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- Appendix B: Model Development and Calibration Technical Memorandum, December 2024
- Appendix C: Recommendations for Updating and Leveraging the Sanitary Sewer Model,
 December 2024
- Appendix D: Task 5 Technical Memorandum Southwest Conveyance Corridor Recommended Plan, May 2024

EXECUTIVE SUMMARY

This report presents the Systemwide Capacity Plan for improving the City of Lawrence's sanitary sewer system. The Systemwide Capacity Plan provides results of capacity evaluations from hydraulic modeling of the sanitary sewer system. Project recommendations were developed by leveraging years of data collection for the sanitary sewer system. The results of the evaluation identified many areas in the system that need to be addressed to provide desired level of service for existing conditions as well as future 2030 and 2040 growth conditions. The plan separates the sanitary system needs into manageable parts and identifies risk levels to establish priorities. The plan also provides estimated costs of projects and improvements and identifies where more information is needed to make improvements more cost-effective.

The approach to developing the Systemwide Capacity Plan began with the Southwest Conveyance Corridor pre-design (summarized in the Task 5 Technical Memorandum, Appendix D), which was a known high priority project area for the City. The recommendations for that area have led directly into design and construction projects. The Systemwide Capacity Plan utilized the SWCC pre-design by incorporating identified pre-design projects when modeling the rest of the system. Some project recommendations outside of the SWCC will require more field verification before implementing. The background and project goals are presented below.

The City of Lawrence, Kansas selected George Butler Associates (GBA) and Black & Veatch (BV) to complete a pre-design study for the Southwest Conveyance Corridor (SWCC), which is summarized in the Task 5 Technical Memorandum (Appendix D). To achieve the pre-design goals, a hydraulic model of the sanitary sewer system was developed and calibrated to flow monitoring data from 2019 and 2020. In addition to the SWCC pre-design and modeling, the City also requested systemwide analysis of sanitary sewer capacities. The systemwide modeling analysis (Chapter 7) and Systemwide Capacity Plan (Chapter 8) incorporate the results of the hydraulic modeling and SWCC pre-design into an overall plan to address capacity deficiencies identified in the modeled sanitary sewer system. As mentioned before, this report presents the Systemwide Capacity Plan to assist with immediate system needs and long-term planning.

The primary objectives and deliverables of this project include:

Pump Station 9 Condition Assessment

The condition of the Pump Station 9 (PS9) facility, a focal point of the SWCC, was evaluated, allowing identification of mechanical and structural deterioration, operational constraints, and reliability concerns. The condition assessment is summarized in Appendix A.

Hydraulic Modeling of Sanitary Sewers

A systemwide collection system model was developed and calibrated using the PCSWMM modeling platform. The model was used to analyze system capacity at key locations and identify improvement projects necessary to meet City goals and requirements. Existing conditions, 2030 growth conditions, and 2040 growth conditions model scenarios were developed using City-provided growth projections. Model development is summarized in Appendix B, and future growth scenarios are summarized in Chapter 5. The model is intended for long-term use for system planning and it is recommended to keep it current with periodic updates and recalibration.

• SWCC Pre-Design with Optimization

Using the calibrated hydraulic model and the Borg Multiobjective Evolutionary Algorithm (MOEA) optimization tool, a recommended set of preliminary improvements and phasing for the SWCC was developed to meet 2030 and 2040 growth conditions. A summary of the SWCC improvements plan is provided in the Task 5 Technical Memorandum (Appendix D).

Systemwide Modeling and Capacity Planning

A plan for systemwide capacity improvements was developed that incorporates the results of the SWCC pre-design improvements. Model simulations of existing conditions, 2030 conditions, and 2040 conditions were used to predict capacity deficiencies in the sanitary sewer system. The modeling analysis and systemwide capacity planning are summarized in Chapters 7 and 8.

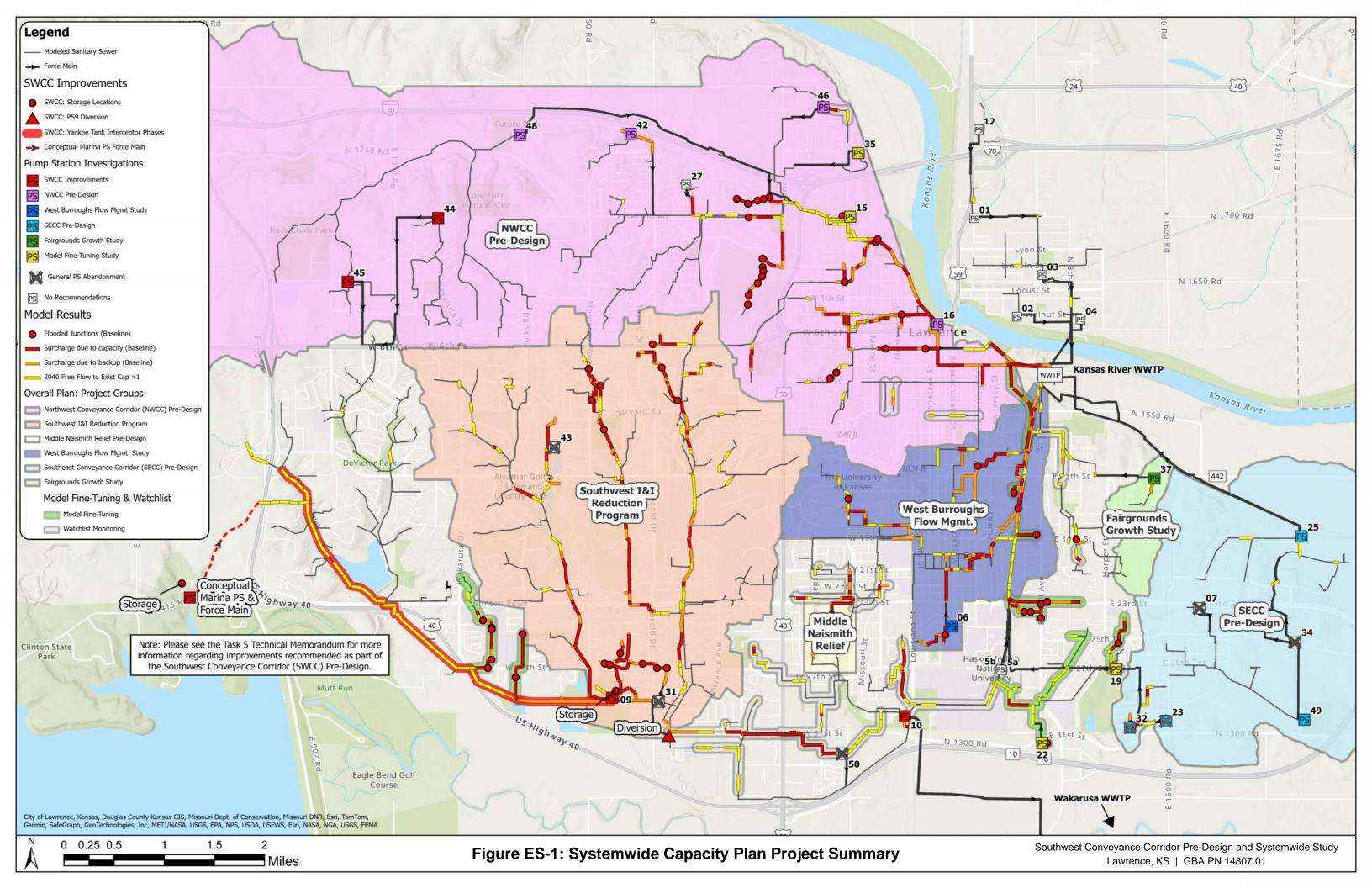
The Systemwide Capacity Plan needed to be both actionable and adaptable to fit the City's ongoing needs and available resources. Modeling results and City staff input were used to shape this systemwide plan and identify a consolidated set of projects to address deficiencies and maintain level of service in Lawrence's sanitary sewer system. Gravity sewer and pump station capacity deficiencies were grouped into larger project areas based on location and relative risk. The resulting project groups were then assigned an order of priority based on risk and importance. Project groups are presented in rank order in Table ES-1 and locations are shown in Figure ES-1. In general, the plan is to be implemented by conducting pre-design phases for major sewer corridors and larger study areas, much like the SWCC pre-design completed for this project. The pre-designs will then lead into detailed design and construction.

				wer Sub-Projects	Pump Station Sub-Projects		Conceptual Cost Ranges		
Priority									Design and Construction
Rank	<u> </u>	Primary Objectives	ID	Name	Risk Cat.		Risk Cat.	Pre-Design / Study Phase	of First Phase of Projects
1	Southwest Conveyance Corridor	□ Address existing deficiencies at PS9	SW-09	Yankee Tank Interceptors		PS9 Improvements	3	\$1.1M	\$20M - \$30M
	(SWCC) Improvements	□ Prepare SWCC to serve future growth west of K-10				PS9 Additional Storage	N/A	(complete)	(see Task 5 Tech Memo)
						PS44 and PS45 Abandonment	N/A		
	Northwest Conveyance Corridor	□ Identify most optimal set of improvements to prepare NWCC for future	NW-01	Stowe Dr		PS10 Improvements PS16	3	\$0.9M - \$1.1M	\$20M - \$30M
2	(NWCC) Pre-Design	□ Perform optimization modeling similar to SWCC Pre-Design	NW-02	PS16 Parallel Interceptors		PS42	3	(Flow Monitoring, Model	(PS16 Expansion or
	(NVVGG)1 Te-Design	□ Investigate options for improving PS16 and its interceptors	NW-03	5th St		PS46	1	Updates, Optimization,	Storage Project)
		□ Investigate modeled gravity deficiencies with targeted flow monitoring	NW-04	Country Club		PS48	1	and Pre-Design)	Glorago i rojecty
		□ Identify upgrades to address existing deficiencies at PS42	NW-05	9th St and Avalon Rd	4		•		
			NW-06	Memorial Hospital	4				
			NW-07	Peterson Rd and Crestline Dr	3				
			NW-08	Centennial Park	2				
			NW-09	Peterson Rd	2				
			DT-01	7th St and 8th St Downtown	4				
			DT-02	KRWWTP Interceptors	2				
3	Southwest I/I Reduction Program	□ Programmatically reduce I/I to improve system capacity and condition	SW-01	Lower Quail Creek	4	N/A		\$1.2M - \$1.4M	\$4M - \$6M
		□ Begin with smaller, leakier basins as pilot projects to confirm reduction	SW-02	Atchison Creek	4			(5 Small Pilot Basins:	(5 Small Pilot Basins:
			SW-04	Upper Quail Creek	3			Field Data Collection	Rehabilitation)
			SW-07	Inverness	3			and Rehab. Design)	40.0 44.04
4	Middle Naismith Relief Pre-Design	□ Identify optimal solution for relieving the gravity sewer capacity issue	SW-03	Middle Naismith		N/A		\$0.1M - \$0.3M	\$0.8 - \$1.2M
5	West Burroughs Flow Mgmt. Study	□ Identify opportunities to strategically reroute flows and improve capacity	BC-01	West Burroughs Creek and KU		PS06	11	\$0.6M - \$0.8M	\$1M - \$2M
6	Southeast Conveyance Corridor	□ Identify most optimal set of improvements to prepare SECC for future	SE-01	Prairie Park	3	PS23	2	\$0.3M - \$0.5M	\$4M - \$6M
	(SECC) Pre-Design	□ Investigate options for rerouting PS49 to Wakarusa WWTP	SE-02	East Hills Business Park	1	PS25	1	(Pre-Design Only)	(Design & Construction of
		□ Investigate options for abandoning PS23 and 32 with new pump station				PS32 PS49	2		PS49 Force Main Reroute)
7	Fairgrounds Growth Study	□ Identify most optimal set of improvements to prepare basin for future	BC-08	Fairgrounds and PS37		PS37	2	\$0.1M - \$0.2M	N/A
8	Model Fine-Tuning and	Model Fine-Tuning:	Model Fine	<u> </u>		PS15	1	\$0.3M - \$0.7M	N/A
O	Watchlist Monitoring	□ Investigate modeled deficiencies where there is lower confidence	BC-02	23rd St and Haskell Ave		PS19	1	(for Watchlist Monitoring,	(No improvements
	Trace met met me	in model results due to poor flow meter coverage	BC-03	Maryland St		PS22	1	initial costs would entail	anticipated in near term)
		□ Identify opportunities to improve the sanitary sewer model	BC-04	Homewood St		PS35	1	field visits and record	,
		□ Field verify system hydraulics to address gaps and limitations in the	BC-05	Ponderosa	3			checks, but costs would	
		existing model network	BC-06	PS19 and Anderson Rd	3			increase if flow meters or	
			BC-07	Hobbs Park	3			HGL analysis is needed)	
			SW-05	Sunflower	3				
			SW-06	Wildflower Dr	3				
		Watchlist Monitoring:	Watchlist I		_				
		□ Monitor low-risk capacity deficiencies identified during modeling	BC-09	Belle Haven	2				
		using stepped approach, beginning with field visits and record checks,	BC-10 BC-11	Brook Creek	2				
		followed by flow metering and HGL analysis if issues are noted □ Track potential capacity deficiencies that may be caused or exacerbated	DT-03	Maple Ln and 21st St Upper Jayhawk	0				
		by upstream growth and development	DT-03	11th St	1				
		□ Update findings and status once every 5-10 years	NW-10	Riverside Dr	1				
		2 5 5 5 5 5 6 6 6 6 6 6 6 6 6 6 6 6 6 6	SW-08	Lower Naismith	2				
			SW-10	31st St	2				
			SW-11	K10 Interceptors at 33rd St	2				
			SW-12	Upper Naismith	2				
9	General Pump Station Abandonment	□ Abandon pump stations by installing new gravity sewer where possible	N/A			PS07	N/A	N/A	N/A
		□ Reduce O&M costs and eliminate aging equipment				PS31	N/A	(Preliminary studies have	(Costs and timing will
						PS34	N/A	been completed)	depend on City
						PS43	N/A		prioritization and budget)
						PS50	N/A		

Total Conceptual Cost Range

\$4.6M - \$6.1M

\$50M - \$75M



1 INTRODUCTION

1.1 Project Description

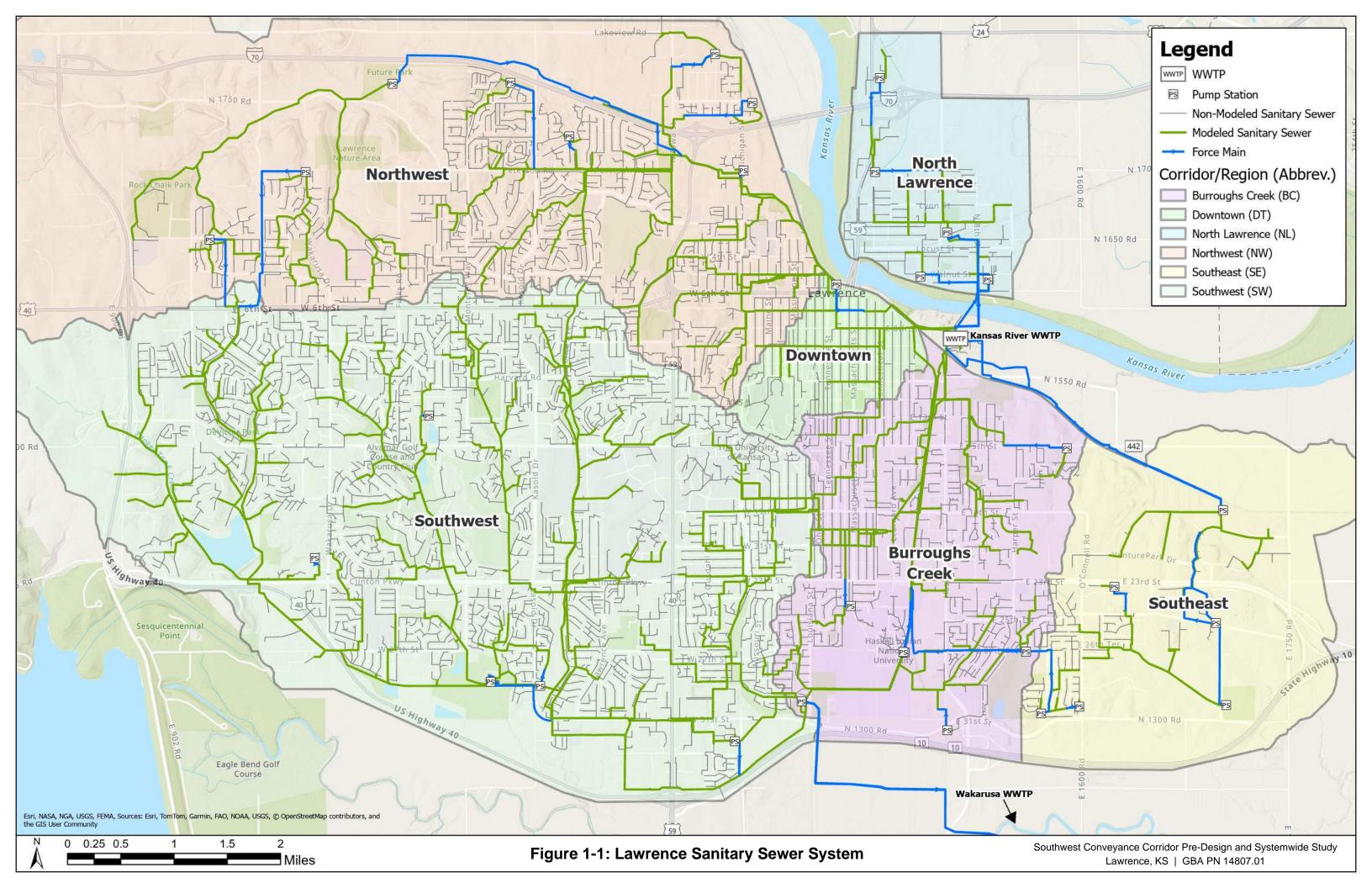
The City of Lawrence, Kansas (City) engaged GBA and Black & Veatch (BV) to complete the study and preliminary design phase of the Southwest Conveyance Corridor (SWCC) Improvements Project. The project included two primary objectives. The first objective was to complete a pre-design of improvements for the SWCC, which was summarized in the Task 5 Technical Memorandum (Appendix D). The second objective was to prepare a systemwide capacity improvements plan that incorporates the results of the pre-design SWCC improvements. This report summarizes the work performed to achieve these objectives and presents the systemwide capacity improvements plan in Chapter 8.

To complete the project objectives, a hydraulic model of the sanitary sewer system was developed in PCSWMM to identify system deficiencies and needs. The model was used to simulate the impact of design storm flows on existing conditions and future growth conditions at the 2030 and 2040 planning windows. The hydraulic model provides the City with another valuable planning tool to be used during future planning and design projects.

1.2 Study Area Description

The City of Lawrence, Kansas is located primarily west and south of the Kansas River. The City was established in 1854 and currently spans approximately 35 square miles. Interstate 70 approximately bounds the city on the north side and K-10 Highway approximately bounds the city on the south side. The City's sanitary sewer system includes over 11,200 manholes, 440 miles of gravity sewer, 32 pump stations, and nearly 28 miles of force main.

The city is served by two Wastewater Treatment Plants (WWTPs) that provide treatment for approximately 100,000 people: the Kansas River WWTP and the Wakarusa WWTP. The City's sanitary sewer system has several major corridors and regions that convey most of the sanitary flow to the WWTPs. These corridors, shown in Figure 1-1, are the backbone sewers that collect and convey sanitary sewer flow from and through each quadrant of the city.



1.3 Project Background

The SWCC was selected by the City for study and pre-design of conceptual improvements because of its overall importance and existing deficiencies (particularly at PS9). The pre-design plan for the SWCC was completed and presented as the Task 5 Technical Memorandum (Appendix D). Initial system needs were identified using the PCSWMM model and the 10-year, 6-hour design storm for existing, 2030 and 2040 growth conditions.

During the development of the SWCC pre-design, growth projections were established that considered the growth anticipated west of K-10. The K-10 Highway expansion project is underway and future sewer crossings in this area were considered in the SWCC pre-design plan as well. The modeling used to develop the SWCC pre-design also provided direction for the Systemwide Capacity Plan.

The previous sanitary sewer plan developed for the City was the "Integrated 2012 Wastewater Utilities Plan." Of the recommended improvements from the 2012 plan, four primary projects have been implemented: construction of the Wakarusa WWTP and PS10, improvements at the Kansas River WWTP, implementation of the Rapid I/I Reduction Program, and construction of the Naismith Valley Interceptor and abandonment of PS8. Projects identified in the 2012 plan were reviewed and compared to projects identified for this project. Most of the CIP projects identified in the 2012 plan have either been implemented or overlap with recommendations provided in this report.

1.4 Scope of Work

The primary objectives of the project were to identify and assess capacity issues in the sanitary sewer system, both for existing conditions and future growth conditions. This was accomplished by development and calibration of a sanitary sewer collection system model to predict areas within the system with existing and future capacity deficiencies. A set of evaluation criteria were developed and applied that identified and prioritized projects.

To complete the project, the following scope of work was accomplished:

- Developed a hydraulic model in PCSWMM that represents the existing conditions.
- Established future growth projections for the 2030 and 2040 planning horizons.
- Identified approximate locations of future growth extensions to be used for connecting future growth areas and flows to the model.
- Established a design storm for the model and ran the model for the existing conditions, 2030 growth conditions, and 2040 growth conditions.
- Performed a condition assessment of the PS9 facility because it is a critical bottleneck in the SWCC and crucial to the SWCC pre-design plan.
- Determined a pre-design plan for the SWCC and identified potential improvement projects by utilizing optimization algorithms paired with the PCSWMM model. Based on selected alternatives from optimization, a recommended improvement plan for the SWCC was

- developed that included phases to accommodate growth. (More details are provided in the Task 5 Technical Memorandum, Appendix D)
- Performed systemwide modeling to identify and evaluate capacity deficiencies throughout the modeled sewer system.
- Developed a Systemwide Capacity Plan that prioritizes capacity improvements throughout the sanitary sewer system and incorporates recommendations from the SWCC pre-design plan.

2 DATA COLLECTION AND REVIEW

Data and documents were collected to support the objectives of the project. The information was used to set up the hydraulic model, forecast growth, and estimate costs.

2.1 Data for Hydraulic Modeling and Future Growth Scenarios

- City GIS Data At the beginning of the project, the City provided to provide the most current and updated sets of GIS data available. The data was reviewed through queries and filters to identify gaps in data needed for the modeling.
- 2012 Model Data Model network information from the Integrated 2012 Wastewater Utilities Plan was used to assist with model development.
- City Flow Data and Reports Flow monitoring data, rainfall data, and reports were referenced throughout the project. Flow data from the 2019 and 2020 flow monitoring periods were primarily used for model calibration. Annual flow monitoring sessions and reports from 2014 through 2021 were used to corroborate model results for capacity issues.
- Pump Station SCADA Data Magnetic meter readings for relevant pump stations were provided by the City for model calibration purposes.
- City Population Dispersion Model The residential growth estimates were provided by the
 City in a GIS-based population dispersion model which spatially assigned growth
 projections throughout the City using traffic analysis zone (TAZ) polygons.
- Plan 2040 The City's most recent comprehensive plan, Plan 2040, was referenced throughout the project, particularly when developing future growth scenarios.

2.2 Data for Cost Estimating

The cost estimating data was collected from a variety of sources.

 Gravity Sewer, Force Mains, Pump Stations and Storage Basins – Estimates were based on cost-curves and tables utilizing bid tabs from previous projects with similar improvements. Escalation of past bid tab data and cost information was performed using the Engineering News Record (ENR) Construction Cost Index (CCI) to account for inflation and increases in construction costs over time.

Historical costs were also compared to applicable cost curves gathered from:

- Environmental Protection Agency documents
- American Public Works Association documents
- Local city and utility company curves such as Johnson County Wastewater (JCW) and Kansas City, Missouri Water Services Department.

2.3 Other Documents and Data

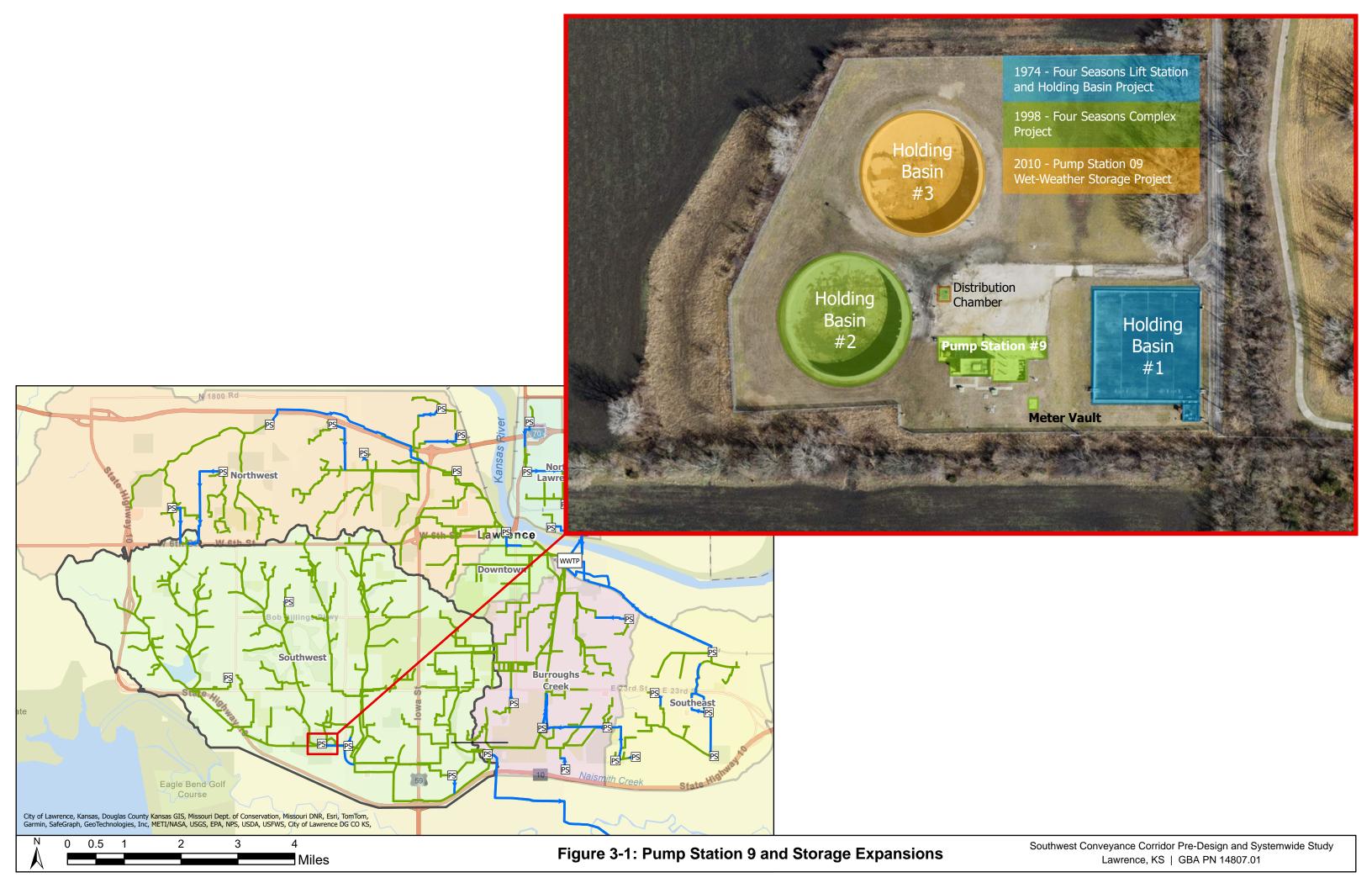
- Capital Improvement Plan (CIP) The city's CIP was reviewed to better understand locations of current and upcoming projects. The CIP was also considered when developing recommendations for the Systemwide Capacity Plan.
- Pump Station 9 Plans and As-Builts These documents were essential for understanding the PS9 facility and developing improvement recommendations.
- City Asset Data Lucity Manhole Inspections were referenced to confirm manhole depths and conditions in certain situations.
- City Design Requirements Referenced to ensure recommendations and level of service goals align with current City standards.
- Integrated Plan Agreement with KDHE and Integrated 2012 Wastewater Utilities Plan –
 This document was referenced to understand previously identified improvements and to
 ensure alignment across planning documents.
- Planning documents and Construction plans for relevant sanitary sewer projects, such as the Naismith Valley Interceptor, Crossing at KU development, and City Field Operations Campus.

