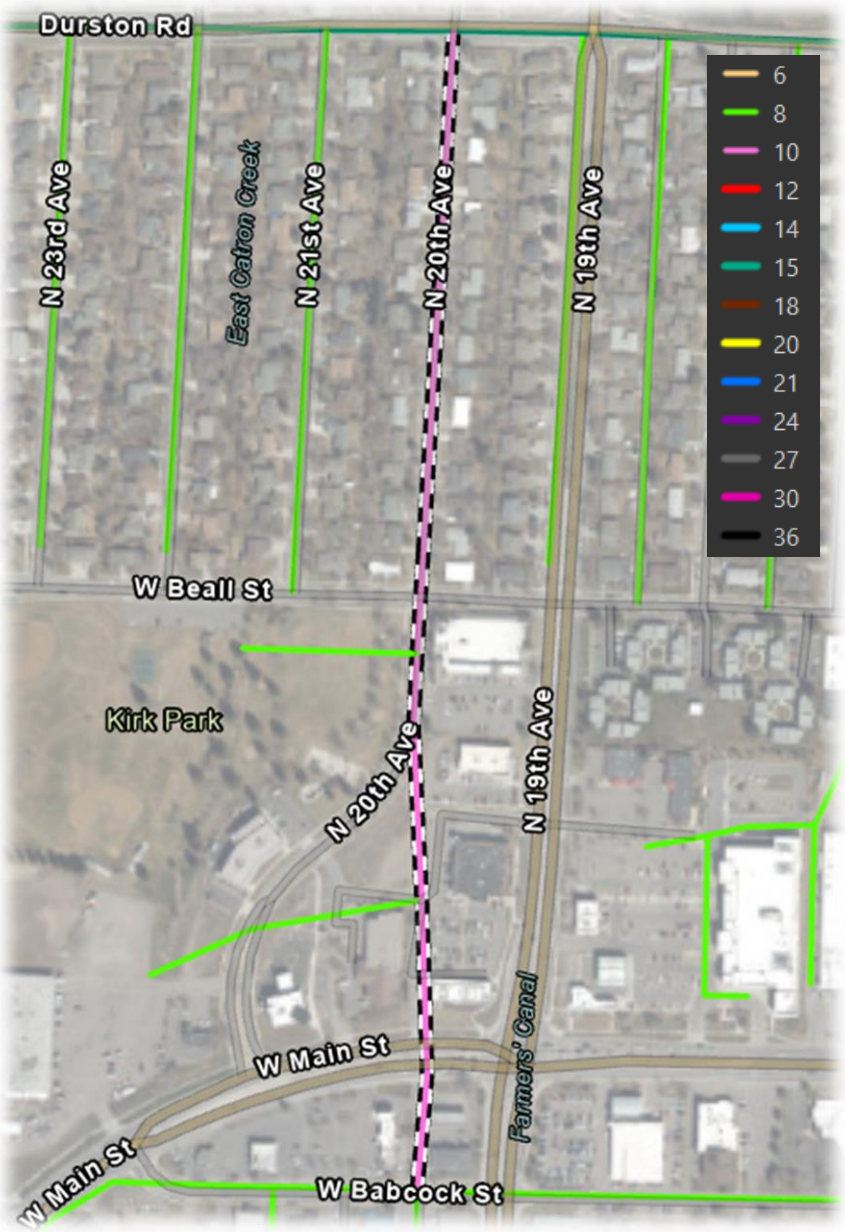


Figure 5-2: Project 10 Extents (checkered line)

5.1.3 Project 11: Upper Front Street Interceptor and Highland Glen Sewer Main Replacement

Project 11 involves replacing the upper portion of the Front Street interceptor and the Highland Glen sewer main extending south. Existing pipe will need to be upsized to meet Infill loading but was sized to provide capacity for the UBO scenario. The project extents are shown below by the checkered line in ***Figure 5-3.*** A total of approximately 6,300 feet of gravity main varying in size from 12- to 18-inch will replace the existing pipe. Under the Increased Density scenario, this interceptor would experience up to 0.90 d/D all the way to Tamarack Street. Additional monitoring and analysis may be warranted as the area contributing builds out.

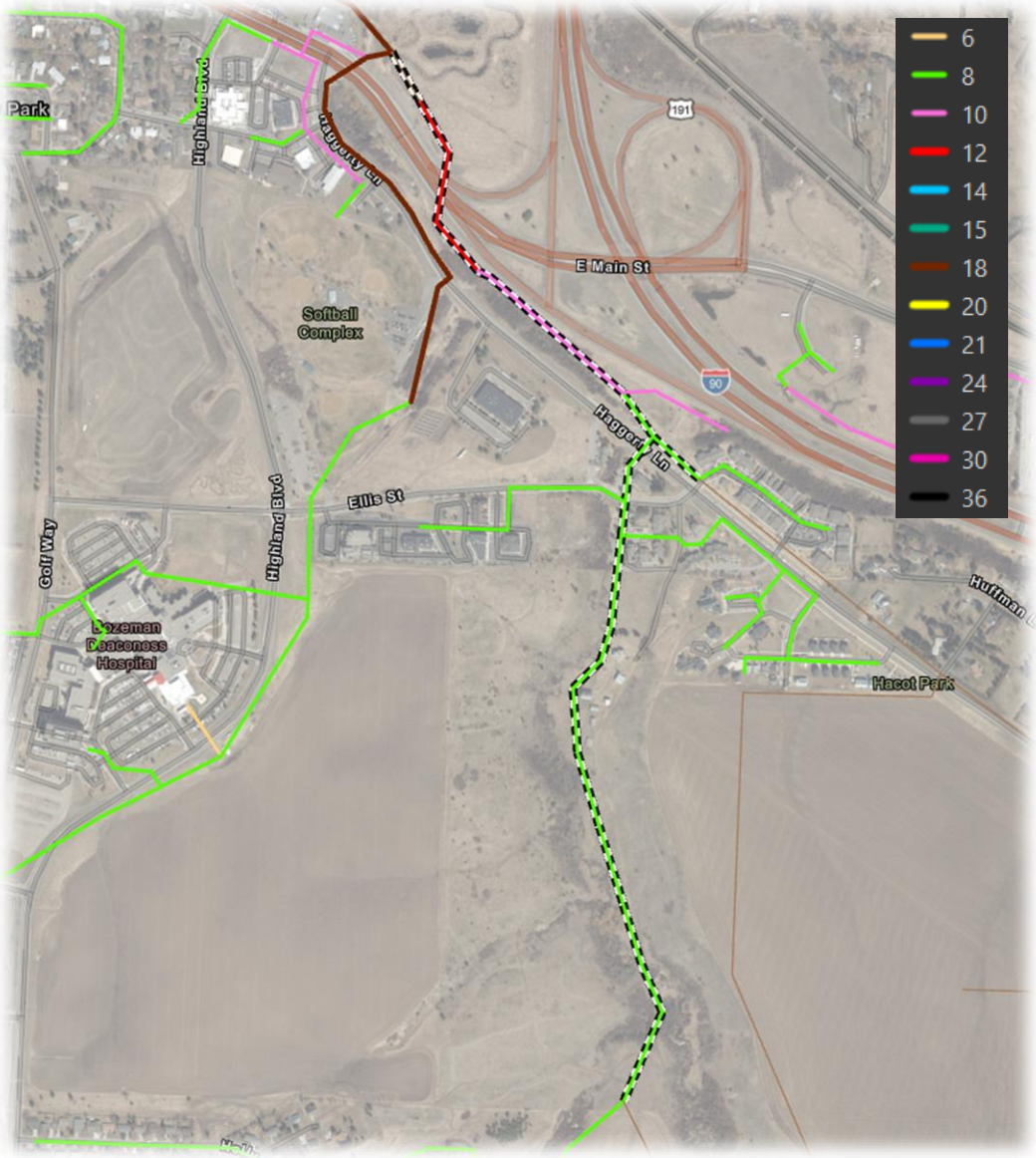


Figure 5-3: Project 11 Extents (checkered line)

5.1.4 Project 12: S Grand Ave Sewer Replacement

This section of pipe begins in the neighborhood just south of the beginning of S Grand Ave. Once the pipe reaches S Grand Ave, it follows S Grand Ave to W Dickerson St. The pipe starts as an 8-inch main, then downsizes to a 6-inch main once the pipe exits the neighborhood. Project 12 encompasses 1,600 feet of pipe. Existing pipe diameters and planned project extents can be seen in ***Figure 5-4***.



Figure 5-4: Project 12 extents (checkered line)

5.1.5 Project 13: N 19th Ave Sewer Replacement

This project includes a 24-inch sewer main that begins at the intersection of W Oak St and N 19th Ave, parallels N 19th Ave until Baxter Ln. The total length of pipe replaced in this project will be 2,700 feet. The extents of Project 13 are outlined by the checkered line and can be seen in ***Figure 5-5***.

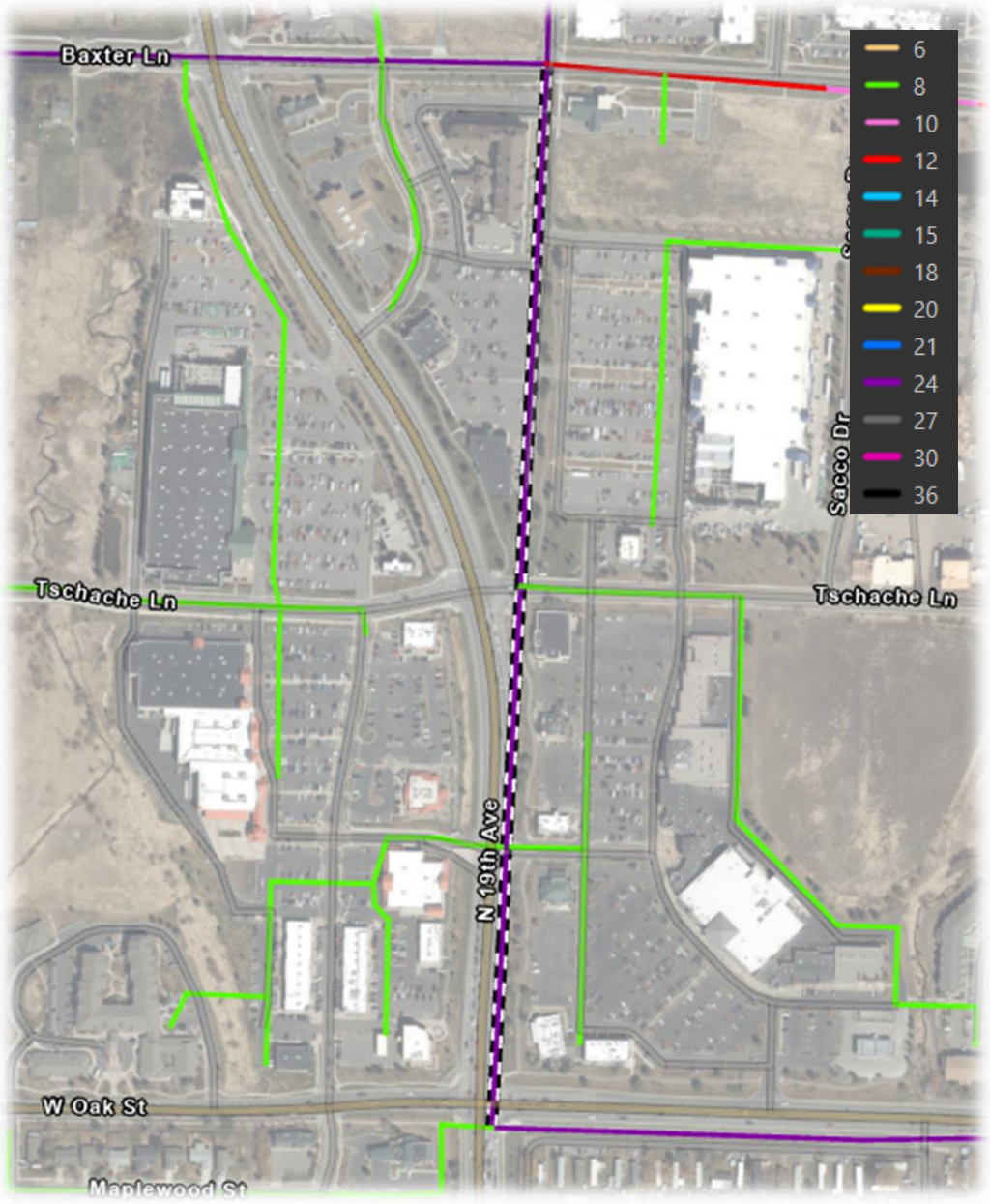


Figure 5-5: Project 13 Extents (checkered line)

5.1.6 Project 14: W Oak St Sewer Replacement

Project 14 includes one section of sewer main that begins at N 19th AVE and follows W Oak St until just beyond N 14th Ave. The section of pipe needing replacement is 2,200 feet long. The extents of the pipe needing replacement in Project 14 can be seen in ***Figure 5-6***.



Figure 5-6: Project 14 Extents (checkered line)

5.1.7 Project 15: E Lamme St Sewer Replacement

This section of sewer main follows E Lamme St from N Trace Ave to just before Plum Ave. This is a combination of three different diameter mains. The first section from N Tracy Ave to N Rouse Ave is a 10-inch main, the second section from N Rouse Ave to N Church Ave is an 8-inch main, and the final section from N Church Ave to Plum Ave is a 6-inch diameter. In total, these three sections add up to 2,650 feet of pipe that need to be replaced.



Figure 5-7: Project 15 Extents (checkered line)

5.1.8 Project 16: Plum Ave Sewer Replacement

Project 16 includes upgrading 750 feet of 6-inch diameter pipe, and 1,200 feet of 8-inch diameter pipe along Plum Ave and Davis St. In total 1,950 feet of pipe needs replacement. The extents of this project can be seen below outlined by the checkered line in ***Figure 5-8.***

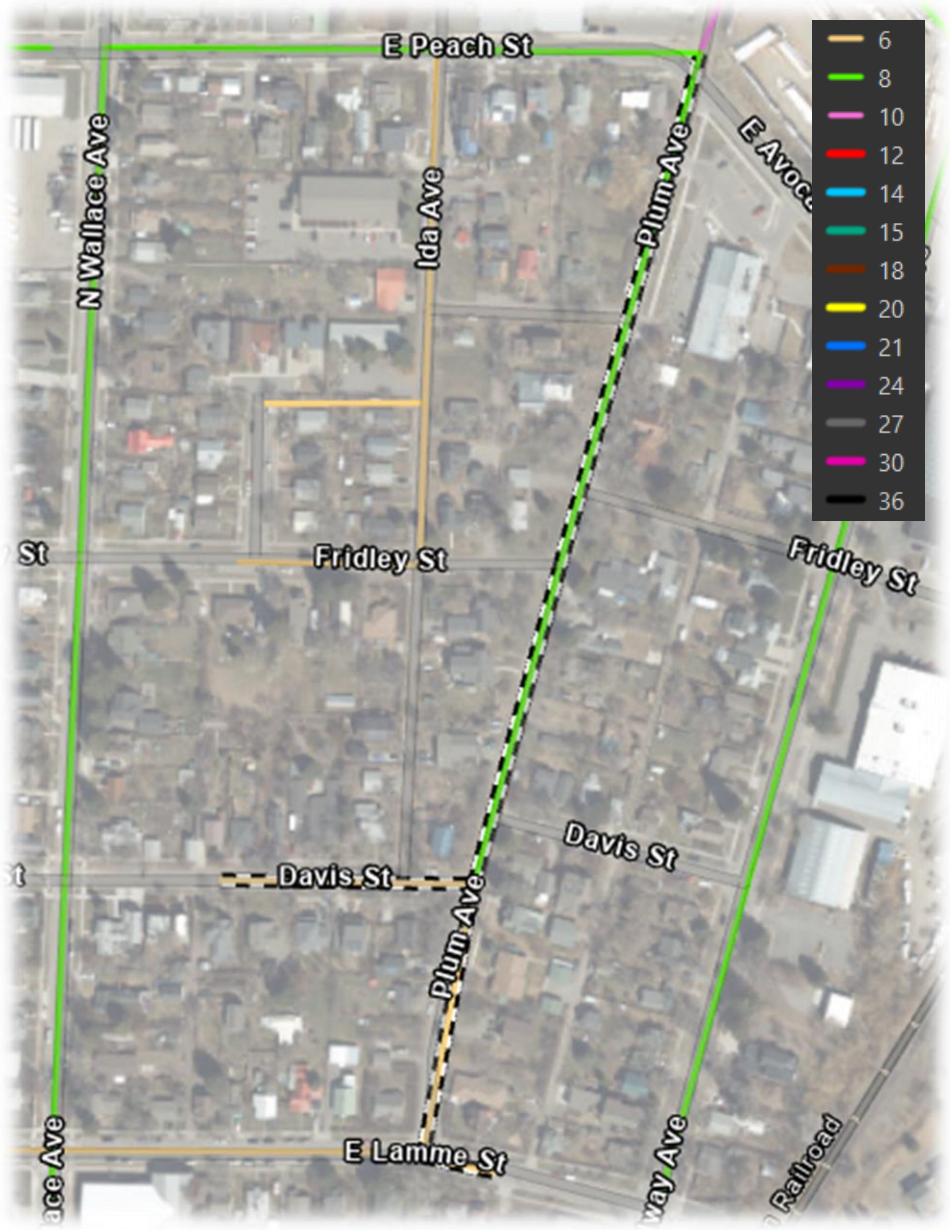


Figure 5-8: Project 16 Extents (checkered line)

5.2 6-inch and Smaller Sewer Main Replacement Projects

The projects included in this section are focused on replacing the old 6-inch vitrified clay pipe (VCP) throughout the sewer collection system.

5.2.1 Small Pipe Project 7: Main Street Sewer Main Replacement

Small Pipe Project 7 includes the replacement of 2,100 feet of 8-inch and 6-inch sewer mains along Main Street from South Tracy Avenue to Babcock Street. The extents of this project can be seen below in ***Figure 5-9.*** All 6-inch and 8-inch VCP mains replaced in this project will be upgraded to 8- or 10-inch diameter PVC pipes.

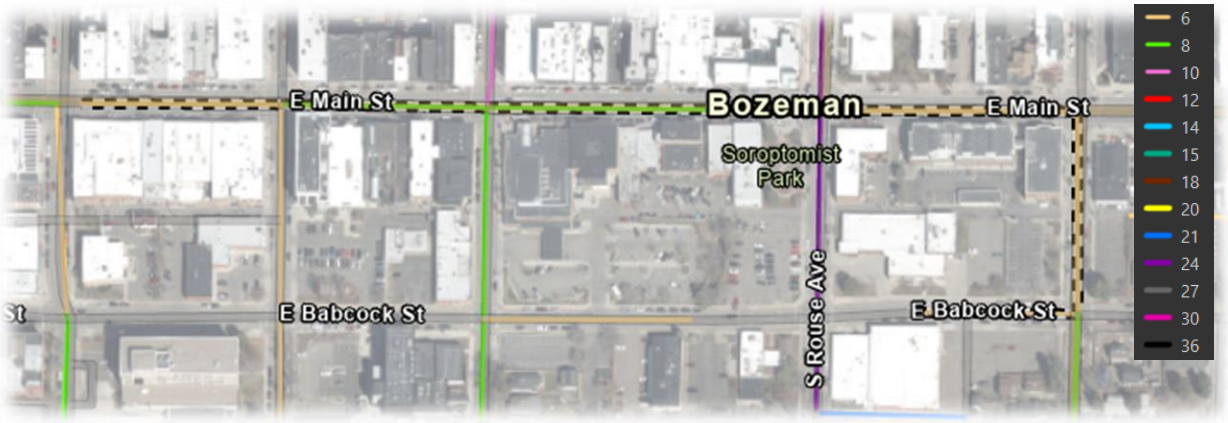


Figure 5-9: Small Pipe Project 7 Extents (checkered line)

5.2.2 Small Pipe Project 8: S Bozeman Ave, E Story St, and Dell Pl Sewer Main Replacement

This project includes the replacement of 6-inch sewer mains along S Bozeman Ave from E Olive St to E Story St, along with a section along S Story St to Bogert Pl. The final section of this project runs along Dell Pl from E Story St to E Alderson St. The pipe replaced in the project totals 2,250 feet. The extents of Small Pipe Project 8 can be seen below in ***Figure 5-10***, outlined by the checkered line. As part of this project, these 6-inch sewer mains will be upsized to 8-inch PVC pipes.

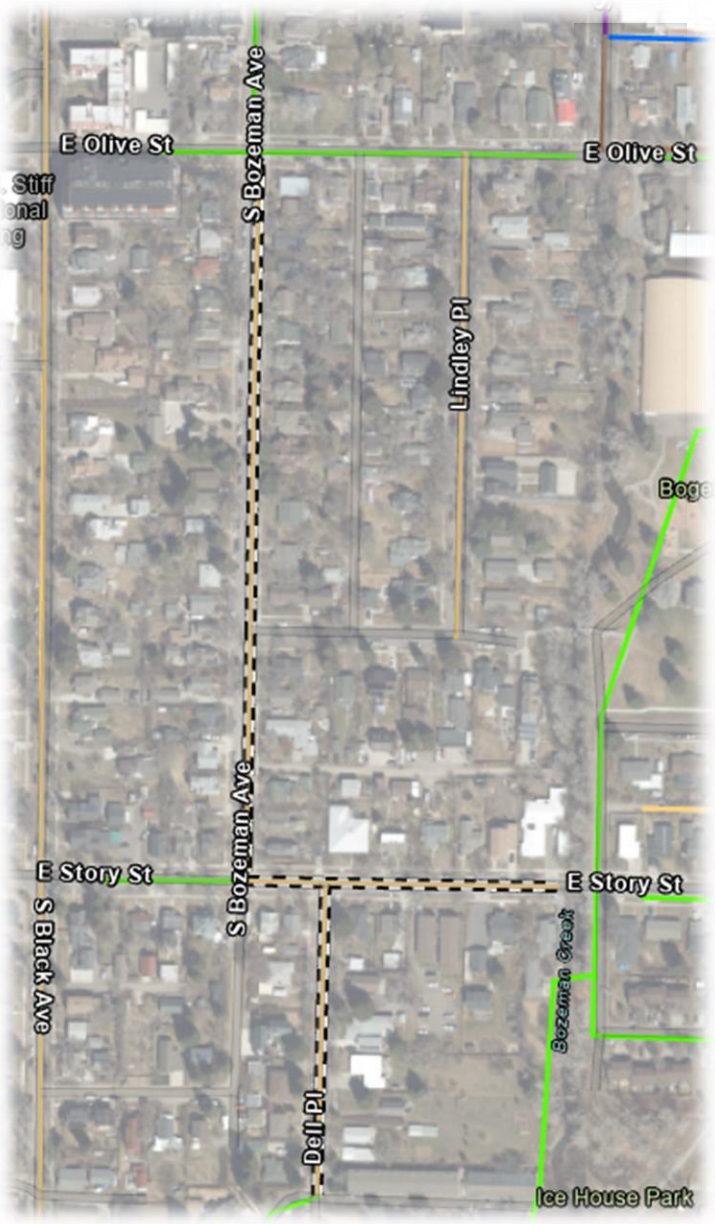


Figure 5-10: Small Pipe Project 8 Extents (checkered line)

5.2.3 Small Pipe Project 9: S 5th Ave and Alleys Sewer Main Replacement

Small Pipe Project 9 involves the replacement of 4,804 feet of pipe along S 5th Ave from just south of W Grant St to W Story Street. Three alley sewer lines are also included in this project. The alleys are between W Dickerson St and W Alderson St, W College St and W Harrison St, and W Story St and W Dickerson St. This sewer main will be upgraded to 8-inch diameter PVC pipe. The extents of this project can be seen outlined by the checkered lines in ***Figure 5-11*** below.

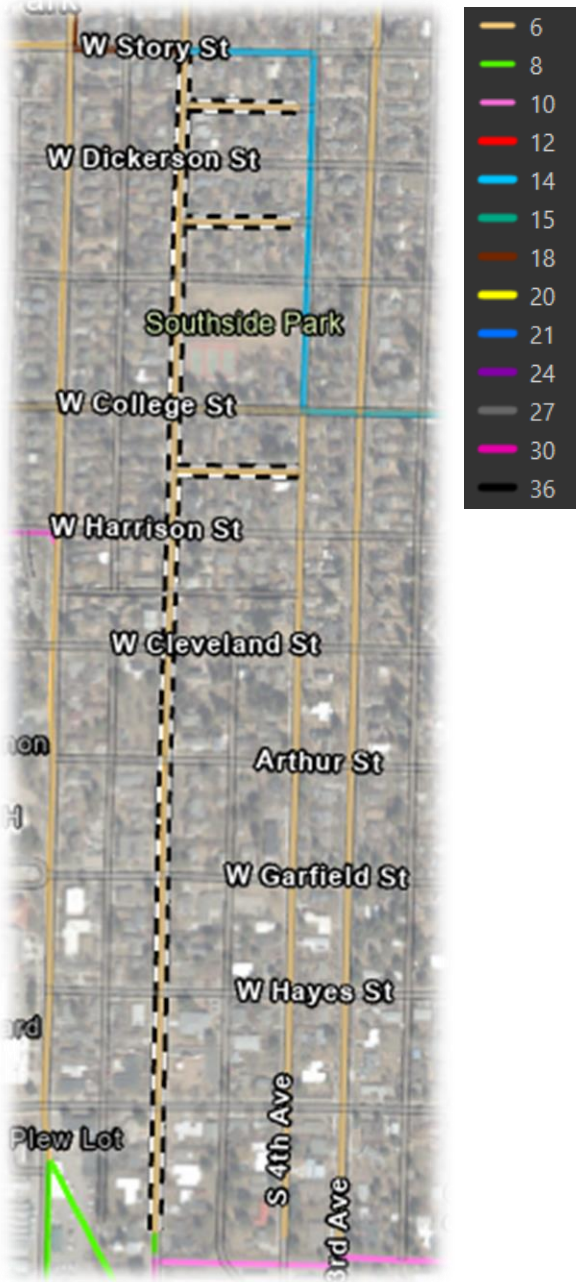


Figure 5-11: Small Pipes Project 9 Extents (checkered line)

5.2.4 Small Pipe Project 10: S 6th Ave Sewer Main Replacement

The sewer main begins just south of W Grant St and continues north to the intersection of W Harrison St. Most of the pipe in this project is a 6-inch diameter main; however, there is a small 46-foot section of 10-inch main included that connects the 6-inch main to W Harrison St. All 6-inch diameter mains will be upsized to 8-inch PVC pipes as part of this project. In total, 1,800 feet of pipe will be upgraded as part of this project. The extents of Small Pipe Project 10 can be seen below, outlined by the checkered line in ***Figure 5-12***.

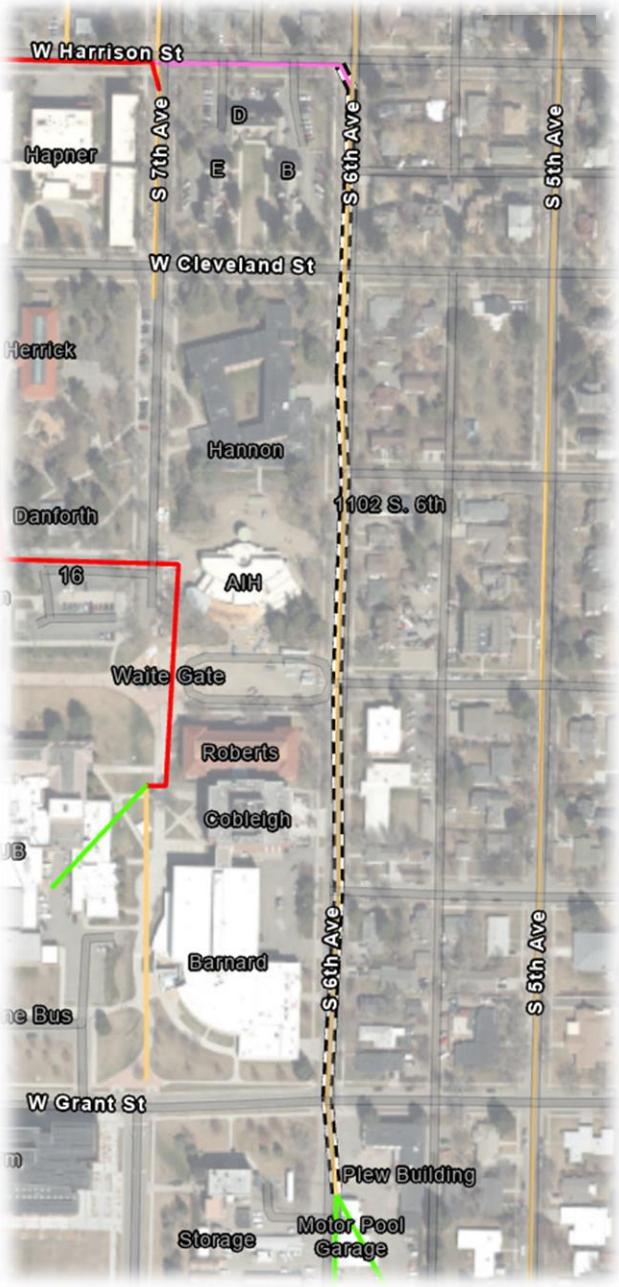


Figure 5-12: Small Pipe Project 10 Extents (checkered line)

5.2.5 Small Pipe Project 11: W Lamme St Sewer Main Replacement

Small Pipe Project 11 includes replacement of a 6-inch main along W Lamme St from N 7th Ave to N Willson Ave. The 1,900 foot 6-inch VCP main will be upgraded to a new, 8-inch PVC pipe. The extents of this project are outlined by the checkered line in ***Figure 5-13*** below.



Figure 5-13: Small Pipe Project 11 Extents (checkered line)

5.2.6 Small Pipe Project 12: S 4th Ave and S 3rd Ave Sewer Main Replacement

This project includes two sections of independent pipe. One segment extends along S 4th Ave from W Hayes St to a block south of W Grant St. The other segment follows S 3rd Ave from W Garfield St to a block south of W Grant St. Both pipes are 6-inch VCP mains that need to be upsized to 8" PVC pipes. The checkered line in ***Figure 5-14*** outlines the extents of the project. In total, 1,900 feet of pipe will be replaced in this project.

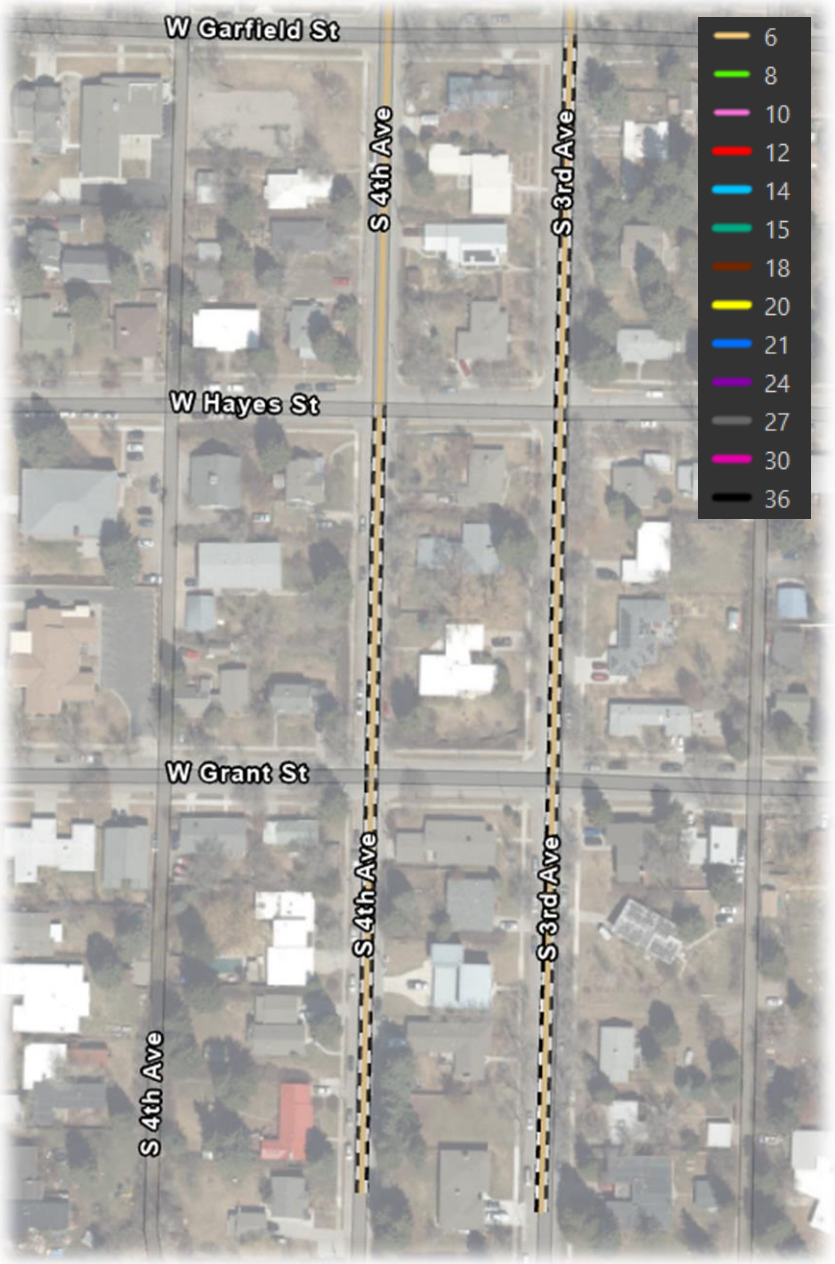


Figure 5-14: Small Pipe Project 12 Extents (checkered line)

5.2.7 Small Pipe Project 13: S 7th Ave Sewer Main Replacement

Small Pipe Project 13 includes the upsizing of a 6-inch sewer main that runs beneath S 7th Ave from W Story St to W Cleveland St. The main is 1,940 feet long and should be upsized to 8-inch diameter. An additional, small section of 12-inch main is also included in this project. The 12-inch main that needs replacement is 50 feet long. The extents of this project can be seen in ***Figure 5-15***.



Figure 5-15: Small Pipe Project 13 Extents (checkered line)

5.2.8 Small Pipe Project 14: S 3rd Ave Sewer Main Replacement

Small Pipe Project 14 includes the upsizing of a 2,200-foot section of 6-inch main to 8-inch diameter along S 3rd Ave. The segment begins at W College Street and ends at W Olive St. The extents of this project can be seen outlined by the checkered line in ***Figure 5-16*** below.

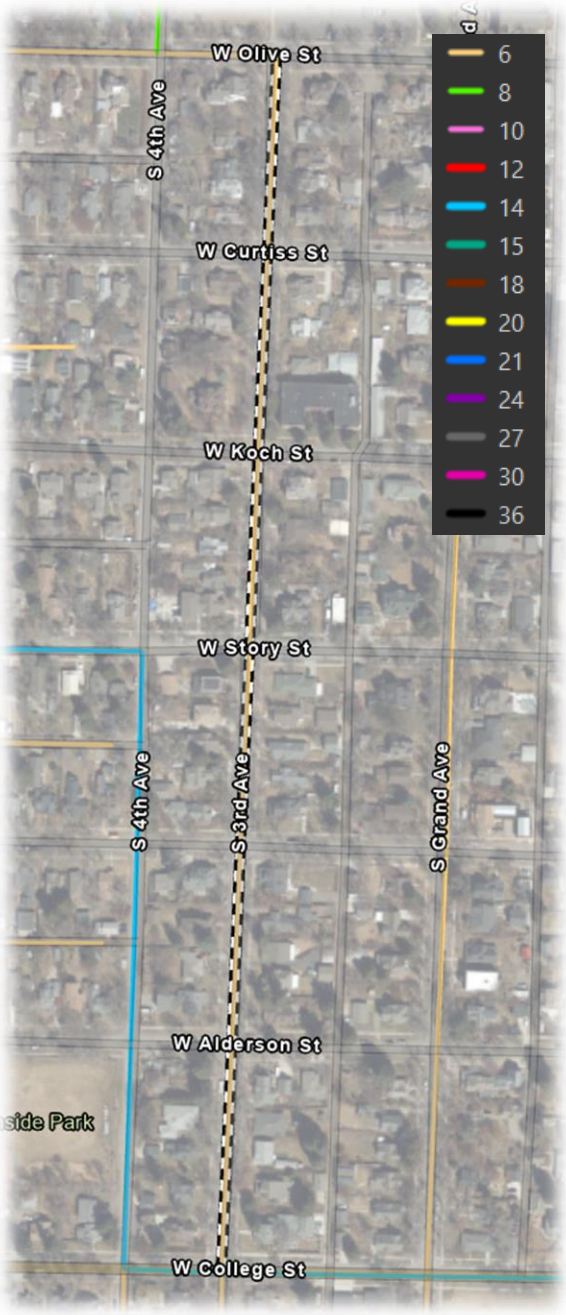


Figure 5-16: Small Pipe Project 14 Extents (checkered line)

5.2.9 Small Pipe Project 15: N Black Ave, E Cottonwood St, and N Tracy Ave Sewer Replacement

This project contains 6-inch and 8-inch sewer mains. The 6-inch main follows N Black Ave from E Beall St to E Cottonwood St, then upsizes to E Cottonwood St to N Tracy Ave, and goes back down to 6-inches as it wraps around back onto N Tracy Ave. All 6-inch mains will be upgraded to an 8-inch diameter in this project. The extents of the project can be seen below in ***Figure 5-17*** outlined by the checkered line. 1,650 feet of pipe will be upgraded as part of this project.

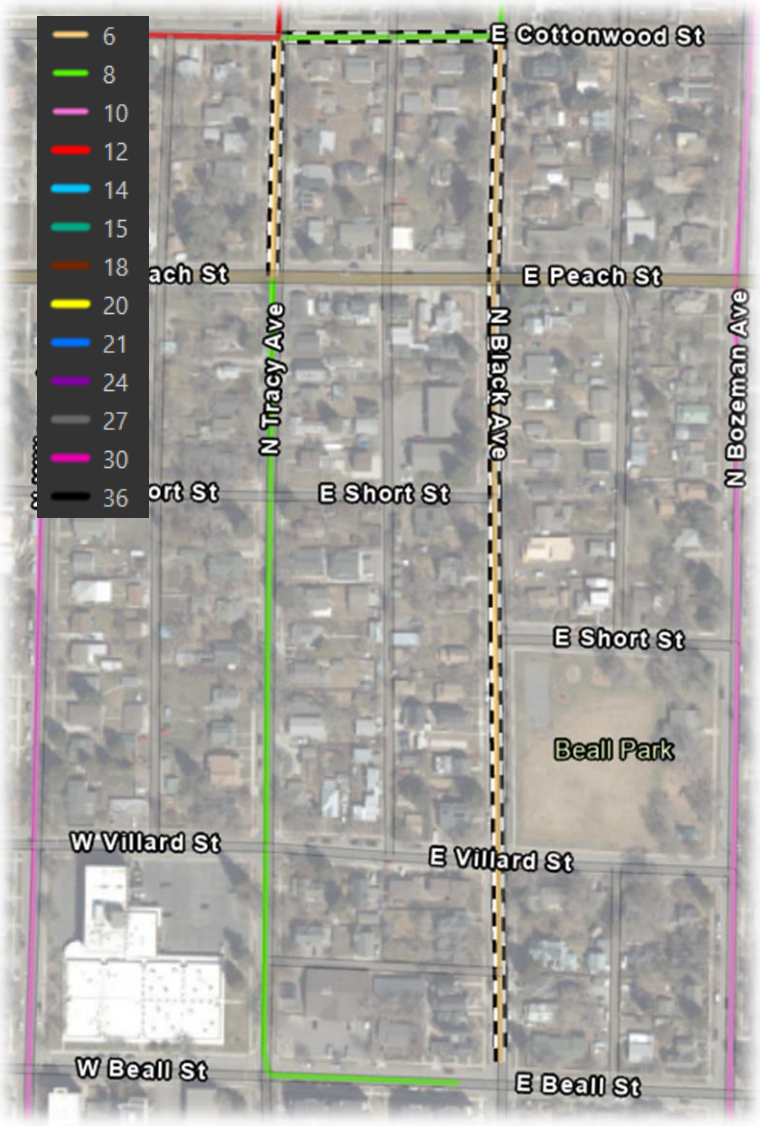


Figure 5-17: Small Pipe Project 15 Extents (checkered line)

5.2.10 Small Pipe Project 16: Ida Ave and Fridley St Sewer Replacement

The 6-inch main begins at the intersection of Fridley St and Brady Ave, then wraps around and extends on Ida Ave to E Peach St. An alley sewer just north of Fridley St is included in this project as well. The 6-inch main will be upgraded and upsized to an 8-inch PVC pipe as part of this project. The extents of the project can be seen below, in ***Figure 5-18*** outlined by the checkered line. In total, 1,200 feet of pipe will be upgraded in this project.

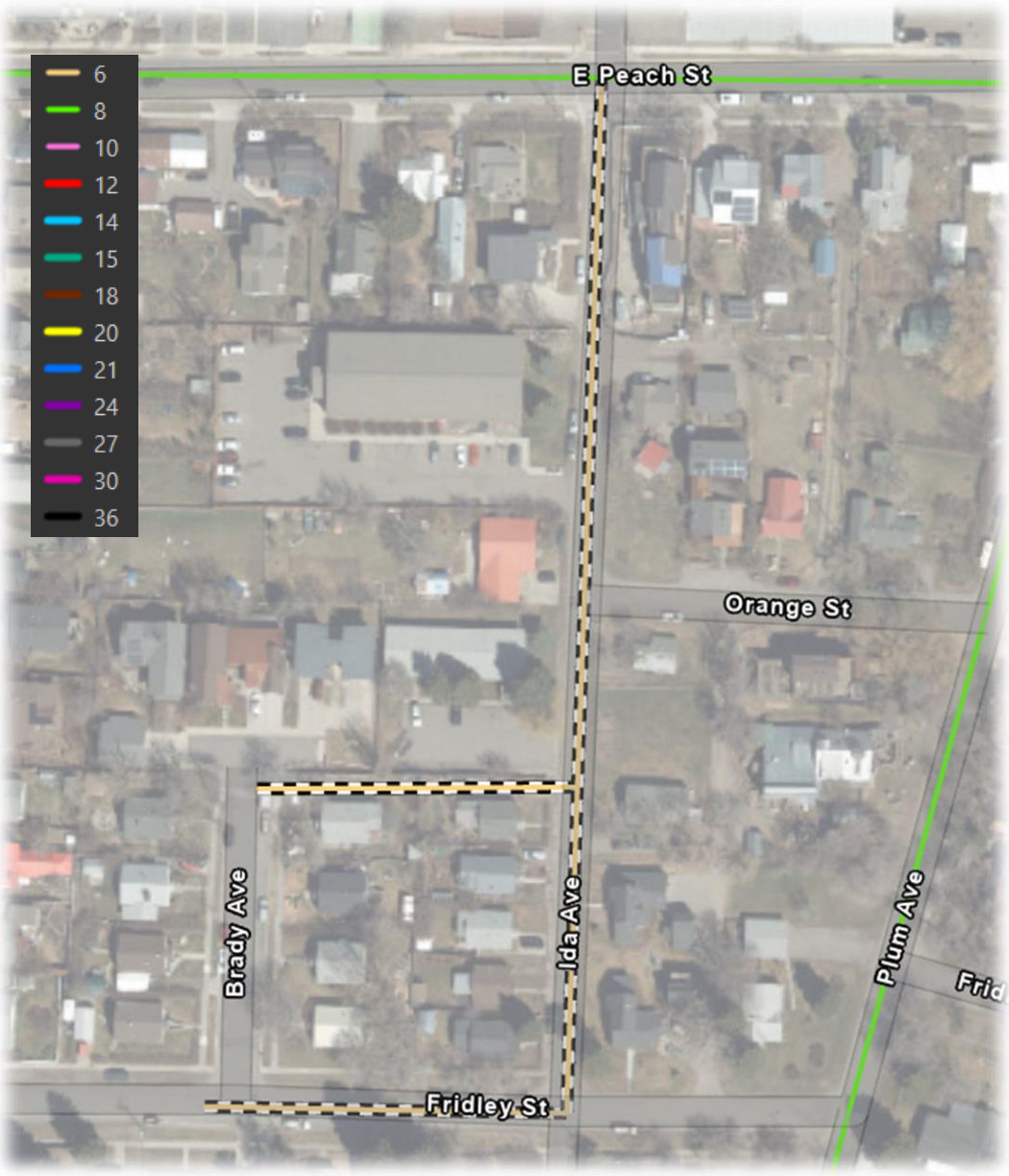


Figure 5-18: Small Pipe Project 16 Extents (checkered line)

5.2.11 Small Pipe Project 17: E Cottonwood St Sewer Replacement

An 1,100-foot section of 6-inch VCP will be upgraded to an 8-inch PVC main in Small Pipe Project 17. The checkered line in ***Figure 5-19*** below outlines the extents of this project. The main runs along E Cottonwood St from N Church Ave to Plum Ave.



Figure 5-19: Small Pipe Project 17 Extents (checkered line)

5.2.12 Small Pipe Project 18: E Aspen St Sewer Replacement

Small Pipe Project 18 includes the 6-inch main along E Aspen St from N Church Ave to Plum Ave. A total of 950 feet of pipe will be upgraded to 8-inch diameter PVC. The extents of the project can be seen below outlined by the checkered line in ***Figure 5-20***.



Figure 5-20: Small Pipe Project 18 Extents (checkered line)

5.2.13 Small Pipe Project 19: N 3rd Ave Sewer Replacement

A 910-foot segment of 6-inch sewer main will be upgraded to 8-inch PVC along N 3rd Ave from W Villard St to W Peach St. The checkered line in ***Figure 5-21*** outlines the extents of this project.

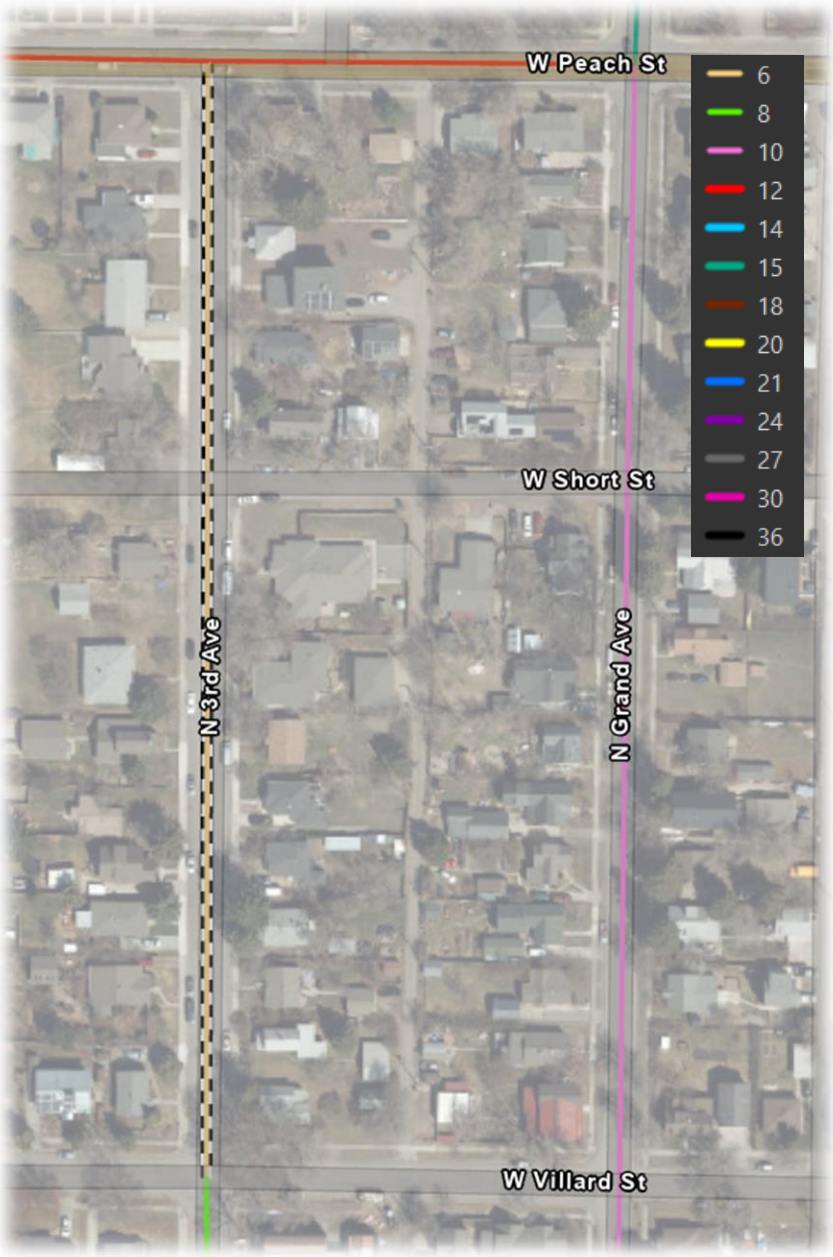


Figure 5-21: Small Pipe Project 19 Extents (checkered line)

5.2.14 Small Pipe Project 20: N 8th Ave Sewer Replacement

Small Pipe Project 20 includes the upsizing and replacement of two segments of 6-inch sewer main. One segment starts at the intersection of N 8th Ave and W Mendenhall St and extends to W Beall St. The second segment starts at N 9th Ave and ends at N 7th Ave. In total, 1,209 feet of pipe will be replaced and upsized to 8-inch PVC. The extents of the project and two segments can be seen below outlined by the checkered line in ***Figure 5-22***.