3 PUMP STATION 9 CONDITION ASSESSMENT

3.1 Condition Assessment Purpose

As shown in Figure 3-1, Pump Station 9 has been in operation in some capacity since 1974, and currently serves approximately one third of Lawrence's land area within city limits. Flows to Pump Station 9 are expected to increase as the City expands west of K-10, and critical components will continue to deteriorate as the facility ages. To continue to serve and meet future demands, a conditions assessment was conducted at Pump Station 9 to identify rehabilitation and replacement projects necessary to keep Pump Station 9 operational through the 2040 planning period. The full findings of this study are available in Appendix A, Pump Station 9 Condition Assessment Technical Memorandum.

Condition Assessment teams from the City, GBA, and BV conducted a detailed assessment of Pump Station 9 and the facilities on February 7, 2022. Using an Asset Risk Methodology (Appendix A, Section 3.1.1), the BV team evaluated the findings of this assessment and categorized improvement recommendations under seven discipline areas. Drawdown testing of the two dry weather pumps was performed on March 3, 2022.



3.2 Engineering Discipline Inspection Reports

Engineering discipline review of Pump Station 9 was conducted for Mechanical Process, Civil, Structural, Architectural, Electrical, Instrumentation and Controls, Mechanical Building. Each discipline provided an Inspection Report that details the recommendations for keeping Pump Station 9 operating at its current capacity. Preliminary costs associated with these recommendations are provided in Tables 5 and 6 of Appendix A, Pump Station 9 Condition Assessment Technical Memorandum. The conditions assessment findings for each discipline area can be found at the following sections of Appendix A:

- Section B.1.0 Mechanical Process Inspection Report
 A list of recommendations is provided in Appendix A , Section B.1.7.
- Section C.1.0. Civil Inspection Report Recommendations are summarized in Appendix A, Section C.1.3.
- Section D.1.0 Structural Conditions Assessment
 Recommendations are summarized in Appendix A, Section D.1.3
- Section E.1.0 Architectural Inspection Report Recommendations are summarized in Appendix A, Section E.1.3.
- Section F.1.0 Electrical Inspection Report Recommendations are summarized in Appendix A, Section F.1.3.
- Section G.1.0 Instrumentation and Control Inspection Report Recommendations are summarized in Appendix A, Section G.1.3.
- Section H.1.0 Building Mechanical Inspection Report
 Recommendations are summarized in Appendix A, Sections H.1.3. through H.1.9.

4 HYDRAULIC MODEL DEVELOPMENT AND CALIBRATION

4.1 Introduction

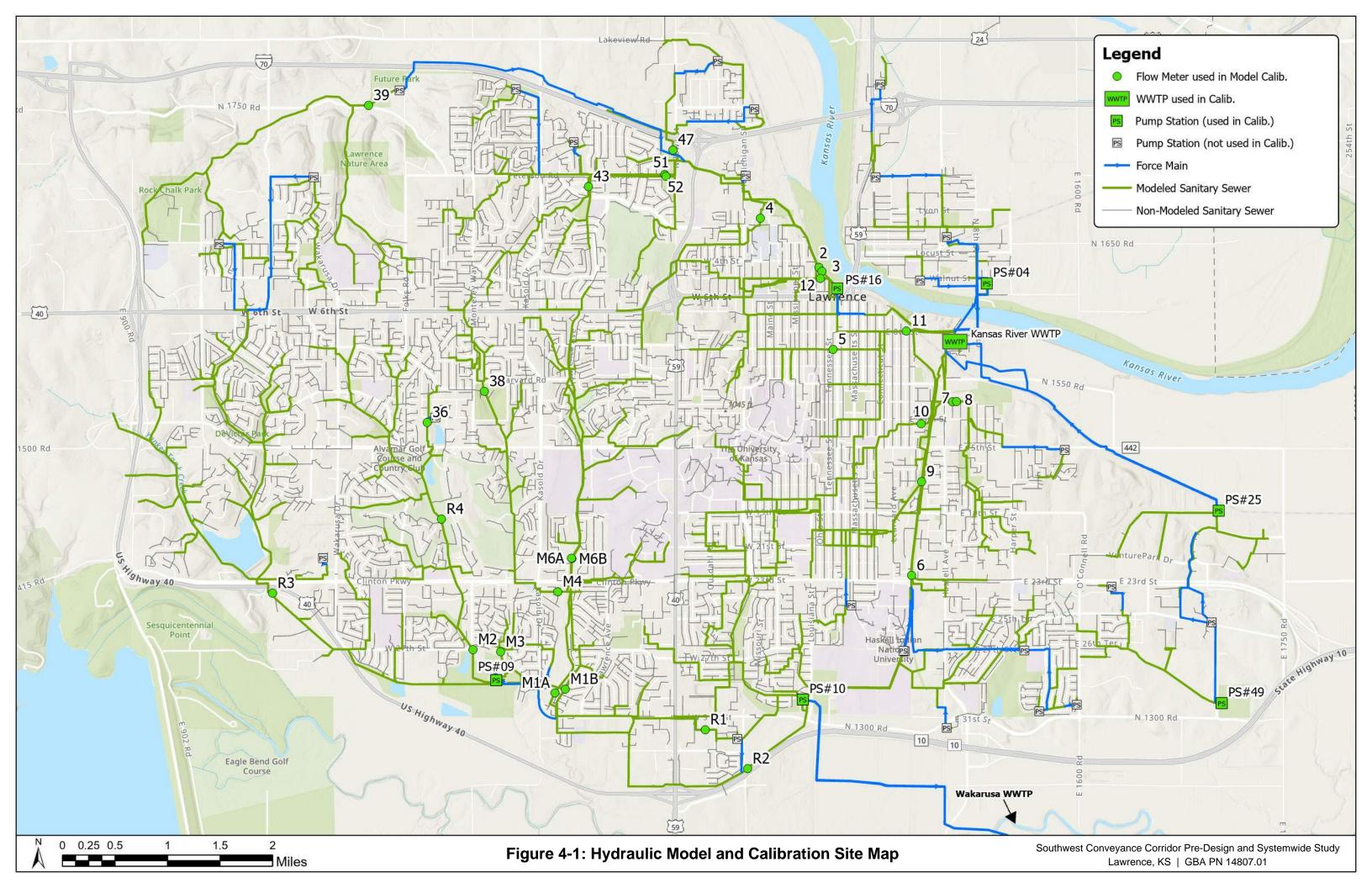
To support capacity analyses of the sanitary sewer system, a systemwide hydraulic model of the sewer system was developed and calibrated in the PCSWMM modeling platform. A more detailed summary of the hydraulic model can be found in Appendix B. The model network was generally limited to pipes and manholes serving at least 20 acres. Historical flow and rainfall monitoring data were used to calibrate the hydraulic model to observed dry and wet weather conditions. Using the calibrated model, a design storm model was developed using a 10-year, 6-hour design storm event from NOAA Atlas 14 with 3.97 inches total rainfall. The model has been a crucial tool in the development of the plan and recommendations of this project.

The completed PCSWMM model developed for this project utilized relevant parts of the hydraulic model completed in 2012 for the City of Lawrence. Utilizing the City's current GIS and previous model network, the model was updated to reflect current conditions. The model was calibrated using 2017, 2019, and 2020 flow meter data collected throughout the sanitary sewer system.

4.2 Hydraulic Model Network Development

As mentioned previously, the PCSWMM hydraulic modeling software was used for the model. The 2012 model network (developed using a different SWMM model platform) served as a foundation for the new model network. Enhancements were then made that included adding new infrastructure, updating manhole rim elevations, updating force main information, and adding pump station data by utilizing City GIS and other data sources. Once updated, the hydraulic model included approximately 732,000 feet of gravity sewer, approximately 136,000 feet of force main, and 30 pump stations. The system that was modeled is shown in Figure 4-1.

Connectivity checks were completed for the existing model network. To confirm connectivity, initial model runs were used to ensure flow entering the system from diurnal inputs equaled flow leaving the system at appropriate locations.



4.3 Hydraulic Model Calibration and Baseline Model Development

The model was calibrated to dry and wet weather conditions using flow monitoring data primarily from 2019, along with supplemental flow meter sites from 2017 and 2020. 31 calibration sites were used in total, as shown in Figure 4-1. Several of the sites were comprised of two flow meters (e.g., Sites 2/3, 7/8, 51/52, etc.), in basins where multiple flow exit points exist. In addition to flow meter sites, SCADA data from pump stations 4, 9, 10, 16, 25, and 49 were used for calibration purposes, as well as influent flow data to the Kansas River WWTP.

Dry weather flow is based on average daily flow from sewer and dry weather infiltration, and naturally fluctuates throughout the day. These flows are comprised of domestic, industrial, and commercial wastewater production. These flows and their fluctuations are then combined into a diurnal curve. The model flows were compared to observed flow monitoring flows during dry weather periods to determine the fitness of calibration.

Wet weather flow includes average daily dry weather flow with additional input from increased inflow and infiltration. Wet weather responses vary by basin and by storm event, as duration and intensity of storms are unique. The model uses the RTK method to simulate wet weather flow responses within the system. Calibration was considered complete once a balance was struck in the parameter settings used across multiple storm event simulations.

After calibration of the model was complete, a "baseline model" was developed that included two important projects: the Crossing at KU (design underway at the time of calibration) and the Naismith Valley Interceptor (construction complete at the time of calibration). The "baseline model" was then used to simulate existing conditions of the system for design storm model runs.

4.4 Design Storm Selection

The design storm was selected after a comparison of model results from the simulation of four different design storms (5-year, 6-hour; 5-year, 24-hour; 10-year, 6-hour; and 10-year, 24-hour). The design storm selected was the 10-year, 6-hour design storm event from NOAA Atlas 14 with 3.97 inches total rainfall. The 10-year, 6-hour storm was selected because it was the design storm previously used by the City for planning purposes, and it provides a conservative approach to capacity modeling. Also, the most conservative storm evaluated, the 10-year, 24-hour event, is not as common to the Midwest, and a 6-hour storm is considered more typical of large late-spring/early-summer storms in Lawrence. The design storm was set up and ran for the baseline model to establish needs for the existing conditions of the system. The design storm was also used for model runs for both the 2030 and 2040 future growth scenarios.

4.5 Recommendations for Model Updates

The City has made a considerable investment in their PCSWMM hydraulic model. The hydraulic model is a useful tool for long term planning for the City as new development inquiries are

submitted to the City and planning is required. It is important for the City to update the model periodically to maintain its utility and relevance. Recommendations for maintaining and updating the model are provided in Appendix C. The maintenance plan focuses on the following data repositories and tasks:

- 1. Sanitary Sewer GIS Network Maintenance and Pump Station Data Repository- Annual
- 2. Flow Monitoring and Data Repository 10 Year Cycle (Systemwide)
- 3. Future Growth Planning Annual
- 4. Model Updates Annual
- 5. Model Calibration 10 Year Cycle

5 FUTURE GROWTH SCENARIOS

5.1 Introduction and Background

Growth projections for the City of Lawrence were incorporated into the sanitary sewer model in PCSWMM to simulate future growth scenarios for the 2030 and 2040 planning periods. These projections covered residential, commercial, and industrial land uses, as well as special growth areas identified by the City. The residential growth estimates were provided by the City in a GIS-based population dispersion model which spatially assigned growth projections throughout the City. Projections of growth-related wastewater flows were refined with the City's input during workshops. This chapter outlines the key tasks performed to analyze these growth projections and integrate them into the hydraulic model to simulate collection system impacts for the 2030 and 2040 growth scenarios.

At a regional level, two growth-stimulating projects are taking place that informed growth assumptions used for this study and are expected to impact growth for the City:

- K-10 Highway Expansion: The Kansas Department of Transportation has initiated the expansion of the K-10 highway from the intersection of K-10 highway at US59 to the intersection of Interstate I-70. This expansion is expected to stimulate growth, both along the corridor of expansion and to the west of K-10 and existing City limits. The City is receiving growing interest in development and expansion of City limits and services west of K-10, and this is a primary driver behind the growth scenarios developed for this study.
- Panasonic Battery Plant: The State of Kansas is incentivizing economic development along the K-10 corridor. The most notable development is the multi-billion-dollar Panasonic Battery Plant in De Soto, Kansas. The plant is expected to have large-scale economic impacts along the corridor, and is anticipated to eventually impact development in Lawrence, particularly in the southeast area where there is potential for industrial and commercial development. It is anticipated that suppliers and partner companies of Panasonic may seek commercial/industrial space near or within Lawrence Venture Park.

5.2 Residential Growth Projections

The population dispersion model provided by the City contained growth projections organized into traffic analysis zone (TAZ) polygons that spanned the entirety of Douglas County. These TAZ polygons indicated general areas where growth is projected to occur. Each TAZ polygon had an existing (2020), 2030, and 2040 population estimate developed by City staff. Of the roughly 300 TAZ polygons used for this analysis, the smallest was 2.5 acres and the largest 1,560 acres. This wide range of TAZ polygon sizes resulted in varying degrees of spatial precision in the population data. In other words, smaller TAZ polygons provided a more precise location of where growth is projected to occur than the larger TAZ polygons.

Although the City's dispersion model provides a spatial distribution of growth projections, the relevant dispersion model polygons needed to be selected and then linked to the hydraulic model to develop wastewater flow estimates for growth scenario modeling in PCSWMM. The following sections describe the tasks completed to incorporate dispersion model projections – both outside and inside current city limits – into the hydraulic model. After summing the selected TAZ polygons in the dispersion model, 16,370 new people were projected to be served by City sewers by 2030, and an additional 7,504 people were projected by 2040.

5.2.1 Residential Growth Outside City Limits

Areas in the dispersion model with projected growth outside of current city limits represent the potential for future annexations and expansion of city limits. These areas are assumed to eventually be served by City sewers, and large capital projects (i.e., new interceptor sewers and pump stations) would be required to extend City sewers to these areas. Large sewer extensions would then add average daily wastewater flow and increased wet weather flows to the existing system.

While the scope of the project did not include modeling of these conceptual extension sewers, the estimated flows from these growth areas needed to be accounted for in the 2030 and 2040 model scenarios. To accomplish this, the most likely TAZ polygons to be incorporated into the City by the 2030 and 2040 planning horizons needed to be identified, and the extent of sewer service area expansion needed to be estimated. With City staff input, the following steps were taken to delineate growth areas outside of city limits and assign residential growth to modeled manholes.

- Selection of TAZ Polygons Outside City Limits: Residential growth zones outside city limits expected to be served by 2030 and 2040 were selected by analyzing TAZ polygons from the City's dispersion model dataset and gathering input from City staff.
- 2. <u>Delineation of Drainage Basins</u>: Topographical drainage basins outside the city were delineated to identify which existing modeled manholes would likely receive flows by gravity from potential future sewer extensions.
- 3. <u>Division of TAZ Polygons</u>: GIS mapping tools were used to intersect drainage basins with the dispersion model TAZ polygons, enabling the division of large TAZ polygons into smaller pieces. In some cases, TAZ polygons were split into two or three pieces depending on topographical constraints. Some polygons were further revised to ensure only relevant portions of land would be used for rainfall-derived infiltration and inflow (RDII) model calculations. These revised TAZ polygons represented more realistic sewer service areas.
- 4. <u>Manhole Assignments</u>: The revised TAZ polygons were assigned to modeled manholes to indicate where flows from outside city limits would enter the modeled system. By assigning polygons to a specific manhole ID, a link was created between the dispersion model growth projections and the hydraulic model manholes.

- 5. <u>Mapping and Review</u>: The population growth estimates were mapped and reviewed as a quality control measure.
- 6. <u>City Collaboration</u>: The approach and findings were presented to the City during meetings on October 28, 2022, and November 8, 2022, where City staff feedback was collected and incorporated into the process.

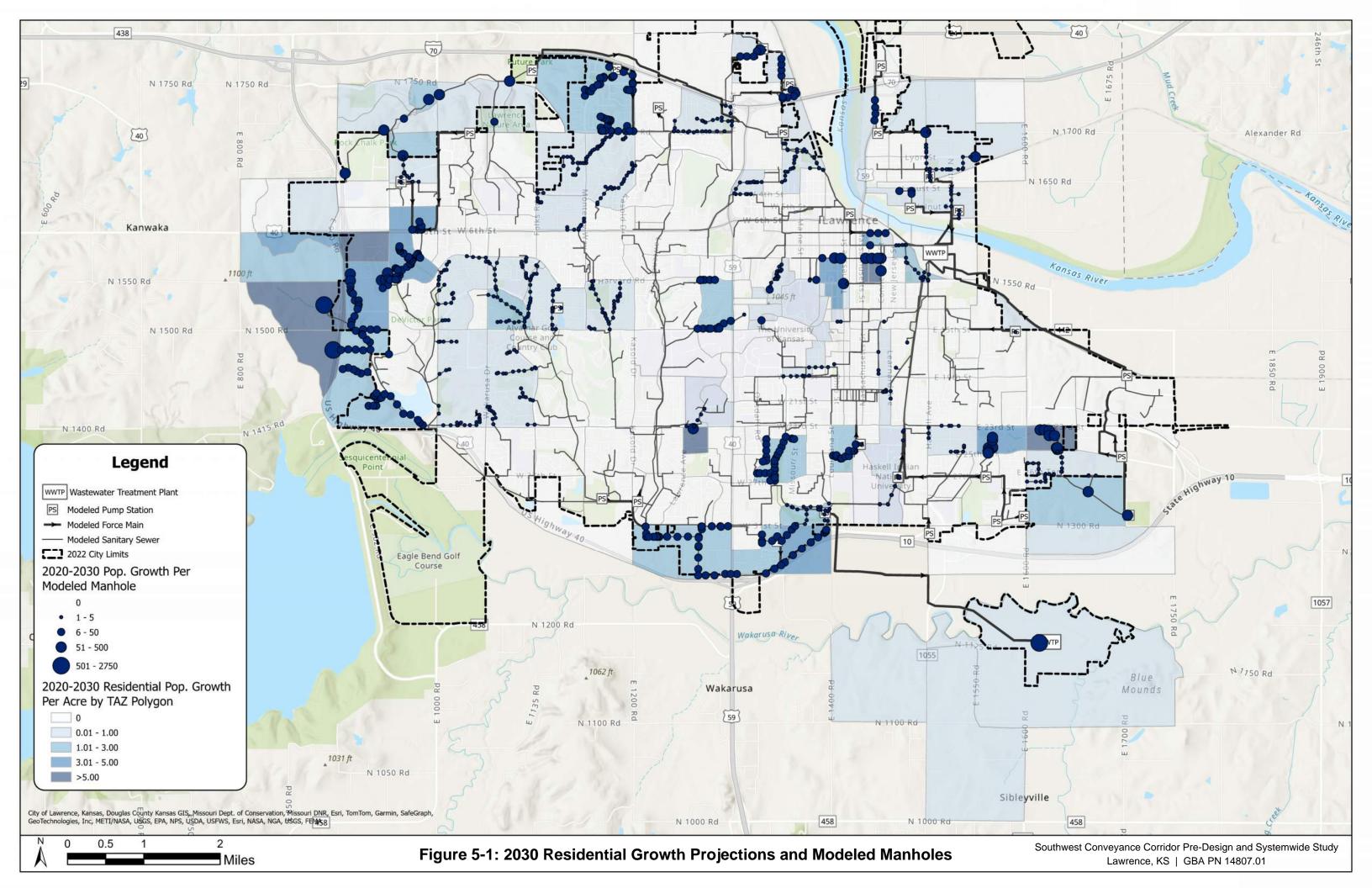
5.2.2 Residential Growth Inside City Limits (Infill)

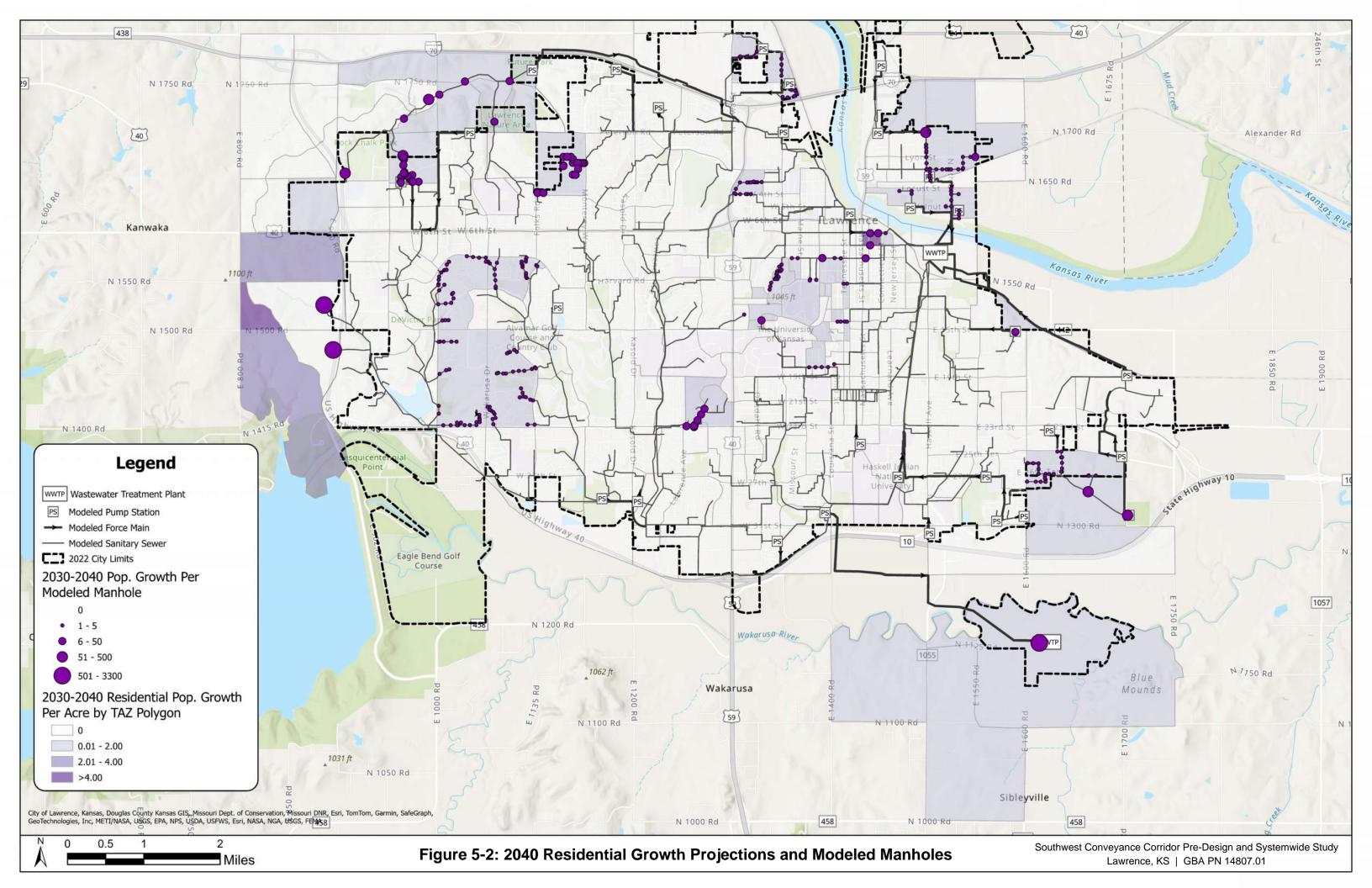
Infill refers to growth within existing city limits due to new development, redevelopment, or densification. Infill growth was treated differently than growth outside of city limits because it is assumed that these areas of development or redevelopment within city limits would tie into existing sanitary sewer infrastructure without the need for large-scale extension sewers. However, infill growth can still cause capacity concerns in the existing sewers if more growth occurs than was originally planned for the existing nearby sewers.

With City staff input, the following steps were taken to identify and assign residential growth within current city limits to modeled manholes.

- 1. <u>Identification of Infill TAZ Polygons</u>: TAZ polygons within current city limits were generally used for infill residential growth projections. Only population changes within these TAZ polygons were used to estimate growth, as it was assumed that all existing population within these polygons are already served by the City's sewer system.
- 2. <u>Manhole Intersection</u>: To link growth projections to modeled manholes, the modeled manholes were intersected with infill TAZ polygons using GIS tools. This resulted in a TAZ polygon being assigned to individual manholes.
- 3. <u>Growth Distribution</u>: Population growth from each infill TAZ polygon was evenly distributed across all intersecting modeled manholes within that polygon. For example, if a TAZ polygon had a population growth estimate of 200 people by 2030 and 10 modeled manholes intersected that polygon, then a population growth of 20 people was assigned to each of the 10 intersecting manholes.
- 4. <u>Manual Adjustments</u>: Manual adjustments were made on a case-by-case basis, redistributing population growth as necessary.
- 5. <u>Mapping and Review</u>: The population growth estimates were mapped and reviewed as a quality control measure.

Figure 5-1 and Figure 5-2 show 2030 and 2040 residential growth projections, respectively. Modeled manholes are symbolized to show relative sums of growth anticipated to be served using the City-provided population dispersion model. The dispersion model TAZ polygons are symbolized to display relative growth densities (population growth per acre) predicted by the City.





5.3 Industrial and Commercial Growth Projections

Industrial and commercial growth estimates were developed separately from residential estimates. Utilizing City staff input, areas most likely to develop with either industrial or commercial land uses by 2030 and 2040 were identified. Industrial and commercial growth estimates were generally derived from undeveloped parcels greater than one acre in size. The following steps were taken to develop these estimates and prepare them for incorporation into the hydraulic model.

- Parcel Identification: Undeveloped parcels of 1 acre or greater with a zoning classification of either "Industrial" or "Commercial" were identified using tools in GIS.
 Other areas with potential for redevelopment were identified manually with input from City staff. Several large sites that are anticipated to develop with industrial land uses were identified using the City-provided "Potential Industrial Sites Map", including sites east of City limits (Noria area) and northwest of City limits (near the I-70 and K-10 interchange).
- 2. <u>Flood Zone Exclusions</u>: Portions of the identified industrial parcels east of the City are within the FEMA 100-year floodplain, and those portions that fall within the floodplain were considered undevelopable for the purposes of this analysis. GIS analysis was performed on the identified parcels to estimate the percentage of land within floodplain. These estimates of floodplain area were then excluded from growth area calculations.
- Manhole Assignment: The identified industrial and commercial parcels were assigned to modeled manholes manually by finding the nearest modeled manhole with sufficient elevation to accept flows by gravity from the parcel.
- 4. <u>Flow Estimation</u>: Water usage data provided by the City was used to calculate average water usage per acre for industrial (312 gpd/ac) and commercial (1,811 gpd/ac) zoning types. 50 gpd/ac was added to these averages to account for groundwater infiltration entering the sewer system. Average water usage estimates were then used to calculate wastewater production estimates for each parcel based on zoning type and area.
- 5. <u>Mapping and Review</u>: The identified parcels and their corresponding flows were mapped and reviewed to confirm alignment with City expectations.
- 6. Development Factors: Growth projections were adjusted for each time horizon using "development factors" to align growth and flow projections with City expectations. These development factors were selected in a meeting with the City on January 17, 2023. Table 5-1 provides a summary of the chosen development factors. For any given parcel identified for commercial or industrial growth, these development factors were applied to reduce the total land area assumed to be developed. These factors were important because commercial and industrial growth projections were calculated using estimates of developable land area, and the factors provided a simple means for adjusting projections to align with City expectations.

Table 5-1: Development Factors Used for Commercial and Industrial Growth Projections

	Development Factor		
Location	2030	2040	
Inside City Limits	50%	75%	
Outside City Limits	25%	50%	

5.4 Special Growth Areas

Three special growth areas were identified by the City that were not included in residential, commercial, or industrial growth areas. The City decided to conservatively assume that these three special areas would tie into the sanitary sewer system by 2030. These areas included:

- The Crossing at KU: This new development located on the KU campus at the intersection of 23rd Street and Iowa Street was conceptualized and designed after SWCC project initiation and needed to be accounted for in growth projections.
- <u>Farmland Remediation Site</u>: This site is owned by the City and will be used for the City's new Field Operations Campus, which will soon be under construction.
- <u>Clinton State Park</u>: There has been discussion in the past of the City eventually
 providing water and wastewater service to Clinton State Park. While it is not certain, the
 City preferred to be conservative in estimates and assume that the state park would be
 served within the planning window.

The following steps outline the approach used to incorporate these special growth areas into the hydraulic model:

- 1. <u>Special Areas Identification</u>: Key areas were identified by the City that were not included in other residential, commercial or industrial estimates.
- 2. <u>Manhole Assignment</u>: These special areas were assigned to the appropriate manholes in the hydraulic model, similar to process taken for the industrial and commercial parcels.
- 3. <u>Flow Estimation</u>: Wastewater flows were estimated using two different methods. Dry weather flow production was estimated for each site using estimates developed by others. Estimates submitted for the City's downstream sanitary sewer analysis were used for the Crossing at KU and Field Operations Campus developments. Design flows from the Clinton State Park wastewater lagoon permit were used for that site. To develop wet weather flow estimates, an estimate of service area for each site was used in the hydraulic model.
- 4. <u>City Feedback</u>: Feedback from the City was gathered in a meeting on January 17, 2023, to confirm the approach.

Figure 5-3 provides a map showing all industrial, commercial and special growth areas selected for growth projections.

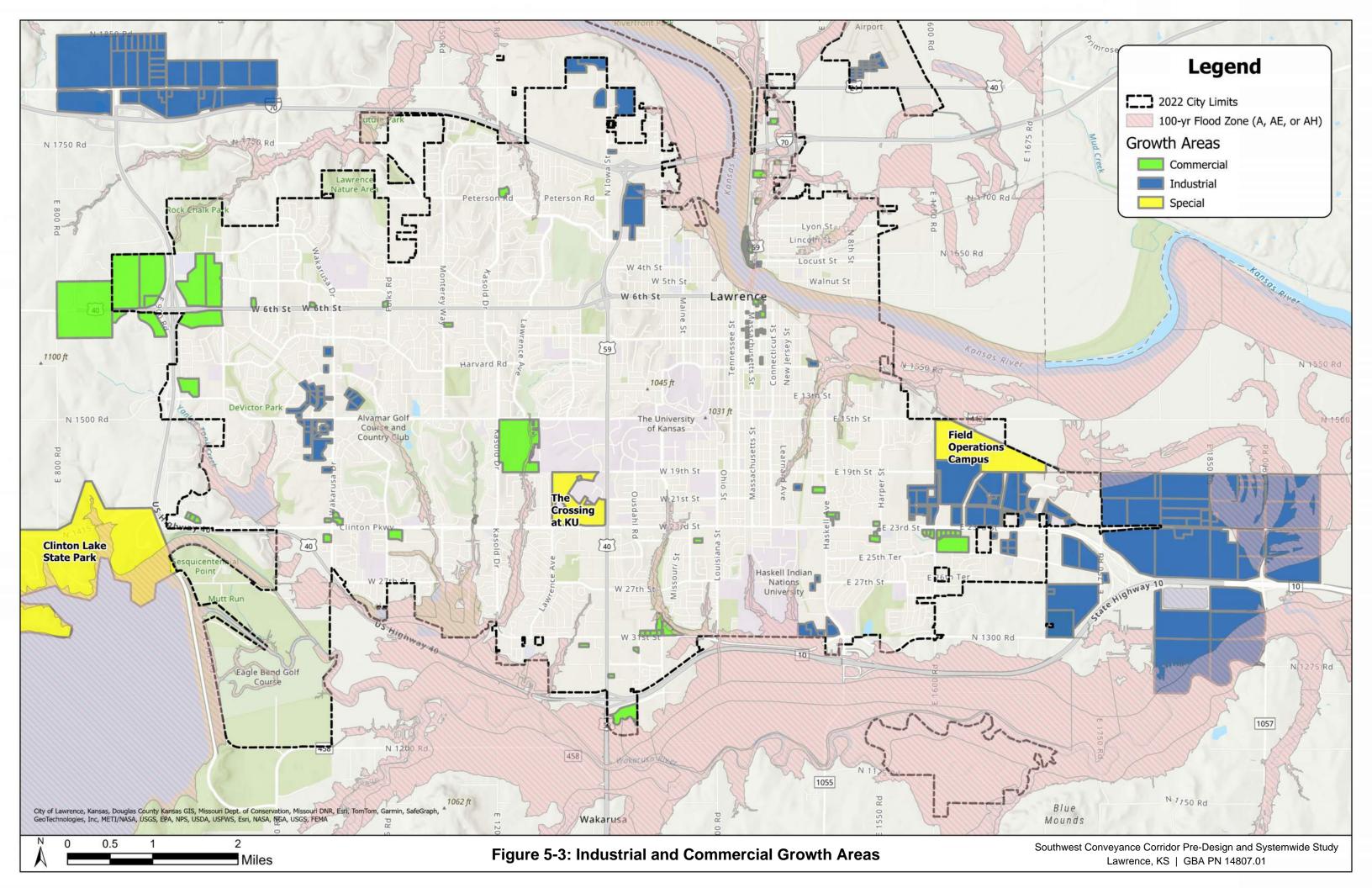


Table 5-2 provides a summary of service area and wastewater contributions by each growth category and at each planning horizon: residential, commercial, industrial, and special areas. Wastewater contribution in Table 5-2 is representative of average daily dry weather flows (ADDF) contributed by each growth category. Service area is the statistic used in the PCSWMM model to estimate peak wet weather flows for the growth areas.

Table 5-2: Projections of Service Area and Wastewater Contribution by Growth Category

	Service	e Area Cont (acres)	ribution	Wastewater (ADDF) Contribution (MGD)			
Category	2030	2040	Total	2030	2040	Total	
Residential	1,524	1,354	2,878	1.64	0.75	2.39	
Commercial	318	183	502	0.59	0.34	0.93	
Industrial	711	585	1,295	0.26	0.21	0.47	
Special	314	-	314	0.49	-	0.49	
Total	2,867	2,122	4,989	2.98	1.30	4.28	

Wastewater Contribution Assumptions:

Residential - Assumes 100 gpd/person. Using City dispersion model data, 16,370 new people are projected to be served by City sewers by 2030, and an additional 7,504 people are projected by 2040. Commercial - Assumes 1,811 gpd/ac, plus 50 gpd/ac for groundwater infiltration. Industrial - Assumes 312 gpd/ac, plus 50 gpd/ac for groundwater infiltration.

5.5 Future Growth Model Scenarios

The final step involved integrating all growth-related flows into the PCSWMM hydraulic model and running model scenarios for both the 2030 and 2040 planning periods.

5.5.1 Incorporating Growth Projections into PCSWMM

Growth projection data was organized into spreadsheets and linked to individual manholes in the hydraulic model using unique manhole IDs. The following approaches were used to incorporate growth projections into the model for each growth type:

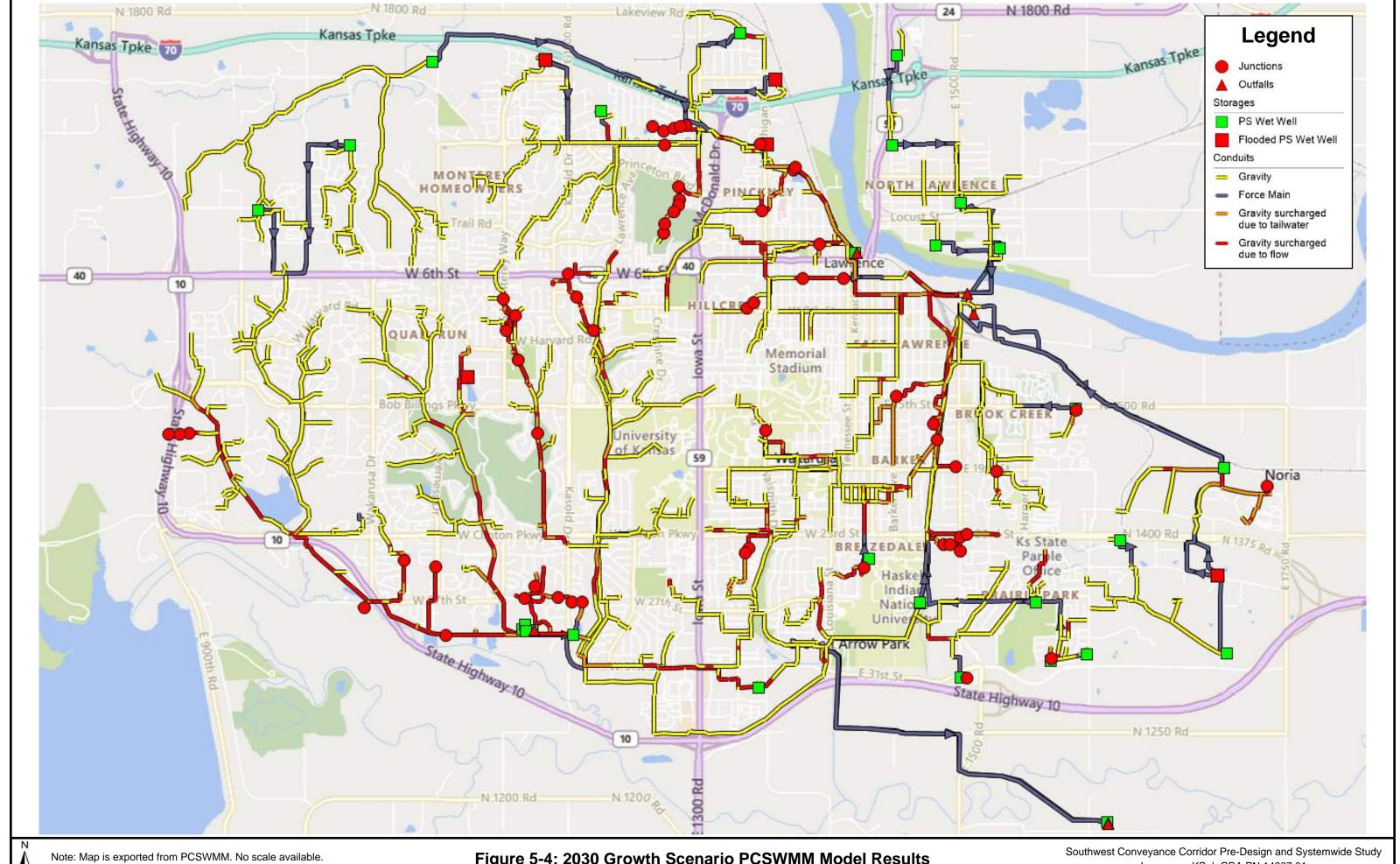
- Residential Growth: Average daily dry weather flows from residential growth were
 estimated by multiplying the incremental population growth estimate by an assumed rate
 of production of 100 gallons per day per capita (a common industry standard). Wet
 weather flows from residential growth were estimated using an estimate of area to be
 developed by the residential growth, which was calculated assuming an average density
 of development of 5 people per acre (estimated from actual residential areas in
 Lawrence).
- Commercial Growth: The area of each commercial growth parcel was used to estimate
 dry weather flows and wet weather flows. The average water usage across commercially
 zoned parcels was estimated at 1,811 gpd/ac based on City-provided water usage data,
 and this factor was used to develop average dry weather wastewater flows. The area of
 each parcel was used as the sewershed area in the model to estimate wet weather
 flows.

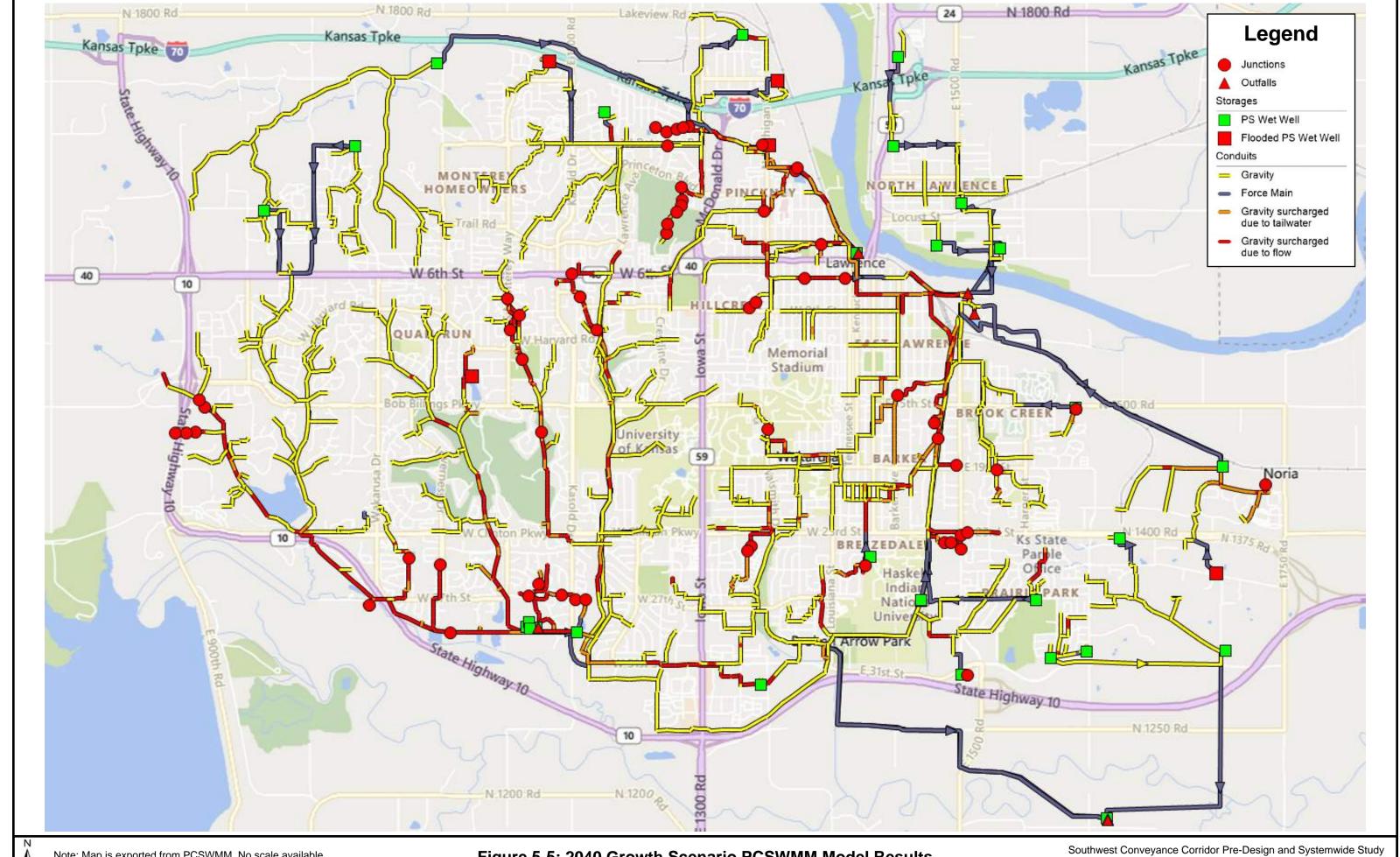
- Industrial Growth: Similar to commercial areas, the area of each industrial growth parcel
 was used to estimate dry weather flows and wet weather flows. The average water
 usage across industrially zoned parcels was estimated at 312 gpd/ac based on Cityprovided water usage data, and this factor was used to develop average dry weather
 wastewater flows. The area of each parcel was used as the sewershed area in the
 model to estimate wet weather flows.
- Special Growth Areas: Flow estimates were previously described in Section 5.4 above.

Regarding residential growth areas, flows were estimated differently for anticipated residential growth inside and outside existing city limits. It should be noted that 2022 city limits were used during this analysis. Flows from residential growth inside of city limits were assumed to produce only increases in average daily flow without impacting wet weather flow production. This is because residential growth within city limits is unlikely to significantly increase the sewered area. However, flows from residential growth outside city limits were assumed to not only increase average daily flows but also increase peak wet weather flows. This is because residential growth outside current city limits will significantly increase the sewered area, thus increasing opportunities for I/I to enter the sewer system. Flows from residential growth outside city limits were assumed to produce peaks similar to flow meter basin R3, which is located on the west side of the City and is representative of newer sewer built within the past three decades.

5.5.2 Model Runs

The 2030 and 2040 growth scenarios were simulated in PCSWMM, and results were mapped and reviewed with the City. Figure 5-4 and Figure 5-5 provide model results from PCSWMM for the 2030 and 2040 scenarios, respectively.





6 SOUTHWEST CONVEYANCE CORRIDOR PRE-DESIGN

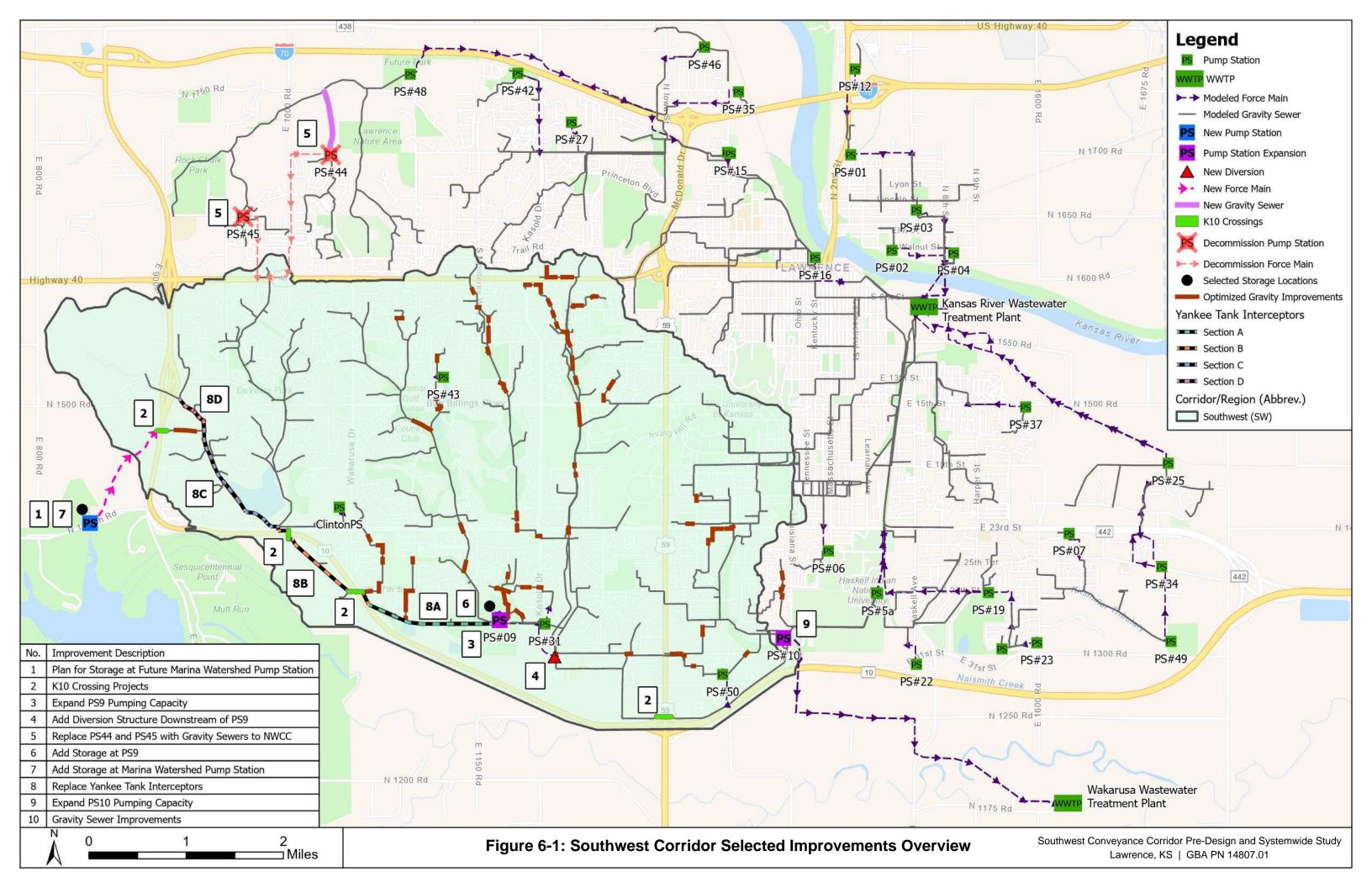
For an in-depth summary of the SWCC pre-design, please see Appendix D, Task 5 Technical Memorandum – Southwest Conveyance Corridor Recommended Plan.

The SWCC sanitary sewer system receives flow from a large portion of western Lawrence. Approximately 8,200 acres of the city are currently served by the SWCC system, which is over one-third (36%) of Lawrence's current land area within city limits. The SWCC has a substantial impact on other portions of Lawrence's sanitary sewer system. The Burroughs Creek Interceptor, which serves much of eastern Lawrence, and Pump Station 5 (PS5) are located directly downstream of the SWCC. However, there is a critical flow split upstream of PS5 at PS10.

Most of the growth anticipated for the City over the next 20 years is projected to occur west of K-10 in an area that will eventually tie into the SWCC. There are also significant bottlenecks and capacity concerns along the SWCC interceptors, particularly at PS9, which is aging and in need of rehabilitation. Overflows and basement backups upstream of PS9 have been a concern during large storm events in the past. To address these growth and capacity concerns, a recommended set of improvements and phasing for the Southwest Conveyance Corridor were developed that will meet sanitary sewer service requirements for 2040 projected growth.

To select an optimal set of improvements for the SWCC system, optimization was used in conjunction with hydraulic modeling to evaluate model results for many different combinations of projects and identify the set of projects that produces the best outcomes as measured by a set of defined criteria. These criteria included minimizing cost, minimizing overflow volume, and minimizing surcharge conditions in the Yankee Tank interceptors.

Summary of selected improvements and phasing for the Southwest Corridor can be found on Figure 6-1. Further detail and estimated capital costs for the improvements can be found in Appendix D.



7 SYSTEMWIDE MODELING AND ANALYSIS

This chapter presents a summary of the hydraulic modeling and analysis of the modeled collection system. Modeling results are used to inform and develop the systemwide improvements plan summarized in Chapter 8, which primarily addresses modeled capacity deficiencies. The calibrated model was used to evaluate system performance during the 10-year, 6-hour design storm event under existing conditions, 2030 growth conditions, and 2040 growth conditions. Model simulations were used to identify capacity deficiencies, analyze corridors of interest, and delineate conceptual project areas.

7.1 Model Simulations

The design storm model scenarios primarily used during capacity analysis and systemwide plan development were the existing conditions scenario (referred to as "Baseline" model), 2030 free flow conditions scenario, and 2040 free flow conditions scenario. Free flow analysis involves a hydraulic modeling scenario in which all flow restrictions in the collection system are removed to represent a maximum, unrestricted flow condition.

7.2 Modeled Capacity Deficiencies – Gravity Sewer

Modeling results from the baseline (existing conditions), 2030, and 2040 scenarios were used to delineate capacity deficiencies within the modeled gravity sewers. Capacity deficiencies were defined by the presence of one or more of the following criteria:

- Flooded manhole junction
- Surcharge caused by inadequate pipe capacity (pipe is flowing full and projected peak flow is greater than the existing pipe capacity)
- Surcharge caused by downstream restriction (pipe is flowing full but projected peak flow is less than the existing pipe capacity)
- Projected free flow peak is greater than the existing pipe capacity

7.2.1 Prioritization of Gravity Sewer Deficiencies

Baseline model results show the 10-year, 6-hour storm event triggers many capacity deficiencies throughout the existing gravity system. Baseline modeling results showed:

- Roughly 19% (138,000 ft) of modeled gravity sewer is predicted to surcharge due to lack of pipe capacity.
- Roughly 10% (75,000 ft) of modeled gravity sewer is predicted to surcharge due to a downstream restriction (e.g., backup from a pump station or downstream bottleneck).
- Roughly 3% of modeled manholes (90) are predicted to overflow due to surcharge conditions.

The common occurrence of overloaded sewers in the baseline model makes prioritizing improvements challenging. It is important to note, however, that model results are an estimate and do not necessarily reflect actual conditions.

According to modeling results, there were many overloaded sewer lines scattered across the system during the 10-year, 6-hour storm event. To simplify results and prioritization, overloaded gravity sewer pipes were consolidated into larger groups representing potential project areas. These project areas were developed manually by grouping overloaded pipes based on proximity to create logical sets of gravity sewer deficiencies that could reasonably be addressed as part of the same project. These project groups are conceptual in nature and actual extents of CIP projects may vary from what is presented in this report.

To organize project groups, a project ID was assigned. Project IDs were comprised of a region abbreviation (see Table 7-1 below) and a number representing the relative priority rank of that project within its region. For example, project NW-01 is the top-ranked priority within the Northwest region.

or minograma. Albanomationo documento io										
Abbreviation										
BC										
DT										
NL										
NW										
SE										
SW										

Table 7-1: Regional Abbreviations Used in Project IDs

A summary of the gravity sewer project areas is presented in Table 7-2 and Figure 7-1. Table 7-2 provides key information regarding each potential project, including a Project ID, Name, and Region/Corridor in which the project is located.

Prioritization of the gravity sewer projects is based on two factors: 1) risk category and 2) modeled overflow volume in the baseline model. Gravity sewer projects were assigned a risk category by using a simple risk scoring system. Four risk criteria were used to calculate the risk category, and for each risk criteria that is met, the project received a point. All points were then summed to determine the risk category. For example, if all four risk criteria were met, then that project was assigned a risk category of 4. The four risk criteria were as follows:

- 1. Criteria 1: If the baseline model predicts peak surcharge levels to come within 5 feet of a manhole rim, the criteria is considered met. This criterion indicates an existing deficiency predicted by the model.
- 2. Criteria 2: If either the 2030 or 2040 future growth models predict peak surcharge levels to come within 5 feet of a manhole rim, the criterion is considered met. This criterion indicates a future deficiency predicted by the model.

- Criteria 3: If the baseline model predicts overflow (surcharge levels reach manhole rim), the criteria is considered met. This criterion indicates a more urgent existing deficiency than Criteria 1.
- 4. Criteria 4: If City staff are aware of existing issues at the location or are concerned about potential issues, OR a nearby flow meter confirms model results, the criteria is considered met. This criterion corroborates model results, confirming the urgency of the deficiency.

Modeled overflow volume from the baseline model was used to rank the project areas within their respective risk categories. This is the order in which projects are presented in Table 7-2: projects are first grouped into risk categories and then ranked by modeled overflow volume (MG) from most to least.

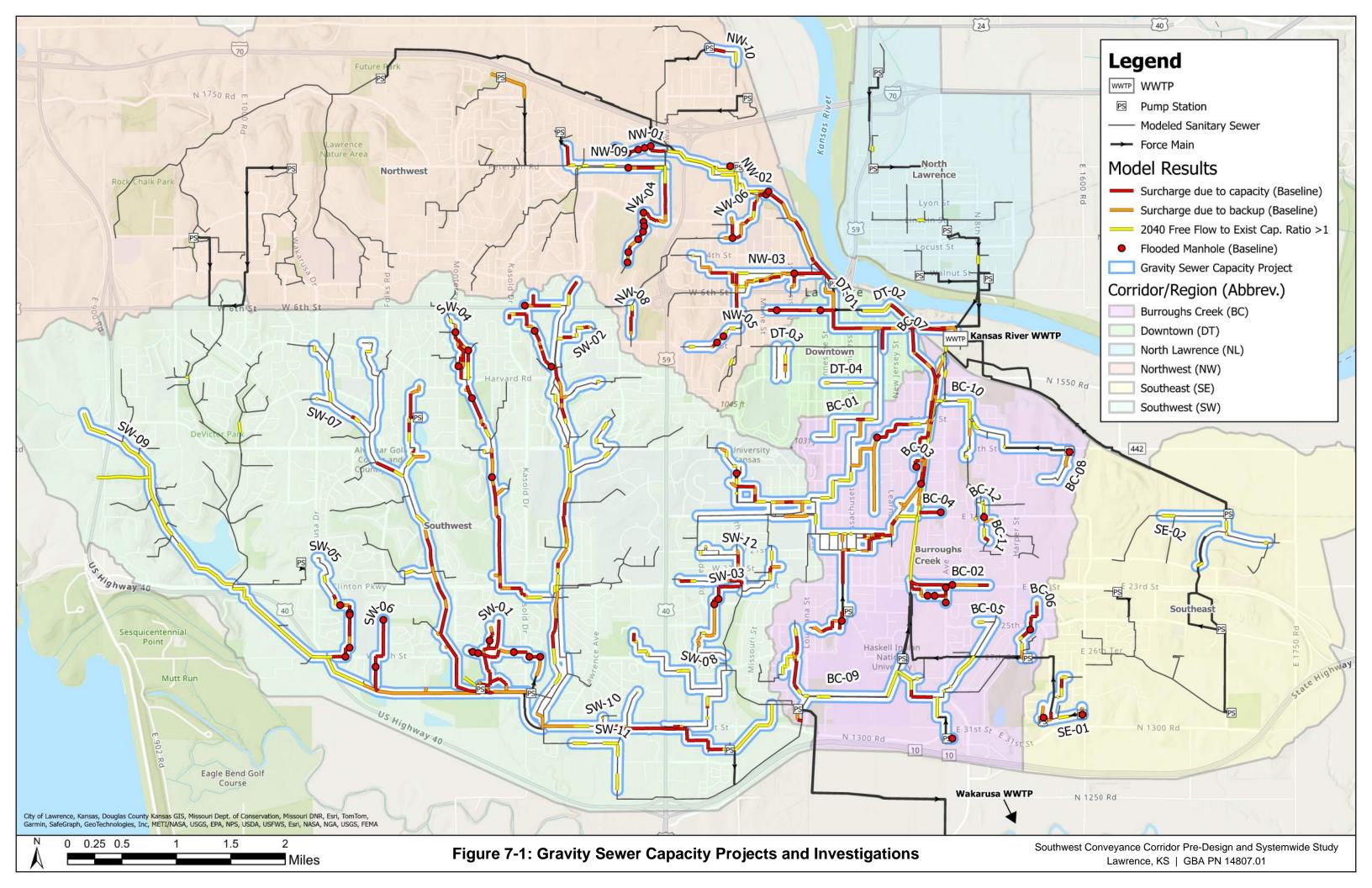
Figure 7-1 depicts the locations and general boundaries of each of the gravity sewer project areas listed in Table 7-2. The project area polygons are labeled using the Project IDs. The regional groupings are also shown using multicolored polygons. Model results of gravity sewers are depicted with red, orange, and yellow lines. Red lines indicate modeled surcharge caused by insufficient pipe capacity in the baseline model; orange indicates modeled surcharge caused by a downstream restriction in the baseline model; and yellow indicates that the pipe may be overloaded by the 2040 time horizon if no bottlenecks exist upstream of that point (i.e., 2040 free flow peak is greater than the existing pipe capacity).