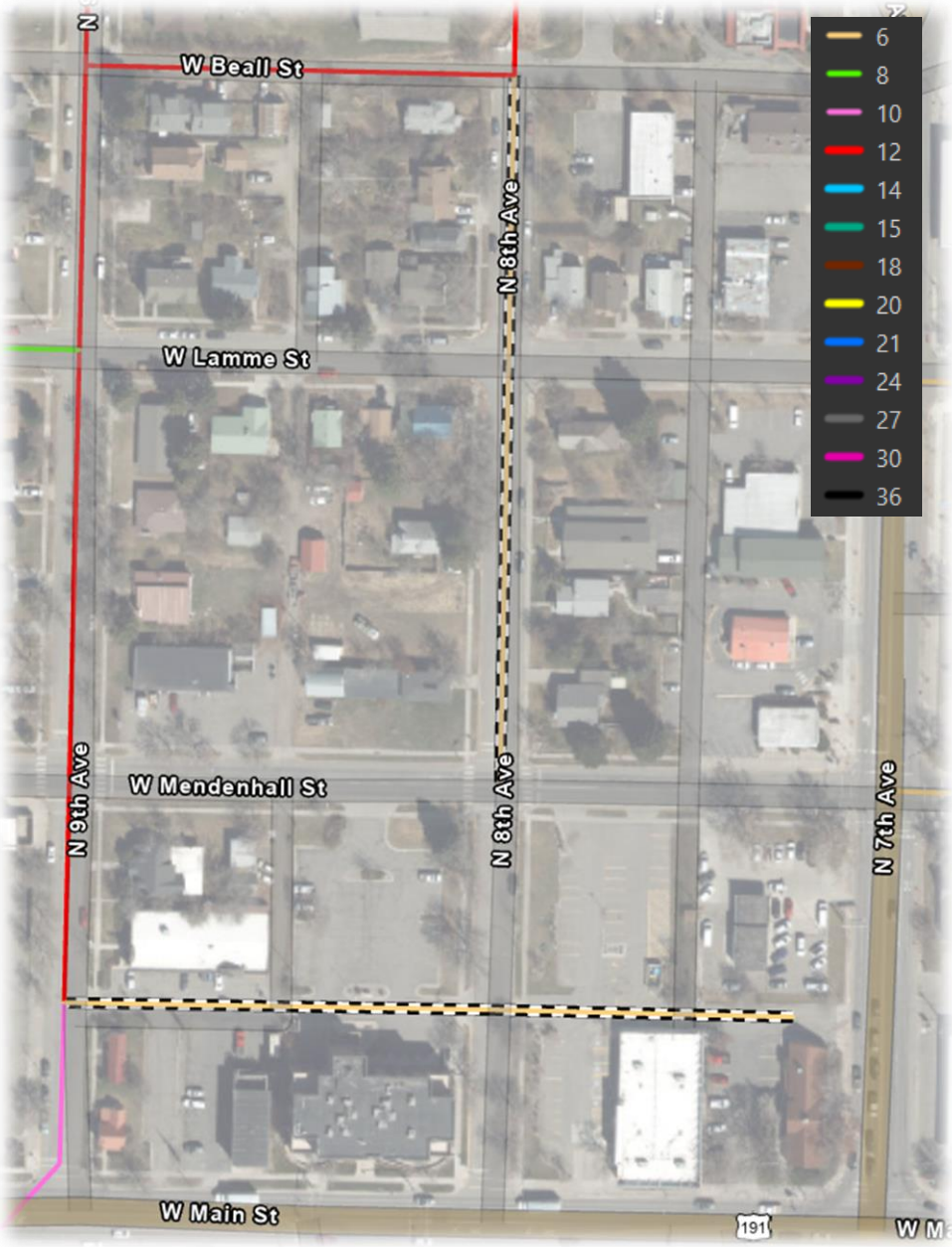


Figure 5-22: Small Pipe Project 20 Extents (checkered line)

5.2.15 Small Pipe Project 21: W Lamme St Sewer Replacement

A short, 500-foot section of pipe will be upgraded to 8-inch PVC in this project. The main starts at the intersection of W Lamme St and an alley just east of N 11th Ave and extends to N 9th Ave. The main is composed of both 8-inch and 6-inch VCP. The 6-inch portion will be upsized to 8-inch as part of this project. The extents of this project can be seen outlined by the checkered line in ***Figure 5-23*** below.

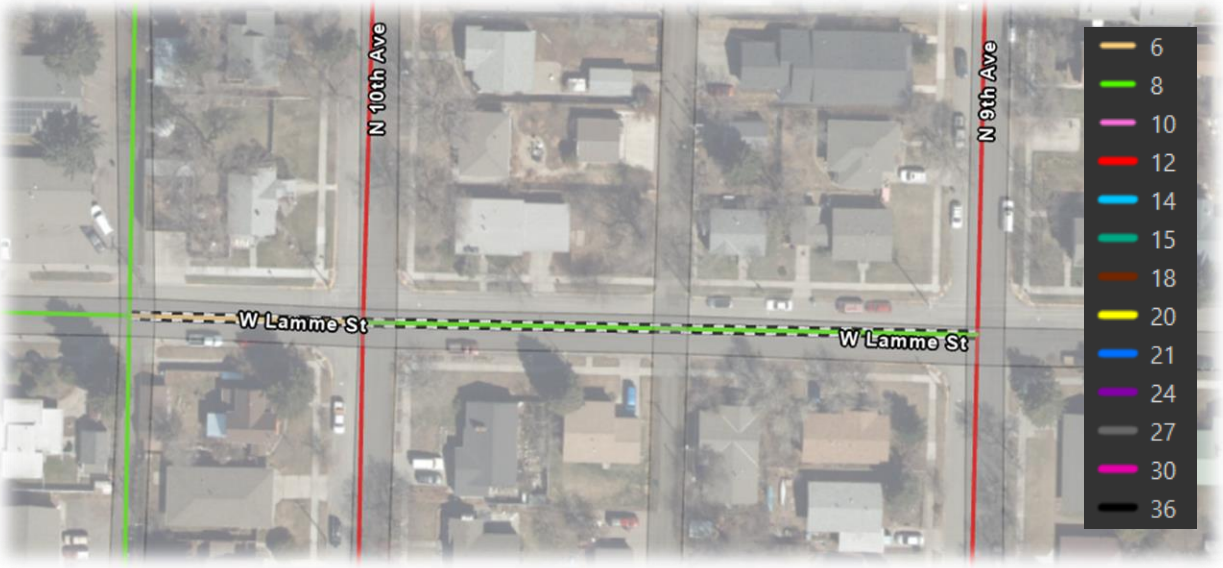


Figure 5-23: Small Pipe Project 21 Extents (checkered line)

5.2.16 Small Pipe Project 22: W Mendenhall St

Small Pipe Project 22 includes the replacement of a sewer main along W Mendenhall St. The portion replaced in this project begins at N 7th Ave and ends at N Tracy Ave. In total, 2,250 feet of pipe will be upgraded to an 8-inch PVC pipe. The checkered line in ***Figure 5-24*** below outlines the extents of this project.



Figure 5-24: Small Pipe Project 22 Extents (checkered line)

5.2.17 Small Pipe Project 23: W Main St and W Babcock St Alley Sewer Replacement

The sewer main lies between W Main St and W Babcock St, and begins near S 11th Ave and extends to S 7th Ave. The existing main is a 6-inch diameter pipe and will be upgraded to 8-inch PVC as part of this project. In total, 1,250 feet of pipe will be replaced and upgraded. The scope of the project can be seen outlined by the checkered line in ***Figure 5-25.***

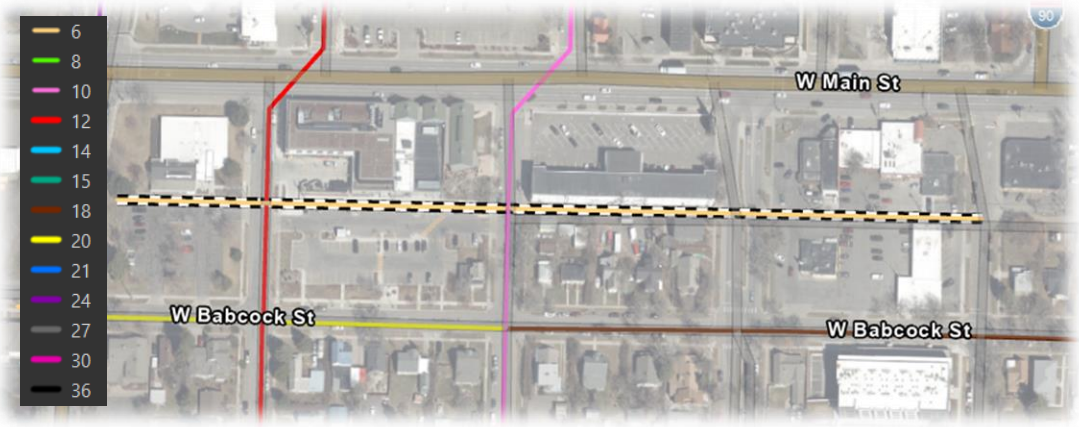


Figure 5-25: Small Pipe Project 23 Extents (checkered line)

5.2.18 Small Pipe Project 24: W Main St Sewer Replacement

This 6-inch diameter sewer main begins near the intersection of W Main St and N 7th Ave, and continues along W Main St until N Grand Ave. This pipe will be upgraded to an 8-inch PVC as part of this project. The extents of the 1,400 feet of pipe replaced is outlined below in ***Figure 5-26*** by the checkered line.



Figure 5-26: Small Pipe Project 24 Extents (checkered line)

5.2.19 Small Pipe Project 25: S 5th Ave Sewer Replacement

In Small Pipe Project 25, 1,350 feet of pipe will be upgraded to 8-inch PVC. Most of the pipe upgraded in this project follows S 5th Ave from W Olive St to W Story St. A small portion extends off this main segment between W Curtiss St and W Koch St. The project extents can be seen below outlined by the checkered line in ***Figure 5-27***.

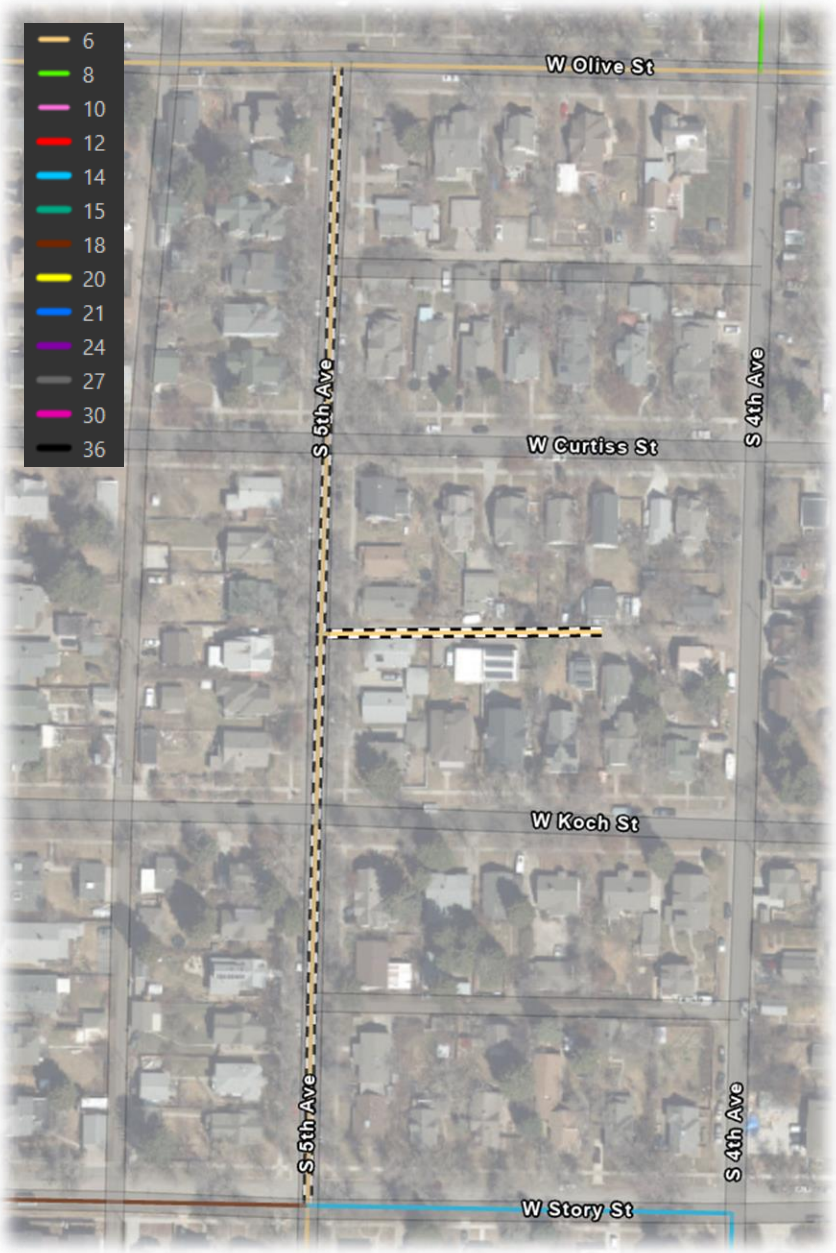


Figure 5-27: Small Pipe Project 25 Extents (checkered line)

5.2.20 Small Pipe Project 26: W Story St and S 6th Ave Sewer Replacement

This project includes two sewer main segments, one which extends east on W Story St from between S 9th Ave and S 8th Ave to S 6th Ave. The other extends south on S 6th Ave from W Story St to W Harrison St. In total, 1,500 feet of pipe will be replaced and upsized to 8-inch PVC. The project is outlined in ***Figure 5-28*** below by the checkered line.

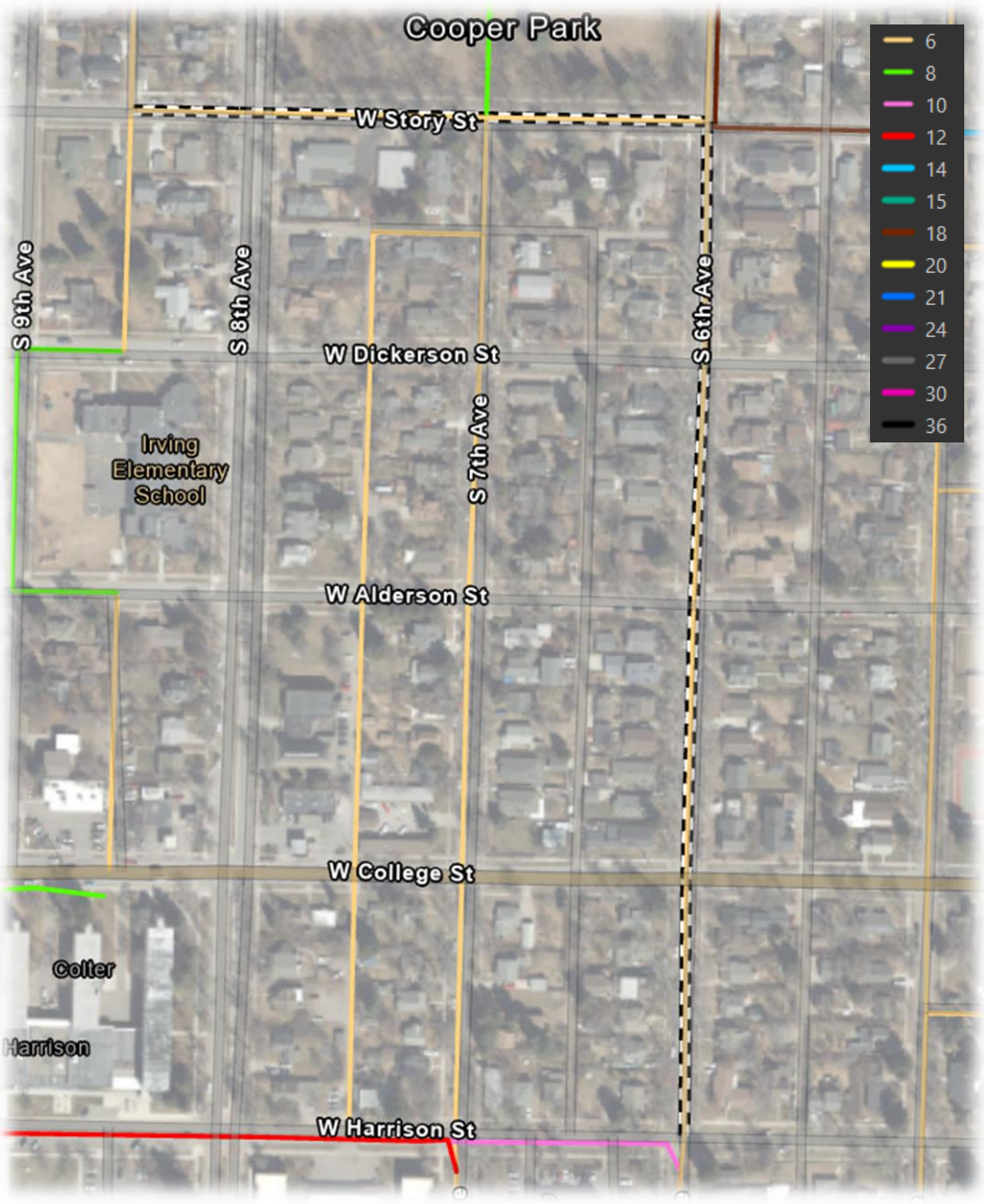


Figure 5-28: Small Pipe Project 26 Extents (checkered line)

5.2.21 Small Pipe Project 27: S 9th Ave and S 8th Ave Alley Sewer Replacement

This project includes upgrading a 6-inch main to 8-inch PVC between S 9th Ave and S 8th Ave. The main extends from just below W Babcock St to W College St, with a break in the middle due to the Irving Elementary School. 2,068 feet of pipe will be replaced in this project. The checkered line in ***Figure 5-29*** below outlines the extents of Small Pipe Project 27.

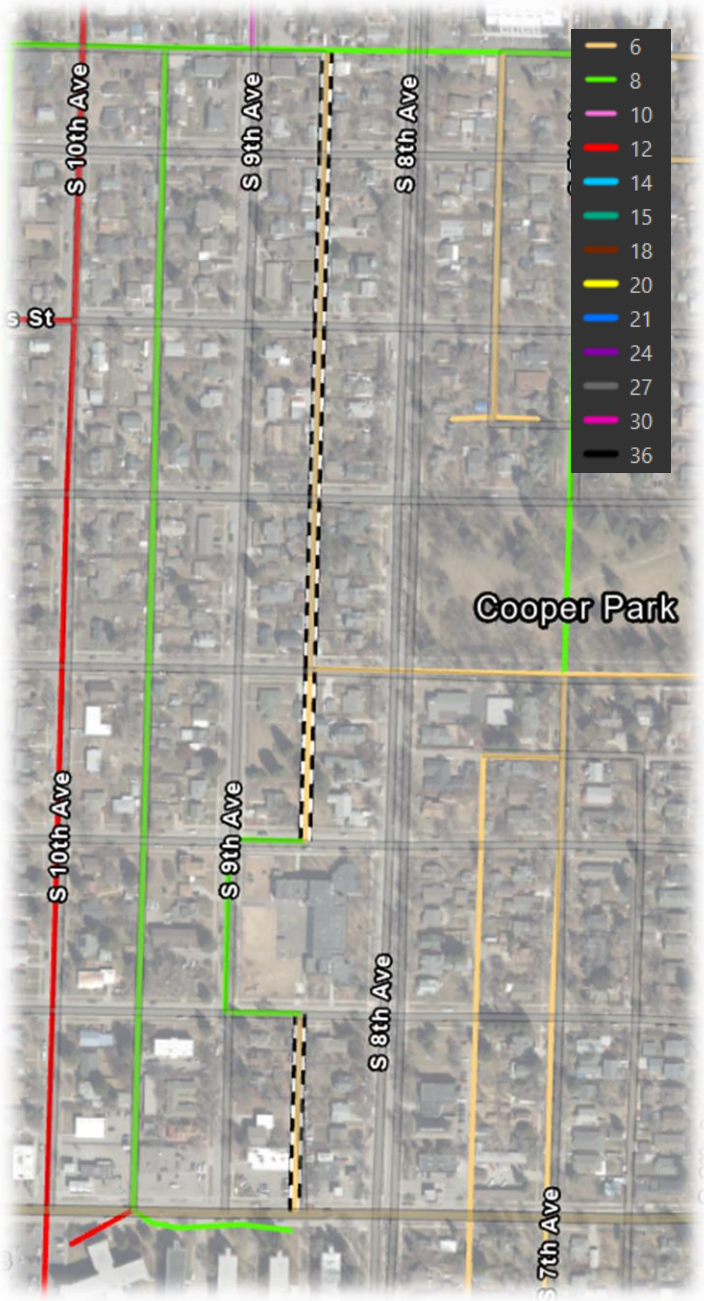


Figure 5-29: Small Pipe Project 27 Extents (checkered line)

5.2.22 Small Pipe Project 28: S 8th Ave and S 7th Ave Sewer Main Replacement

Small Pipe Project 28 involves the replacement of a 1,350-foot section of 6-inch sewer main. The main begins on W Harrison St between S 8th Ave and S 7th Ave, and continues north before turning right between W Story St and W Dickerson St to intersect S 7th Ave. This pipe will be upgraded to an 8-inch PVC pipe as part of this project. The extents of this project are outlined in ***Figure 5-30*** below.



Figure 5-30: Small Pipe Project 28 Extents (checkered line)

5.2.23 Small Pipe Project 29: S Wallace Ave Sewer Replacement

A total of 900 feet of 6-inch diameter sewer main along S Wallace Ave and just north of E Babcock St will be replaced with an 8-inch diameter PVC pipe in this project. The extents of this project can be seen below in ***Figure 5-31*** outlined by the checkered line. Note that the segment along Wallace Avenue between Babcock Street and the alley was replaced with an 8-inch PVC sewer in 2020.

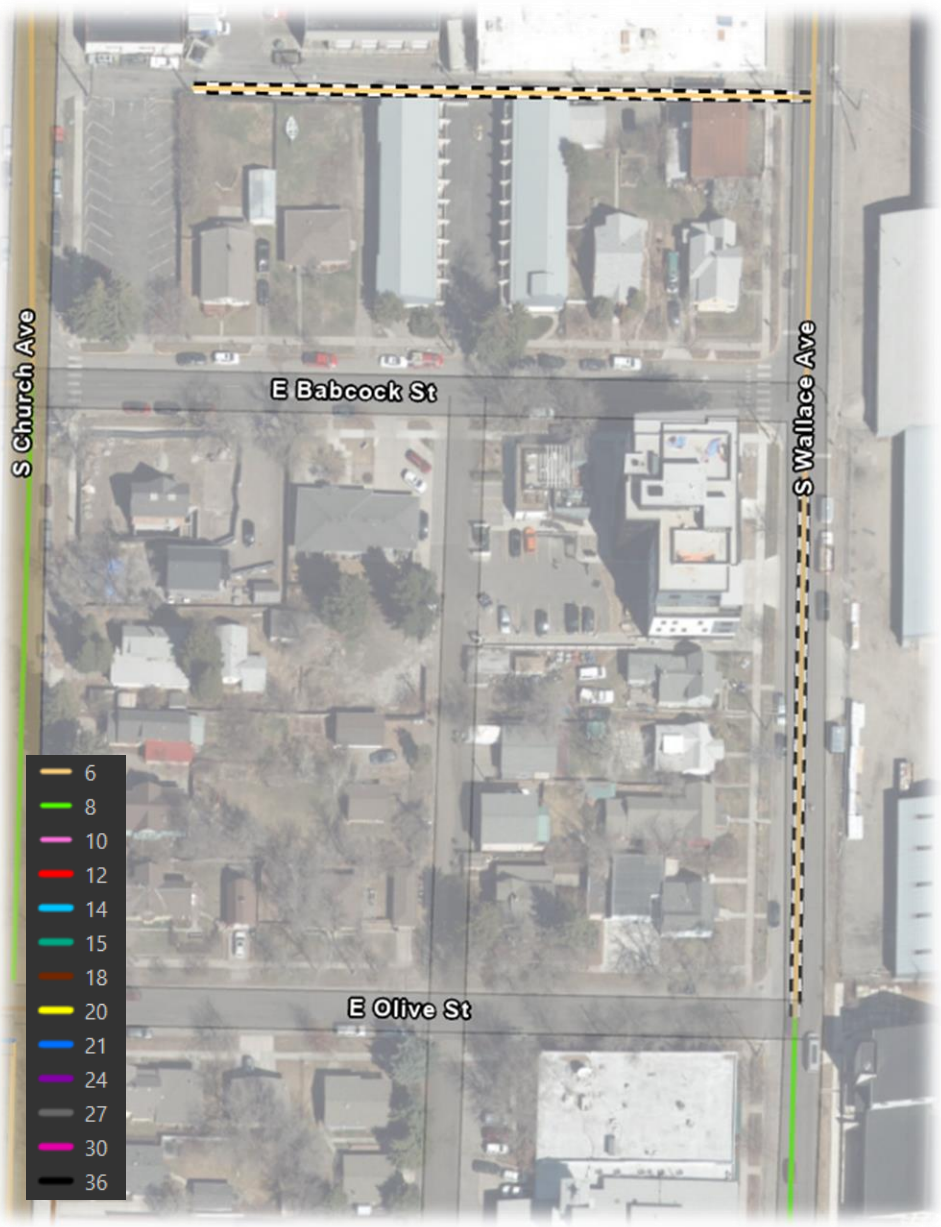


Figure 5-31: Small Pipe Project 29 Extents (checkered line)

5.2.24 Small Pipe Project 30: E Main St Sewer Replacement

Two segments of 6-inch sewer main along E Main St will be replaced in Small Pipe Project 30. The two segments combined total 800 feet that will be upgraded to 8-inch PVC. The project extents are outlined by a checkered line in ***Figure 5-32*** below.

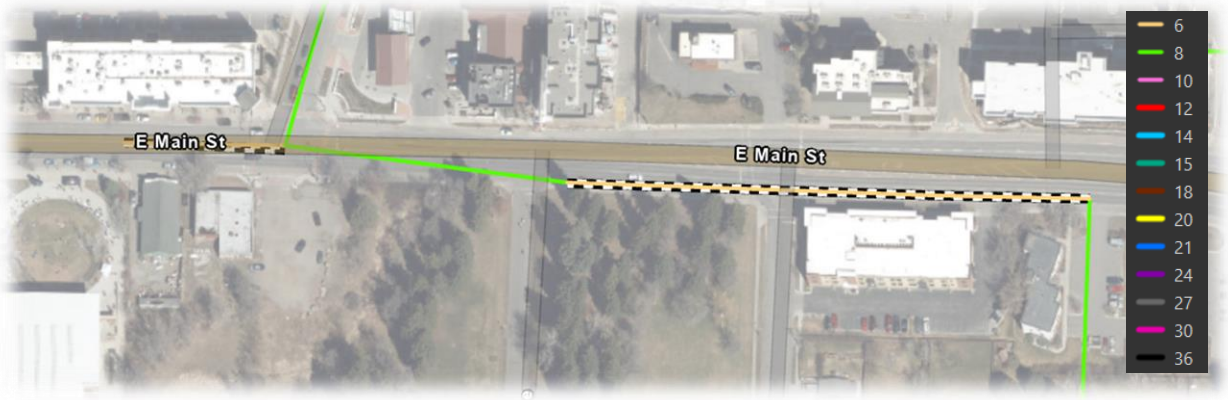


Figure 5-32: Small Pipe Project 30 Extents (checkered line)

5.2.25 Small Pipe Project 31: E Mendenhall St Sewer Replacement

Small Pipe Project 31 includes the replacement of a 6-inch sewer main that follows E Mendenhall St from N Tracy Ave to N Broadway Ave. In total, 2,900 feet of pipe will be upgraded to 8-inch PVC. The checkered line in ***Figure 5-33*** below shows the extents of the project.



Figure 5-33: Small Pipe Project 31 Extents (checkered line)

5.2.26 Small Pipe Project 32: S Church Ave Sewer Replacement

The 1,700-foot 6-inch sewer main that runs from E Olive St to around E Story St along S Church Ave will be replaced and upgraded with 8-inch PVC. An additional 350 feet of sewer main that extends west above E Story St will also be replaced and upgraded. The extents of this project can be seen below outlined by the checkered line in ***Figure 5-34***.

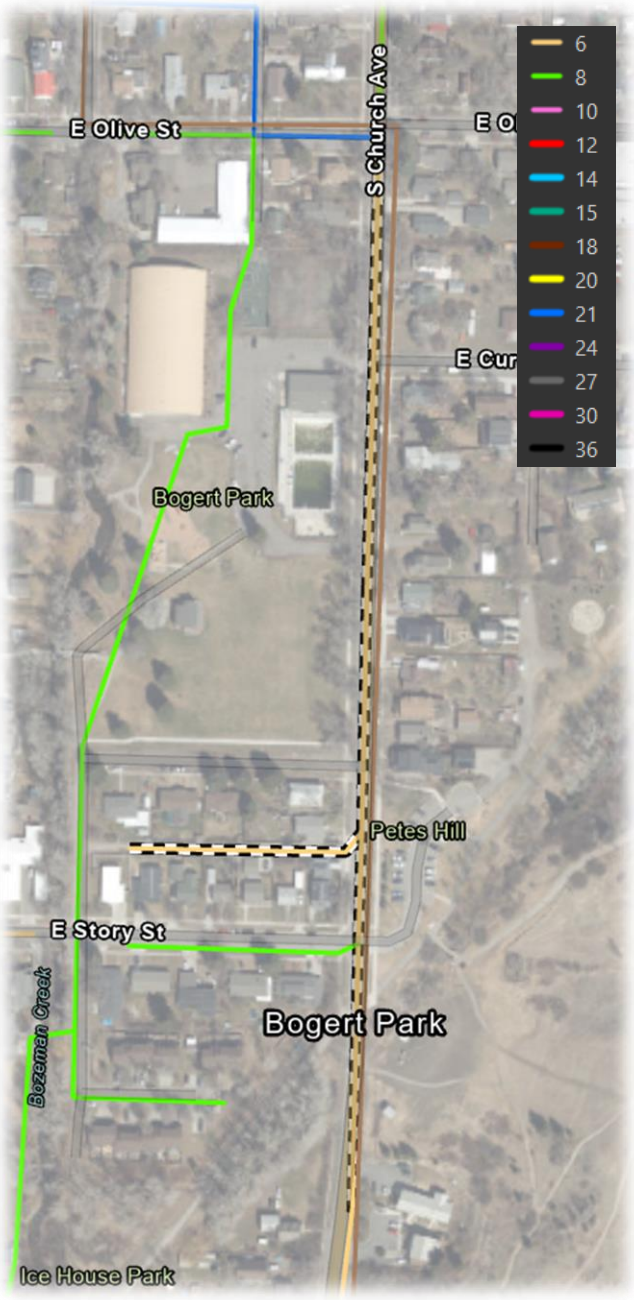


Figure 5-34: Small Pipe Project 32 Extents (checkered line)

5.2.27 Small Pipe Project 33: W Babcock St Sewer Replacement

In Small Pipe Project 33, 760 feet of 6-inch sewer main will be upgraded to 8-inch PVC along W Babcock St. Outlined by a checkered line, the extents of this project can be seen in ***Figure 5-35***.



Figure 5-35: Small Pipe Project 33 Extents (checkered line)

5.2.28 Small Pipe Project 34: S 6th Ave Sewer Replacement

Two segments of pipe will be replaced in this project, totaling 550 feet. These two pipes will be upgraded from 6-inch to 8-inch PVC. One pipe extends north on S 6th Ave, and the other west between W Curtiss St and W Koch St. The outline of the project extents can be seen below in ***Figure 5-36***.



Figure 5-36: Small Pipe Project 34 Extents (checkered line)

5.2.29 Small Pipe Project 35: W Babcock Ave, W Olive St, and S 7th Ave Sewer Main Replacement

In Small Pipe Project 35, 1,050 feet of 6-inch pipe will be upgraded to 8-inch PVC. The mains extend along W Olive St, run north along S 7th Ave, and west between W Olive St and W Babcock St. The checkered line outlines the project extents in ***Figure 5-37***.



Figure 5-37: Small Pipe Project 35 Extents (checkered line)

5.2.30 Small Pipe Project 36: W Main St, S Tracy Ave, and E Babcock St Sewer Main Replacement

Small Pipe Project 35 includes replacing the existing 6-inch with new 8-inch PVC along W Main St from S Willson Ave to N Tracy Ave and along S Tracy Ave to E Babcock Ave. Additionally, the existing 6-inch will be replaced with new 8-inch PVC along E Babcock St from S Bozeman Ave to S Rouse Ave. In total, 1,100 feet of pipe will be replaced in this project. The checkered line in ***Figure 5-38*** below outlines the extents of this project.



Figure 5-38: Small Pipe Project 36 Extents (checkered line)

5.3 Lift Station Improvement Projects

Additional lift station capacity will be needed to convey increased flows to the wastewater reclamation facility under future growth conditions. Both the new lift stations and the existing lift station capacity expansions presented in this section are sized to meet buildout growth conditions. The need for the lift stations presented in this section will be driven by the timing of new growth.

5.3.1 Lift Station Project 2: Coulee Drive

The Coulee Drive Lift Station (shown in ***Figure 5-39***) is needed to support new growth within the City. This 3.27 MGD lift station project includes 13,500 feet of new 14-inch diameter force main.

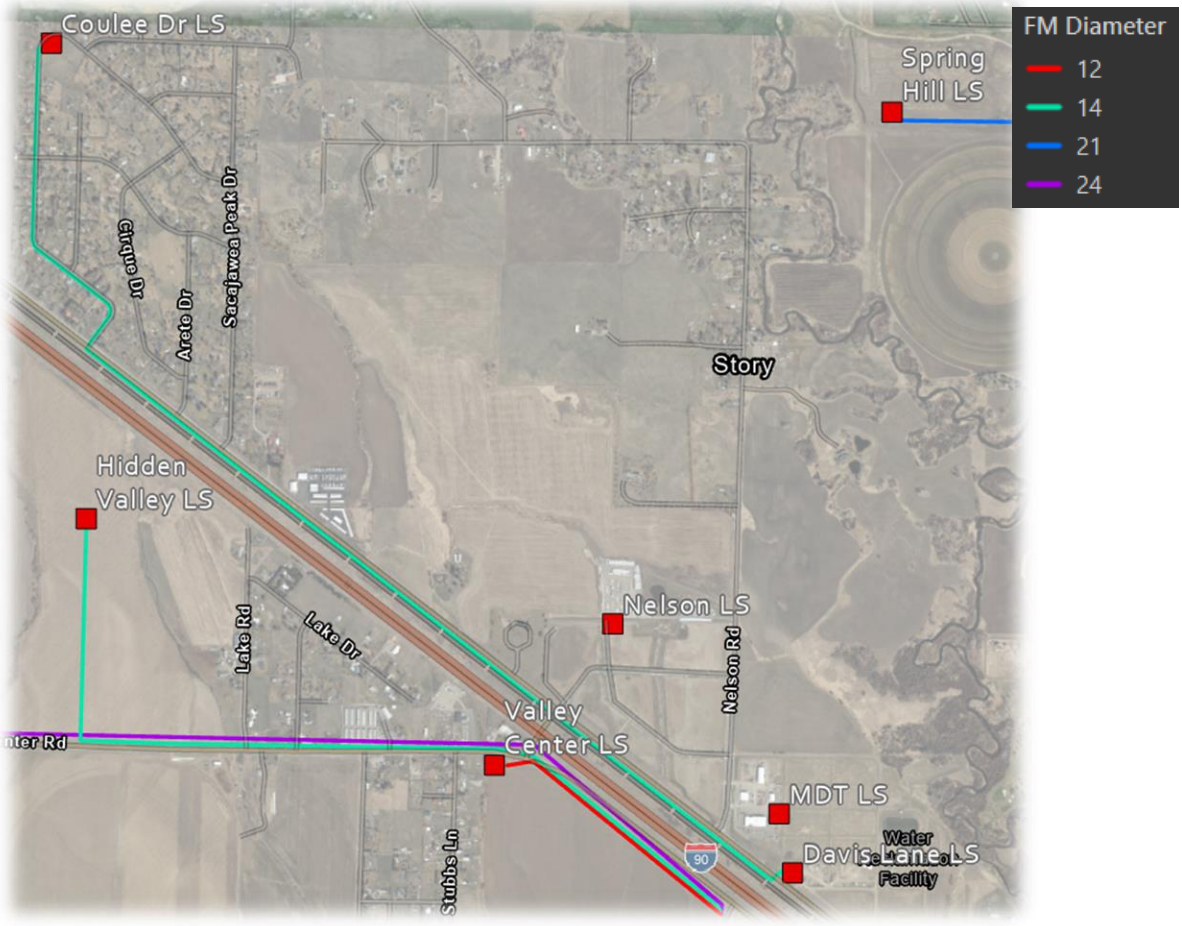


Figure 5-39: Coulee Drive LS

5.3.2 Lift Station Project 3: Spring Hill

The Spring Hill Lift Station (shown in ***Figure 5-40***) is needed to support new growth within the City. This 7.89 MGD lift station project includes 12,050 feet of new 21-inch diameter force main.

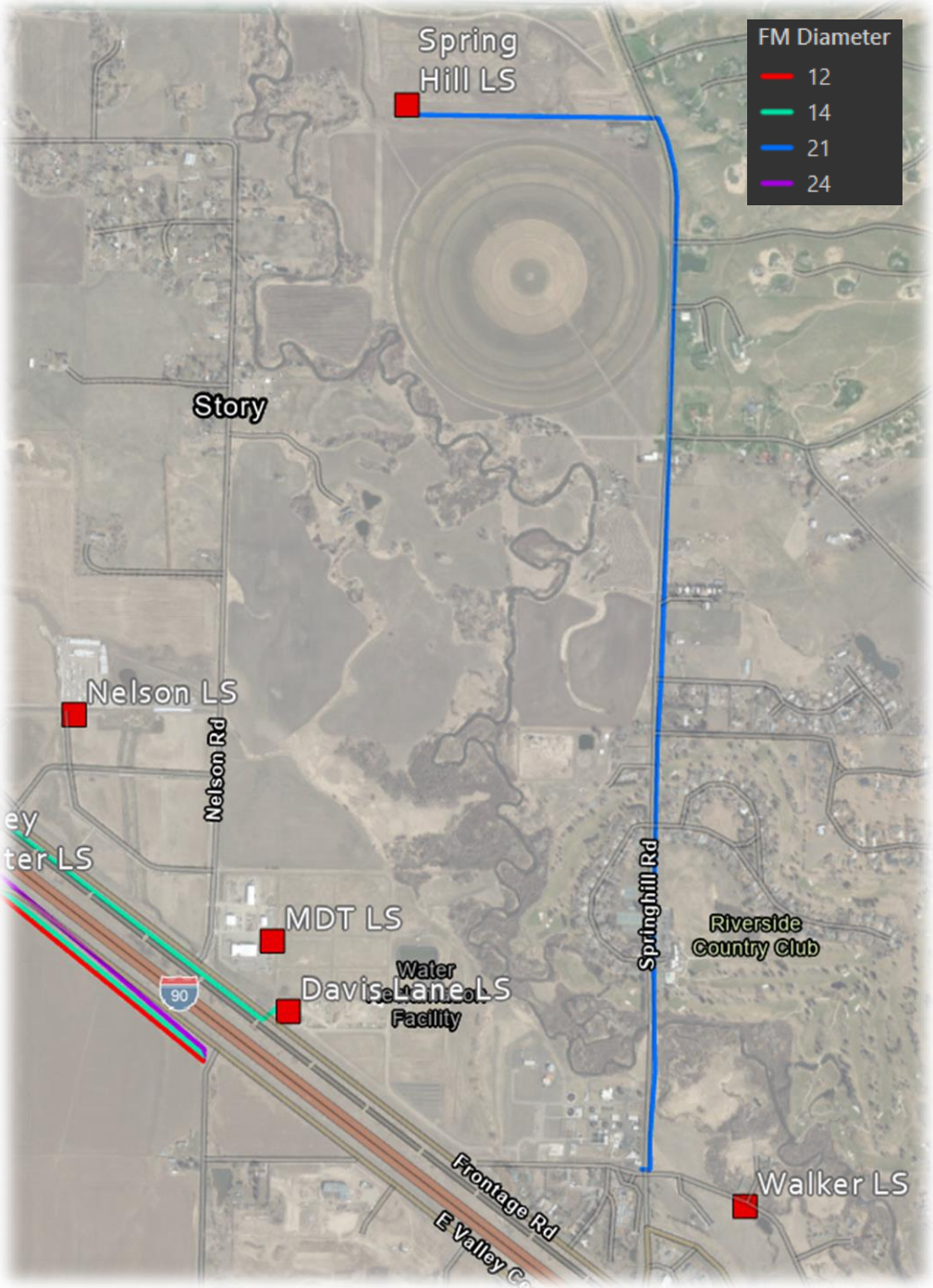


Figure 5-40: Spring Hill Lift Station

5.3.3 Lift Station Project 4: Gooch Hill

The Gooch Hill Lift Station (shown in ***Figure 5-41***) is needed to support new growth within the City. This 9.75 MGD lift station project includes 11,200 feet of new 24-inch diameter force main.



Figure 5-41: Gooch Hill Lift Station

5.3.4 Lift Station Project 5: Hidden Valley

The Hidden Valley Lift Station (shown in ***Figure 5-42***) is needed to support new growth within the City. This 3.21 MGD lift station project includes 9,900 feet of new 14-inch diameter force main.

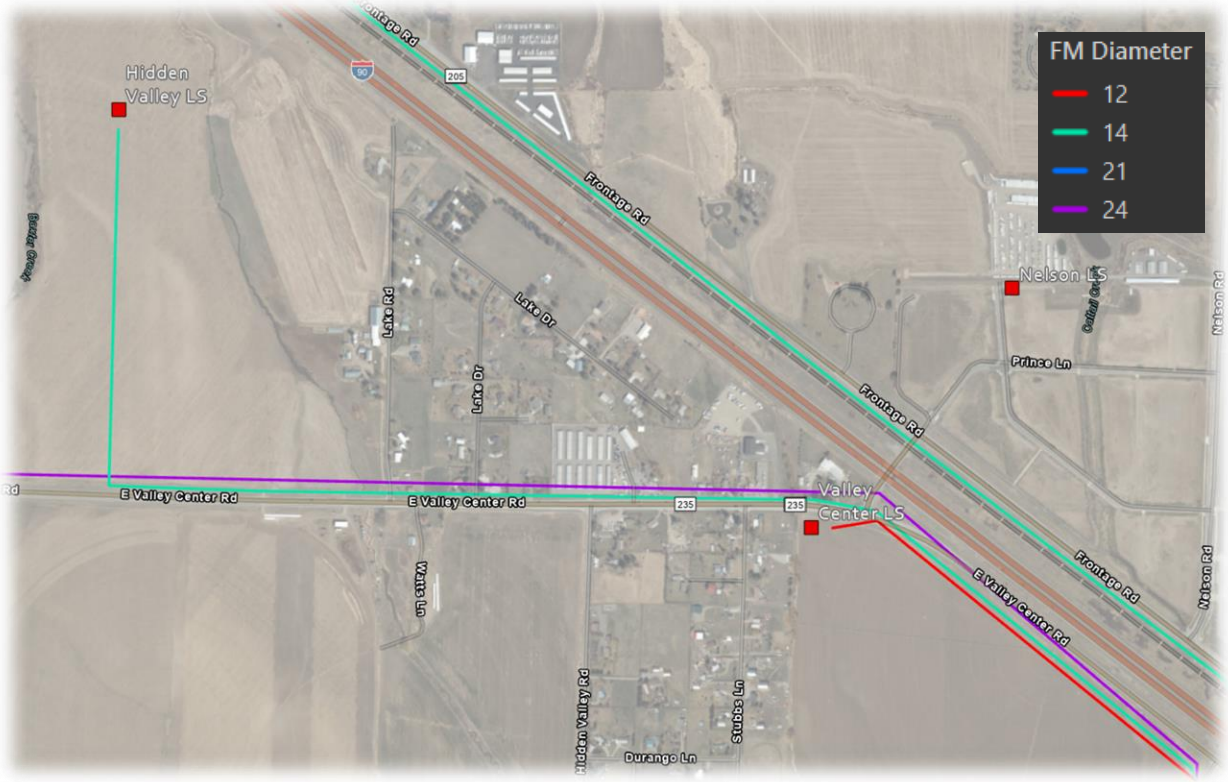


Figure 5-42: Hidden Valley Lift Station

5.3.5 Lift Station Project 6: Davis Lane

The Davis Lane Lift Station upsizing (shown in ***Figure 5-43***) is needed to support new growth within the City. This 7.2 MGD lift station will need to be upsized to 22.72 MGD to meet buildout conditions. This project includes 3,700 feet of a parallel 18-inch diameter force main. Since this corridor is already full of pipes, and this would be the third parallel force main, it is likely that a single line with the capacity of the combined force mains will be the preferred alternative.

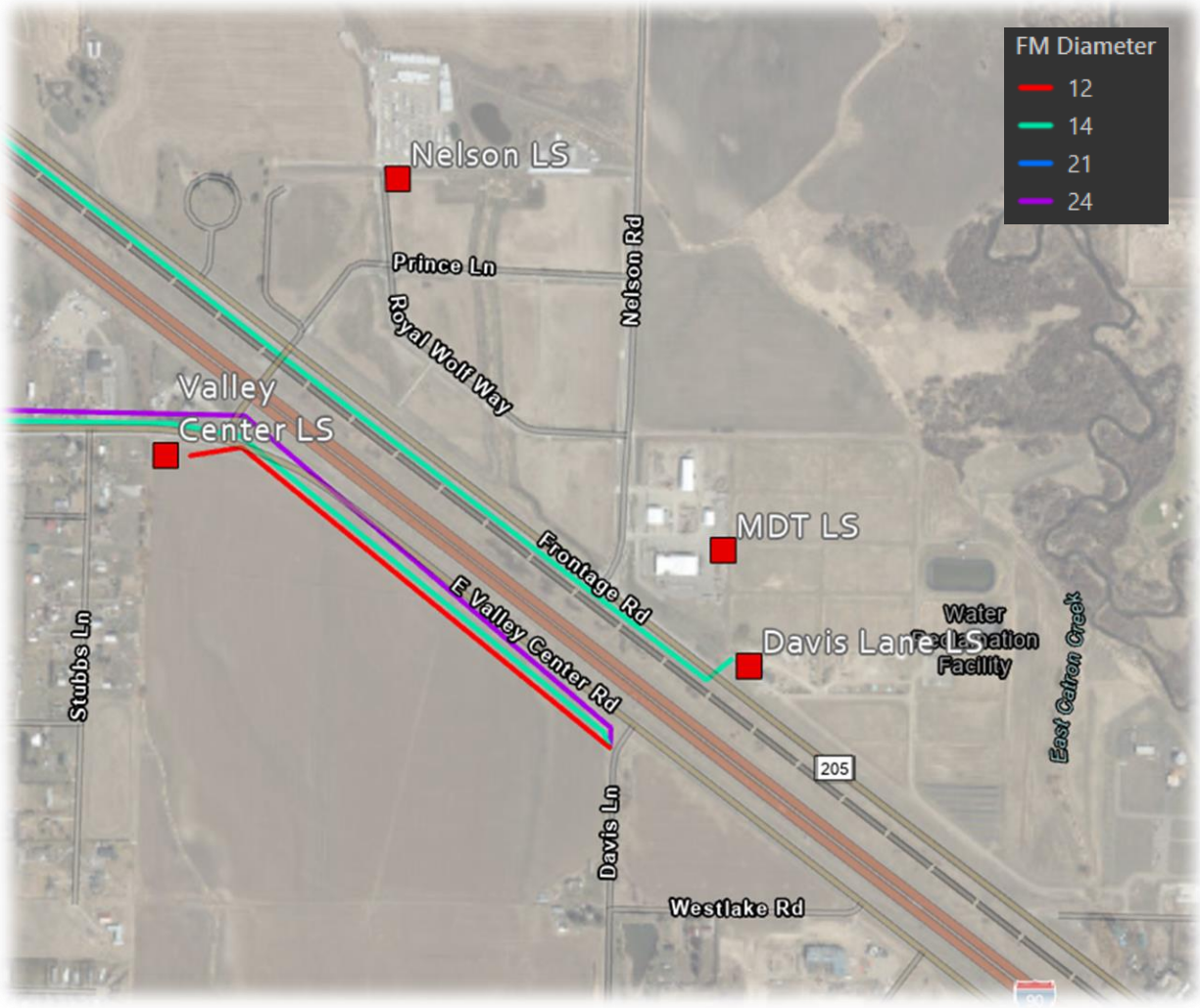


Figure 5-43: Davis Lane Lift Station

5.3.6 Lift Station Project 7: Laurel Glen

The Laurel Glen Lift Station upsizing (shown in ***Figure 5-44***) is needed to support new growth within the City. This 0.65 MGD lift station will need to be upsized to 0.78 MGD to meet buildout conditions.