It should be noted that there are several pipes that were not grouped into project areas where the 2040 free flow peak is predicted to be greater than the existing pipe capacity. These locations are relatively low risk because they are either isolated or indicate insufficient pipe slope data was available at the time of modeling.

Part Care								[Risk Categorization ⁽³⁾							
Pose									Criteria 1							
Work	Sewer	Gravity Sewer Project Name	_	with Capacity Restrictions (Baseline Model,	Surcharge Confirmed by Nearby Meter	and/or City		Eliminate with Targeted	Surcharge: Minimum Distance To	Model Surcharge: Minimum Distance To	Overflow Caused by Capacity	Confirmed by City and/or Nearby Flow	Risk Category	Total Overflow	OPCC: Replacement Cost + 30%	Capital Cost: OPCC + 20% Soft
No. No. Control Cont	NW-01	Stowe Dr	Northwest	2,060	-	Yes	-	Yes	✓	✓	✓	✓	4	0.57	\$ 682,000	\$ 818,000
Mode Southern So	NW-02	PS16 Parallel Interceptors	Northwest	4,190	Yes	Yes	Yes	-	✓	✓	✓	✓	4	0.51	\$ 19,988,000	\$ 23,986,000
Second Second Context Southwest Second Context Southwest Second Context Secon	NW-03	5th St	Northwest	5,610	Yes	Yes	-	-	✓	✓	✓	✓	4	0.35	\$ 2,758,000	\$ 3,310,000
Section Social Content Social Section Social Sect	NW-04	Country Club	Northwest	2,900	-	Yes	-	Yes	✓	✓	✓	✓	4	0.28	\$ 1,654,000	\$ 1,985,000
Middle Nationarch Scathward 2,050 Ves -	SW-01	Lower Quail Creek	Southwest	,	Yes	Yes (I/I)	-	-	✓	✓	✓	✓	4			
	SW-02	Atchison Creek	Southwest		Yes	Yes (I/I)	-	-	✓	✓	✓	✓	4		\$ 12,140,000	
Fig. 2 Fig. 2 Fig. 2 Fig. 2 Fig. 3 F	SW-03	Middle Naismith	Southwest	2,050	-	Yes	-	-	✓	✓	✓	✓	4	0.12	\$ 636,000	\$ 763,000
May-20 Miss and Avalon RQ Northwest 50 Yes Yes Y Y Y 4 0.05 \$ 22,10.00 \$ 385,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00 \$ 1,0.00	BC-01	West Burroughs Creek and KU	Burroughs	16,040	Yes	Yes	-	-	✓	✓	✓	✓	4	0.09	\$ 12,779,000	\$ 15,335,000
Non-color Non-	DT-01	7th St and 8th St Downtown	Downtown	5,420	Yes	Yes	-	-	✓	✓	✓	✓	4	0.05	\$ 4,904,000	\$ 5,885,000
New Or Pelluroum Rd and Creditive Dr. Northwest 1,070 Buckup Only	NW-05	9th St and Avalon Rd	Northwest		-	Yes	-	Yes	✓	✓	✓	✓	4			
SCAPE 2301 St tand Planekell Ave Burnoughs 3,80 	NW-06	Memorial Hospital	Northwest	1,510	Yes	-	-	-	✓	✓	✓	✓	4	0.01	\$ 761,000	\$ 913,000
SW-04 Upper Quali Creek Southwest 10,150	NW-07	Peterson Rd and Crestline Dr	Northwest	1,070	Backup Only	-	-	Yes	✓	✓	✓	-	3	0.37	\$ 647,000	\$ 776,000
BC-08 Maryland SI Burroughts 400 - - - - - - -	BC-02	23rd St and Haskell Ave	Burroughs	3,620	-	-	-	Yes	✓	✓	✓	-	3	0.21	\$ 1,529,000	\$ 1,835,000
BC-04 Homeword St Burroughs B10 - - - - - - -	SW-04	Upper Quail Creek	Southwest	10,150	-	Yes (I/I)	-	-	✓	✓	✓	-	3	0.07	\$ 6,664,000	\$ 7,997,000
EE-01 Plainie Park Southwest 1,270 - - Yes V V V - 3 0.01 \$ 55,100 \$ 661,000 \$ \$ \$ \$ \$ \$ \$ \$ \$	BC-03	Maryland St	Burroughs	400	-	-	-	Yes	✓	✓	✓	-	3	0.04	\$ 191,000	\$ 229,000
SW-05 Sunflower Southwest 3,000 Yes V V V - 3 0,01 \$ 1,104,000 \$ 1,325,000	BC-04	Homewood St	Burroughs	810	-	-	-	Yes	✓	✓	✓	-	3	0.03	\$ 248,000	\$ 298,000
SW-60 Wildflower Dr Southwest 3,000 - - - Yes - - Yes - - - - - - - - -	SE-01	Prairie Park	Southeast	1,270	-	-	-	Yes	✓	✓	✓	-	3	0.01	\$ 551,000	\$ 661,000
BC-08 PS19 and Anderson Rd Burroughs 3,490 - - - Yes V V - 3 0.00 \$ 1,843,000 \$ 2,212,000 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00 \$ 0.00	SW-05	Sunflower	Southwest	2,870	-	-	-	Yes	✓	✓	✓	-	3	0.01	\$ 1,104,000	\$ 1,325,000
BC-06 PS19 and Anderson Rd Burroughs 17:30 - - Yes V V V - 3 0.00 \$ 582,000 \$ 674,000 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500 \$ 500	SW-06	Wildflower Dr	Southwest	3,000	-	-	-	Yes	✓	✓	✓	-	3	0.00	\$ 953,000	\$ 1,144,000
SW-07 Inverness Southwest 11,350 Yes Yes (II) - -	BC-05	Ponderosa	Burroughs	3,490	-	-	-	Yes	✓	✓	✓	-	3	0.00	\$ 1,843,000	\$ 2,212,000
BC-07 Hobbs Park Burroughs 1,770 - Yes - - Yes - - - 3 0.00 \$ 721,000 \$ 885,000	BC-06	PS19 and Anderson Rd	Burroughs	1,730	-	-	-	Yes	✓	✓	✓	-	3	0.00	\$ 562,000	\$ 674,000
BC-08 Fairgrounds and PS37 Burroughs 0 - - Yes -	SW-07		Southwest		Yes	Yes (I/I)	-	-	✓	✓	-	✓	3			
NW-08 Centennial Park Northwest 980 - - - Yes V V - - 2 0.00 \$ 280,000 \$ 312,000	BC-07	Hobbs Park	Burroughs	1,770	-	-	-	Yes	✓	✓	✓	-	3	0.00	\$ 721,000	\$ 865,000
SW-08 Lower Naismith Southwest 1,800	BC-08	Fairgrounds and PS37	Burroughs	0	-	-	Yes	-	✓	✓	-	-	2	0.28	\$ 135,000	\$ 162,000
NW-09 Peterson Rd	NW-08	Centennial Park	Northwest	980	-	-	-	Yes	✓	✓	-	-	2	0.00	\$ 260,000	\$ 312,000
DT-02 KRWWTP Interceptors Downtown 3,230 Yes Yes 2 0.00 \$ 9,032,000 \$ 10,838,000 \$ SW-09 Yankee Tank Interceptors Southwest 440 Backup Only - Yes -	SW-08	Lower Naismith	Southwest	1,800	-	-	-	-	✓	✓	-	-	2	0.00	\$ 727,000	\$ 872,000
SW-09 Yankee Tank Interceptors Southwest 440 Backup Only - Yes -	NW-09	Peterson Rd	Northwest	1,680	-	-	-	Yes	✓	✓	-	-	2	0.00	\$ 871,000	\$ 1,045,000
SW-10 31st St Southwest 7,790 Backup Only - Yes -	DT-02	KRWWTP Interceptors	Downtown	3,230	-	-	Yes	-	✓	✓	-	-	2	0.00	\$ 9,032,000	\$ 10,838,000
BC-09 Belle Haven Burroughs 3,550 Backup Only - - Yes V V - - 2 0.00 \$ 5,308,000 \$ 6,370,000 BC-10 Brook Creek Burroughs 300 Backup Only - - - V V - - 2 0.00 \$ 767,000 \$ 920,000 SW-11 K10 Interceptors at 33rd St Southwest 580 - - - - V V V - - 2 0.00 \$ 1,246,000 \$ 1,495,000 SW-12 Upper Jayhawk Downtown 430 - - Yes - V V V - - 2 0.00 \$ 111,000 \$ 133,000 SW-12 Upper Naismith Southwest 2,660 - - - V V V - - 2 0.00 \$ 833,000 \$ 1,000,000 SE-02 East Hills Business Park Southeast 250 - - Yes - V V - - 1 0.00 \$ 612,000 \$ 734,000 SW-10 Thin Step On the standard of the	SW-09	Yankee Tank Interceptors ⁽⁵⁾	Southwest	440	Backup Only	-	Yes	-	✓	✓	-	-	2	0.00	N/A	N/A
BC-10 Brook Creek Burroughs 300 Backup Only - - - √ ✓ - - 2 0.00 \$ 767,000 \$ 920,000 SW-11 K10 Interceptors at 33rd St Southwest 580 - - - - ✓ ✓ - - 2 0.00 \$ 1,246,000 \$ 1,495,000 DT-03 Upper Jayhawk Downtown 430 - - Yes - ✓ ✓ - - 2 0.00 \$ 111,000 \$ 133,000 SW-12 Upper Naismith Southwest 2,660 - - - - ✓ ✓ - - 2 0.00 \$ 833,000 \$ 11,000 \$ 833,000 \$ 1,000,000 SE-02 East Hills Business Park Southeast 250 - - Yes - - ✓ - - 1 0.00 \$ 612,000 \$ 734,000 NW-10 Riverside Dr Northwest 980<	SW-10	31st St	Southwest	7,790	Backup Only	-	Yes	-	✓	✓	-	-	2	0.00	\$ 24,455,000	\$ 29,346,000
SW-11 K10 Interceptors at 33rd St Southwest 580 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -	BC-09	Belle Haven	Burroughs	3,550	Backup Only	-	-	Yes	✓	✓	-	-	2	0.00	\$ 5,308,000	\$ 6,370,000
DT-03 Upper Jayhawk Downtown 430 - - Yes - ✓ ✓ - - 2 0.00 \$ 111,000 \$ 133,000 SW-12 Upper Naismith Southwest 2,660 - - - - ✓ ✓ - - 2 0.00 \$ 833,000 \$ 1,000,000 SE-02 East Hills Business Park Southeast 250 - - Yes - - ✓ - - 1,000,000 NW-10 Riverside Dr Northwest 980 Yes - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -	BC-10	Brook Creek	Burroughs	300	Backup Only	-	-	-	✓	✓	-	-	2	0.00	\$ 767,000	\$ 920,000
SW-12 Upper Naismith Southwest 2,660 - - - - - V V - - 2 0.00 \$ 833,000 \$ 1,000,000 SE-02 East Hills Business Park Southeast 250 - - Yes - - V - - 1 0.00 \$ 612,000 \$ 734,000 NW-10 Riverside Dr Northwest 980 Yes - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -	SW-11	K10 Interceptors at 33rd St	Southwest	580	-	-	-	-	✓	✓	-	-	2	0.00	\$ 1,246,000	\$ 1,495,000
SE-02 East Hills Business Park Southeast 250 - - Yes - - V - - 1 0.00 \$ 612,000 \$ 734,000 NW-10 Riverside Dr Northwest 980 Yes - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -					-	-	Yes	-	✓	✓	-	-	2			
NW-10 Riverside Dr Northwest 980 Yes - - - - - - - - - - - 509,000 \$ 611,000 DT-04 11th St Downtown 790 - - - - - - - 1 0.00 \$ 222,000 \$ 266,000 BC-11 Maple Ln and 21st St Burroughs 560 - - - - - - - - - 143,000 \$ 172,000 BC-12 Maple Ln and 19th St ⁽⁶⁾ Burroughs 480 - Yes - - J J J - 0.02 N/A N/A	SW-12	Upper Naismith	Southwest	2,660	-	-	-	-	√	✓	-	-	2	0.00	\$ 833,000	\$ 1,000,000
DT-04 11th St Downtown 790 - - - - - - - - 222,000 \$ 266,000 BC-11 Maple Ln and 21st St Burroughs 560 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - <td< td=""><td>SE-02</td><td>East Hills Business Park</td><td>Southeast</td><td>250</td><td>-</td><td>-</td><td>Yes</td><td>-</td><td>-</td><td>√</td><td>-</td><td>-</td><td>1</td><td>0.00</td><td>\$ 612,000</td><td>\$ 734,000</td></td<>	SE-02	East Hills Business Park	Southeast	250	-	-	Yes	-	-	√	-	-	1	0.00	\$ 612,000	\$ 734,000
BC-11 Maple Ln and 21st St Burroughs 560 - - - - - - - - 172,000 BC-12 Maple Ln and 19th St ⁽⁶⁾ Burroughs 480 - Yes - - J J J - 0.02 N/A N/A	NW-10	Riverside Dr	Northwest		Yes	-	-	-	-	-	-	✓	1			
BC-12 Maple Ln and 19th St ⁽⁶⁾ Burroughs 480 - Yes V	DT-04	11th St	Downtown	790	-	-	-	-	-	✓	-	-	1	0.00	\$ 222,000	\$ 266,000
	BC-11	Maple Ln and 21st St	Burroughs	560	-	-	-	-	-	-	-	-	0	0.00	\$ 143,000	\$ 172,000
Notes:		·	Burroughs	480	-	Yes	-	-	√	√	√	√	-	0.02	N/A	N/A

Notes

- 1) Future Growth Concern: Locations where significant development is expected to eventually occur upstream, which may lead to capacity issues if no action is taken.
- 2) Potential to Eliminate with Targeted Analysis: Locations where predicted surcharge in the model is questionable due to sparse/distant flow meter coverage. Targeted analysis (such as flow metering and HGL analysis) may eliminate these from consideration.
- 3) Risk Categorization: Risk categories were assigned by summing each of the four risk criteria if they were met.
 - Criteria 1: If the baseline model predicts peak surcharge levels to be within 5 feet of a manhole rim, the criteria was considered met.
 - Criteria 2: If either the 2030 or 2040 future growth models predict peak surcharge levels to be within 5 feet of a manhole rim, the criteria was considered met.
 - Criteria 3: If the baseline model predicts overflow (surcharge levels reach manhole rim), the criteria was considered met.
 - Criteria 4: If City staff are aware of existing issues at the location or are concerned about potential issues, OR a nearby flow meter confirmed model results, the criteria was considered met.
- 4) Conceptual OPCC: Costs were assigned using gravity sewer replacement cost equations developed for this project. Please see the Task 5 Technical Memorandum for more information regarding replacement costs.
- 5) Yankee Tank Interceptors: Conceptual costs for phased replacement of the Yankee Tank interceptors are provided in the Task 5 Technical Memorandum.
- 6) Maple Lane and 19th Street: This project is currently under design, and therefore, no risk category or cost was assigned.



7.2.2 Confirmation of Model Results

Two key columns presented in Table 7-2 include the "Modeled Surcharge Confirmed by Nearby Meter Data" and "Existing Issue and/or City Concern". These columns indicate whether a modeled gravity sewer deficiency has been corroborated, at least in part, by available information independent of model results.

GBA has provided flow monitoring services to the City since 2014, and many flow meters have been deployed that were not used for model calibration. If a historical flow meter not used for calibration was located within reasonable proximity to the modeled deficiency, meter data was reviewed to determine if capacity deficiencies were apparent in the available flow data. Under the "Modeled Surcharge Confirmed by Nearby Meter Data" column, "Yes" indicates a historical meter shows capacity deficiencies in the project area, and "Backup Only" indicates the historical meter only shows backup surcharge caused by an unidentified downstream restriction.

The "Existing Issue and/or City Concern" column indicates whether City staff have prior knowledge of capacity issues or concerns in the vicinity of a project area. A workshop was held with City staff on January 17, 2024 to review and discuss baseline model results across the modeled sanitary sewer system. City staff provided insight into various locations in the sanitary sewer system that have historically caused either capacity-related issues or operational issues. "Yes" indicates the modeled capacity deficiency generally aligns with known issues described by City staff.

7.2.3 Potential to Eliminate Projects

Table 7-2 also contains a column labeled "Potential to Eliminate with Targeted Analysis". "Yes" under this column indicates there is lower confidence that the modeled surcharge actually exists. These modeled deficiencies have a lower confidence level because of their location within the model and their proximity to a flow meter used for calibration. Locations in the model where there was sparse flow meter coverage during calibration are less likely to reflect actual conditions because the flow meter used to calibrate these areas were located relatively far downstream. Actual flow conditions at these locations can be verified using targeted analysis, such as with a flow meter at or near the deficiency in question, followed by HGL analysis. It is thought that several of the locations on this list could be eliminated from consideration by using a flow meter to recalibrate the model and confirm the original model results are overly conservative.

7.2.4 Conceptual Replacement Costs

Conceptual replacement costs for upsized pipes are provided in Table 7-2 for each project area. These estimates represent a total upsizing cost for all pipes that the model predicted as being overloaded. These costs were calculated using model results and the replacement cost equation described in the Task 5 Technical Memorandum. These conceptual costs merely provide a sense of scale of investment that may be required if the City were to upsize all currently undersized

pipes in a given project area. However, pipe upsizing is not always the most cost-effective approach to addressing capacity deficiencies. Actual improvement recommendations may involve other approaches such as I/I reduction, rerouting of flows, parallel relief sewer, or storage. Project recommendations are discussed in more depth in Chapter 8.

7.3 Modeled Capacity Deficiencies – Pump Stations

Modeling results from the baseline (existing conditions), 2030, and 2040 scenarios were also used to identify potential capacity deficiencies at sanitary sewer pump stations. A summary of pump stations, model findings, and risk categories is presented in Table 7-3. Risk categories and locations for each pump station are mapped in Figure 7-2.

SWMM models require the existing capacity of each pump station as an input during model setup. However, not all pump station capacities were field verified prior to model setup. Rather, most pump station capacities were assumed using pump curves collected during past City planning studies and are listed in Table 7-3 under "Modeled Existing Capacity (MGD)". Field verification of pump stations was not included in the scope of the SWCC project. Therefore, it is recommended that the City field verify pump station capacities prior to proceeding with extensive pump station upgrades or improvements.

Using the provided pump station capacities, a comparison was made between capacities and modeled peak flows predicted at each pump station during the baseline, 2030, and 2040 scenarios. Using baseline model results, flow conditions immediately upstream of each pump station were checked to see if the model predicted backup surcharge caused by a pump station's lack of capacity. To assess 2030 and 2040 conditions, a free flow peak was compared against the existing capacity of the pump station. If the modeled free flow peak is greater than the existing capacity, then the pump station is a future capacity concern.

Similar to some modeled gravity sewer deficiencies, several pump stations had modeled capacity issues that may not reflect actual conditions. Although pump stations 15, 19, 22, and 35 showed capacity deficiencies during modeling, there were no major issues found during the City's review of available SCADA data. Therefore, it is recommended that the model be recalibrated using pump station SCADA data for these four pump stations to verify actual field conditions.

7.3.1 Prioritization of Pump Stations

Prioritization of pump stations needing capacity improvements is based on an assigned risk category, and pump stations are grouped in Table 7-3 by risk category. Pump stations were assigned a risk category by using a simple risk scoring system, similar to what was used for gravity sewers as described in chapter 7.2.1. Three risk criteria were used to calculate the pump station risk category, and for each risk criteria that is met, the pump station receives a point. All points are then summed to determine the risk category. For example, if all three risk criteria are met, then that pump station is assigned a risk category of 3. The three risk criteria are as follows:

Criteria 1: If the baseline model predicts that the pump station will cause backup surcharge
in upstream sewers such that the peak surcharge level comes within 5 feet of a manhole
rim, the criteria is considered met. This criterion indicates an existing capacity deficiency
predicted by the model.

- Criteria 2: If City staff are aware of existing issues at the pump station or are concerned about potential issues based on a recent review of SCADA data, the criteria is considered met. This criterion corroborates model results, confirming the urgency of the pump station deficiency.
- 3. Criteria 3: If significant growth or development is expected upstream of the pump station by either the 2030 or 2040 time horizons, the criterion is considered met. This criterion indicates that the pump station may pose capacity risks if upgrades are not implemented to accommodate upstream growth.

7.3.2 City SCADA Review

The City provided review of SCADA data for eleven of the modeled pump stations, many of which showed deficiencies in the model results. The following pump stations were of note:

- Pump Station 6: This is an older station that the City believes is in need of upgrades.
 Concerns are related more to condition rather than capacity. SCADA data suggests that
 the station cannot keep up during larger storm events, but this may be due to pumps
 malfunctioning rather than overall station capacity. There is very little growth anticipated
 upstream of this pump station in the future.
- Pump Station 37: Located in the Fairgrounds basin, this pump station showed issues in the model but kept up well with wet weather flows based on City SCADA review. The main concern with this pump station is the potential for significant upstream development. The City is interested in eventually studying this pump station and basin to develop a plan for serving the potential growth.
- Pump Station 42: Located in the Northwest Conveyance Corridor, this pump station demonstrated issues in the model as well as in its SCADA data. The City has concerns with the age, location, and accessibility of this pump station, as well as the potential for further growth upstream. For these reasons, this pump station is considered higher risk.

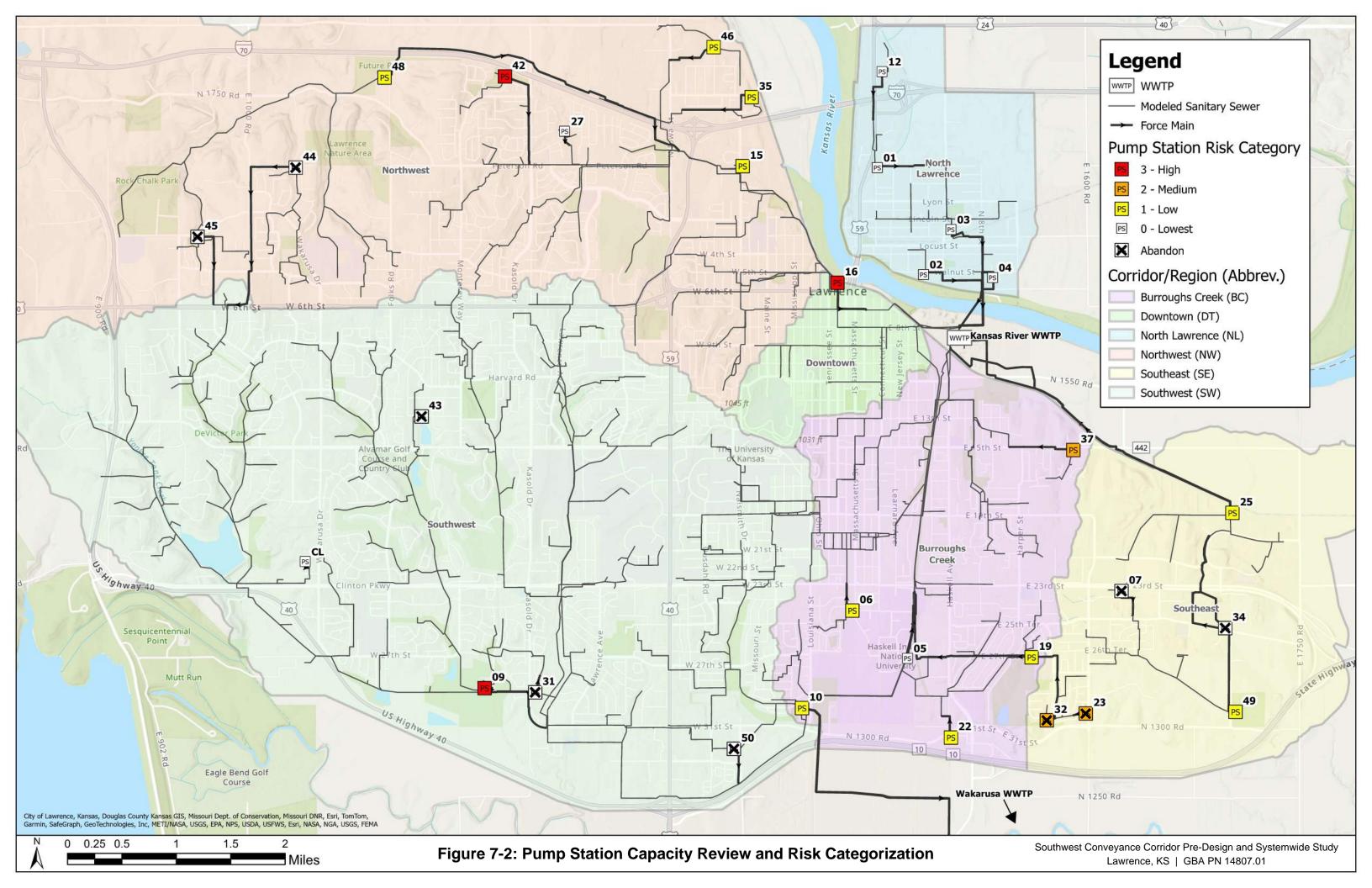
7.3.3 Pump Station Abandonment

Generally, it is beneficial to eliminate pump stations where possible, as pump stations can be costly to operate and maintain. Several of the City's pump stations have the potential to be abandoned by replacing them with gravity sewer. These pump stations show "Yes" under the "Potential to Abandon PS with Gravity Sewer" column in Table 7-3. Separate studies have been performed by the City to investigate the potential to abandon these pump stations. Performing pump station abandonment will depend on the feasibility and cost-effectiveness of investing in abandonment and rerouting by gravity. Pump Stations 44 and 45 have been recommended to be abandoned as part of the Southwest Conveyance Corridor improvements because their abandonment would have a long-term positive impact on flow conditions in the SWCC. Pump Stations 23 and 32 located in the Southeast Conveyance Corridor have the potential to be abandoned only if a regional pump station replaces them.