Figure 5-44: Laurel Glen LS

5.3.7 Lift Station Project 8: Loyal Gardens

The Loyal Garden Lift Station upsizing (shown in ***Figure 5-45***) is needed to support new growth within the City. This 0.52 MGD lift station will need to be upsized to 0.76 MGD to meet buildout conditions.

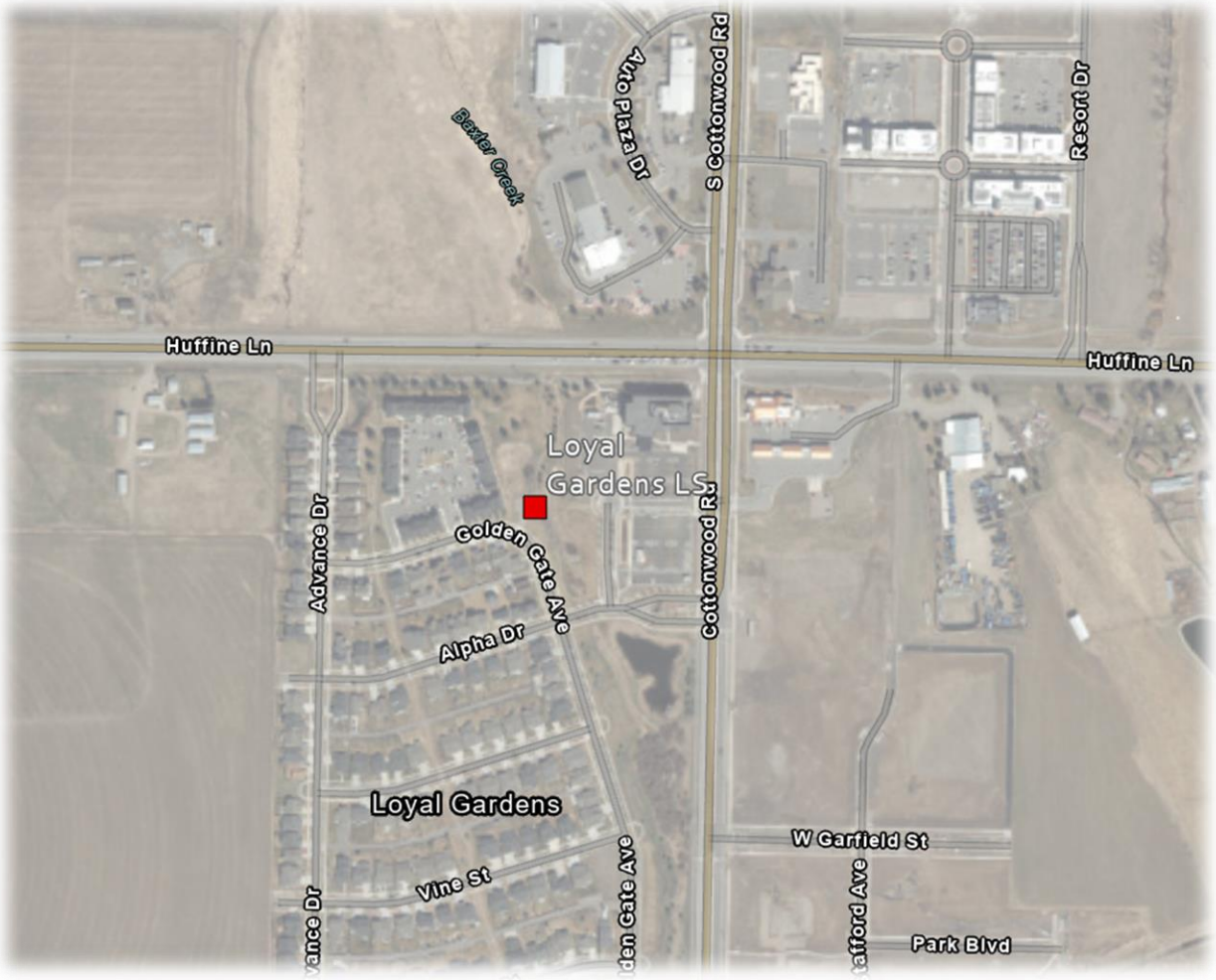


Figure 5-45: Loyal Gardens LS

5.4 Summary of Long-Term Capital Improvement Projects

A summary of the costs associated with the long-term capital improvement projects is included in ***Table 5-1***.

Table 5-1: Summary of Long-Term Capital Improvement Projects

Improvement ID	Location of Improvement	Opinion of Probable Cost (2024 $)
Project 9	N Grand Ave Sewer Main Replacement	$2,081,600
Project 10	N 20th Ave Sewer Main Replacement	$1,470,100
Project 11	Upper Front Street Interceptor and Highland Glen Sewer Main Replacement	$2,488,300
Project 12	S Grand Ave Sewer Main Replacement	$2,691,500
Project 13	N 19th Ave Sewer Main Replacement	$1,316,700
Project 14	W Oak St Sewer Main Replacement	$1,031,400
Project 15	E Lamme St. Sewer Main Replacement	$1,489,800
Project 16	Plum Ave Sewer Main Replacement	$1,136,900
Subtotal for 8-inch and Larger Sewer Main Replacement Projects		***$13,706,300***
Lift Station Project 2	Coulee Drive Lift Station	$13,673,200
Lift Station Project 3	Spring Hill Lift Station	$16,208,000
Lift Station Project 4	Gooch Hill Lift Station	$17,366,100
Lift Station Project 5	Hidden Valley Lift Station	$10,472,200
Lift Station Project 6	Davis Lane Lift Station	$12,091,700
Lift Station Project 7	Laurel Glen Lift Station	$703,900
Lift Station Project 8	Loyal Gardens Lift Station	$1,008,400
Subtotal for Lift Station Projects		***$69,935,500***
Small Pipe Project 7	Main St and S Church Ave Sewer Replacement	$1,207,400
Small Pipe Project 8	S. Bozeman, E Story St, and Dell Pl. Sewer Main Replacement	$1,502,400
Small Pipe Project 9	E Main St and Church Ave Sewer Main Replacement	$2,907,400
Small Pipe Project 10	S 6th Ave Sewer Main Replacement	$921,300
Small Pipe Project 11	E Main St and Church Ave Sewer Main Replacement	$1,221,400
Small Pipe Project 12	S 3rd Ave and S 4th Ave Sewer Main Replacement	$1,125,200
Small Pipe Project 13	S 7th Ave Sewer Main Replacement	$1,131,200
Small Pipe Project 14	S 3rd Ave Sewer Main Replacement	$1,379,800
Small Pipe Project 15	N Tracy Ave, E Cottonwood St, N Black Ave Sewer Main Replacement	$1,278,700
Small Pipe Project 16	Ida Ave, Fridley St Sewer Main Replacement	$721,100
Small Pipe Project 17	E Cottonwood Ave Sewer Main Replacement	$609,500
Small Pipe Project 18	E Aspen St. Sewer Main Replacement	$455,400
Small Pipe Project 19	N 3rd Ave Sewer Main Replacement	$627,000
Small Pipe Project 20	N 8th Ave Sewer Main Replacement	$690,500
Small Pipe Project 21	W Lamme St Sewer Main Replacement	$274,500
Small Pipe Project 22	E Lamme St Ave Sewer Main Replacement	$1,459,400

Small Pipe Project 23	W Main St/W Babcock St Sewer Main Replacement	$699,300
Small Pipe Project 24	W Main St Sewer Main Replacement	$869,600
Small Pipe Project 25	S 5th Ave Sewer Main Replacement	$970,500
Small Pipe Project 26	W Story Ave and S 6th Ave Sewer Main Replacement	$1,045,100
Small Pipe Project 27	S 9th Ave/S 8th Ave Sewer Main Replacement	$1,229,600
Small Pipe Project 28	S 8th Ave/ S 7th Ave Sewer Main Replacement	$844,300
Small Pipe Project 29	S 6th Ave Sewer Main Replacement	$532,200
Small Pipe Project 30	E Main St Sewer Main Replacement	$379,000
Small Pipe Project 31	E Mendenhall St Sewer Main Replacement	$1,706,600
Small Pipe Project 32	S Church Ave Sewer Main Replacement	$1,020,300
Small Pipe Project 33	W Babcock Ave Sewer Main Replacement	$464,500
Small Pipe Project 34	S 6th Ave Sewer Main Replacement	$373,400
Small Pipe Project 35	W Babcock Ave/W Olive St, S 7th Ave Sewer Main Replacement	$530,700
Small Pipe Project 36	W Main St, S Tracy Ave, E Babcock St Sewer Main Replacement	$739,100
Subtotal for 6-inch and Smaller Sewer Main Replacement Projects		***$28,916,400***
Total 6-20-Year Project Costs		***$112,558,200***

Chapter 6 Relevancy of Previously Recommended Yet to be Constructed CIP's

There are several collection system capital improvement projects yet to be completed from the previous wastewater masterplan and the City's ongoing 5-year CIP plan. A high-level review was completed to assess if these projects are still recommended. These projects are summarized in the following paragraphs.

North Frontage Road Interceptor (CIP Project WWIF20): Development of the east side of land within the Community Plan Boundary will be collected by the North Frontage Road Interceptor. Portions of the interceptor are at or near capacity and more segments will be at capacity when the Existing and Obligated areas are developed. The buildout of the interceptor includes parallel trunk sewers of varying sizes. This project consists of two main components: (1) replacement of portions of existing parallel trunk sewer including upsizing 4,725 ft of existing pipe to 36-inch diameter pipe and (2) installation of new parallel trunk sewer in areas with single trunk sewers including 6,200 ft of 27-inch through 36-inch diameter pipe. This project is scheduled to be completed in 2026, with an estimated cost of $4.6M. The results of the risk analysis also show the need for this project, driven primarily by the material (vitrified clay) and remaining useful life of most of the pipes along North Frontage Road.

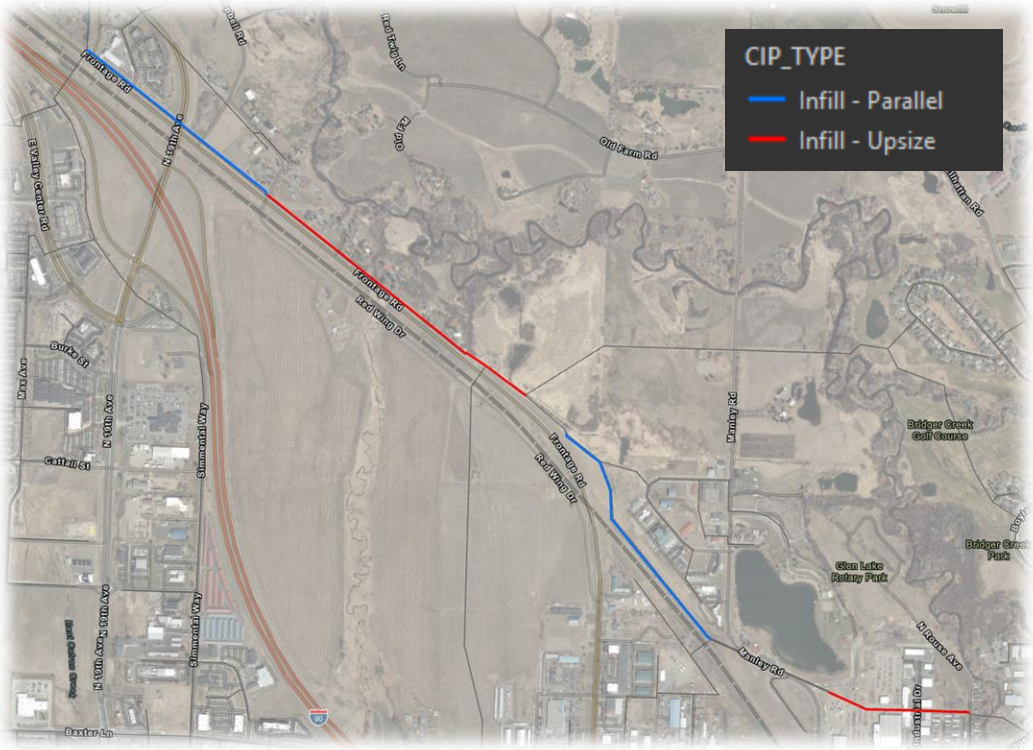


Figure 6-1: North Frontage Road Interceptor

Davis-Fowler Interceptor (CIP Project WWIF22): The 2015 master plan states "The interceptor between Durston Road and West Oak Street will eventually exceed capacity as the Baxter Creek drainage basin develops. In order to convey the ultimate build-out flow, the interceptor will need to be increased from an 18-inch diameter pipe to a 24-inch diameter pipe." This project was originally scheduled to be completed in 2023 at a cost of $1.25M. The timing of this project will be dictated by the growth in the area and other City infrastructure projects (i.e., Fowler Avenue Connection). The Hydraulic Model Development and Results Technical Memorandum (TM 7) summarizes the recommended sizing for this project when it is needed. The results of the risk analysis also show the need for this project, driven primarily by large flows and depth-to-diameter ratios more than 50%.

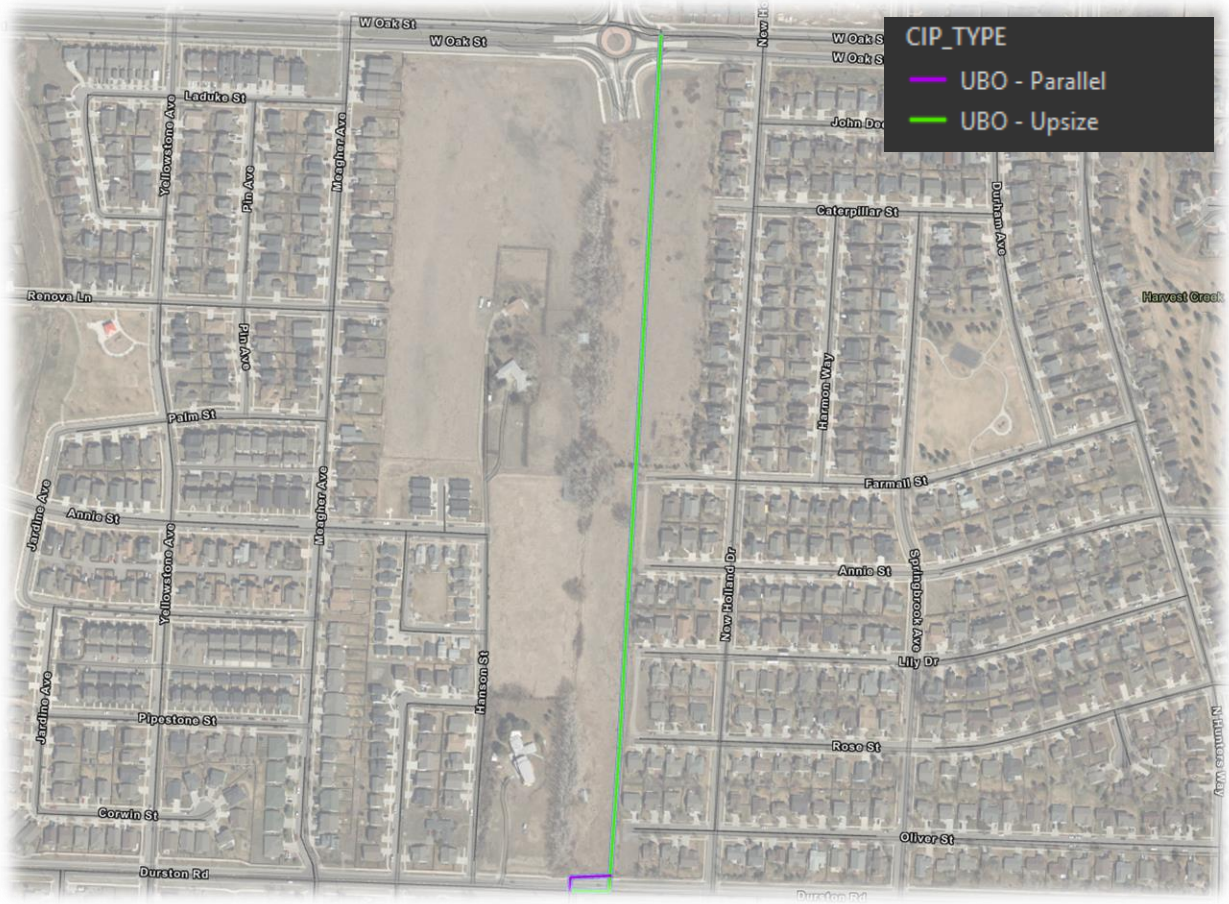


Figure 6-2: Davis-Fowler Interceptor

WRF Interceptor (CIP Project WWIF44): Previous planning efforts identified the need to upsize the existing 30-inch interceptor from I-90 to the WRF with a 48-inch interceptor. This project was scheduled to be completed in 2024 with an estimated cost of $0.55M. The results of the risk analysis also show the need for this project, driven primarily by large flows, depth-to-diameter ratios more than 50%, and low remaining useful life. This project is still recommended, and the previously recommended timing is appropriate.

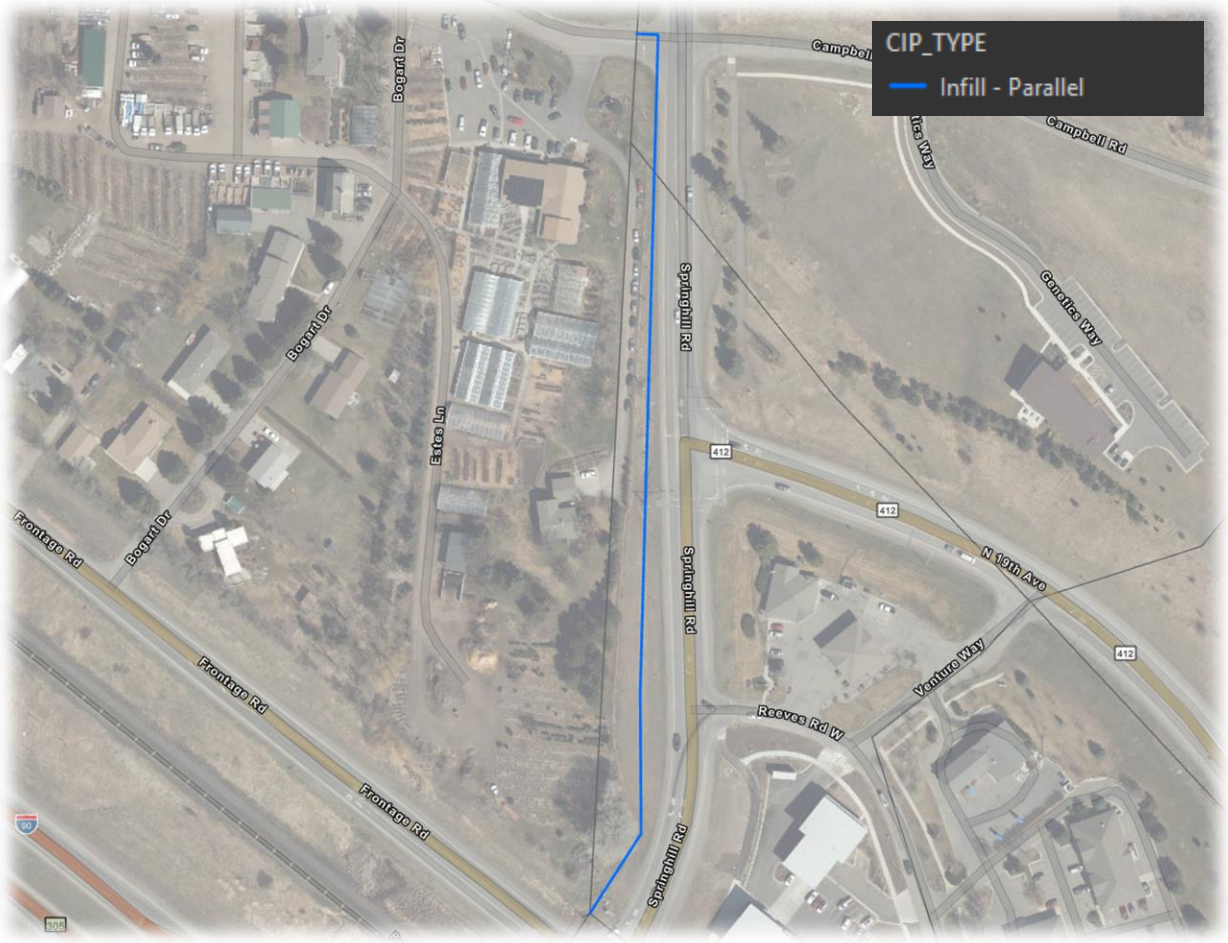


Figure 6-3: WRF Interceptor

Cottonwood Road Sewer Capacity (CIP Project WWIF53): The City is mindful of growth and has recognized that when annexation occurs in the western portion of the City, interceptor capacity along Cottonwood Road will quickly become a priority. To extend the capacity of the interceptor along Cottonwood Road, the City would install approximately 3,100 feet of 21-inch sewer extending the Cottonwood-Davis Interceptor from Babcock Street to south of Huffine Lane. The timing of this project will depend on growth. The current estimated cost to complete this project is $2M.

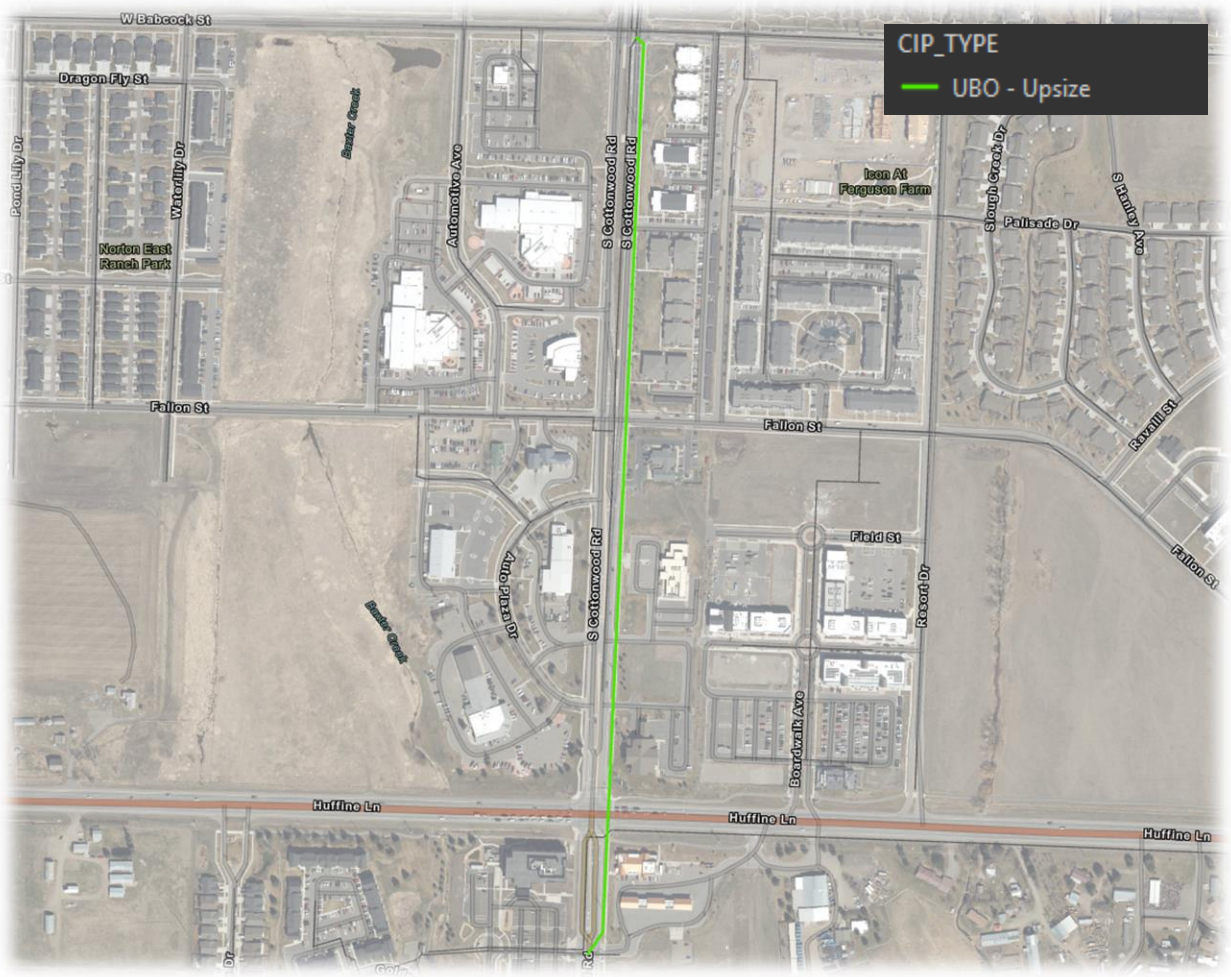


Figure 6-4: Cottonwood Rd Capacity

Blackwood Groves Sewer Oversizing (CIP Project WWIF52): As the Blackwood Groves Subdivision is developed, the City is participating in the oversizing of the sewer main for future growth capacity. The construction of this project is ongoing and phase dependent. The estimated completion date is 2028, at a total cost to the City of $0.2M.

Northwest Crossings Sewer Oversizing (CIP Project WWIF54): As the Northwest Crossing Subdivision is developed, the City is participating in the oversizing of the sewer main for future growth capacity. The construction of this project is ongoing and phase dependent. The estimated completion date is 2028, at a total cost to the City of $0.3M.

Chapter 7 Conclusion

This collection system Capital Improvement Plan will allow the City to address the most pressing infrastructure needs while continuing to maintain and operate at a high level of service. Below is a summary of the key points discussed in more detail within this Technical Memorandum:

- The cost estimates developed for these recommendations are generally based on 2022 unit prices and assumptions and are considered Class 4 estimates typically ranging from -30 to +50 percent accuracy.
- The near-term projects were selected based on risk and assumed immediacy of the growth/development pressure.
- The Increased Density analysis flagged three interceptor projects that would require a nominal pipe size increase to meet the increased demands. These projects include the Cottonwood Road Interceptor (from Huffine to Babcock), the Front Street Interceptor (from the Softball Complex to Tamarack), and the Bozeman Trail Interceptor through the Highland Glen open space.
- When new information becomes available (e.g., CCTV data, pipe breaks, manhole backup records), the City's risk model should be updated which may impact the timing of the recommended capital improvement projects
- The long-term improvement recommendations are growth dependent; and therefore, implementation will vary with development pressure. Additionally, these long-term recommendations should continue to be evaluated with each new Facility Plan update to ensure adequate existing and future conditions are utilized in the analysis.

10.0

Asset Management Coordinate System Technical Memorandum

Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

Table of Contents

Chapter 1 Introduction & Purpose 2

Chapter 2 Current Methods 3

2.2 Vertical Datum 3

2.2.2 Vertical Datum Conversions 3

2.3 Future Vertical Datum 4
2.4 Horizontal Coordinate System 4
2.5 MSU CORS Base Station 4
2.6 PLSS Monumentation and Record Drawings 5
2.7 Local Survey Control Monuments 5

Chapter 3 Summary of Recommendations 7

3.1 Horizontal Coordinate System 7
3.2 Vertical Datum 7
3.3 Global Positioning System City Base Station 7
3.4 Permanent Control Point Monuments 8

Appendix A - Example Monuments 9

Chapter 1 Introduction & Purpose

The purpose of the Asset Management Coordinate System Technical Memorandum (TM 10) is to provide recommendations to the City of Bozeman (City) to transition to a uniform coordinate system. The City is growing rapidly and older methods are not keeping up with the times. This report summarizes the currently adopted coordinate system and provides a recommendation to ensure all drawings and surveys are in a uniform vertical and horizontal coordinate system moving forward. This is critical for the City to effectively and efficiently manage the enormous amount of data associated with the rapid expansion.

Chapter 2 Current Methods

Currently, there is no official policy in the City requiring developers to submit digital .dwg or shapefiles covering newly installed City assets. In the past, when the City received digital information, there has not been a consistent vertical datum or horizontal coordinate system. Recently, the City adopted Resolution 5113 (in coordination with Ordinance 2032), which establishes North American Vertical Datum 1988 (NAVD 88) as the City's vertical datum. However, there is still no formal resolution setting a uniform horizontal coordinate system or projection. The lack of consistency has led to inefficient workflows within and across City departments.

Moving forward, the City should adopt a standard horizontal coordinate system and ensure it is incorporated into the Engineering Design Standards. All future development review submittals shall follow these standards. This report provides additional details on various coordinate systems used in the area and recommends a path forward.

2.2 Vertical Datum

The City in the past used a local vertical datum based on benchmarks that are located on fire hydrants. This datum is out of date and generally unreliable because of poor benchmark survey and modifications to the hydrants due to new construction and distribution system updates. Vertical datum conversions can be performed but should be carefully considered. Nationwide vertical datum conversions are most widely used for the study of plate tectonics; therefore, the conversions are not always helpful for local projects.

2.2.2 Vertical Datum Conversions

The approximate conversions from the City's datum to the National Geodetic Vertical Datum of 1929 (NGVD 29) and the North American Vertical Datum of 1988 (NAVD 88) are shown in ***Table 2.1.***

Table 2.1: Vertical Datum Conversions

	Conversion to NGVD 1929	Conversion to NAVD 1988
City of Bozeman Vertical Datum	+15.44 feet	+19.4 feet

2.3 Future Vertical Datum

The National Geodetic Survey (NGS) will be replacing the North American Vertical Datum of 1988 (NAVD 88) in 2024. Additional information and details about this vertical datum update can be accessed through the National Geodetic Survey webpage: https://geodesy.noaa.gov/datums/newdatums/index.shtml.

With the integration of a City-wide vertical survey network tied into the existing National Geodetic Survey (NGS) benchmarks and Montana State University (MSU) Continuously Operating Reference Station (CORS), future vertical datum updates will be computed based on the published vertical adjustments provided by NGS when the nationwide vertical datum is updated. This allows simple conversion in the future to any new NGS datum. It is recommended that the City adopt the latest NGS vertical datum when it becomes the national standard.

2.4 Horizontal Coordinate System

There is no standard horizontal coordinate system adopted by the City. Local Engineers and Surveyors tend to use State Plane Coordinate System (SPCS) with a local projection established by the MSU CORS station, which is known as the Bobcat projection. This coordinate system and projection are very common in the area but are not officially required by the City.

Horizontal coordinate system conversions are normally made using computer programs such as Geographic Information System (GIS) software or NGS' Coordinate Conversion and Transformation Tool (NCAT). The City should adopt a standard practice for receiving digital data from Developers to ensure a consistent coordinate system.

It is recommended that the City adopt the State Plane Coordinate System Bobcat projection and incorporate it into its Engineering Design Standards. All electronically submitted CAD and/or GIS data shall be in this coordinate system.

2.5 MSU CORS Base Station

There is an NGS Continuously Operating Reference Station (CORS), which is a Global Positioning System (GPS) station located on the Montana State University Campus. This station is continuously maintained by Montana State University (MSU). The CORS station will allow for conversions from NAVD 88 to the future vertical datum using the conversion provided by NGS.

The CORS station provides published horizontal coordinates in latitude & longitude, State Plane & Universal Transverse Mercator (UTM). The CORS station will allow for horizontal coordinate conversion between existing and future coordinate systems. The CORS station is a very useful tool but has its dangers. The horizontal and vertical location being broadcasted can be altered

by MSU when updates to the GPS unit are performed.

The City of Bozeman should consider developing its own permanent GPS base station or CORS Station. The development of an additional permanent GPS base station within the city would ensure that the surveying and engineering community has a reliable connection to precise geodetic data.

2.6 PLSS Monumentation and Record Drawings

It is not recommended that Public Land Survey System (PLSS) monuments be used in the City coordinate system. These monuments are easily disturbed by construction and over time are recalculated by many different surveyors. The recalculated positions can sometimes differ greatly to their original location resulting in errors. Therefore, it is recommended that the City sets and maintains local survey control monuments.

2.7 Local Survey Control Monuments

To maintain spatial continuity, it is important for the City of Bozeman to create and adopt Survey Design Standards that are required on all surveys and drawings. These standards will outline the basis for how surveys are completed and ensure the necessary documentation is provided to the City. The Survey Design Standards should generally include the elements listed below.

- A City-wide horizontal and vertical control network should be set and maintained under the direct supervision of a Licensed Professional Land Surveyor.
- The control network could consist of, but not be limited to, the existing NGS benchmarks. It is recommended that the City sets and maintains additional monuments beyond the current NGS monuments.
- These additional monuments should be set in safe and accessible locations, such as City parks or rights-of-way (recommend approximately one-mile grid). Monuments should be set in areas away from overhead impediments to allow for easier and more accurate use by global positioning systems.
- Each monument should be documented using a standard form stating the date set, horizontal & vertical coordinates, and a description of the monument and its location. These forms should be readily available for use by engineering and surveying firms for City projects.
- The monuments should be durable and built to standards to avoid disturbance. Example monuments are provided in Appendix A and were obtained from the US Army Corps of Engineers.
- The monuments can be referenced from the new City horizontal coordinate system to the Montana State Plane Coordinate system to provide seamless integration into the

City GIS with the use of the CORS station at MSU.

- The equipment required to maintain a horizontal and vertical survey network would consist of survey grade GPS receivers, robotic or traditional total station, and a survey grade spirit level.
- It is suggested that the initial control network be set up by a single entity to minimize the errors.

Chapter 3 Summary of Recommendations

3.1 Horizontal Coordinate System

It is recommended that the City adopt a coordinate system from the currently available and published Low Distortion Projections (LDP) that encompasses the City limits. Low Distortion Projections help minimize the difference between the distance on a map and the actual distances on the ground. LDPs are conformal map projections and can cover large areas. The published LDP for this area is called the Bobcat Coordinate System and is currently readily available in GIS and AutoCAD software. Additionally, this projection is commonly used by multiple local engineering and survey firms.

3.2 Vertical Datum

It is recommended that the City continue the use of NAVD 88 as the City-wide vertical datum and incorporate it into the Engineering Design Standards.

3.3 Global Positioning System City Base Station

It is recommended that the City sets up and maintains a GPS base station to be used by the public surveying and engineering community. Providing an easy-to-use public connection to the precise geodetic position would promote the use of the available connection and willingness by engineers and land surveyors to provide precise as built locations of city infrastructure. This would provide a seamless way to tie into the City's accepted horizontal coordinate system and vertical datum. It is recommended that the City set up and maintain the GPS base station using the procedures specified by the National Geodetic Survey (NGS) for the Continuously Operating Reference Network (CORS) base stations. This will ensure the reliability of the base station and integration into the NGS CORS network if the station at MSU becomes obsolete. Unfortunately, at this time the City would not be able to enter the base station into the CORS network because it would not meet the NGS requirements of being 70 km from an existing GPS base station using the NGS requirements.

It is recommended that the City complete a study to determine the optimal location for a GPS base station using the NGS requirements. This study would cost approximately $10,000 and include the following tasks:

- Determine the best location for a GPS base station for complete city-wide coverage and for future developments based on coverage, land availability/access, and security.
- Review NGS specifications for placement and permanent mounting requirements for future integration to the NGS CORS network or the Montana State Reference Network (MTSRN) that is currently in development.

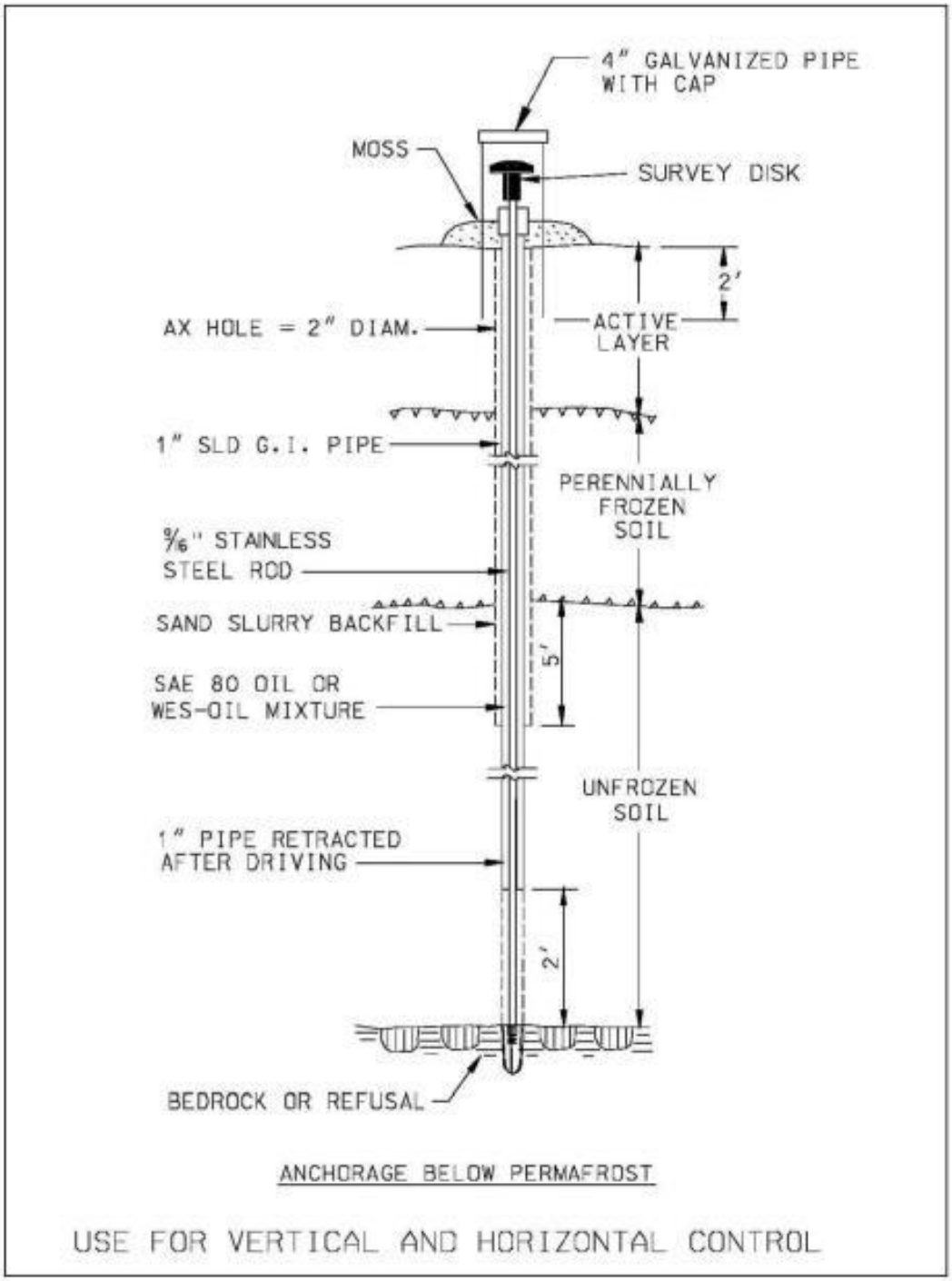
- Provide recommendations for available base station makes and models along with any additional required components. Develop cost estimates for equipment and installation of GPS units and additional components needed per manufacturer recommendations.

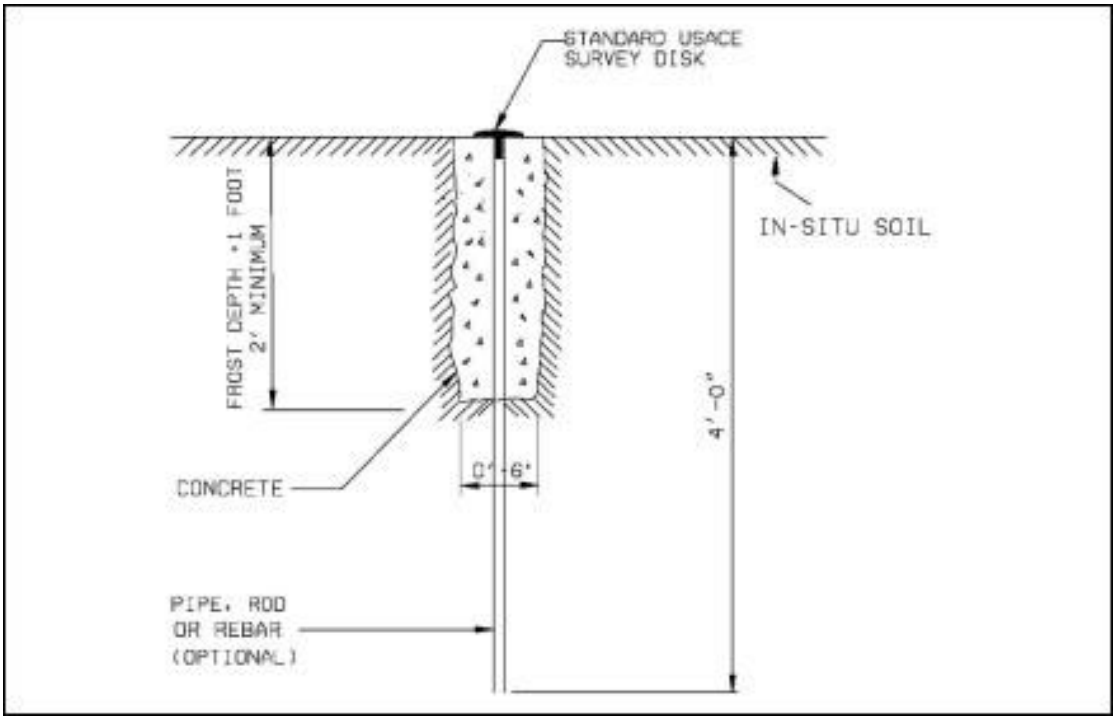
3.4 Permanent Control Point Monuments

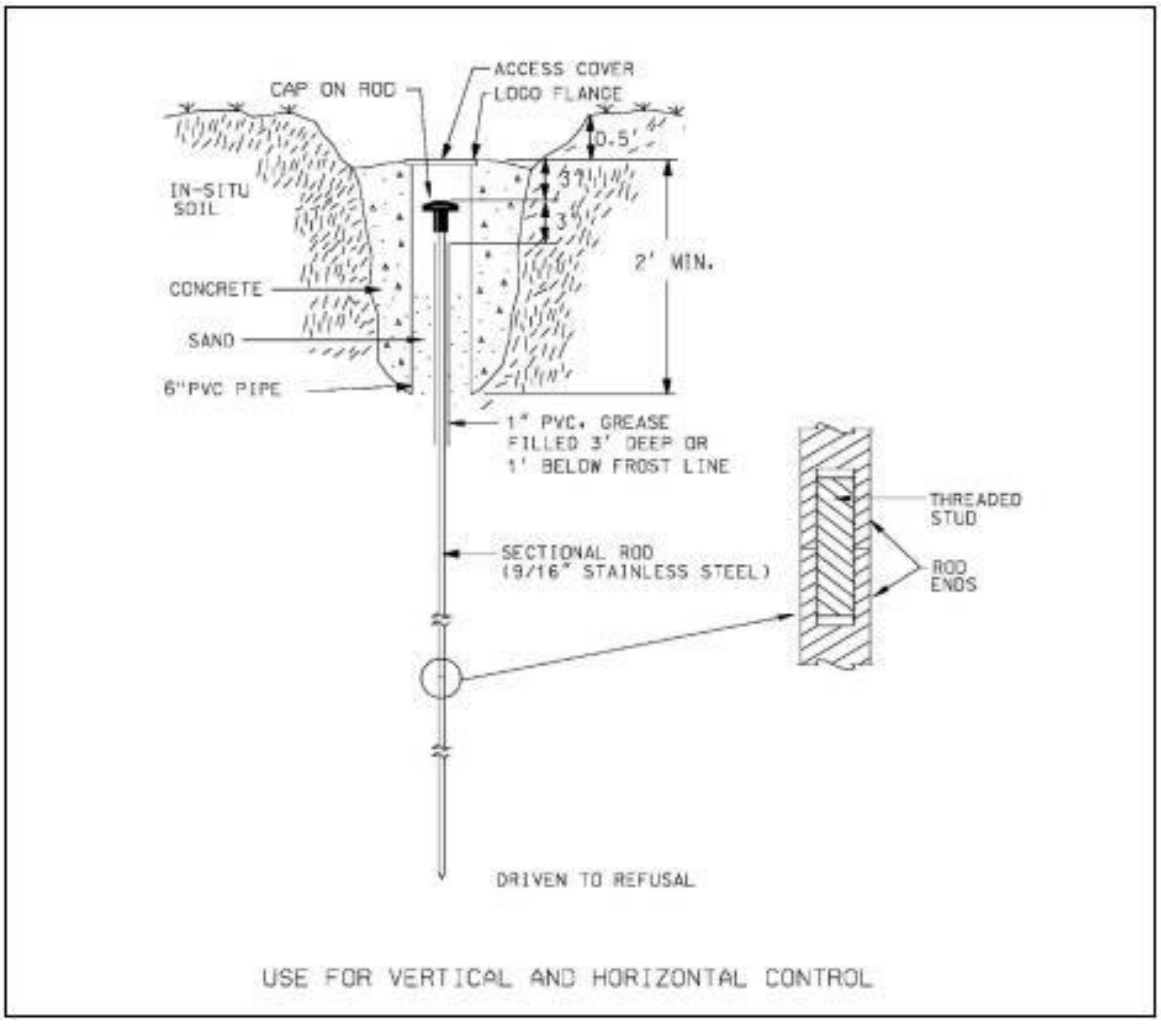
It is recommended that the City sets permanent control point monuments around the City and a study be performed to determine the best proposed location for setting permanent monuments using the following requirements:

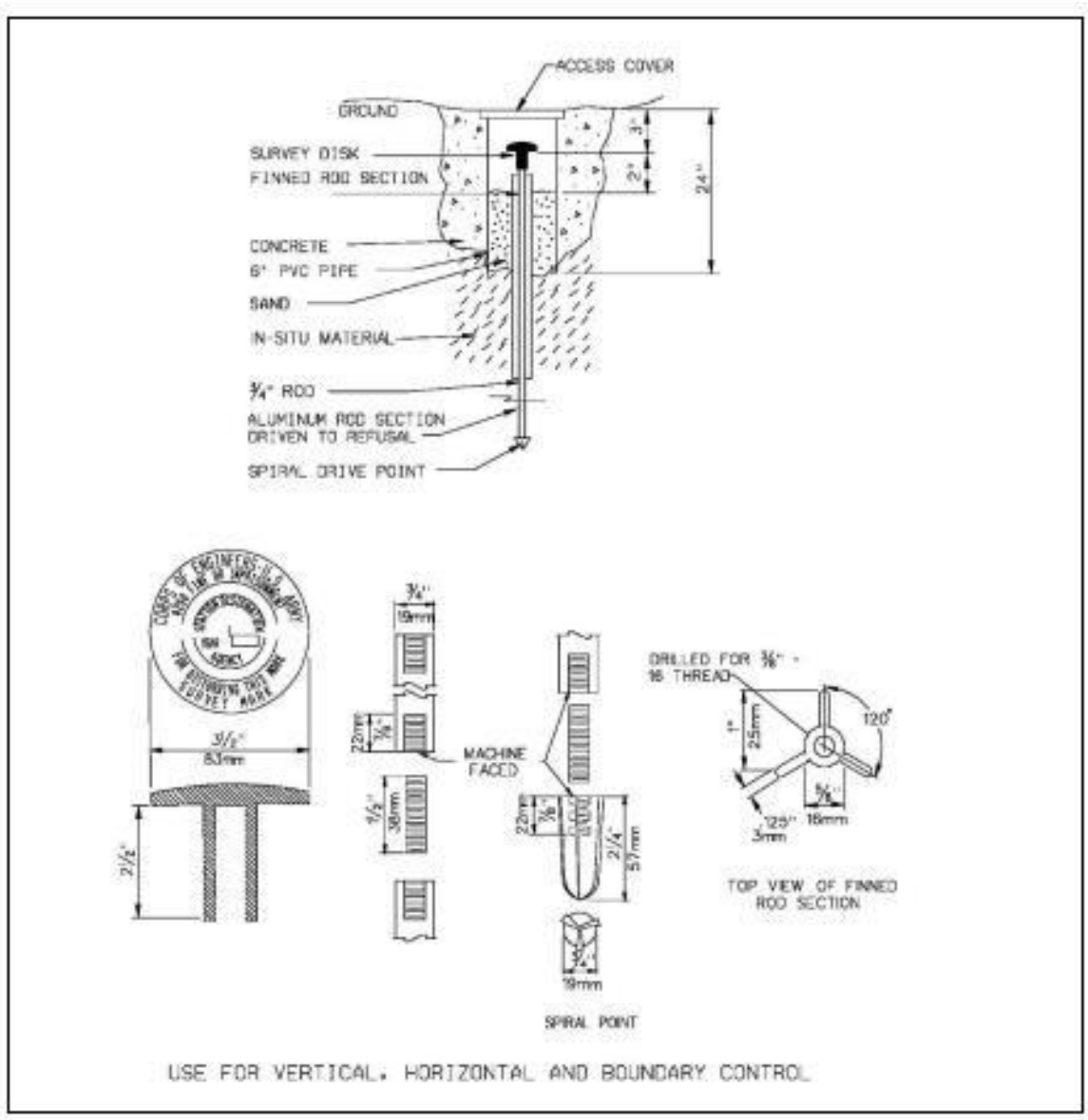
1. No overhead obstructions for the use of GPS survey equipment.
2. Within public parks or rights-of-way for easy public access.
3. Separation of a maximum of one mile between monuments.
4. Usable for future City-wide aerial survey control.