									Risk Categorization ⁽³⁾				
									Criteria 1	Criteria 2	Criteria 3		
Pump Station No.	Region / Corridor	Modeled Existing Capacity (MGD)	Baseline Surcharge Caused by PS Backup	2030 Free Flow Peak Greater than Exist. Capacity	2040 Free Flow Peak Greater than Exist. Capacity	SWCC Pre-Design Recommend- ation or Assumption ⁽¹⁾	Recommend Recalibrating with PS SCADA Data ⁽²⁾	Potential to Abandon PS with Gravity Sewer	Surcharge ≤5' From Surface Caused By PS (Baseline Model)	Known Deficiency Based on City Review of SCADA Data	Future Growth Concern	Pump Station Risk Category (Sum of Criteria)	
9	Southwest	8.0	Yes	Yes	Yes	Upgrade	-	-	✓	✓	✓	3	
16	Northwest	16.2	Yes	Yes	Yes	-	-	-	✓	✓	✓	3	
42	Northwest	0.55	Yes	Yes	Yes	-	-	-	✓	✓	✓	3	
23	Southeast	0.05	Yes	Yes	Yes	-	-	Yes ⁽⁵⁾	✓	-	✓	2	
32	Southeast	0.79	Yes	Yes	Yes	Reroute	-	Yes ⁽⁵⁾	✓	-	✓	2	
37	Burroughs	0.11	Yes	Yes	Yes	-	-	-	✓	-	✓	2	
6	Burroughs	2.2	Yes	Yes	Yes	-	-	-	-	✓	-	1	
10	Southwest	12.5	-	Yes	Yes	Upgrade	-	-	-	-	✓	1	
15	Northwest	0.29	Yes	Yes	Yes	-	Yes	-	✓	-	-	1	
19	Burroughs	1.9	Yes	Yes	Yes	-	Yes	-	-	-	✓	1	
22	Burroughs	0.12	Yes	Yes	Yes	-	Yes	-	✓	-	-	1	
25	Southeast	1.8	-	Yes	Yes	-	-	-	-	-	✓	1	
35	Northwest	0.11	Yes	Yes	Yes	-	Yes	-	✓	-	-	1	
46	Northwest	1.1	-	Yes	Yes	-	-	-	-	-	✓	1	
48	Northwest	3.5	-	Yes	Yes	Store	-	-	-	-	✓	1	
49	Southeast	1.1	-	Yes	Yes	Reroute	-	-	-	-	✓	1	
1	North Law.	1.2	-	-	-	-	-	-	-	-	-	0	
2	North Law.	0.5	-	-	-	-	-	-	-	-	-	0	
3	North Law.	2.1	-	-	-	-	-	-	-	-	-	0	
4	North Law.	3.6	-	-	-	-	-	-	-	-	-	0	
5 ⁽⁴⁾	Burroughs	13.8	-	-	-	-	-	-	-	-	-	0	
12	North Law.	0.4	-	-	-	-	-	-	-	-	-	0	
27	Northwest	0.5	-	-	-	-	-	-	-	-	-	0	
7	Southeast	0.3	-	-	-	-	-	Yes	-	-	-	N/A	
31	Southwest	0.2	-	-	-	-	-	Yes	-	-	-	N/A	
34	Southeast	0.09	Yes	Yes	Yes	-	-	Yes	√	-	✓	N/A	
43	Southwest	0.08	Yes	Yes	Yes	-	-	Yes	√	✓	-	N/A	
44	NW/SW	1.9	-	N/A	N/A	Abandon	-	Yes	-	-	-	N/A	
45	NW/SW	0.8	-	N/A	N/A	Abandon	-	Yes	-	-	-	N/A	
50	Southwest	0.6	-	-	-	Abandon	-	Yes	-	-	-	N/A	

Notes:

- 1) Project identified or assumed as part of the Southwest Conveyance Corridor Pre-Design study.
- 2) Three newer pump stations (15, 22, 35) showed capacity deficiencies during modeling, but had no evidence of issues based on City review of SCADA data. These model issues could potentially be eliminated upon recalibration with SCADA data. PS19, an older pump station, may also benefit from recalibration.
- 3) Risk Categories are a sum of points assigned if any of the following criteria are met: 1) Significant surcharge caused by PS in existing conditions (baseline) model; 2) Known deficiency based on City review of SCADA data; or 3) Future growth concern.
 - 3 = High
 - 2 = Medium
 - 1 = Low
 - 0 = Negligible (No known current or future capacity concerns)
 - N/A = Pump Station recommended for eventual abandonment
- 4) PS5 is made up of two pump stations (5A and 5B) located within the same facility. The City assumes that the maximum combined capacity of PS5 will remain at approx. 15 MGD due to site constraints.
- 5) Pump Station 23 and 32 are located in the Southeast Conveyance Corridor (SECC). Abandonment of these two pump stations with a new regional station should be explored as part of the SECC study.



7.4 Corridors of Interest

The Southwest Conveyance Corridor (SWCC) was studied in-depth as part of the Task 5 effort, and findings are summarized in Appendix D. While the SWCC was the focus area of Task 5 of this project, there are other critical corridors within the City's collection system that require further evaluation and planning. The Burroughs Creek Conveyance Corridor (BCCC), the Northwest Conveyance Corridor (NWCC), and the Southeast Conveyance Corridor (SECC) each have unique characteristics and drivers that must be considered when developing a plan for systemwide improvements. Figure 7-1 and Figure 7-2 both show the general boundaries of these corridors of interest.

7.4.1 Burroughs Creek Conveyance Corridor

Description

The Burroughs Creek Conveyance Corridor (BCCC) generally begins at the discharge point of PS5, on the northeast corner of the Haskell Indian Nations University campus, and flows northeast until reaching the Kansas River WWTP. This network of parallel interceptors is one of the oldest portions of the City's collection system and serves a large swath of the southeast and south-central portions of the City. Due to its age and relatively flat slopes, there are many interconnections and flow splits along the Burroughs Creek interceptors that create complexity and redundancy in the corridor's hydraulics. The older neighborhoods served by the Burroughs Creek interceptors have demonstrated excessive I/I levels in past flow monitoring studies (e.g., flow meter site 9).

The Burroughs Creek Corridor begins as two parallel interceptors at the PS5 discharge point at 23rd Street. At 19th Street, a third parallel interceptor joins the other two interceptors and runs along the west side of the Burroughs Creek Trail, while the other two interceptors run along the east side of the trail.

Critical Locations along Burroughs Creek Corridor

Critical sites along the Burroughs Creek Corridor include:

- a) 24-to-30-inch Interceptor West of Burroughs Creek Trail
 The interceptor running west of the Burroughs Creek Trail from approximately 12th
 Street to 19th Street collects flow from a majority of the Burroughs Creek basin,
 PS6, and portions of the Naismith basin and KU via several diversions.
- b) Interconnections at 12th Street and Haskell Avenue The Brook Creek interceptors tie into to the Burroughs Creek interceptors at this intersection, which includes a diversion structure between manholes SE311220-164 and SW321220-224, and a flow split at manhole SE311220-059.
- c) Interconnections at 13th Street and Oregon Street The two parallel interceptors running east of the Burroughs Creek Trail connect via a pair of diversion manholes near this intersection. This configuration is partly a result of building the sewers around an old storm tunnel that is now abandoned.

d) PS5

Pump Station 5 is a key upstream driver when considering capacity along Burroughs Creek. As part of the SWCC planning effort, the City assumed that PS5 would not be expanded beyond its current capacity of approximately 15 MGD due to site constraints.

Modeling Results - Burroughs Creek Corridor

Baseline (Existing Conditions) Model

The baseline (i.e., existing conditions) model, simulated with a 10-year, 6-hour design storm, predicts minimal surcharge conditions in the two parallel interceptors on the east side of the Burroughs Creek Trail. However, the 24 to 30-inch interceptor west of the trail demonstrates more significant surcharge conditions. Seventeen of the twenty-seven manholes along this stretch of interceptor between the BNSF Railyard (north of 11th Street) and 19th Street were surcharged more than 2 feet above the crown of pipe during the baseline model scenario. However, only five of these manholes surcharged within 5 feet of the manhole rim, and they were all located between 15th and 19th Street.

Historical flow monitoring at flow meter Site 9, located on the interceptor west of the Burroughs Creek Trail near Lasalle Street, demonstrated repeated wet weather surcharge events during previous flow monitoring periods. These surcharge events were sometimes caused by backup from a downstream flow restriction, and at other times, they were caused by lack of capacity in the metered pipe. Seven surcharge events were recorded during springtime flow monitoring performed at Site 9 from 2014 to 2021.

It is important to note that PS8, which used to send flow to Site 9, was abandoned in 2022. Therefore, due to this flow reduction, it is likely that flow conditions have improved at meter Site 9 since flow monitoring ceased. However, the baseline model accounts for this flow reduction because PS8 has been replaced by the new Naismith Valley Interceptor in the baseline model. Despite these system changes, the historical flow monitoring at Site 9 helps confirm the modeled capacity deficiencies along this interceptor running west of the Burroughs Creek Trail.

As noted above, minimal surcharge conditions are predicted by the model along the two parallel interceptors east of the Burroughs Creek Trail. The only location that shows surcharge greater than 2 feet above crown of pipe is at the 13th Street and Oregon Street interconnection, but the modeled surcharge here is at low risk of overflow under design storm conditions (i.e., minimum freeboard reaches just under 5 feet from the manhole rim at MH SE311220-086). During the January 17, 2024 workshop to discuss systemwide model results, the City noted that there are some sewers at 13th and Oregon that were installed to go around an old storm tunnel that is now abandoned. The City is interested

in finding ways to improve these legacy configurations that limit hydraulic capacity along Burroughs Creek. However, based on model results, this pipe configuration at 13th and Oregon is at a lower risk in terms of capacity concerns.

Future Growth Models

Under 2030 and 2040 growth conditions, capacity concerns along the Burroughs Creek Corridor do not significantly worsen. The 2040 free flow model scenario shows a 1.5 MGD increase in combined peak wet weather flows from PS5 and PS19 (13.9 to 15.4 MGD), which is likely a result of upstream flow restrictions being removed. There is minimal growth anticipated along the Burroughs Creek Corridor over the next twenty years because a majority of the Burroughs Creek basin and its contributing areas were developed many decades ago. As stated previously, the City has decided to assume PS5 will not expand beyond 15 MGD, which greatly diminishes capacity risks along the Burroughs Creek Corridor, both now and in the future. Based on modeling results, the primary capacity deficiencies are in the interceptor running west of the Burroughs Creek Trail, particularly between 15th and 19th Street.

<u>Conclusions – Burroughs Creek Corridor</u>

- The 24-to-30-inch Interceptor West of Burroughs Creek Trail: The interceptor running west of the Burroughs Creek Trail from approximately 12th Street to 19th Street demonstrates significant surcharging in the existing conditions model. The Burroughs Creek Corridor should be studied to determine the most cost-effective approach for relieving this west interceptor and other areas within the basin (see Section 8.2.4 for a description of this study).
- Legacy Hydraulic Issues at 13th & Oregon (and Other Locations): The City has expressed interest in modernizing the Burroughs Creek Corridor by removing legacy hydraulic issues and bottlenecks, such as the interconnections found at 13th Street and Oregon Street. Although the model does not indicate these to be high risk in terms of capacity, the system routing may be simplified and operations and maintenance improved by addressing these legacy issues.

7.4.2 Northwest Conveyance Corridor

Description

The Northwest Conveyance Corridor (NWCC) generally begins at the Baldwin Creek interceptor, which currently runs from Rock Chalk Drive and K-10 to PS48, near where Baldwin Creek crosses I-70. From PS48, flow is pumped via force main paralleling I-70 over two miles before discharging into a pair of 24-inch parallel interceptors near the intersection of McDonald Drive and I-70. From there, the parallel interceptors continue southeast, increasing in diameter and paralleling the BNSF Railroad along the Kansas River. Finally, the interceptors reach PS16, a focal point of the NWCC, which pumps flow through downtown before discharging into an interceptor on 7th Street that ultimately conveys flow east toward the Kansas River WWTP.

The NWCC is a combination of newer infrastructure built within the last twenty years (e.g., Baldwin Creek Interceptor and PS48) and older infrastructure built primarily between the 1950s and 1990s. There are several significant interceptors that connect to the NWCC, including parallel interceptors along Peterson Road, a 15-inch interceptor serving the business and industrial parks and neighborhoods north of I-70, an interceptor serving the Centennial basin west of the Kaw WTP, and a pair of interceptors serving the Windmill basin and portions of the Old West Lawrence neighborhood.

<u>Critical Locations – NWCC</u>

Critical sites along the NWCC include:

- a) PS16 and 24-inch Force Main
 - PS16 currently serves over 5,000 acres, which is over one-fifth (22%) of Lawrence's current land area within city limits. Almost all flow from the NWCC must be pumped by PS16 via a 24-inch force main through downtown Lawrence, making PS16 a significant focal point of the NWCC.
- b) Parallel Gravity Interceptors from PS16 Upstream to Iowa Street There are two parallel interceptors that flow from Iowa Street to PS16, collecting flow from most of the NWCC. These interceptors are prone to surcharge based on historical flow monitoring. The condition of these interceptors is also a concern, particularly some stretches of CMP pipe.
- c) PS48 and 16-to-24-inch Force Main PS48 serves the Baldwin Creek basin in the westernmost reach of the NWCC. There is growth anticipated upstream of PS48, and it is anticipated that this upstream growth will eventually require expansion at PS48, though the exact timing of such an expansion is not certain.

Modeling Results - NWCC

PS16 Modeling

PS16's current maximum pumping capacity is approximately 16 MGD. According to model results, when peak flows at PS16 exceed roughly 18.8 MGD, the PS16 bypass line to the Kansas River is activated, triggering an overflow event. Table 7-4 below summarizes the peak flows predicted at PS16 by each design storm (10-year, 6-hour event) model run, along with the anticipated excess volume that would bypass at PS16 assuming no improvements.

Rough estimates of costs for conceptual improvement alternatives (pump station expansion versus storage) are also provided in Table 7-4. Cost equations developed under Task 5 of this project were used to estimate high-level costs. Costs for pump station and force main expansion to convey peak flows are provided alongside costs to build a storage facility to store excess volumes, for comparison purposes only. Like the SWCC optimization effort, optimization modeling is recommended to determine the most appropriate improvements to address capacity concerns at PS16 and throughout the NWCC.

Table 7-4: Pump Station 16 Model Results and Conceptual Improvement Alternatives

			Alt. A: Pui	mp Station Ex	pansion ⁽¹⁾	Alt. B: Cover	red Storage ⁽²⁾	
							Concept.	
					Concept.	Concept.	Storage	
	PS16	PS16	Concept.	Concept.	Total	Storage	Capital	
	Peak	Excess	New PS	Parallel 36"	Expansion	OPC,	Cost,	
Model	Flow	Volume	Facility OPC	Force Main	Capital Cost	Cumulative	Cumulative	
Type	(MGD)	(MG)	(\$M)	OPC (\$M)	(\$M)	(\$M)	(\$M)	
Normal	24	1.7				\$6.9M	\$8.3M	
Free Flow	36	4.9				\$16.2M	\$19.4M	
Free Flow	39	6.4	\$20.5M	\$3.3M	\$28.6M	\$20.1M	\$24.1M	
	Type Normal Free Flow	Model Flow Type (MGD) Normal 24 Free Flow 36	Model Type Peak Flow (MGD) Excess Volume (MG) Normal 24 1.7 Free Flow 36 4.9	PS16	PS16	PS16	PS16	

Notes:

Other Model Findings

- PS48 has been considered a potential site for storage of excess wet weather flow volumes. However, storage of flows at PS48 would not eliminate capacity concerns at the downstream PS16. Peak flow from PS48 only makes up roughly 18% of the 2040 free flow peak at PS16. This means that even if PS48's peak flows were eliminated, PS16 would still overflow under 2040 conditions. However, storage at PS48 could still help reduce peaks at PS16; therefore, optimization modeling should be used to evaluate the cost-effectiveness of such a project.
- The parallel interceptors upstream of PS16 will likely require improvements. There
 is a history of surcharge along these interceptors based on historical flow
 monitoring at Sites 2 and 3. Hydraulics (inverts, slopes) need to be confirmed along

⁽¹⁾ Assumed new PS16 expansion would be designed to meet 2040 free flow growth conditions. Therefore expansion costs for Baseline and 2030 Growth Conditions are not provided.
(2) Assumed concrete storage with cover due to proximity to downtown corridor and residential neighborhoods. Storage costs are cumulative according to total excess volume stored.

these interceptors due to some questionable inverts and negative slopes in City GIS. Existing conditions model results during design storm conditions indicate critical surcharge levels, such that from PS16 upstream to manhole NE251219-208:

- 9 of 22 manholes have a maximum surcharge level within 3 feet of the manhole rim along the North/East parallel interceptor, and
- 16 of 27 manholes have a maximum surcharge level within 3 feet of the manhole rim along the South/West parallel interceptor.

Conclusions - NWCC

The NWCC is at high risk for sanitary sewer capacity issues. The primary capacity risk is PS16 and the potential bottleneck it creates as development occurs upstream. However, if PS16 were expanded, downstream force main and interceptors in downtown Lawrence would also require costly improvements. An optimization pre-design project is recommended for the NWCC, similar to the SWCC pre-design effort. Due to the risk the NWCC represents, a pre-design study should be implemented in the near term.

7.4.3 Southeast Conveyance Corridor

Description

The Southeast Conveyance Corridor (SECC) generally encompasses the sanitary sewer service area in the southeast portion of Lawrence served by Pump Stations 25 and 49. Currently, PS49 conveys flow to PS25, and PS25 then conveys flow to the Kansas River WWTP. PS49 primarily receives flow from residential areas south of 23rd Street, while PS25 primarily receives flow from the industrial East Hills Business Park/Venture Park north of 23rd Street. Most sanitary sewer infrastructure in this region is built after 1980, and a majority has been built within the last twenty years. Recently there has been increased development interest in the SECC, particularly for industrial uses, which will likely drive the need for improvements in the region.

<u>Critical Locations – SECC</u>

Critical sites in the SECC include:

- a) PS25 and Parallel Force Main Nearly all flow from the SECC is pumped by PS25 via a pair of parallel force mains that run beside a railroad from southeast Lawrence to the Kansas River WWTP, making PS25 a significant focal point of the SECC.
- b) PS49 and 12-inch Force Main PS49, located along E 1700 Road near the Kitsmiller Tributary stream, serves a portion of the SECC and currently pumps flow north to PS25. There is growth anticipated upstream of PS49, and it is anticipated that this upstream growth will

eventually require flow from PS49 to be re-routed south to the Wakarusa WWTP. PS49 was designed to accommodate this eventual change in flow direction.

c) PS23 and PS32

Two small pump stations located west of O'Connell Road and north of 31st Street have maintenance concerns. PS23 pumps flow to PS32, and PS32 pumps flow to PS19 (which sends flow to the Burroughs Creek Corridor). Based on previous investigations, the City believes it would be beneficial to abandon PS23 and PS32, possibly replacing them with a larger pump station near the intersection of O'Connell Road and 31st Street. This option has been studied in the past. PS32's force main is a source of H₂S, and it is not feasible to add a chemical feed H₂S control device at PS32 due to lack of space.

Modeling Results - SECC

Assuming PS49 still pumps to PS25, the 2030 free flow model suggests that PS25 will be undersized to handle the free flow peak (10-year, 6-hour design storm) of 4.2 MGD under 2030 growth conditions (PS25's existing firm capacity is 3.6 MGD). PS49's existing capacity is approximately 1.2 MGD, and if PS49 is rerouted, PS25 would receive 2030 free flow peaks closer to 3 MGD rather than 4.2 MGD. Therefore, PS25 would not need to be expanded by 2030 growth conditions if PS49 were rerouted to pump to the Wakarusa WWTP. Improvements may not be required by 2030, however, if growth does not occur as quickly as was assumed for this study.

Conclusions – SECC

The SECC is at risk for sanitary sewer capacity issues if growth occurs as anticipated. The primary capacity risk is at PS49 and PS25 as development occurs upstream of these two pump stations. By 2030 growth conditions, peak flows from PS49 are expected to increase to a point that would require a capacity expansion at PS25. Currently, PS49 pumps flow to PS25, which then pumps to the Kansas River WWTP. PS49 was designed to pump to PS25 initially because the Wakarusa WWTP had not yet been built at the time of its construction. However, the City has maintained the possibility of eventually rerouting PS49 to pump to Wakarusa WWTP. To address this potential capacity deficiency, the City will need to pursue one of three alternatives: a) expand PS25's capacity, b) reroute PS49 to Wakarusa WWTP, or c) add storage capacity at PS49 or PS25 to attenuate peak wet weather flows.

The City would prefer to send PS49's flow to the newer Wakarusa WWTP rather than continuing to send flow a farther distance to the Kansas River WWTP via PS25. Therefore, the City should pursue a project to reroute PS49 before flows increase to a point that would trigger an expansion of PS25. The City has already budgeted for an eventual project in the SECC. The most recent CIP (FY2025-2029) lists Project MS1-00019 SE Lawrence Wastewater Conveyance Imp. (Phase 1) as "funded", with the 2026, 2027, and 2028

allocations as \$300,000, \$1,500,000, and \$2,000,000 respectively, for a total of \$3.8 million over three years. Modeling results confirm that the City will eventually require a project to study, design, and construct improvements to address SECC capacity concerns.

As is later discussed in Section 8.2.5, the conceptual design and construction costs of rerouting PS49 to the Wakarusa WWTP may be upwards of \$4 to \$6 million, depending on the chosen force main alignment and a variety of contingencies, such as utility conflicts and highway and stream crossings. Therefore, the MS1-00019 project budget in the current CIP will likely need to be increased to fully fund the anticipated improvements needed in the SECC.

It is important to note that the feasibility of rerouting PS49 depends on the availability of capacity at the Wakarusa WWTP. Per discussions with the City, it was assumed that the Wakarusa WWTP would be expanded by 2030 growth conditions, and the PCSWMM model reflects this assumption. Further study and coordination are required to determine the appropriate timing of PS49's reroute, with special consideration of the available capacity at the Wakarusa WWTP.

In addition to studying and designing the reroute of PS49, it is recommended that the potential to eliminate PS23 and PS32 be explored. There are maintenance concerns at both existing pump stations, and reducing the number of pump stations would help reduce operations and maintenance costs. Based on topography in the area, it may be possible to reroute PS49 toward Wakarusa WWTP by crossing under K-10 at O'Connell Road (E 1600 Rd), while also placing a booster pump station near K-10 and O'Connell Road that would tie into the PS49 force main. This would allow for flow by gravity from the locations of PS23 and PS32 to this conceptual booster station near K-10 and O'Connell Road. In case of a future need, this would also open up the possibility of rerouting PS19 toward this booster station by building gravity sewer through Prairie Park along the east side of Mary's Lake.

8 SYSTEMWIDE CAPACITY PLAN

A comprehensive plan is necessary to systematically address the modeled capacity deficiencies identified and summarized in Chapter 7. This systemwide plan needs to be both actionable and adaptable to fit the City's ongoing needs and available resources. Modeling results and City staff input were used to shape this systemwide plan and identify a consolidated set of projects to address deficiencies and maintain level of service in Lawrence's sanitary sewer system. While the systemwide plan incorporates Southwest Conveyance Corridor pre-design improvements, summaries of those improvements are presented in the Task 5 Technical Memorandum (Appendix D).

8.1 Overview of Recommended Projects

Gravity sewer and pump station capacity deficiencies described in Section 7.2 and 7.3 were logically grouped into larger project areas based on location and relative risk. The resulting project groups were then assigned an order of priority based on risk and importance. Project groups are presented in rank order in Table 8-1 and locations are shown in Figure 8-1. Each project is summarized in Section 8.2 "Project Descriptions".

It is important to note that the recommended projects described in this chapter will begin as either a preliminary design (pre-design) or study, and the full design phase of one or more CIP projects may follow once the preliminary design or study phase is complete. For the purposes of this report, a "study" is used to refer to a project where it is unknown whether full design will follow immediately after the study is complete. A "preliminary design" is used to refer to a project where it is anticipated that a conceptual design (or set of conceptual designs) will be produced, and full design will follow soon after.

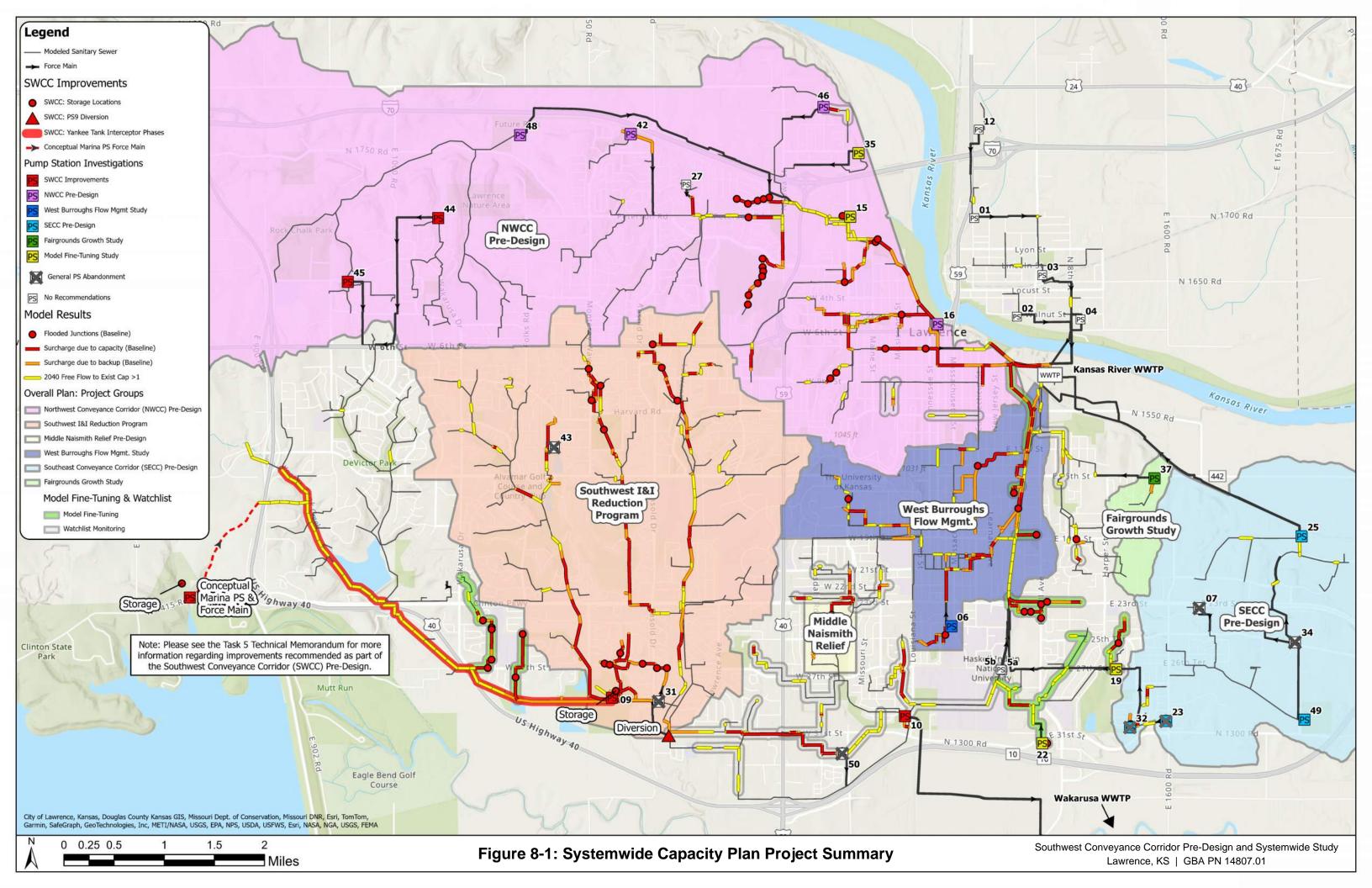
Table 8-1: Systemwide Capacity Plan Project Summary

			Gravity Sewer Sub-Projects			Pump Station Sub-Projects		Conceptual	Cost Ranges
Priority									Design and Construction
Rank	Project Group Name	Primary Objectives	ID	Name	Risk Cat.	1 1	Risk Cat.	Pre-Design / Study Phase	of First Phase of Projects
1	Southwest Conveyance Corridor	□ Address existing deficiencies at PS9	SW-09	Yankee Tank Interceptors	2	PS9 Improvements	3	\$1.1M	\$20M - \$30M
	(SWCC) Improvements	□ Prepare SWCC to serve future growth west of K-10				PS9 Additional Storage	N/A	(complete)	(see Task 5 Tech Memo)
						PS44 and PS45 Abandonment	N/A		
2	Northwest Conveyores Consider	I doubtify an act antimed act of improvements to many any NIMCO for fixture	NIM O1	Ctours Dw	4	PS10 Improvements	1	#O ONA #4 4NA	#20N4 #20N4
2	Northwest Conveyance Corridor (NWCC) Pre-Design	□ Identify most optimal set of improvements to prepare NWCC for future □ Perform optimization modeling similar to SWCC Pre-Design	NW-01 NW-02	Stowe Dr PS16 Parallel Interceptors	4	PS16 PS42	3 3	\$0.9M - \$1.1M (Flow Monitoring, Model	\$20M - \$30M (PS16 Expansion or
	(NVVCC) Fre-Design	□ Investigate options for improving PS16 and its interceptors	NW-02	5th St	4	PS46	3 1	Updates, Optimization,	Storage Project)
		□ Investigate modeled gravity deficiencies with targeted flow monitoring	NW-04	Country Club	4	PS48	1	and Pre-Design)	Glorage Projecty
		□ Identify upgrades to address existing deficiencies at PS42	NW-05	9th St and Avalon Rd	4	1 545	•	and the Besign,	
		a taoning apgrades to data eac ontaining activities at the tight	NW-06	Memorial Hospital	4				
			NW-07	Peterson Rd and Crestline Dr	3				
			NW-08	Centennial Park	2				
			NW-09	Peterson Rd	2				
			DT-01	7th St and 8th St Downtown	4				
			DT-02	KRWWTP Interceptors	2				
3	Southwest I/I Reduction Program	□ Programmatically reduce I/I to improve system capacity and condition	SW-01	Lower Quail Creek	4	N/A		\$1.2M - \$1.4M	\$4M - \$6M
		□ Begin with smaller, leakier basins as pilot projects to confirm reduction	SW-02	Atchison Creek	4			(5 Small Pilot Basins:	(5 Small Pilot Basins:
			SW-04	Upper Quail Creek	3			Field Data Collection	Rehabilitation)
			SW-07	Inverness	3			and Rehab. Design)	
4	Middle Naismith Relief Pre-Design	□ Identify optimal solution for relieving the gravity sewer capacity issue	SW-03	Middle Naismith	4	N/A		\$0.1M - \$0.3M	\$0.8 - \$1.2M
5	West Burroughs Flow Mgmt. Study	□ Identify opportunities to strategically reroute flows and improve capacity	BC-01	West Burroughs Creek and KU	4	PS06	1	\$0.6M - \$0.8M	\$1M - \$2M
6	Southeast Conveyance Corridor	□ Identify most optimal set of improvements to prepare SECC for future	SE-01	Prairie Park	3	PS23	2	\$0.3M - \$0.5M	\$4M - \$6M
	(SECC) Pre-Design	□ Investigate options for rerouting PS49 to Wakarusa WWTP	SE-02	East Hills Business Park	1	PS25	1	(Pre-Design Only)	(Design & Construction of
		□ Investigate options for abandoning PS23 and 32 with new pump station				PS32 PS49	2		PS49 Force Main Reroute)
7	Fairgrounds Growth Study	□ Identify most optimal set of improvements to prepare basin for future	BC-08	Fairgrounds and PS37	2	PS37	2	\$0.1M - \$0.2M	N/A
8	Model Fine-Tuning and	Model Fine-Tuning:	Model Fine	<u> </u>		PS15	1	\$0.3M - \$0.7M	N/A
O	Watchlist Monitoring	□ Investigate modeled deficiencies where there is lower confidence	BC-02	23rd St and Haskell Ave	3	PS19	1	(for Watchlist Monitoring,	(No improvements
	Tale met met met me	in model results due to poor flow meter coverage	BC-03	Maryland St	3	PS22	1	initial costs would entail	anticipated in near term)
		□ Identify opportunities to improve the sanitary sewer model	BC-04	Homewood St	3	PS35	1	field visits and record	,
		□ Field verify system hydraulics to address gaps and limitations in the	BC-05	Ponderosa	3			checks, but costs would	
		existing model network	BC-06	PS19 and Anderson Rd	3			increase if flow meters or	
			BC-07	Hobbs Park	3			HGL analysis is needed)	
			SW-05	Sunflower	3				
			SW-06	Wildflower Dr	3				
		Watchlist Monitoring:	Watchlist I	•					
		□ Monitor low-risk capacity deficiencies identified during modeling	BC-09	Belle Haven	2				
		using stepped approach, beginning with field visits and record checks,	BC-10	Brook Creek	2				
		followed by flow metering and HGL analysis if issues are noted	BC-11	Maple Ln and 21st St	0				
		□ Track potential capacity deficiencies that may be caused or exacerbated	DT-03	Upper Jayhawk	2				
		by upstream growth and development	DT-04	11th St	1				
		□ Update findings and status once every 5-10 years	NW-10	Riverside Dr	7				
			SW-08 SW-10	Lower Naismith 31st St	2				
			SW-10 SW-11	K10 Interceptors at 33rd St	2				
			SW-11	Upper Naismith	2				
9	General Pump Station Abandonment	□ Abandon pump stations by installing new gravity sewer where possible	N/A	оррог тапопппп		PS07	N/A	N/A	N/A
· ·	The state of the s	□ Reduce O&M costs and eliminate aging equipment	.,,,			PS31	N/A	(Preliminary studies have	(Costs and timing will
		20 - 4				PS34	N/A	been completed)	depend on City
						PS43	N/A		prioritization and budget)
						PS50	N/A		,

Total Conceptual Cost Range

\$4.6M - \$6.1M

\$50M - \$75M



8.2 Project Descriptions

A summary is provided below for each pre-design or study recommended as part of the systemwide plan. Southwest Conveyance Corridor recommendations are provided in the Task 5 Technical Memorandum (Appendix D). All cost ranges provided are conceptual in nature and are based on preliminary assumptions. Actual project costs may differ at the time of scoping.

8.2.1 Northwest Conveyance Corridor (NWCC) Pre-Design

Description

A map of the NWCC is provided in Figure 8-2. The NWCC comprises the northwestern portion of Lawrence's collection system generally located north of 6th Street and west of the Kansas River. This corridor currently serves roughly a quarter of the City by area, and Pump Station 16 is generally considered the downstream terminus. All flow from the NWCC is conveyed by PS16 through downtown Lawrence to the Kansas River WWTP via a single 24-inch force main.

The primary objective of the NWCC Pre-Design is to identify the most optimal set of improvements to address existing capacity concerns and prepare the corridor to serve anticipated growth upstream. To achieve this, the pre-design will take a similar approach as the Southwest Conveyance Corridor Pre-Design, utilizing hydraulic modeling and optimization tools to identify potential solutions. There were relatively few flow meter sites used for calibration of the NWCC during the SWCC Pre-Design project. Therefore, flow monitoring throughout the corridor, along with partial re-calibration of the hydraulic model, is also recommended.

Key focus areas of the pre-design include the following:

- PS16: This station conveys all flow from the NWCC through downtown Lawrence towards the Kansas River WWTP. There are concerns about PS16's capacity, both now and for the future.
- Existing Interceptors Upstream and Downstream of PS16: These have demonstrated capacity concerns in both historical flow monitoring and hydraulic modeling. There are also condition concerns, particularly for the sections of CMP pipe.
- Optimization Modeling of Various Improvements: Improvement alternatives that may be evaluated during optimization modeling include but are not limited to:
 - PS16 Pumping Capacity Expansion and Force Main Upsizing
 - PS16 Excess Volume Storage Basin
 - PS48 Excess Volume Storage Basin Note: Although this alternative is not expected to completely relieve PS16's capacity concerns, its cost-effectiveness needs to be further evaluated.
 - Reroute Gravity Lines in Windmill Watershed This would involve sending flow by gravity east along 7th and/or 9th Street instead of north towards PS16, which may reduce peaks at PS16 by upwards of 3 MGD.

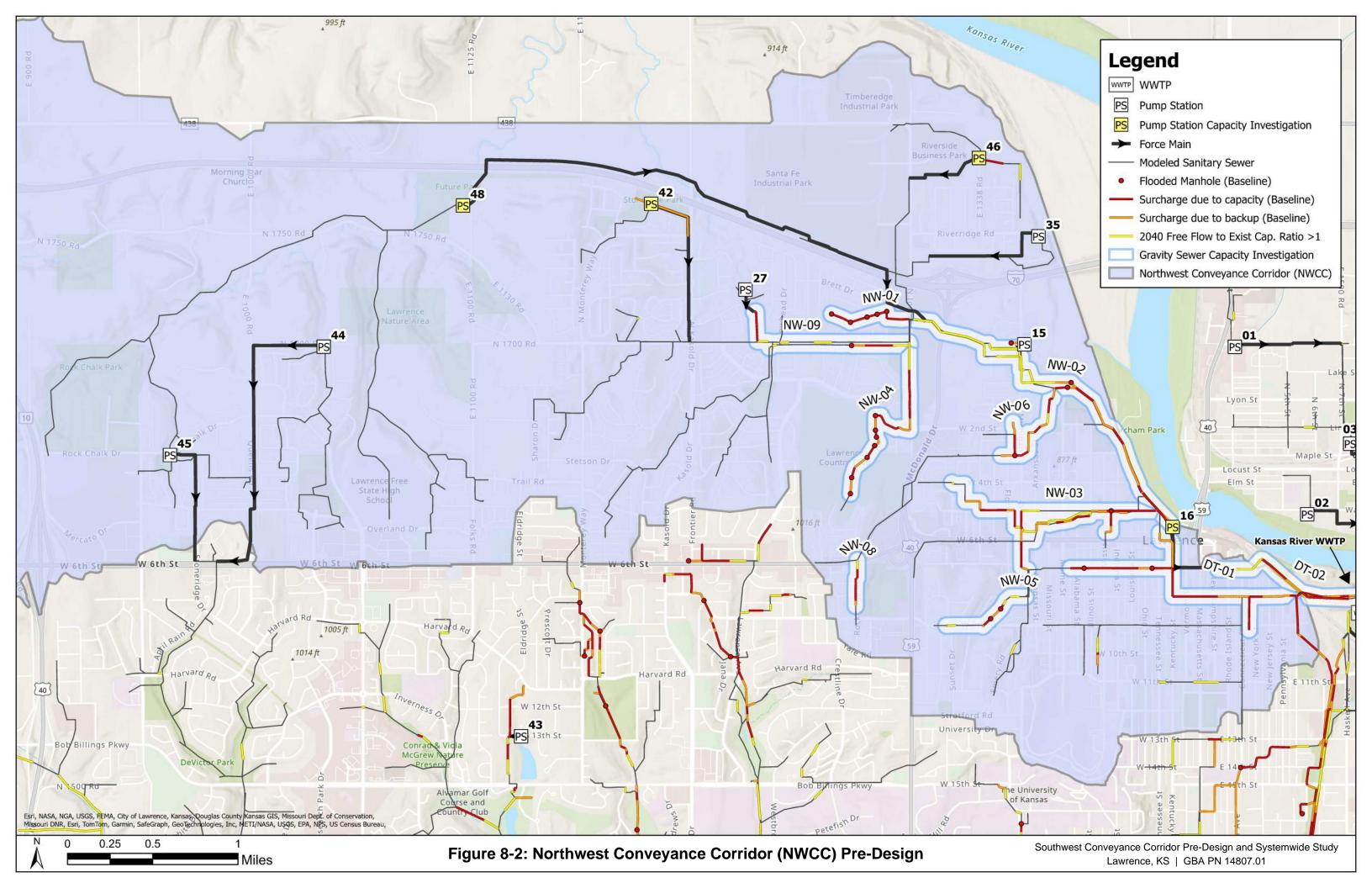
- Investigations of Various Modeled Capacity Deficiencies: Eleven of the gravity sewer
 deficiencies listed in Table 7-2 are included as sub-projects to this pre-design. Through
 targeted flow monitoring and investigation of these areas of concern, capacity issues can
 be verified, and conceptual improvements can be developed as needed.
- PS42: There are known issues and City concerns regarding this facility.
- PS48: The timing of upstream development and expansion of this pump station is tied to the overall capacity of the NWCC.

Justification

There are existing and future capacity concerns found not only in the primary corridor but also throughout several interceptors that feed into the corridor. PS16 is a major downstream bottleneck because it is the only facility that conveys NWCC flows to the Kansas River WWTP; and it has only one force main, which runs through a heavily congested downtown corridor. Growth is anticipated in the corridor, primarily upstream of PS48 in the Baldwin Creek watershed. Much of the Baldwin Creek watershed remains undeveloped, particularly west of K-10, and the City anticipates growth to continue in this region. Therefore, the NWCC's existing capacity concerns will only intensify as growth occurs.

Conceptual Cost Range and Scope Assumptions

- Pre-Design: \$0.9M \$1.1M
 - Spring flow meter session of approximately 15-20 flow meters. Note: Some meters would address model calibration needs, while others would provide targeted metering of capacity concerns to verify the presence of deficiencies.
 - HGL analysis at 5-10 sites to confirm capacity deficiencies.
 - Recalibration of the PCSWMM model using the new flow meter data.
 - Condition assessment and drawdown testing at PS16 and PS42.
 - Optimization using PCSWMM Model.
 - Conceptual design of improvements.
 - Workshop facilitation and reporting.
- First Phase of Projects: \$20M \$30M
 - PS16 expansion or storage project. Estimated using cost equations described in the Task 5 Technical Memorandum.



8.2.2 Southwest Inflow and Infiltration (I/I) Reduction Program

Description

The primary objective of the Southwest I/I Reduction Program is to improve gravity sewer condition and capacity by programmatically rehabilitating sewers and reducing I/I in basins where high levels of I/I are suspected to cause capacity deficiencies.

A conceptual improvements plan was developed for the SWCC, as summarized in the Task 5 Technical Memorandum (Appendix D). Improvements were recommended primarily at PS9 and along the main trunk line from the Yankee Tank Interceptors to PS10. However, there were modeled capacity concerns identified in basins tributary to the SWCC that would need to be addressed as part of a separate effort. The southwestern basins tributary to the SWCC with the most capacity issues identified during modeling are the Atchison, Inverness, and Quail Creek basins. The modeled capacity issues in these basins are suspected to be the result of excessive I/I. These three basins are mostly developed, with little space remaining for significant growth.

Eleven (11) flow meter sites were monitored in 2019 within these three primary basins, and a majority of this 2019 flow meter data was used to calibrate the PCSWMM model. Excessive I/I flow parameters were determined for these basins by data analysis of these meters, as per the 2019 monitoring report. In addition, City personnel have indicated that this area has had numerous issues, and excessive I/I is suspected to have caused surcharging and backups during strong wet weather events. PCSWMM modeling results for existing (baseline) conditions identified more than 120 pipe segments totaling over 31,000 feet that surcharge due to lack of capacity during the 10-year design storm event.

The City has conducted the EcoFlow I/I Reduction Program to address I/I issues in older, eastern portions of the collection system. It is recommended that a similar approach be adopted for the Southwest I/I Reduction Program, including identification and removal of both public and private I/I sources. The basins metered in 2019 that fall within the Southwest I/I Reduction Program extent are listed in Table 8-2 and assigned an order of priority based on estimated I/I levels. The Southwest I/I Reduction Program basins, 2019 meter locations, and baseline model results are shown in Figure 8-3.

The five flow meter basins ranked highest for I/I (36, 37, 38, M3, and M7) are highlighted in Table 8-2 and Figure 8-3. 36, 37, and 38 are small basins in the Western Hills area. M3 is located at the southern end of the Quail Creek watershed and overlaps the "Lower Quail Creek" gravity sewer project (SW-01) listed in Table 7-2. M7 encompasses the upstream-most portion of the Atchison Creek watershed. It is recommended that the City begin the program with these five basins as pilot projects. These pilot projects would allow the City to cost-effectively target smaller areas with high levels of I/I and test available reduction techniques to better understand the degree of reduction that may be reasonably expected for this program.

<u>Justification</u>

According to existing conditions model results for the 10-year, 6-hour design storm event, 22% of the modeled sewer length within the Southwest I/I Reduction Program area is expected to be fully surcharged under peak flow conditions due to lack of pipe capacity. However, if I/I-induced peaks are reduced by 20% across all pipes in the Southwest I/I Reduction basins, then only 10% of the modeled sewer length is expected to be fully surcharged due to lack of pipe capacity – a 12% reduction in surcharging pipe from existing conditions. While the degree of I/I reduction cannot be guaranteed during any given project, a peak flow reduction goal of up to 20% is considered reasonable for areas of excessive I/I. Past results from the City's EcoFlow program may also provide insight into how much reduction may be achieved.

Based on an analysis of pipe capacities in the Southwest I/I Reduction area, the level of investment required to achieve significant I/I reduction is likely similar in magnitude to the level of investment required to upsize pipe that would otherwise be relieved by I/I reduction efforts. In other words, the I/I reduction approach to capacity improvements can often be just as expensive as the pipe upsizing approach. However, the clear advantage of I/I reduction is that it decreases downstream impacts by decreasing wet weather flows. Upsizing pipe will simply improve capacity of that upsized pipe, but it will also put additional stress on downstream infrastructure by conveying more flow. By reducing I/I, more of the collection system benefits: less flow needs to be pumped and treated, thus reducing costs at downstream facilities, and downstream bottlenecks are not worsened from the removal of an upstream bottleneck.

Therefore, pursuing the Southwest I/I Reduction Program in basins that are known to have I/I issues will not only benefit the overloaded pipes in those basins, but it will also reduce strain on downstream interceptors (such as the 31st Street Interceptors), pump stations (such as PS9 and PS10), and treatment plants.

Conceptual Cost Range and Scope Assumptions

- Pre-Design: \$1.2M \$1.4M
 - o Assumes the top 5 leakiest flow meter basins from 2019 are pursued first.
 - Assumes a conceptual cost of roughly \$10 per linear foot of pipe within a basin for field data collection (flow monitoring, manhole inspections, CCTV, smoke testing, and dye testing) and rehabilitation design.
- First Phase of Projects: \$4M \$6M
 - o Assumes the top 5 leakiest flow meter basins from 2019 are rehabilitated first.
 - Assumes a conceptual cost of roughly \$40 per linear foot of pipe within a basin for public I/I defect rehabilitation and construction (a mixture of manhole lining and repairs, lateral connection repairs, CIPP, point repairs, and total line replacement).
 - Private I/I defects are not included under this conceptual estimate.

Table 8-2: Southwest I/I Reduction Program Metered Basins

				2019		2019			E	Estimated		
	Approx. Total		2019	Subsystem		Subsystem			F	Field Data	ſ	Estimated
	Length of	2019	Meter	Infiltration	2019	1-Year Storm	2019	Overall	С	ollection &	C	onstruction
	Sewers Within	Meter	Subsystem	Rate	Infiltration	Inflow Rate	Inflow	Priority	De	esign Costs		Costs
Watershed	Watershed (ft)	Site ID	Length (ft)	(gpd/IDM)	Ranking ⁽¹⁾	(gpd/1000ft)	Ranking ⁽¹⁾	Ranking ⁽²⁾		(\$) ⁽³⁾		(\$) ⁽⁴⁾
Atchison	244,000	M1(A/B)	78,730	5,630	4	35,570	6	6	\$	787,000	\$	3,149,000
		M6(A/B)	91,480	3,750	8	35,190	7	7	\$	915,000	\$	3,659,000
		M7(A/B)	67,060	5,540	5	45,090	2	3	\$	671,000	\$	2,682,000
Quail	162,000	38	6,010	9,030	2	38,050	3	2	\$	60,000	\$	240,000
		M3	39,160	5,440	6	36,390	4	5	\$	392,000	\$	1,566,000
		M4	103,900	3,560	9	24,800	8	8	\$	1,039,000	\$	4,156,000
Inverness	191,000	35 ⁽⁵⁾	5,750	(8,250)	11	(26,670)	11	11	\$	58,000	\$	230,000
		36	6,400	18,460	1	84,950	1	1	\$	64,000	\$	256,000
		37	3,710	8,560	3	35,840	5	4	\$	37,000	\$	148,000
		M2	60,030	4,820	7	15,540	10	9	\$	600,000	\$	2,401,000
		R4	112,710	2,840	10	21,060	9	10	\$	1,127,000	\$	4,508,000
								Total	\$	5,750,000	\$:	22,995,000
Subtotal, Top 5 Ranked Basins								\$	1,224,000	\$	4,892,000	

Notes:

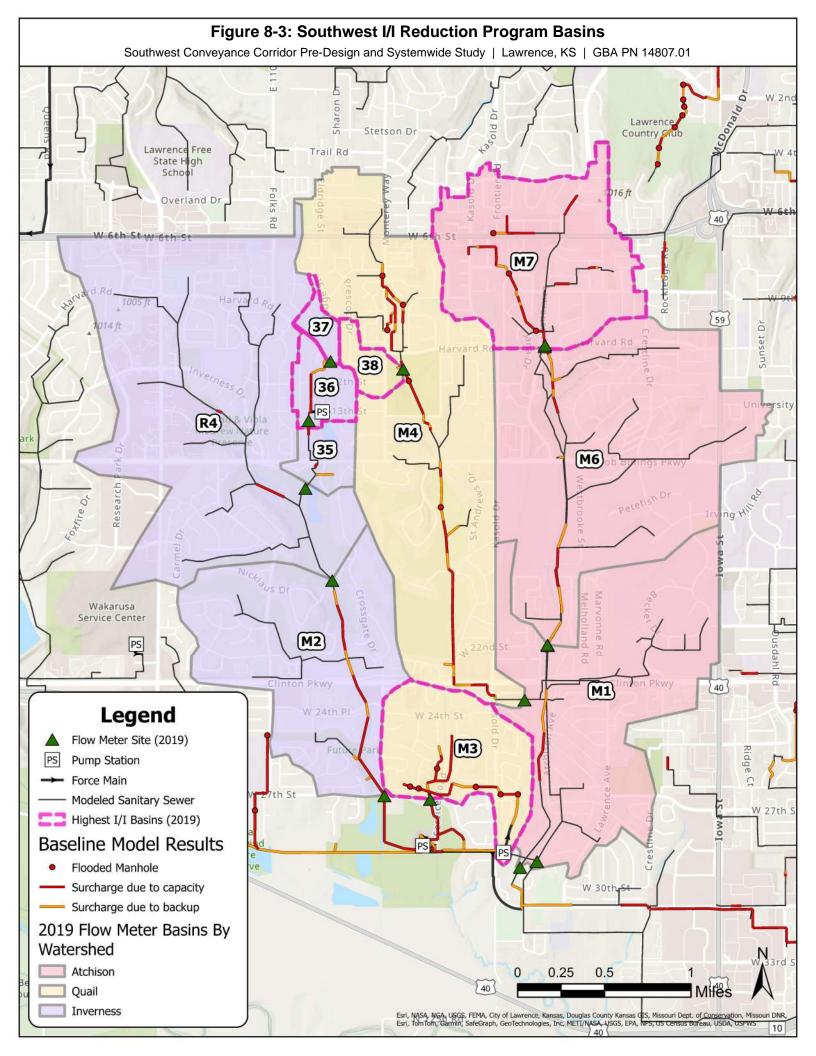
⁽¹⁾ Infiltration and Inflow rankings are based on only those meter basins located within the Southwest I/I Reduction Program project area.

⁽²⁾ Overall Priority Ranking based on sum of inflow and infiltration ranks.

⁽³⁾ Estimated field data collection and design costs are based on a conceptual cost of \$10 per linear foot of pipe within the basin.

⁽⁴⁾ Estimated construction costs are based on a conceptual cost of \$40 per linear foot of pipe within the basin, and excludes construction phase services.

⁽⁵⁾ Meter Site 35: Negative infiltration and inflow rates were calculated. Negative subsystem statistics can occur in very small interior basins where inaccuracies can compound.



8.2.3 Middle Naismith Relief Pre-Design

Description

Primary Objective: Identify and conceptualize the best solution for relieving gravity sewer capacity deficiencies in the middle section of the Naismith Watershed, near the intersection of 24th Street and Ousdahl Road.

Background: This gravity sewer deficiency (SW-03 in Table 7-2) was identified from hydraulic modeling. The gravity sewers with capacity concerns are shown in Figure 8-4. They were built prior to the construction of the Naismith Valley Interceptor, completed in 2022. Now that the Naismith Valley Interceptor has been constructed, these sewers should be relieved by rerouting flow more directly to the Naismith Valley Interceptor.

Recommended Approach: Hydraulic analysis along with an alternatives analysis is recommended for this area to determine the most strategic location for rerouting flow with a new relief line.

Justification

City staff have noted that this area is a known concern and that the original alignment and hydraulics are no longer appropriate now that Pump Station 8 is decommissioned and the Naismith Valley Interceptor is constructed. Based on the higher risk of overflow indicated by model results, it is recommended that this project be implemented within the next five years.

Conceptual Cost Range and Assumptions

- Pre-Design + Full Design: \$0.1M \$0.3M
 - Includes both pre-design effort (alternatives analysis, hydraulic calculations, etc.)
 and design for sanitary improvements only.
- Construction: \$0.8M \$1.2M
 - Assumes higher expenditures due to fully developed and more congested project area, which often involve more utility conflicts and project contingencies.

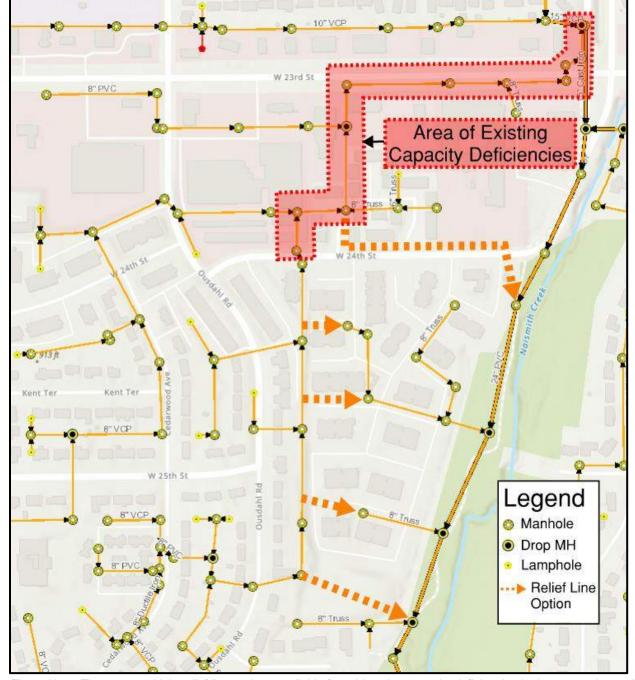


Figure 8-4: Middle Naismith Relief Options

Figure Note: There are multiple relief line options available for addressing capacity deficiencies in the sewers located between 23rd and 24th Street.

8.2.4 West Burroughs Flow Management Study

Description

Primary Objective: Identify strategic opportunities to reroute or divert flows to improve capacity at key places throughout the Burroughs Creek collection system. The general project area is shown in Figure 8-5.

Background: Several capacity concerns were identified during modeling in the collection system located west of the Burroughs Creek interceptors and east of the KU campus. This portion of Lawrence's collection system is relatively old, with much of the sewers having been installed in the 1930s. There are many flow splits throughout this area, which add hydraulic complexity. A flow split is considered any place in the system where flow is allowed to exit in more than one direction from a structure, such as at a diversion structure or a high-point manhole. Flow monitoring in this area has indicated higher levels of I/I, and the 2012 Integrated Plan noted the need for a capacity improvement in the vicinity of the curvilinear pipe near Liberty Memorial Central Middle School (14th Street and New York Street). City staff expressed concern with any project that would involve open cut replacement of the overloaded curvilinear sewers, as the neighborhood is relatively dense and construction corridors would be challenging.

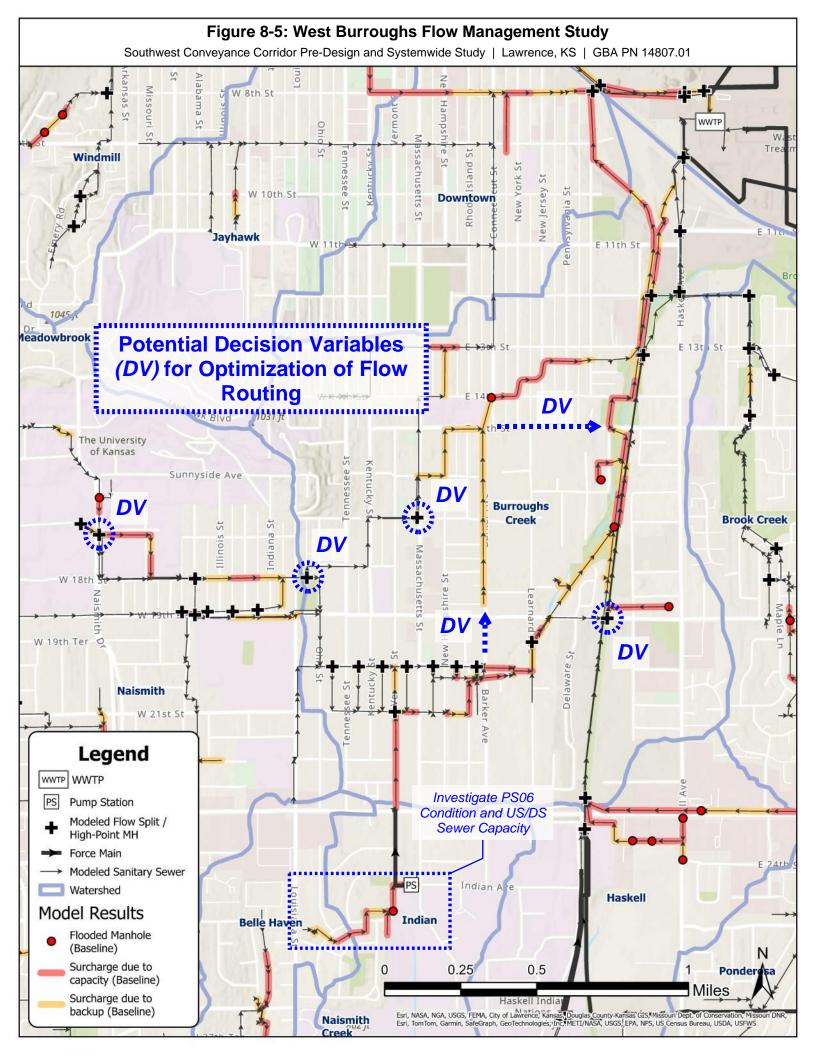
Recommended Approach: Due to the complex interconnections and flow splits throughout the project area, it is recommended that optimization with the hydraulic model be used to determine the most strategic improvements to address capacity concerns. Decision variables to be used during optimization analysis could include key diversions and potential reroute options as shown in Figure 8-5. It is also recommended that Pump Station 6's capacity and condition be assessed, along with its upstream and downstream sewers, to identify any potential improvements. Pump Station 6 pumps into the Burroughs Creek collection system, making any improvements at PS6 relevant to the plan for the entire project area.