Appendix A - Example Monuments




STANDARD USACE
SURVEY DISK
FROST DEPTH +1 FOOT
2' MINIMUM
IN-SITU SOIL
4'-0"
0'-6"
CONCRETE
PIPE, ROD
OR REBAR
(OPTIONAL)


CAP ON ROD
ACCESS COVER
LOCO FLANGE
0.5'
3'
3'
2' MIN.
IN-SITU SOIL
CONCRETE
SAND
6"PVC PIPE
1" PVC, GREASE FILLED 3' DEEP OR 1' BELOW FROST LINE
THREADED STUD
ROD ENDS
SECTIONAL ROD (9/16" STAINLESS STEEL)
DRIVEN TO REFUSAL
USE FOR VERTICAL AND HORIZONTAL CONTROL


ACCESS COVER
GROUND
SURVEY DISK
FINNED ROD SECTION
CONCRETE
6" PVC PIPE
SAND
IN-SITU MATERIAL
¾" ROD
ALUMINUM ROD SECTION
DRIVEN TO REFUSAL
SPIRAL DRIVE POINT
3"
2"
24"
MACHINE FACED
DRILLED FOR ⅜" - 16 THREAD
120°
TOP VIEW OF FINNED ROD SECTION
SPIRAL POINT
USE FOR VERTICAL, HORIZONTAL AND BOUNDARY CONTROL

11.0

Updating Model Development Loading Technical Memorandum

Wastewater Collection System Facility Plan Update

December 2024

BOZEMAN MT

Table of Contents

Chapter 1 Updating Model Development Loading 1

1.1 Review of Existing System Model Scenarios 1
1.2 Review of Development Analysis Scenarios 3
1.3 Identify Manhole ID(s) Affected by the Development 5
1.4 Calculate Development Loading 5
1.5 Update Model Loading 6
1.5.1 Development Domestic Sanitary Loading 6
1.5.2 Development Groundwater Loading 8
1.5.3 Development RDII 11
1.6 Query and Track Development Loading 13
1.6.1 Identify manholes that have development loading: 13
1.6.2 Add Development Manholes to a Domain 15
1.7 Conclusion 17

Chapter 1 Updating Model Development Loading

The purpose of this technical memorandum is to provide an overview of the process and steps used to update and track Development loading within the wastewater collection system model. The process described herein is specifically for development loading review and includes the following:

- **Step 1:** Review of Existing System Model Scenarios
- **Step 2:** Review of Development Demand Scenarios
- **Step 3:** Identify Manhole IDs Affected by the Development
- **Step 4:** Calculate Development Loading
- **Step 5:** Update Model Loading
- **Step 6:** Query and Track Model Loading

These steps are covered in detail in this technical memorandum.

1.1 Review of Existing System Model Scenarios

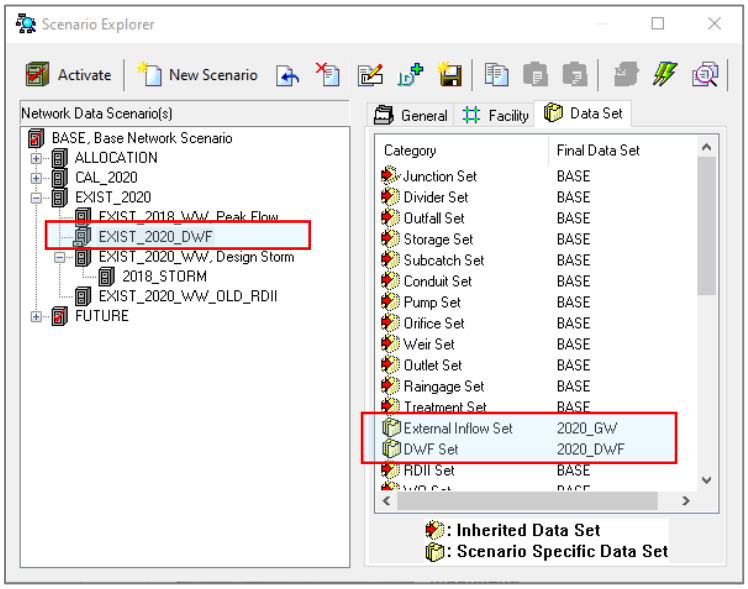
This section provides an overview of the scenarios and data sets for analyzing the existing wastewater collection system. This review is presented to provide an understanding of the starting point for scenarios created for the development review process. The hydraulic model has two scenarios for dry weather and wet weather that are the base scenarios and used for the analysis of existing system conditions. The scenarios and data sets used for dry weather and wet weather analyses are summarized below:

- **EXIST_2020_DWF_Scenario:** This scenario is the base scenario used to analyze dry weather flow conditions for the existing wastewater collection system.
  - *External Flow Data Set:* **2020_GW, Base GW during winter 1.5 MGD total**
    - This data set represents a constant ground water base flow of 1.5 MGD.
  - *DWF Data Set:* **2020_DWF, February 2020 Base Flow with Patterns**
    - This data set represents a domestic sanitary flow of 3.8 MGD.
- **EXIST_2020_WW Scenario:** This scenario is the base scenario used to analyze wet weather flow conditions.
  - *Raingage Data Set:* **DESIGN_STORM**
    - This data set represents a 25-year, 24-hour, 1.99-inch rain event with a Soil Conservation Service (SCS) Type I distribution.
  - *External Flow Data Set:* **2020_WW, Base GW during spring 5.7 MGD total**
    - This data set represents a constant ground water base flow of 5.7 MGD representing high ground water and peak infiltration conditions.
  - *DWF Data Set:* **2020_DWF, February 2020 Base Flow with Patterns**
    - This data set represents a domestic sanitary flow of 3.8 MGD
    - This is the same data set that is used for the dry weather analysis.

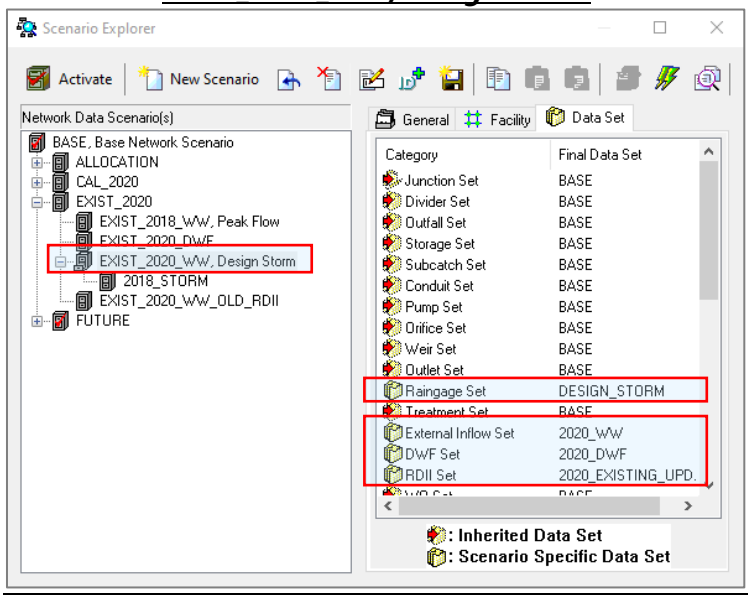
- *RDII Data Set:* **2020_EXISTING_UPDATE_THIESSEN**
  - This data set represents the sewershed area for each manhole and is used in the model to calculate rainfall derived inflow and infiltration (RDII) during the design storm.

The data sets for the existing scenarios are shown below as viewed in the *InfoSWMM Scenario Manager*.

EXIST_2020_DWF



EXIST_2020_WW, Design Storm



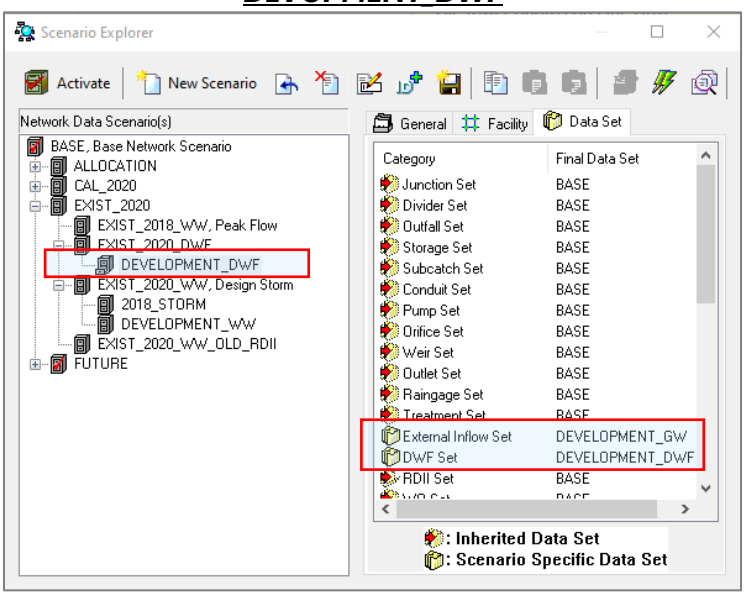
1.2 Review of Development Analysis Scenarios

The existing system scenarios were cloned to create two development analysis scenarios to analyze dry weather and wet weather conditions with additional development loading. These two scenarios are used for assessing increased domestic sanitary loading, increased base groundwater flow (if applicable), and additional acreage for rainfall derived inflow and infiltration (if applicable). The scenarios and data sets used for development dry weather and wet weather flows are summarized below:

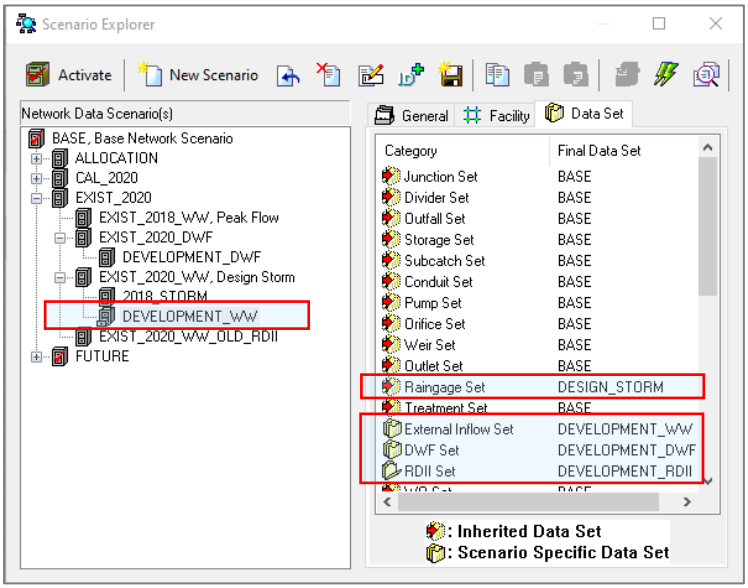
- **EXIST_2020_DWF_DEV_Scenario:** This scenario is used to analyze dry weather flow conditions with additional development loading.
  - *External Flow Data Set:* **DEVELOPMENT_GW**
    - This data set started as a copy of the *2020_GW* data set.
    - Additional base dry weather groundwater can be added to this data set, if required, for the Development.
  - *DWF Data Set:* **DEVELOPMENT_DWF**
    - This data set started as a copy of the *2020_DWF* data set.
    - Additional domestic sanitary flow can be added to this data set for the Development.
- **EXIST_2020_WW_DEV_Scenario:** This scenario is used to analyze wet weather flow conditions with additional development loading.
  - *Raingage Data Set:* **DESIGN_STORM**
    - This data set does not change and is the same as described in the existing system scenario.
  - *External Flow Data Set:* **DEVELOPMENT_WW**
    - This data set started as a copy of the *2020_WW* data set.
    - Additional base wet weather groundwater can be added to this data set, if required, for the development.
  - *DWF Data Set:* **DEVELOPMENT_DWF**
    - This data set started as a copy of the *2020_DWF* data set.
    - Additional domestic sanitary flow can be added to this data set for the development.
    - This is the same data set that is used for the development dry weather analysis.
  - *RDII Data Set:* **DEVELOPMENT_RDII**
    - This data set started as a copy of the *2020_EXISTING_UPDATE_THIESSEN* data set.
    - Sewershed area contributing RDII to the manhole(s) can be adjusted, if applicable, for the Development.

The data sets for the development scenarios are shown below as viewed in the *InfoSWMM Scenario Manager*.

DEVOPMENT_DWF



DEVELOPMENT_WW



1.3 Identify Manhole ID(s) Affected by the Development

Modeling a development requires identification of manholes affected by the development loading. A list of development manholes external to the model is recommended for record keeping. The list can be used for comparison and verification of loading that gets added to the model. The following information is recommended for external recording keeping and development review:

- Development Name.
- Manhole ID(s) affected by the development.
- Allocated development loading including:
  - Domestic Sanitary Flow.
  - Groundwater Flow Adjustments (if applicable).
  - RDII Adjustments (if applicable).
- Development Allocation Code (discussed further in Section 1.5).

1.4 Calculate Development Loading

Modeling a development requires three types of loading calculations. Calculations are completed external to the modeling software. The calculations include determining domestic sanitary flow and determination if groundwater flow or RDII acreage factors should be adjusted, and if so, by the calculated amount.

- *Domestic Sanitary Flow:*
  - Domestic sanitary flow needs to be calculated for the development. This calculation excludes ground water and excludes rainfall derived inflow and infiltration.
  - Domestic sanitary flow is dependent on the characteristics of the development and will require housing units, unit type (e.g. single family, medium density residential, etc.), or zoning or land use classification.
  - Refer to the *Wastewater Collection System Facility Plan Update* for recommended loading values.
- *Groundwater Flow:*
  - The existing system model includes base groundwater flow for dry weather and wet weather scenarios.
  - The Modeler must decide whether the development will require an increase to the groundwater component of the modeling scenarios. This calculation will be development specific. Values can be determined based on size and length of pipe within the development or based on acreage of the development.

    - Refer to the Wastewater Collection System Facility Plan Update for recommended loading values.
        - Note that two values may be required.
            - Ground Water for dry weather base infiltration.
            - Ground Water for wet weather base infiltration.
- *Area for RDII:*
    - Manholes within the model are assigned an acreage that represents a sewershed area of influence. The acreages were calculated based on Thiessen polygons generated from the modeling software. The acreage is used during the wet weather scenario to calculate rainfall derived inflow and infiltration for each manhole.
    - The modeler will need to determine if the acreage assigned to the manholes should be modified, calculate, and adjust accordingly. Acreage adjustments, if any, will be development specific.

1.5 Update Model Loading

The process for updating development loading is a manual process and consists of updating loading for three components:

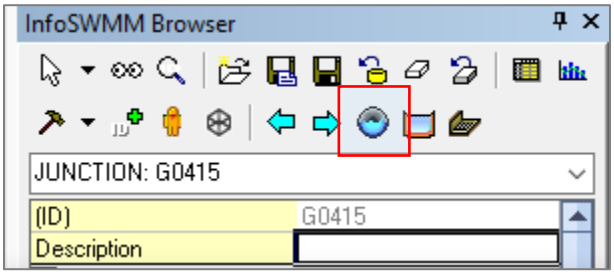
- Updating Domestic Sanitary Loading,
- Updating Groundwater Loading, and
- Updating RDII Acreage.

Updating each factor is discussed further in the following paragraphs.

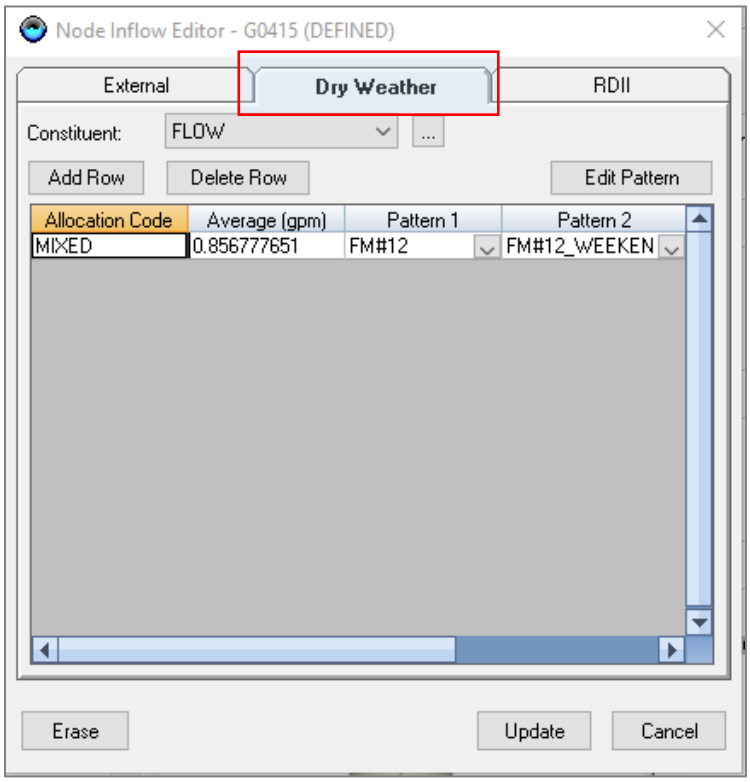
1.5.1 Development Domestic Sanitary Loading

Updating the development domestic sanitary loading within the model consists of the following steps:

- Select the desired Manhole.
- In the *InfoSWMM Browser*, Select the *Node Inflow Editor* icon.

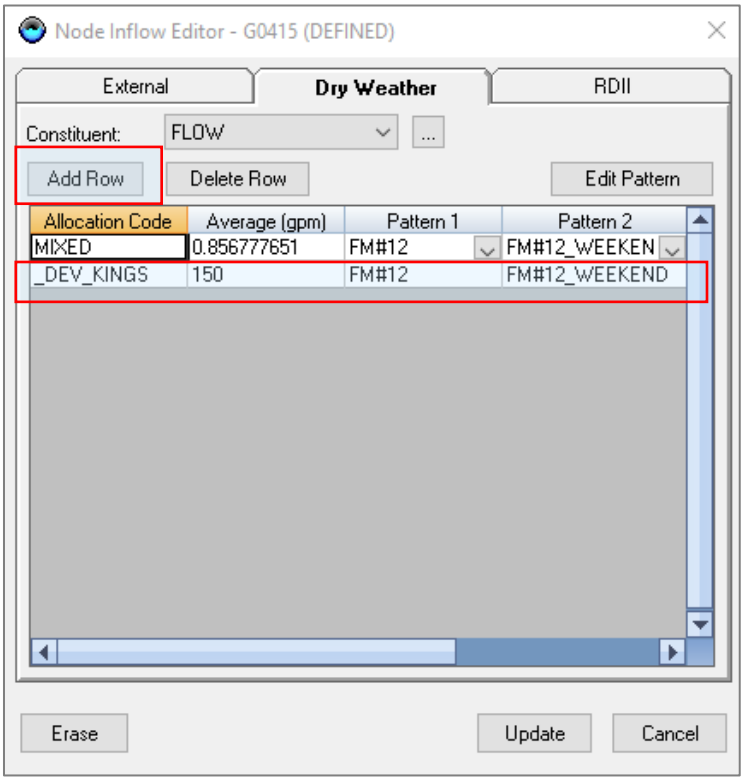


- The *Node Inflow Editor Window* opens.
- Click on the *Dry Weather* tab.
    - This window shows any current loading assigned to the manhole.



- To add Development Loading:
    - Click *Add Row*.
    - Set the *Constituent* to be *Flow*.
    - In the *Allocation Code* cell assign an Allocation Code.
        - Start the allocation code using the prefix text: "**_DEV**"
        - Follow the prefix text with an appropriate Development name:
            - e.g. if the development is called the "Kings Development" use and allocation code of "_DEV_KINGS".
        - The prefix "_DEV" is used to track, sort, and filter Development loading.
    - In the *Average (gpm)* cell assign the domestic sanitary loading.
        - Enter the average development domestic sanitary loading in gallons per minute to represent the dry weather domestic sanitary flow.
    - Assign the weekday *Pattern 1* and weekend *Pattern 2*.

- The assigned pattern depends on the location of the manhole within the system.
    - If there is existing loading assigned to the manhole, use the same patterns as the existing loading.
    - If there is no existing loading assigned to the manhole, review downstream manholes until existing loading is encountered. Then assign the same patterns to the new Development loading.