Justification

While capacity deficiencies could be addressed with pipe replacement and upsizing, it is recommended that this complex project area be studied further to determine if more strategic and cost-effective solutions are possible for addressing capacity concerns. The complexity of flow splits and diversions in this area requires further analysis before design can begin. Optimization may be the most appropriate tool for testing the many combinations of solutions available to determine the most ideal flow routing scenario.

Conceptual Cost Range and Assumptions

- Study Phase: \$0.6M \$0.8M
 - Approximately 10 flow meters, targeted model calibration, optimization, Pump Station 6 condition assessment and drawdown testing, and reporting.
- First Phase of Projects: \$1M \$2M (Depends significantly on study findings)



8.2.5 Southeast Conveyance Corridor (SECC) Pre-Design

Description

Primary Objectives: Identify the most optimal set of improvements to prepare the SECC for future development. This will involve investigating options for rerouting PS49 to Wakarusa WWTP and investigating opportunities to abandon PS23 and PS32 with a new regional pump station. A figure of the SECC along with a conceptual alignment of PS49's new force main is provided in Figure 8-6.

Background: This project is currently identified as Project Number MS1-00019 in the City's CIP and is scheduled for the years 2026-2028. PS49 currently pumps to PS25, which pumps to the Kansas River WWTP. However, as growth in the eastern portions of Lawrence require expansion of PS25, PS49 is planned to be rerouted south to pump to the Wakarusa WWTP. It was assumed during modeling and optimization for the Southwest Conveyance Corridor that PS49 will be rerouted to the Wakarusa WWTP by 2040. City staff have expressed interest in investigating options for improving or replacing PS23 and PS32, near 31st Street and O'Connell Road.

Recommended Approach: The SECC is smaller and less complex than the SWCC or NWCC, and therefore optimization is likely unnecessary for the purposes of the project. Flow monitoring and hydraulic modeling is recommended to assess the existing and future capacities of gravity sewers and pump stations in the corridor.

Key Focus Areas:

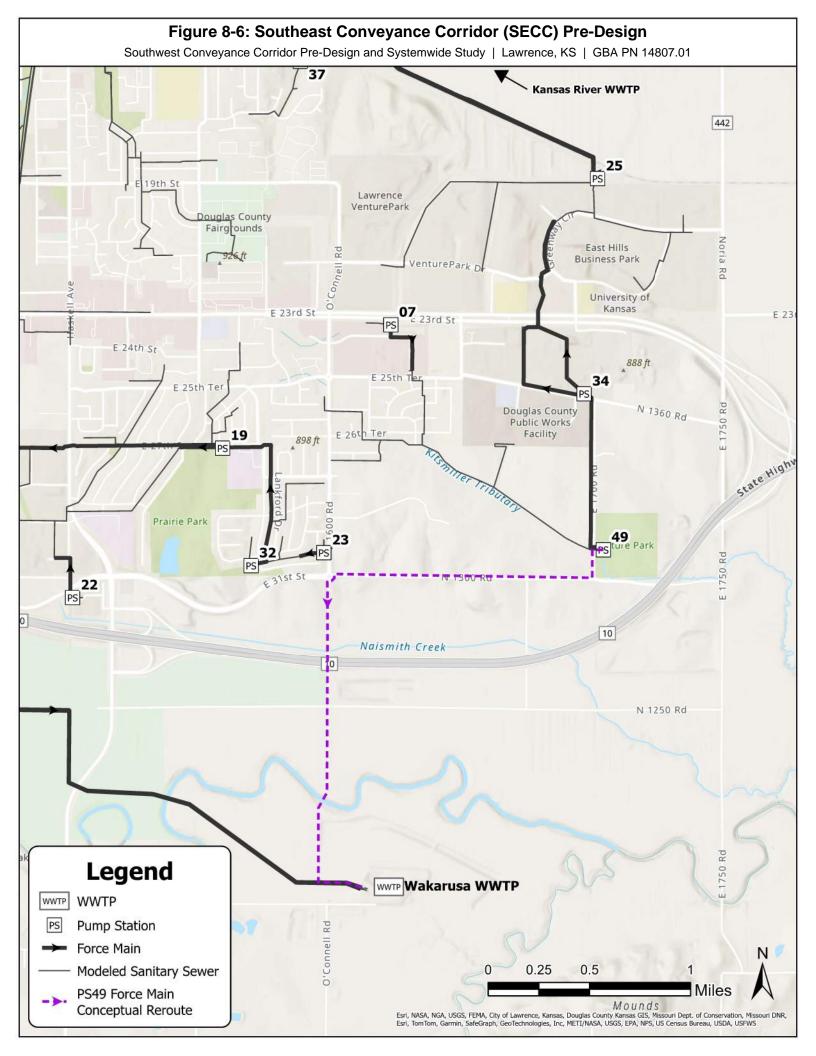
- PS49's capacity, condition, and its potential impacts on PS25 and the Wakarusa WWTP
- PS23 and PS32 and the potential to reroute or abandon these pump stations with a new regional pump station
- Gravity sewer deficiencies in the vicinity of PS32
- Future gravity sewer concerns in the vicinity of East Hills Business Park and updates to the VenturePark development assumptions

Justification

This project is largely growth-driven because there are few existing deficiencies that have been identified in the corridor. A large portion of the SECC remains undeveloped and has potential to be served by City sewers in the future. Timing the reroute of PS49's flows to Wakarusa WWTP is important for maintaining service in the SECC.

Conceptual Cost Range and Assumptions

- Pre-Design: \$0.3M \$0.5M
 - Approx. 4 flow meters, model calibration and analysis, alternatives analysis for PS23 and 32, and conceptual alignment of PS49's rerouted force main.
 - Options for a shorter, more direct force main route than the one depicted in Figure
 8-6 may be evaluated.
- Design and Construction of PS49's Reroute to Wakarusa WWTP: \$4M \$6M
 - Assumes the existing PS49 facility will remain in service, with pumps and piping being adjusted according to the new design.
 - Assumes a new force main alignment of roughly 13,300 feet that generally follows N 1300 Rd (31st St) and O'Connell Rd down to the Wakarusa WWTP.
 - Contingencies of unknown scale involving potential utility conflicts, a crossing under K-10, and a crossing under the Wakarusa River should be considered.



8.2.6 Fairgrounds Watershed Growth Study

Description

Primary Objectives: Study potential growth scenarios and identify necessary improvements to prepare the Fairgrounds Watershed collection system to meet future service demands.

Background: The Fairgrounds Watershed is a narrow watershed generally located south of 15th Street and north of 23rd Street, and east of Harper Street and west of O'Connell Road. It currently encompasses most of the Douglas County Fairgrounds, Harper Woods mobile home park (MHP), and Brookwood MHP. The southern (upstream) portions of the watershed are at least partially served by sewers in the Brook Creek watershed to the west, with flows from the two mobile home parks being conveyed through the Maple Lane and Brook Creek interceptors. Flow monitoring of the two MHPs in 2016 indicated the presence of excessive I/I. Most of the City-owned sewers serving the Fairgrounds Watershed are situated in the northern (downstream) portion, and are ultimately served by Pump Station 37, which pumps flows west towards the Brook Creek and Burroughs Creek interceptors.

While the Fairgrounds Watershed and PS37 are relatively small compared to other parts of the system, there are concerns that the existing infrastructure will not meet future service demands in the event of significant development or redevelopment. There are parcels of undeveloped land in the watershed, and there is also the possibility that one or both the MHPs would eventually be redeveloped. The City has received interest and a recent proposal for high density developments in the area, and the capacity of PS37 has been a point of discussion.

Recommended Approach: Future growth scenarios should be explored, and various sewer improvements should be analyzed to determine what will be needed to serve potential growth in the basin. Potential projects include:

- Expanding PS37
- Extending and/or upsizing the existing interceptors flowing to PS37
- Rerouting flows from the MHPs and Douglas County Fairgrounds

Justification

This study will prepare the City to successfully serve future developments in the basin.

Conceptual Cost Range and Assumptions

- Study Phase: \$0.1M \$0.2M
 - Two flow meters, model calibration and analysis, PS37 condition assessment and drawdown testing, alternatives analysis, and reporting.
- Design and Construction Phase: Unknown; will greatly depend on growth demands.

8.2.7 Model Fine-Tuning and Watchlist Monitoring

Description

Model Fine-Tuning

Primary Objectives: Investigate modeled deficiencies where there is lower confidence in model results; identify opportunities to improve the sanitary sewer model; field verify system hydraulics to address gaps and limitations in the existing model network. The location of each modeled deficiency to be investigated is shown in Figure 8-7, along with Watchlist Monitoring locations.

Background: Systemwide hydraulic model development and calibration was included under the SWCC scope of services. A limited number of calibration sites were scoped under model development. Calibration sites were selected from available flow meter site datasets (i.e., there were no new flow meters deployed during the SWCC pre-design). Flow meter sites chosen for calibration provided good coverage for calibrating the SWCC, but coverage was less dense in other portions of the system, such as the NWCC and Burroughs Creek Corridor. Although calibration was implemented for the entire system, it was determined that more dense coverage of flow meters in certain areas would benefit the model's functionality.

During model analysis, some portions of the collection system showed high risk capacity deficiencies (i.e., overflows and heavy surcharging) in places where City staff either have no record of issues or where the nearest calibration meter is located far downstream of the deficiency. In these situations, it is reasonable to have lower confidence in model results. Therefore, it is recommended to investigate these sites to either confirm or deny the presence of capacity issues. The sites include 8 gravity sewer deficiencies and 4 pump stations.

Recommended Approach: Targeted flow monitoring, field investigations, and City record checks are recommended to collect more information regarding the sites in question. With flow meter data, hydraulic grade line (HGL) analysis or modeling can be performed to check sewer capacities. Drawdown testing and SCADA checks at pump stations and field verifications of questionable pipe inverts and slopes are also recommended.

Watchlist Monitoring

Primary Objectives: Investigate low-risk capacity deficiencies identified during modeling on a regular basis to verify status and relative risk. Track potential capacity deficiencies that may be caused or exacerbated by upstream growth and development.

Background: During modeling of the sanitary sewer system, many locations throughout the system were predicted to surcharge during the 10-year, 6-hour design storm event. These locations of capacity deficiencies are summarized in Table 7-2 and Figure 7-1. However, the level of risk varies from site to site. All of the lowest risk deficiencies were compiled into a "watchlist"

for future monitoring. Deficiencies were generally considered low risk if the model did not predict significant surcharge or overflows, or the capacity issue only appeared in future growth model scenarios. Each watchlist location is shown in Figure 8-7.

Recommended Approach: Monitoring should be performed at regular intervals. Performing monitoring investigations once every five to ten years is considered adequate due to the low-risk nature of watchlist deficiencies, provided the City has no reason to believe any deficiency has worsened or any significant upstream development/redevelopment is proposed.

A stepped approach is recommended for investigations of watchlist deficiencies:

- Step 1 Field Visits and Record Checks: Each site on the watchlist should be visited. At least one manhole for every pipe segment predicted as surcharging should be opened and visually inspected for signs of debris or high-water marks indicating surcharge. Manhole checks should be targeted to areas where the model predicts surcharge to occur. City records (water in basement complaints, backups, etc.) should also be checked for each watchlist location.
- 2. Step 2 Flow Monitoring and HGL Analysis: If during Step 1 any signs of surcharge or capacity issues are found during field visits or record checks, then the City should pursue Step 2 investigations. At least one targeted flow meter may be installed towards the downstream end of each site requiring further review. Capturing flow meter data during at least three storm events with ≥0.5 inches of rainfall is recommended to estimate peak wet weather flows. Once flow data is collected, an HGL analysis may be performed to assess capacities and project a peak flow rate for the design storm event.
- 3. <u>Step 3 Preliminary Design</u>: If, after performing Step 2 HGL Analysis, any site is predicted to surcharge within three feet or less of a manhole rim during the design storm, then preliminary design of improvements should be initiated for that site.

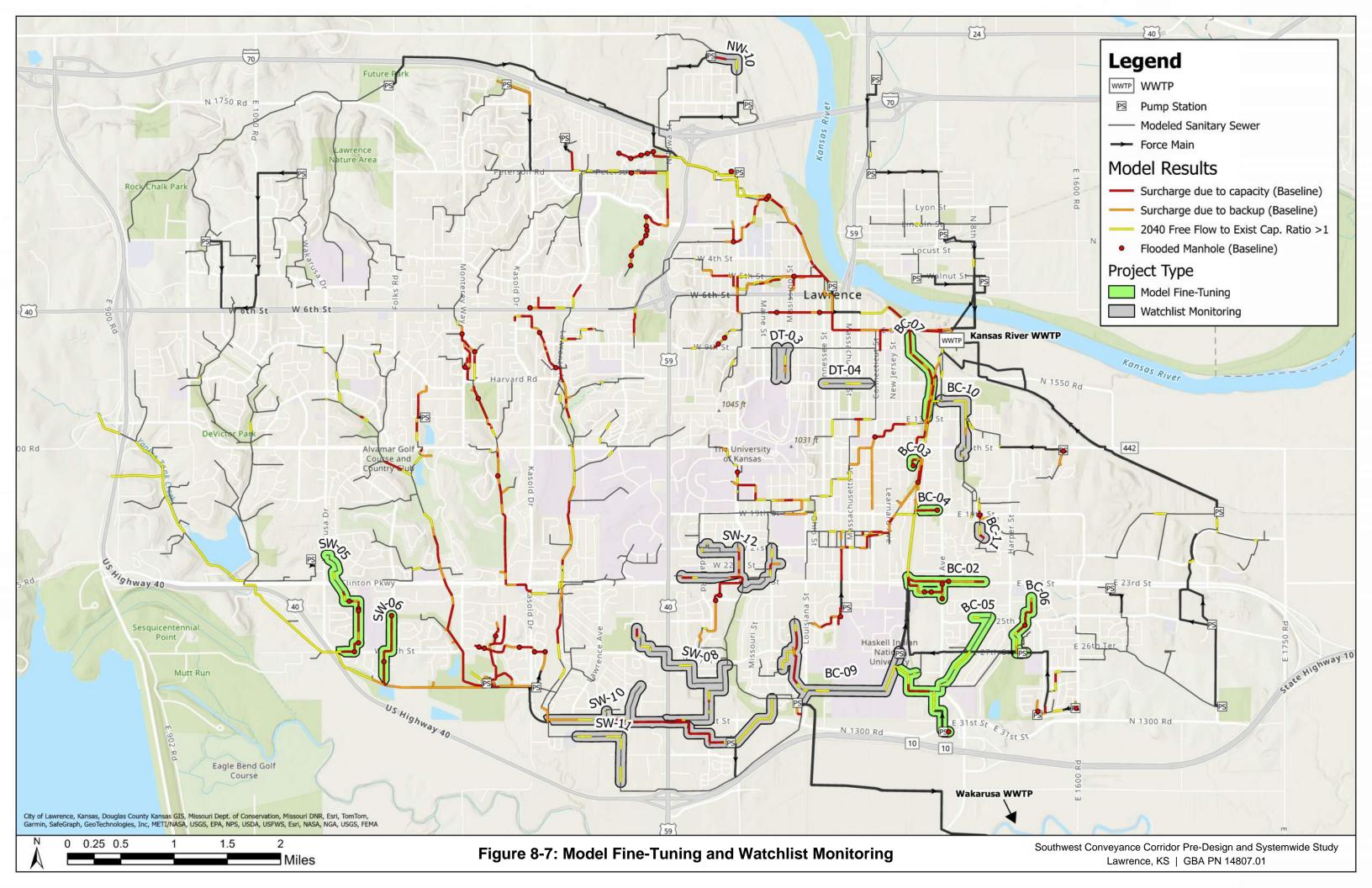
Justification

- Model Fine-Tuning: This study would improve the City's hydraulic model and help confirm
 or deny the necessity for capacity improvements. It is expected that capacity concerns will
 be eliminated or reduced at most of the sites listed.
- Watchlist Monitoring: Regular monitoring of lower-risk, modeled deficiencies is a proactive approach to ensuring system reliability and preventing costly backups and overflows.

Conceptual Cost Range and Assumptions

- Model Fine-Tuning:
 - Study Phase: \$0.2M \$0.4M
 - Roughly 10 flow meter sites, 8 HGL investigations, 4 pump station drawdown tests, field investigations, and reporting.

- Watchlist Monitoring:
 - Step 1 Field Visits and Record Checks: <\$0.1M
 - o Step 2 Flow Monitoring and HGL Analysis: \$0.1M \$0.2M
 - Step 3 Preliminary Design: Unknown
- Total Study Phase: \$0.3 \$0.7M
- Design and Construction: N/A, no improvements are anticipated in the near term.



8.2.8 General Pump Station Abandonment

Description

Primary Objectives: Reduce operations and maintenance (O&M) costs, reduce risk of mechanical or electrical failure, and eliminate aging equipment through pump station abandonment and new gravity sewer.

Background: The City has already begun studying options for abandoning select pump stations, such as PS07, PS34, PS43, and PS50. Abandonment of PS31 has also been considered. Figure 8-1 shows the locations of each pump station being considered for abandonment.

Recommended Approach: It is recommended that the City rank potential pump stations for abandonment in priority order and pursue abandonment as budget allows. It is also possible that certain pump station abandonments will be strategic or necessary for capacity or O&M reasons. For example, PS43 has historically caused operational issues and is located in an area with excessive I/I. Therefore, pursuing abandonment of PS43 may be higher priority than other pump stations.

Justification

Eliminating pump stations with gravity sewer is a beneficial practice that reduces O&M costs over the long term, reduces strain on City operational staff, and improves system reliability by avoiding reliance on mechanical systems.

Conceptual Cost Range and Assumptions

N/A. Preliminary studies have already been conducted. Costs and timing of abandonments will depend largely on City priorities and budget.

8.3 Projects Not Included

The projects included as part of this Systemwide Capacity Plan are focused on addressing known or suspected capacity deficiencies in the modeled collection system. The Systemwide Capacity Plan does not include other types of wastewater projects that are necessary to maintaining wastewater service. Projects excluded from this Systemwide Capacity Plan include, but are not limited to:

- Ongoing sewer extensions and improvements to serve growth.
- Specific accommodations for new wastewater connections by large users (such as heavy industrial or commercial land uses).
- Ongoing condition assessment and rehabilitation of the collection system.
- Ongoing operations and maintenance of the collection system.
- WWTP upgrades, expansions, or operations.
- Emergency repairs.
- Sanitary sewer hydraulic model maintenance and master plan updates (Please see Appendix C for further recommendations).

APPENDICES

Appendix A: Pump Station 9 Condition Assessment Technical Memorandum, April 2022

Appendix B: Model Development and Calibration Technical Memorandum, December 2024

Appendix C: Recommendations for Updating and Leveraging the Sanitary Sewer Model, December 2024

Appendix D: Task 5 Technical Memorandum – Southwest Conveyance Corridor Recommended Plan, May 2024

TASK 5 TECHNICAL MEMORANDUM

SOUTHWEST CONVEYANCE CORRIDOR RECOMMENDED PLAN

CITY OF LAWRENCE, KANSAS

MAY 2024





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APPENDIX

Memorandum: Southwest Conveyance Corridor (SWCC) Improvements Questionnaire, June 2023

ACRONYMS AND ABBREVIATIONS

ADDF Average daily dry-weather flow CIP Capital Improvement Plan

DIP Ductile iron pipe

ENR Engineering News-Record

EPA United States Environmental Protection Agency

FEMA United States Federal Emergency Management Agency

fps Foot per second GA Genetic algorithm

GIS Geographic information system

gpdpa Gallons per day per acre

HP Horsepower

K-10 Kansas State Highway 10

KDWP Kansas Department of Wildlife and Parks

LF Linear foot MG Million gallons

MGD Million gallons per day

MOEA Multiobjective Evolutionary Algorithm

NPV Net present value

NWCC Northwest Conveyance Corridor O&M Operations & maintenance

PS Pump Station PVC Polyvinyl chloride

RCP Reinforced concrete pipe

RDII Rainfall dependent inflow and infiltration

SWCC Southwest Conveyance Corridor SWMM Storm water management model (EPA)

SSOAP Sanitary sewer overflow analysis and planning

USACE United States Army Corps of Engineers

WWTP Wastewater treatment plant YTC Yankee Tank Creek

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DEFINITIONS

- **Binary Decision** "Yes" or "No" decision.
- **Exterior basin** sanitary sewer subbasin that contributes flow downstream and has no other tributary subbasins.
- **Free Flow Analysis** hydraulic modeling scenario in which all flow restrictions in the collection system are removed to represent a maximum, unrestricted flow condition.
- **Interceptor** largest type of gravity sewer main receiving wastewater from multiple trunk sewers and flows toward the wastewater treatment facility or pump station.
- **Interior basin** sanitary sewer subbasin that receives contributing flow from an upstream subbasin.
- **Node** modeled sanitary structure that is nonlinear. Examples include manholes, diversion structures, weirs, etc.
- **Northwest Conveyance Corridor** northwest portion of Lawrence's collection system, generally located north of 6th Street/US-59 and served by Pump Station 16
- **Optimization** an algorithmic approach to evaluate many different combinations of projects and identify the set of projects that produces the best performance as measured by a set of defined criteria.
- **Southeast Conveyance Corridor** southeast portion of Lawrence's collection system, generally located east of Burroughs Creek and served by Pump Stations 19, 25, and 49.
- **Southwest Conveyance Corridor** generally defined as the sanitary sewer interceptors beginning to the south and west of Lake Alvamar and continuing east through Pump Station 9 to Pump Station 10.
- **Subcatchment** a divided area of either existing or future sewered land used for modeling purposes.
- **Subbasin** a portion of the collection system monitored by a flow meter, and whose boundaries are defined by the downstream flow meter and any upstream flow meters.
- **Thiessen Polygon Method** used to estimate a uniform rainfall depth of precipitation across a drainage area or subbasin.
- **Unit Hydrograph** hydrograph used to provide an estimate of flow response in a sewer given an amount of precipitation.
- **Yankee Tank Interceptor** interceptor sewer that generally follows the Yankee Tank Creek in the southwest portion of the City.

1 INTRODUCTION

1.1 Introduction

This Task 5 technical memorandum summarizes the recommended set of improvements and phasing developed for the Southwest Conveyance Corridor (SWCC) in Lawrence, Kansas. The SWCC collects wastewater from approximately one-third of the City's total land area. The SWCC is shown in Figure 1-2, along with an overview of Lawrence's sanitary sewer system. The improvements for the SWCC are recommended to meet the level of service requirements of the separate sanitary sewer system for the 2040 planning horizon. This plan has been developed by the GBA and Black & Veatch (BV) team (referred to as Engineer) for and in partnership with the City of Lawrence Municipal Services and Operations Department (referred to as City) as part of Project MS-20-0015: Southwest Conveyance Corridor Improvements Study and Preliminary Design Phase.

This memorandum summarizes the work completed as part of Task 5 of the Engineer's scope of services for Project MS-20-0015 and provides a phasing plan necessary for scoping the initial design phase of SWCC improvements.

1.2 Other Tasks and Project Documentation

A summary of all other tasks completed as part of the Engineer's scope of services can be found in the report titled "Southwest Conveyance Corridor Pre-Design and Systemwide Study". Task items covered in that report include:

- Summary of Work Completed
- Pump Station 9 Condition Assessment (Separate Technical Memorandum)
- Summary of Hydraulic Model Development
- Summary of Projected Future Growth Conditions
- Systemwide Improvements Plan

The Systemwide Improvements Plan (Task 6) will utilize modeling results and recommendations from the Task 5 SWCC Pre-Design as presented in this Task 5 Memorandum.

1.3 Task 5 Purpose

The purpose of Task 5 of the Engineer's scope of services is to develop a recommended set of improvements and phasing for the Southwest Conveyance Corridor that will meet sanitary sewer service requirements for 2040 projected growth. To accomplish this purpose, the Engineer used the calibrated hydraulic model developed as part of Task 4 along with the Borg Multi-objective Evolutionary Algorithm (MOEA) for optimization purposes.

Optimization is an algorithmic approach to evaluate many different combinations of projects and identify the set of projects that produces the best performance as measured by a set of defined criteria. For this project, optimization involved running the hydraulic model thousands of times to test various improvement scenarios and identify the most optimal solution set. After identifying solutions from the optimization evaluations that would meet 2040 projected growth needs, the Engineer collaborated with City staff to develop a phased set of solutions for the SWCC that meet the long-term City goals.

A simple flow chart summarizing major stages of the project is provided in Figure 1-1. The stages of the Task 5 effort are circled and are the focus of this memorandum.

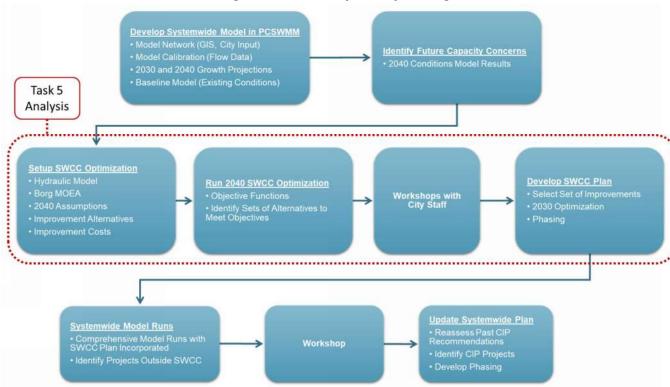


Figure 1-1: Summary of Project Stages

1.4 Background

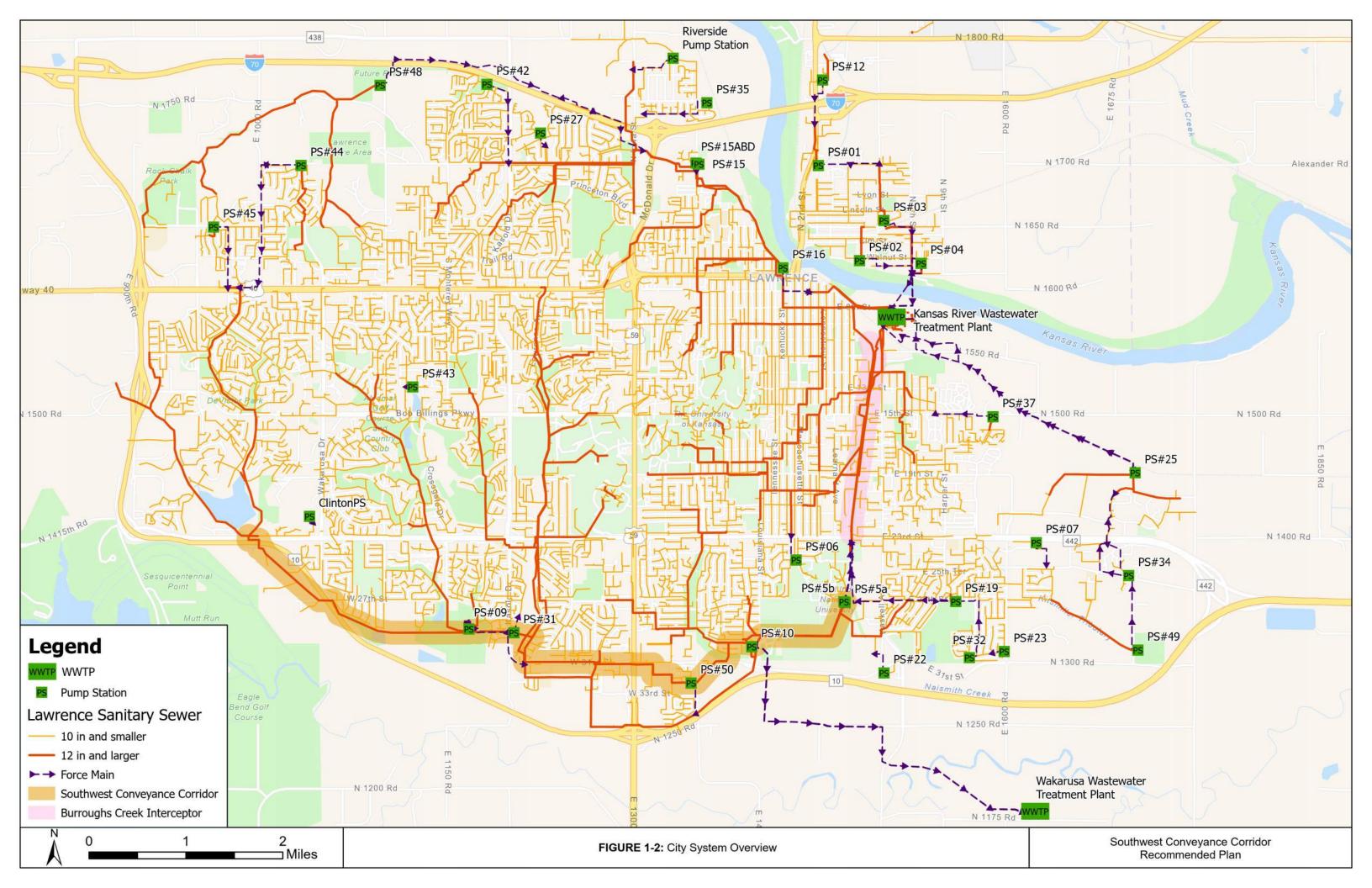
Project MS-20-0015 was initiated after the City had identified the need for wastewater conveyance system improvements within the SWCC. The SWCC is generally defined as the sanitary sewer interceptors beginning to the south and west of Lake Alvamar and continuing east through Pump Station 9 (PS9) to Pump Station 10 (PS10).