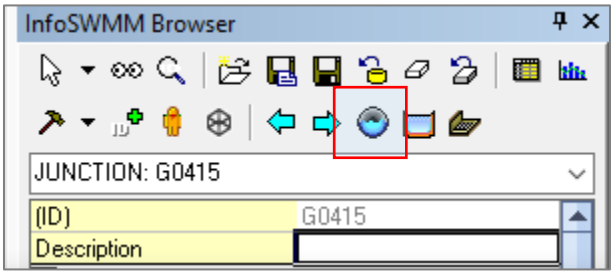


1.5.2 Development Groundwater Loading

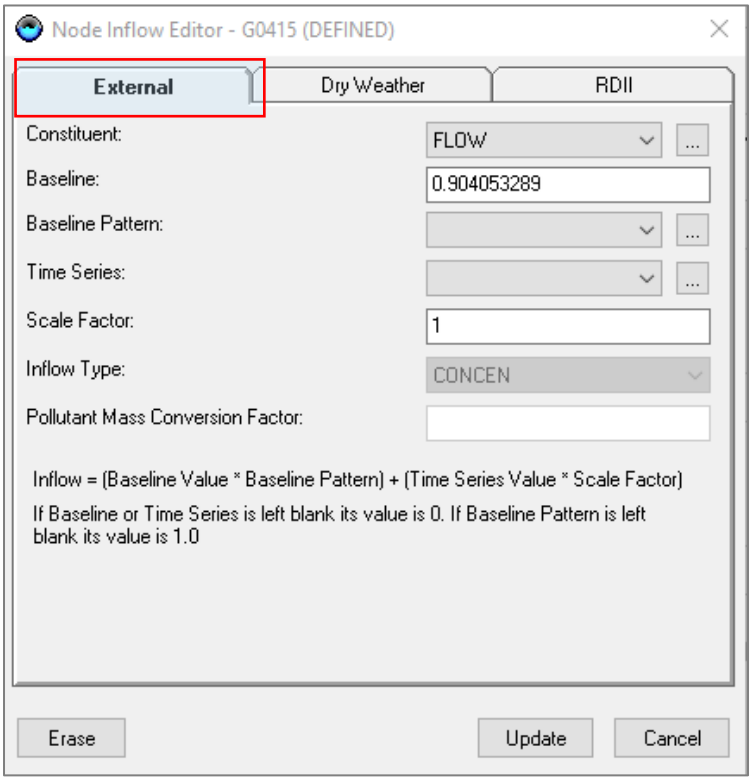
The following steps are used to update development groundwater loading should the Modeler determine that the ground water base flow needs to be updated. Updating the development groundwater loading within the model consists of the following steps:

- This process must be completed twice:
    - First iteration: Complete for the Dry Weather Groundwater scenario.
        - Use appropriate dry weather groundwater infiltration loading factors.
    - Second iteration: Complete for the Wet Weather Groundwater Scenario.
        - Use appropriate wet weather groundwater infiltration loading factors.

- In the *InfoSWMM Browser*, Select the *Node Inflow Editor* icon.

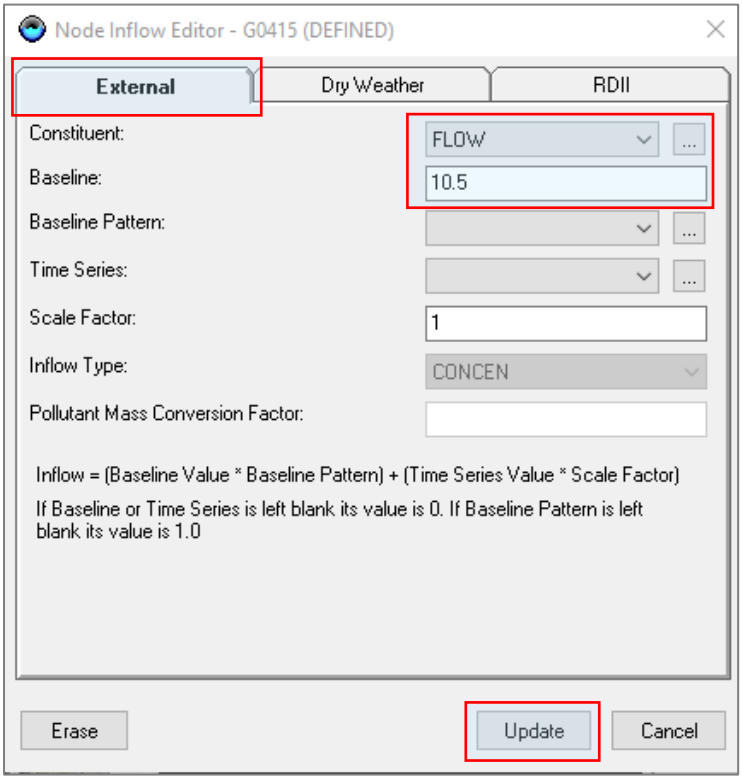


- The *Node Inflow Editor Window* opens.
- Click on the *External* tab.
    - This window shows any current loading assigned to the manhole.



- To add development groundwater loading:

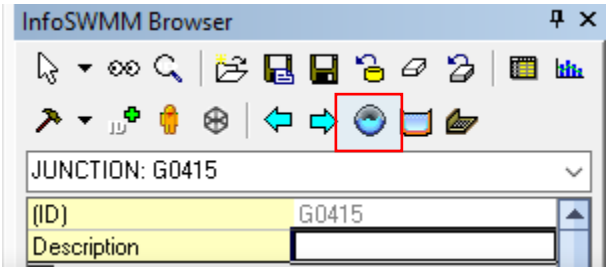
- **Note:** Only a single value can represent the groundwater flow in the database for an individual manhole.
- Set the *Constituent* type to *Flow*.
- In the *Baseline* cell:
  - If no flow is present, then enter the new development groundwater flow as a constant flow in gallons per minute.
  - If flow is present, then add the development groundwater flow to the existing flow (gpm).
- Click *Update* to save changes.
- Track and acknowledge ground water adjustment in external documentation as noted in Section 1.3.
- Reminder: this must be completed for both the Dry Weather scenario and the Wet Weather scenario.



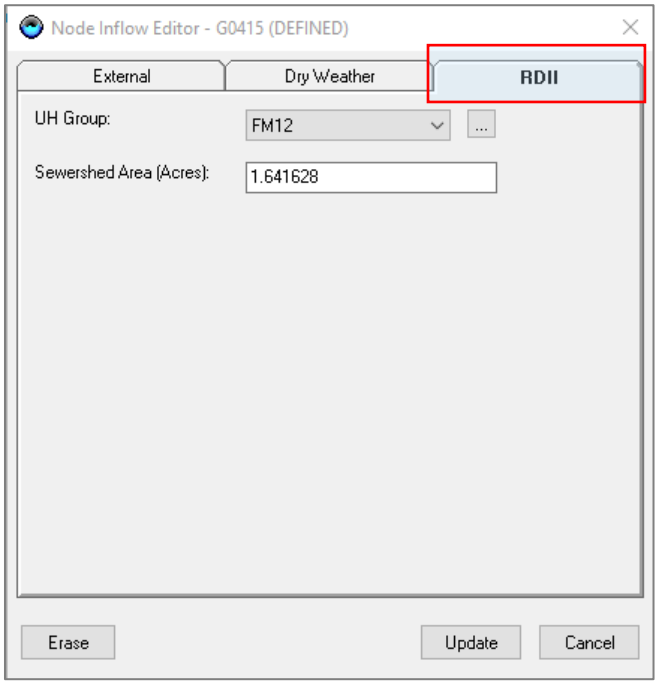
1.5.3 Development RDII

The following steps are used to update development RDII acreage should the modeler determine that the acreage needs to be updated. Updating the development RDII acreage within the model is best done manually at each manhole.

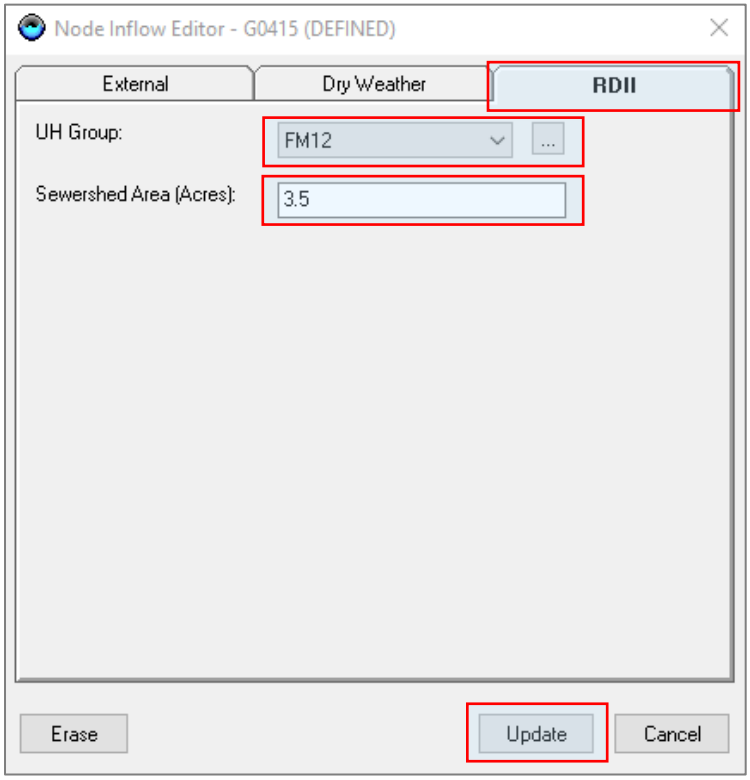
- Select the desired Manhole.
- In the *InfoSWMM Browser*, Select the *Node Inflow Editor* icon.



- The *Node Inflow Editor Window* opens.
- Click on the *RDII* tab.
    - This window shows any current acreage and unit hydrograph (UH) assigned to the manhole.



- To add development RDII acreage:
  - **Note:** Only a single value can represent the acreage in the database for an individual manhole.
  - *UH* (Unit Hydrograph) *Group*:
    - If an UH is already selected, then do not change.
    - If an UH is not selected, then review downstream manholes and use the same UH assigned to them.
  - In the *Sewershed Area (Acres)* cell:
    - If no acreage is present, then enter the new development sewershed area (acres).
    - If acreage is present, then add (or adjust as appropriate) the development RDII area (acres).
  - Click *Update* to save changes.
  - Track and acknowledge RDII acreage adjusted as noted in Section 1.3.



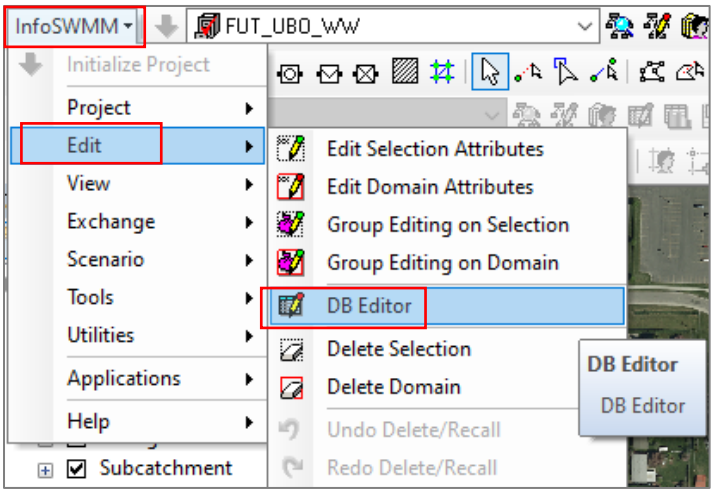
1.6 Query and Track Development Loading

Manholes with development domestic sanitary flow cannot be directly queried. There are two options for querying development manholes in the model.

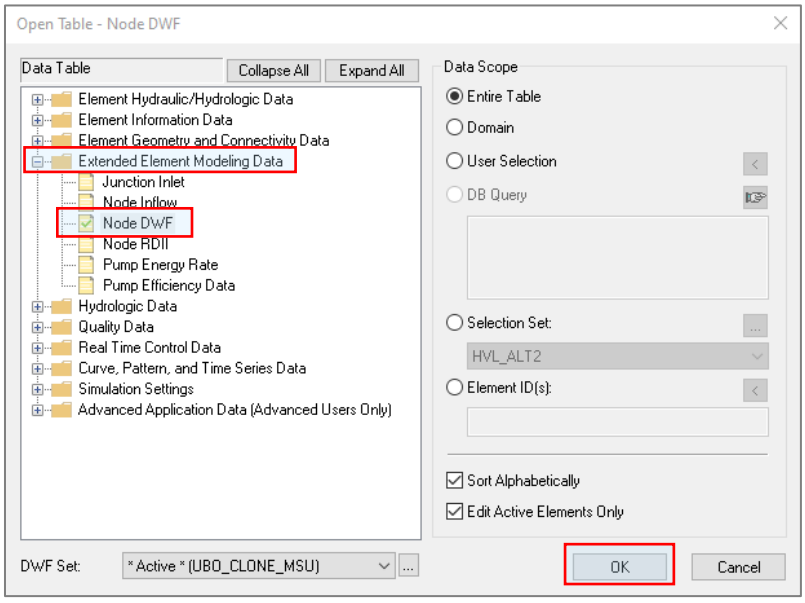
- Option 1: Use the dry weather *Allocation Code* created in Section 1.5.1 to identify manholes that have development loading.
    - This method is discussed further in the following paragraphs.
- Option 2: Create an attribute field that is specifically used to identify manholes that have added Development loading. This will require the Modeler to manually update the attribute field for each manhole used for development loading.
    - This method is not discussed in this memorandum.

1.6.1 Identify manholes that have development loading:

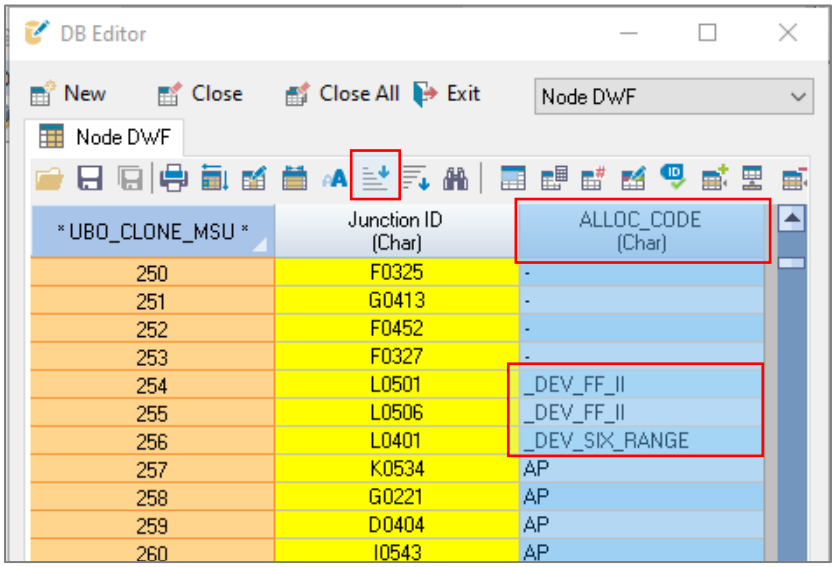
- In the *InfoSWMM* drop down menu select *Edit* and then *DB Editor* to open the database editor.



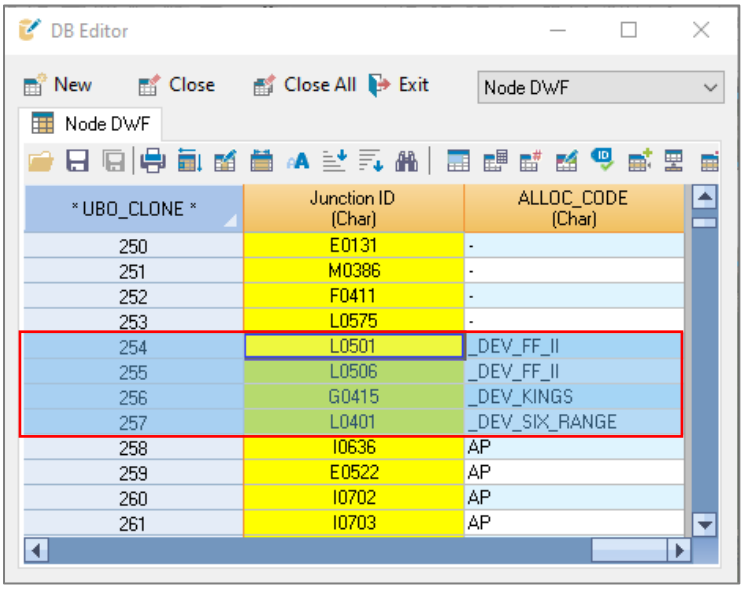
- In the *Database Editor Window* select *Extended Element Modeling Data*, then *Node DWF*, then *OK*.



- Sort the allocation code column ("*ALLOC_CODE*") in ascending order.
  - Left click on the "*ALLOC_CODE*" column header.
  - Select the *Sort Ascending* icon or Right click and choose *Sort Ascending*.
- Scroll down until you reach the allocation codes starting with the text "**_DEV**".

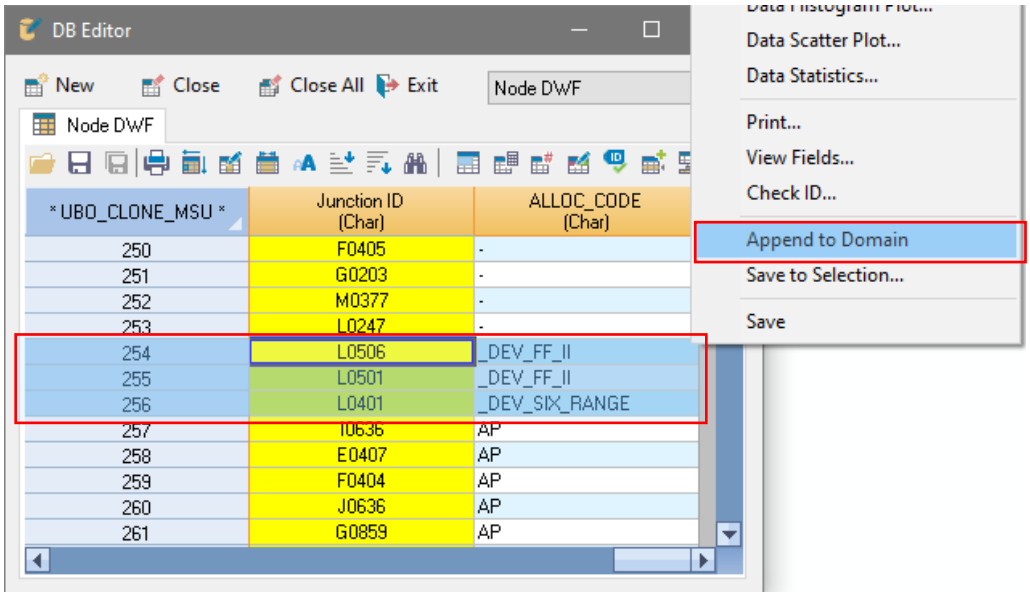


- Left click on the row number of the first manhole that has the development code.
- Hold *Shift* and Left click on the on the row number of the last manhole that has the Development code.
    - The selected rows highlight in blue.
- The selected data can be copied (right click and *copy*) and then pasted into external documents.

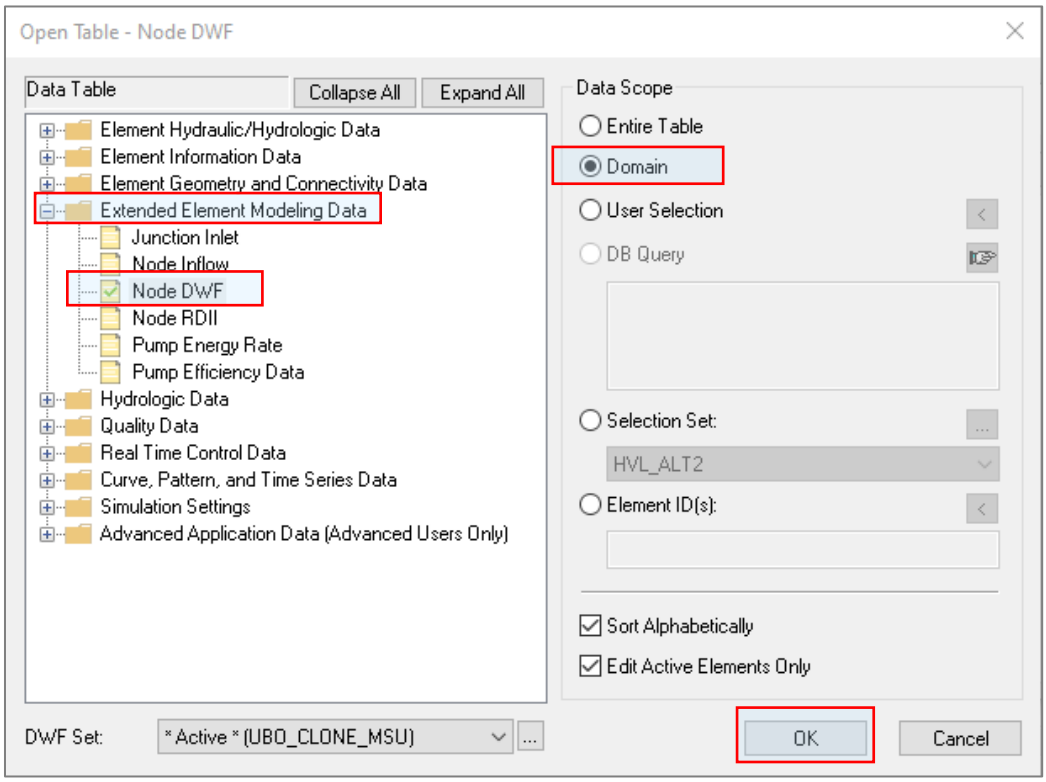


1.6.2 Add Development Manholes to a Domain

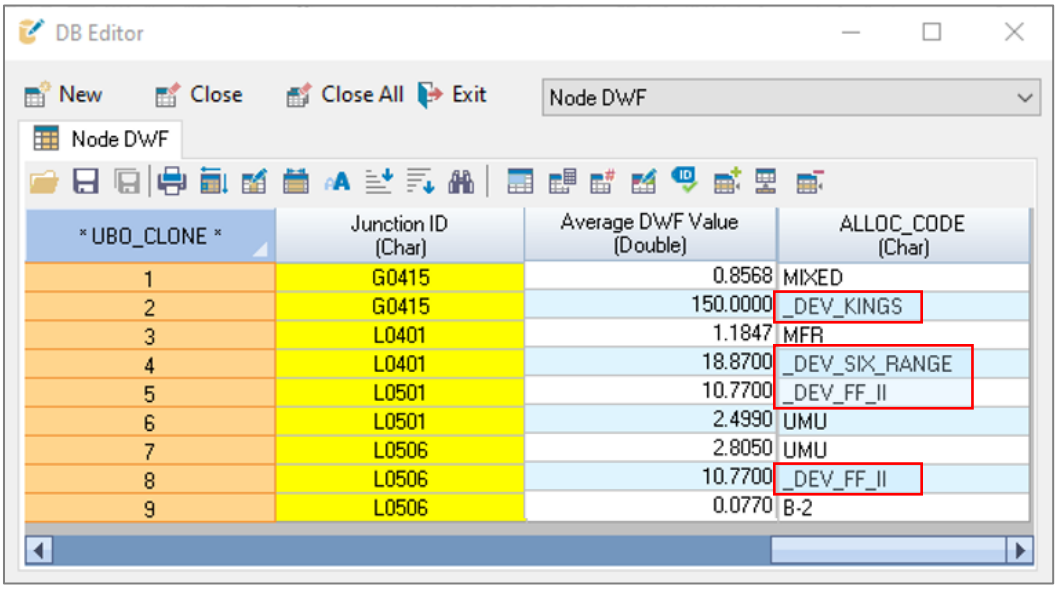
- The manholes can be added to a domain as well:
- Follow the steps in the previous paragraph. Once the manholes that have development loading are highlight in the *DB Editor* table, complete the following:
    - *Right Click* and choose "*Append to Domain*".
        - Manholes with Development loading are now added to the domain.



- Review Domain Data:
  - You can now view element data using the "*Domain*" as the selection criteria.
    - Open the *Database Editor*.
    - Select *Extended Element Modeling Data* then *Node DWF*
    - Under *Data Scope* select *Domain*, then *OK*.



- **Note:** DWF data will include ALL domestic sanitary flow assigned to the manholes including existing and new development loading. The data can be copied out to external files and filtered or organized as required.
- In the example database table below, each manhole has at least two different loading allocation types. One type (e.g. MFR) is associated with a land use loading and the other type is associated with Development loading. The *Allocation Code* starting with the prefix "***_DEV***" identifies development loading.



* UBO_CLONE *	Junction ID (Char)	Average DWF Value (Double)	ALLOC_CODE (Char)
1	G0415	0.8568	MIXED
2	G0415	150.0000	_DEV_KINGS
3	L0401	1.1847	MFR
4	L0401	18.8700	_DEV_SIX_RANGE
5	L0501	10.7700	_DEV_FF_II
6	L0501	2.4990	UMU
7	L0506	2.8050	UMU
8	L0506	10.7700	_DEV_FF_II
9	L0506	0.0770	B-2

1.7 Conclusion

Following the model loading update process within this memorandum will allow the City to update and track development loads allocated within the model. The City will continually be able to review new developments and assess capacity of the wastewater collection system and determine if the system has the ability to handle the increased flow from development.