The SWCC sanitary sewer system receives flow from a large portion of western Lawrence. Approximately 8,200 acres of the city are currently served by the SWCC system, which is over

one-third (36%) of Lawrence's current land area within city limits. The SWCC has a substantial impact on other portions of Lawrence's sanitary sewer system. The Burroughs Creek Interceptor, which serves much of eastern Lawrence, and Pump Station 5 (PS5) are located directly downstream of the SWCC. However, there is a critical flow split upstream of PS5 at PS10.

Flows from the SWCC can either be sent to the Wakarusa Wastewater Treatment Plant (WWTP) via PS10 or conveyed past PS10 to the Kansas River WWTP via PS5 and the Burroughs Creek Interceptor. This makes PS10 a focal point in the system, where the flow split between the Wakarusa and Kansas River WWTPs is decided.

Planning and design for the Kansas Highway 10 (K-10) Expansion project occurred concurrently with this SWCC project. The City will need to relocate and replace some sewers and consider sizing of crossings to meet growth needs. As part of the SWCC project, planning level design flows and future tributary area discharge points were identified. These flows were used to size crossings to be installed prior to the K-10 Expansion. The City began design of these crossings under a separate contract (MS1-00001) and coordinated the design with the SWCC recommendations.



Previous studies, including the 2012 Integrated Wastewater Utility Plan, identified a need for improvements in the SWCC. The 2012 Plan primarily focused recommendations on expanding the pumping capacity of PS9. However, there have been more recent issues observed in the SWCC since 2012 that motivated the City to pursue this pre-design effort as part of Project MS-20-0015. Issues observed in the SWCC within the last several years include: PS9 having inadequate pumping capacity during large back-to-back storm events, sanitary sewer overflows and backups into homes upstream of PS9, poor condition of facilities at PS9 due to age, high wet weather flows due to inflow and infiltration (I/I), and challenges determining the optimal protocol for pumping and storing at PS9 during wet weather. There is also a concern that if PS9's capacity is significantly increased, the downstream system may not be able to handle the additional flow without improvements.

PS9 is considered a major collection point and bottleneck within the SWCC, where sanitary flows from a majority of the Yankee Tank Creek (YTC) watershed collects. The YTC watershed includes, among others, the Atchison Creek, Quail Creek, Inverness Creek, and Lake Alvamar sub-watersheds. Once flow reaches PS9, it is pumped downstream to the 36-inch diameter interceptor along 31st Street, which conveys flow to PS10. It should be noted that most sanitary flows from the Atchison and Quail Creek watersheds do not flow directly to PS9 but are allowed to divert to PS9 during high flow events via a pair of diversion structures near 29th Terrace and Atchison Avenue. The 31st Street Interceptor and another 24-inch diameter interceptor (referred to as the K-10 Interceptor) conveys most of the flow from the Atchison and Quail Creek watersheds towards PS10.

PS9 operates satisfactorily under dry weather conditions but struggles to meet demands under heavy wet weather conditions. As previously mentioned, this has historically led to overflows and sewer backups. Excess flows can be stored at PS9 during wet weather events at three storage basins. However, PS9's limited pumping capacity cannot adequately recover storage capacity after large storm events if the storage basins are full and storm events arrive in close succession.

PS9, previously known as the Four Seasons complex, was first constructed in 1974 along with Holding Basin #1 (approximately 1.25 MG of covered storage). A major update to the facility occurred in 1998 when Holding Basin #2 (approximately 2.5 MG of uncovered storage) and the current PS9 building were constructed. In 2011, Holding Basin #3 (approximately 2.5 MG of uncovered storage) was constructed for additional wet-weather storage capacity. A condition assessment of PS9 was conducted in the Spring of 2022 as part of Task 3 of the Engineer's scope of services for this project. Results of this assessment are summarized in *Technical Memorandum 1: Pump Station 9 Condition Assessment*, which was submitted to the City.

Besides existing challenges in the system, sanitary sewer service demands based on 2040 population projections exceed the current pumping and storage capacity at PS9. Population growth models developed by the City show a strong potential for growth west of K-10. Currently,

there is no major City infrastructure located west of K-10. Expansion of the sanitary sewer system will need to be proactive and responsive to meet the demands of westward expansion. For the purposes of this study, it was assumed the construction of a third WWTP west of K-10 is unfeasible due to regulatory concerns and topographical constraints. As such, the SWCC and NWCC will require additional capacity to convey flows from west of K-10 to either of the City's two existing WWTPs. Therefore, any improvements in the SWCC need to not only address issues within the existing system but also prepare the City to serve growth west of K-10.

In summary, the purpose of Task 5 was to develop a cost-effective plan for improvements along the SWCC that addresses both the needs of the existing SWCC system and the needs of future growth conditions.

1.5 Work Completed

Work completed in support of and prior to the Task 5 effort included:

- Data Collection and Review
- Pump Station 9 Condition Assessment (Fitness for Service, Detailed Assessment, Site Visits, and Draw Down Testing)
- Hydraulic Model Development and Calibration
- Development of Future Growth Projections for Model Simulation
- Initial Model Runs of Existing Conditions, 2030 Growth Conditions, and 2040 Growth Conditions

Work completed and summarized in this Task 5 Memorandum includes:

- Prepare Optimization Model of SWCC Sewer System
- Prepare Baseline Model that Includes Recent Projects
- Establish Cost Curves for Types of System Improvements (Relief sewers, pump station installation, force main installation, equalization basins)
- Establish Alternatives for Optimization Runs including Rerouting Sewers
- Prepare Future Growth Modeling Scenarios for 2030 and 2040
- Conduct Workshops with City Staff to Evaluate Optimization Results and Establish Direction
- Determine Recommended Plan for SWCC
- Prepare Phasing Plan for SWCC Improvements

2 OPTIMIZATION MODEL SETUP

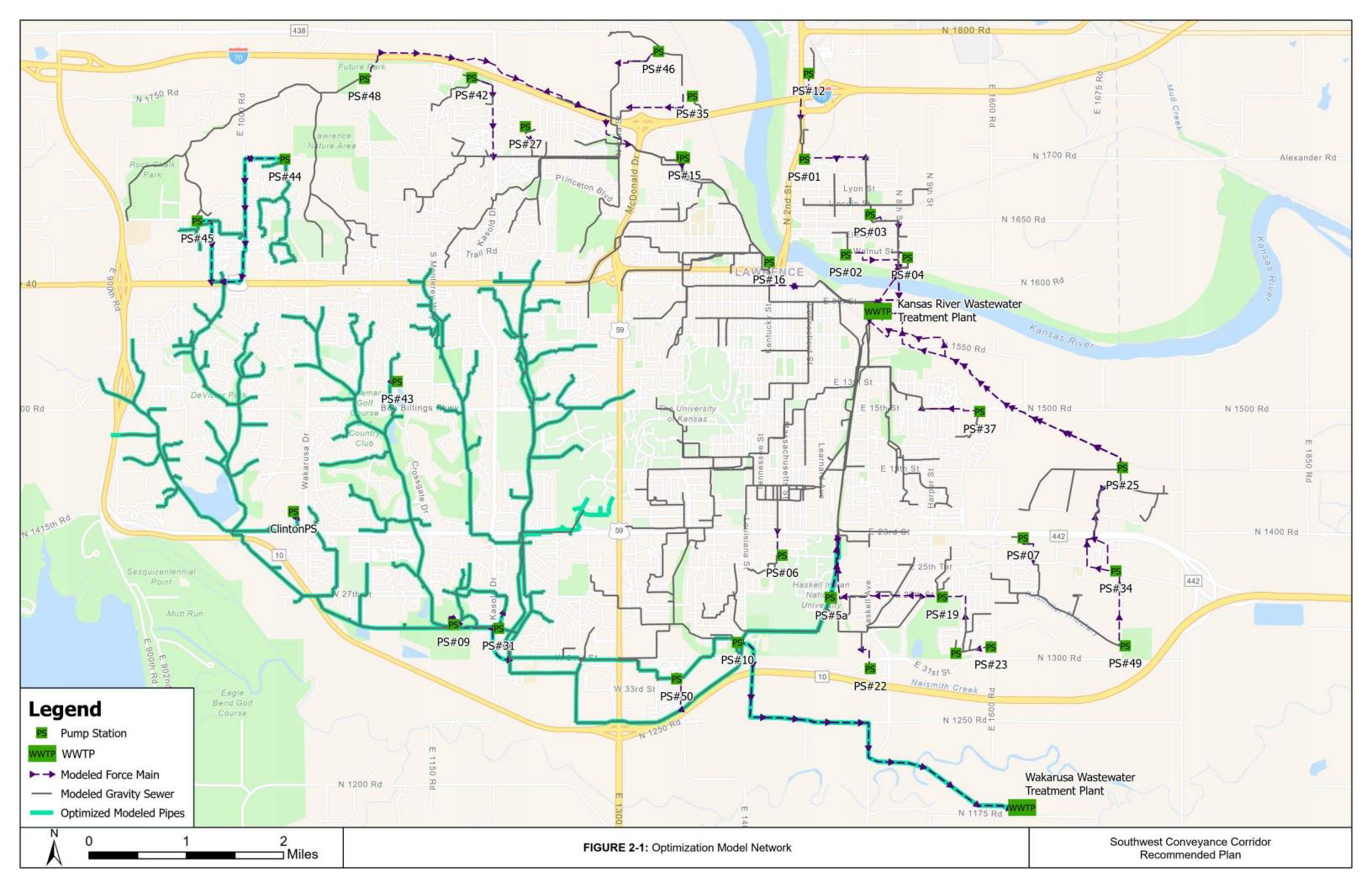
The goal of this project is to identify logical and cost-effective improvements for the SWCC that will meet the service demands of 2040 growth projections. To accomplish this goal, optimization was chosen as the means for evaluating many potential improvement alternatives dispersed throughout the SWCC. Optimization provides an automated and efficient means for evaluating many combinations of improvement alternatives within a digital model environment. Further discussion of the optimization process is provided in Chapter 5. As part of Task 5, the Engineer performed optimization of the SWCC under 2030 and 2040 growth conditions using the hydraulic model developed as part of Task 4.

However, before optimization could be performed, the hydraulic model needed to reflect several key assumptions about the future collection system. This chapter provides details of the assumptions that went into setting up the hydraulic model for 2030 and 2040 optimization.

2.1 Hydraulic Model

To perform optimization and develop improvement recommendations for the SWCC, a systemwide model was developed and calibrated in the PCSWMM hydraulic and hydrologic modeling platform. A more detailed summary of the hydraulic model can be found in the Southwest Conveyance Corridor Pre-Design and Systemwide Study. The model network was generally limited to pipes and manholes serving at least 20 acres. Historical flow and rainfall monitoring data were used to calibrate the hydraulic model to observed dry and wet weather conditions. Using the calibrated model, a design storm model was developed using a 10-year, 6-hour design storm event (NOAA Atlas 14) with 3.97 inches total rainfall. The model has been a crucial tool in the development of the SWCC plan. The model was used to identify capacity issues in the SWCC, develop potential improvement alternatives to be evaluated in optimization, and was run in conjunction with Borg MOEA.

Although a systemwide model was developed and calibrated that covers the existing Lawrence service area, a unique model was developed for optimization of the SWCC improvement alternatives that excluded much of the sewer system not directly impacting the SWCC. An overview of this SWCC-focused model network used for optimization can be found in Figure 2-1.



To convert the calibrated model (representative of existing conditions) to the 2030 and 2040 growth conditions models, updates were required. These updates ensured the models reflected assumptions about conditions and major changes expected to occur by the 2030 and 2040 planning windows. These updates are described below. The following updates and changes to the model were not treated as improvement alternatives during optimization but were instead hard coded into the hydraulic model's structure.

2.2 Recent Projects and "Baseline" Model

The hydraulic model was calibrated using flow meter data from 2019 and 2020 and is reflective of system conditions at that time. However, two recent changes to the City's collection system were considered important enough to incorporate into the model prior to optimization. These changes are the construction of the Naismith Valley interceptor and the design of The Crossing at KU development. The resulting model update was referred to as the "Baseline" model, as it represents a baseline for assessing the more recent post-calibration flow conditions. The Baseline model was considered representative of existing conditions in the SWCC.

The Naismith Valley interceptor project, constructed in 2022, connects the Naismith subbasin and the SWCC. This interceptor allowed for PS8 to be decommissioned and removed from service. This project was recommended as part of the 2012 Integrated Wastewater Utility Plan. Prior to decommissioning, PS8 would pump flow from the upper Naismith basin into the Burroughs Creek basin, downstream of PS5. Now, the Naismith Valley interceptor conveys flow by gravity toward PS10. PS8 was still in service during the 2019 and 2020 flow meter seasons used for calibration. Therefore, the calibrated model needed to be updated to reflect current-day flows from the Naismith Valley interceptor into the SWCC.

The Crossing at KU is a large, mixed-use development that will be constructed on the University of Kansas (KU) campus at the northwest corner of 23rd Street and Iowa Street. This development is expected to significantly increase wastewater flows within the Atchison Creek basin, which flows into the SWCC. The development will connect to the existing sanitary sewer system in the vicinity of Clinton Parkway and Atchison Creek. The Baseline model was updated to reflect the impact of this development.

2.3 Pump Station 50 (PS50) Abandonment

At the City's request, it was assumed that Pump Station 50 (PS50) would be removed from operation by the year 2040. PS50 was installed to service an apartment complex ("The Connection at Lawrence") and to direct flow to the 24-inch diameter interceptor parallel to K-10. A 36-inch interceptor, which conveys flow from PS9 to PS10 generally along 31st Street, passes within 20 feet of PS50. At the time of construction, the 36-inch interceptor was determined to be at capacity and was unable to convey the additional flow. However, PS50 was built with the understanding that it could be decommissioned and removed from operation once additional

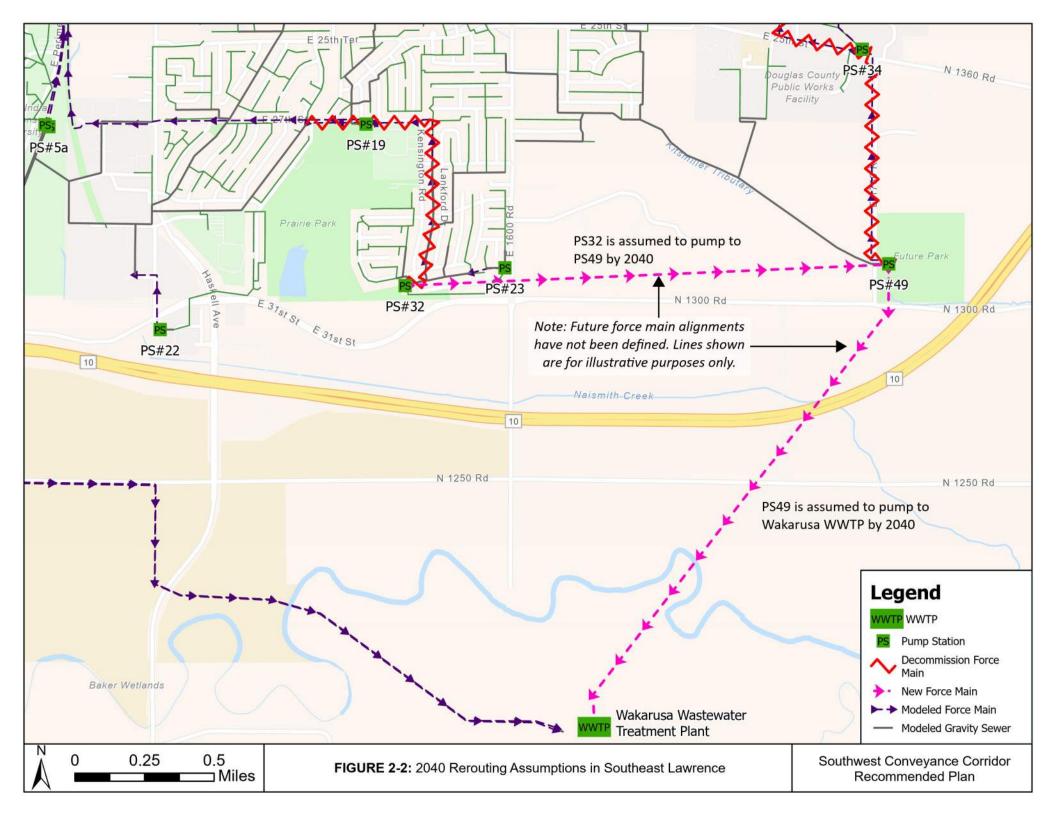
improvements were made in the SWCC. The project to decommission PS50 was not considered as a SWCC improvement alternative because it is expected to be implemented regardless of other SWCC improvements. Therefore, the 2040 conditions hydraulic model excludes PS50 and shows its flow being directed to the 36-inch interceptor.

2.4 Future Conditions Rerouting Assumptions

The Southeast Conveyance Corridor (SECC) is the southeast portion of the City's collection system, generally located east of Burroughs Creek and served by Pump Stations 19, 25, and 49. PS49, located northwest of the intersection of N 1300 Road and the K-10 overpass, currently pumps north toward PS25, which is located on the north side of the Lawrence VenturePark business park. PS25 collects and pumps a majority of SECC flows to the Kansas River WWTP. However, PS49 was designed with the option of eventually rerouting flows south toward the Wakarusa WWTP. However, no sewer force main currently exists between PS49 and the Wakarusa WWTP. The option of pumping from PS49 to the Wakarusa WWTP was considered due to capacity constraints expected at PS25.

PS32, located near the intersection of 30th Street and Kensington Road, currently pumps flows north from the Prairie Park basin toward PS19, which then pumps toward PS5 and the Burroughs Creek interceptors. As part of a previous study, a conceptual pump station was considered at the northeast corner of N 1300 Road and O'Connell Road, which would receive flow from PS32 and PS23 and send it to PS49.

Because PS32 is expected to eventually pump to PS49 and PS49 is expected to eventually pump to the Wakarusa WWTP, the City decided to assume that both these pump stations would be rerouted by 2040. Therefore, PS32 pumps to PS49 and PS49 pumps to the Wakarusa WWTP in the 2040 conditions hydraulic model. These assumptions about the SECC have implications for the SWCC because the capacity at the Wakarusa WWTP influences the types and capacities of improvements that might be acceptable upstream of the Wakarusa WWTP. As more treatment and storage capacity is used up at the Wakarusa WWTP by flows from PS49, flows from the SWCC to the Wakarusa WWTP may need to decrease accordingly. This reduction in available treatment capacity at the Wakarusa WWTP is therefore taken into account in the 2040 conditions hydraulic model. It is also taken into account that the Wakarusa WWTP capacity will be expanded by 2040 to accommodate more flows. The rerouting assumptions for the SECC are shown in Figure 2-2.



2.5 Wakarusa WWTP Capacity Expansion

The Wakarusa WWTP site was designed to accommodate two parallel treatment trains, but currently has only one constructed and operable treatment train. The second treatment train was planned to be phased in later when treatment demand required it. The City decided to assume that the second treatment train would be built at Wakarusa WWTP by 2030 to accommodate growth and increased flows in the SWCC. By adding the second treatment train, the plant's capacity would be able to handle PS10's pumping capacity as well. This assumption regarding the Wakarusa WWTP's capacity increase by 2030 was built into the 2030 and 2040 model scenarios.

2.6 Wakarusa WWTP and Pump Station 10 Operational Assumptions

Operational set points were established within the hydraulic model to account for future capacity changes at the Wakarusa WWTP. The current capacity of PS10 is 12.5 MGD, while the Wakarusa WWTP has a wet weather capacity of 7.5 MGD. Since there could be more flow coming from PS10 than could be treated at the WWTP, there is a 5 MG storage basin at the WWTP. As mentioned above, the Wakarusa WWTP capacity will be increased in the future by adding another treatment train, which will bring the plant's capacity to 12.5 MGD. For the model scenarios covering 2030 and 2040, the Wakarusa WWTP was assumed to have a capacity of 12.5 MGD.

PS10 takes flow off the main interceptors upstream of PS5, offloading the interceptor system that conveys flow to the Kansas River WWTP. During the calibration period model simulations (spring and summer of 2019 primarily), the flow from PS10 to the Wakarusa WWTP were included as a pumped flow determined by the observed data. For the simulation of future conditions, a wet weather operational plan was implemented to reflect the current operational preference of maintaining a baseflow average at the Wakarusa WWTP. 2.5 MGD baseflow is pumped from PS10 to Wakarusa WWTP, which allows the WWTP to operate in a near steady state condition. This operational procedure is assumed to continue in the 2030 and 2040 model scenarios.

During wet weather, more flow is pumped by PS10 to the Wakarusa WWTP. For the baseline, 2030, and 2040 model simulations, this is accomplished by pumping more flow at PS10 when the flow at PS5 increases. Table 2-1 presents the PS10 pump rules used in the hydraulic model to control flows to the Wakarusa WWTP.

Table 2-1. PS10 Pump Control Rules

Flow to PS5 (MGD)	PS10 Flow (MGD)
< 5	2.5
≥8	5
≥ 10	7.5
≥ 10 And Wakarusa Storage Available	12.5

2.7 Pump Station 5 Capacity Limitation

PS5 is located near Haskell Indian Nations University (HINU), downstream of PS10. It is the most downstream point included in the SWCC optimization model network. PS5 is important to the SWCC because it conveys the flows that cannot be conveyed by PS10. PS5 pumps northward into the Burrough's Creek interceptors, which eventually terminate at the Kansas River WWTP.

For the purposes of modeling and optimization, it was assumed that PS5 would not pump any more flow than it is able to pump today. There were several reasons for this assumption. City staff indicated during workshop meetings that they had difficulty increasing the pumping capacity of PS5 beyond its current capacity when attempting to do so previously. There are downstream limiting factors that constrain the ability to upsize PS5, such as the parallel interceptors that run underneath of 23rd Street, just downstream of PS5's force mains. City staff indicated that the difficulty of upsizing PS5 was part of the reason the Wakarusa WWTP was built, and that PS10 would relieve PS5 of that pumping burden. Finally, there are site footprint limitations. PS5 is built on HINU land and is located adjacent to a cemetery owned and maintained by HINU, so attempting to expand PS5's footprint would be challenging. Therefore, the City decided it would be most conservative to assume that PS5's maximum capacity of approximately 15 MGD will remain the same for the purposes of optimization.

3 SELECTION OF IMPROVEMENT ALTERNATIVES FOR OPTIMIZATION

Specific improvement alternatives (also referred to as projects or decision variables) were chosen for evaluation in optimization. These projects reflect conceptual alternatives for addressing SWCC capacity issues identified during modeling of 2040 growth conditions. Optimization will allow for the efficient and comprehensive evaluation of the many possible combinations of these improvement alternatives.

3.1 Initial Model Results

Prior to developing improvement alternatives for optimization, several hydraulic model scenarios were run to identify sanitary sewer infrastructure within the SWCC that may require improvements. The Baseline, 2030, 2040, and 2040 Free Flow model scenarios were run and reviewed to identify trends in hydraulic capacity.

3.2 Improvement Alternatives Workshop

The Engineer hosted a workshop with key City staff on February 9, 2023 to define the list of SWCC alternatives to be evaluated using the Borg MOEA optimization software. Optimization setup, parameters, and assumptions were also reviewed with the City. Several subsequent workshops were held after the February workshop to confirm and further define the alternatives and assumptions prior to running the optimization engine. The improvement alternatives presented in this chapter were developed and refined using City staff feedback and insight collected during these workshop meetings.

3.3 Gravity Sewer Improvement Alternatives

Gravity sewer improvements can encompass either upsizing via replacement of the existing sewers with larger pipe or adding in parallel piping to provide hydraulic relief of the overloaded lines. However, the gravity sewer options considered in optimization for the SWCC assume replacement sewers. It was decided by the City at the February 9, 2023 SWCC workshop that replacement sewers are preferred in most cases over parallel sewers. Parallel sewers will only be considered during design in project areas where parallel sewers may be more practical than replacement sewers.

The evaluation process for gravity sewer replacement began by identifying overloaded sewers in the 2040 model scenario. This was accomplished by determining the sewers projected to have higher peak flows than available capacity. The peak flows were determined using a free flow model of 2040 conditions while sewer capacity was estimated using Manning's equation for gravity sewers. A free flow model has adequate sewer and pump station capacity to prevent flow restrictions while still fully utilizing dedicated storage facilities, such as PS9 holding basins. There

were over 300 gravity sewer segments in the SWCC identified as being undersized during projected 2040 growth conditions.

Once the overloaded gravity sewers had been identified, each was considered a binary decision variable for optimization. In each case, the overloaded gravity sewers could remain the same diameter or be increased to the 2040 free flow diameter, which would provide adequate capacity to convey the 2040 free flow peak. The optimization algorithm can cycle through thousands of combinations of gravity sewer relief combinations to determine which sewers need to be replaced to achieve the lowest cost, prevent surcharging, and avoid overflows.

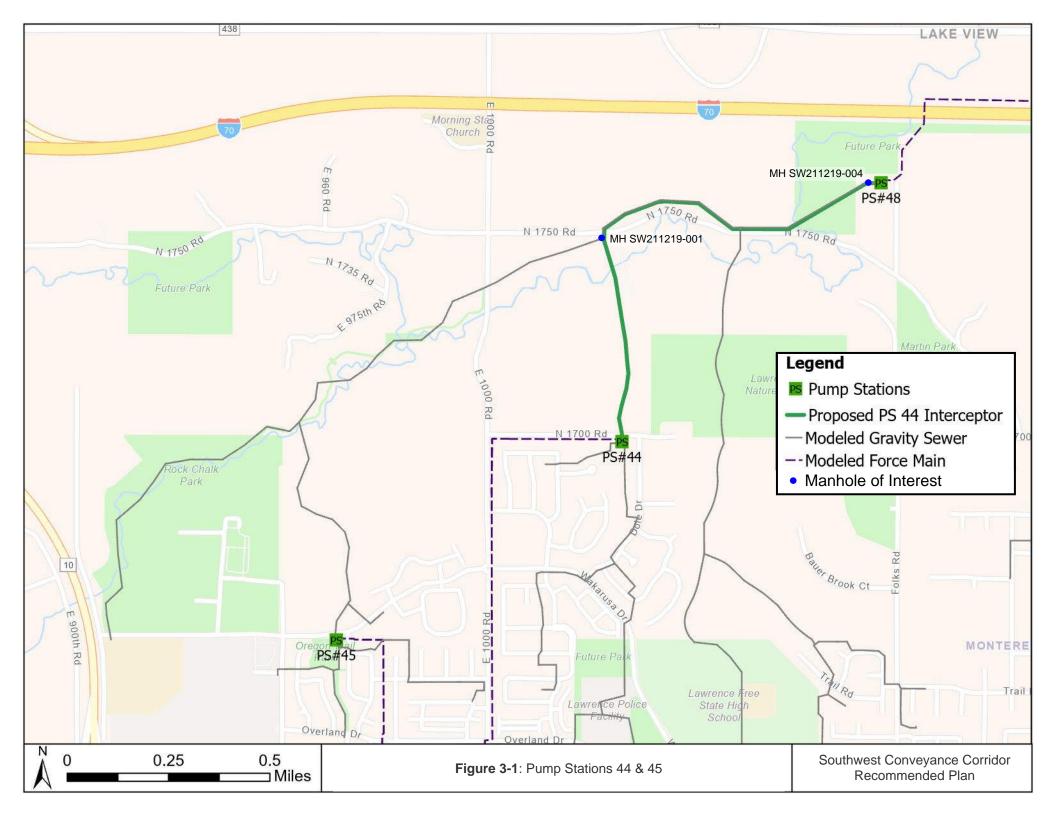
3.4 Rerouting Alternatives

3.4.1 Rerouting PS44 and PS45 to NWCC

PS44 and PS45 are located north of 6th Street, along N 1700 Road and Rock Chalk Drive respectively. These pump stations serve portions of the Baldwin Creek watershed, and pump into the SWCC via the interceptor east of Lake Alvamar. These pump stations are shown in Figure 3-1.

It was decided that projects in the Northwest Conveyance Corridor (NWCC) will not be optimized because the NWCC is outside the scope of this project. However, rerouting PS44 and PS45 will be considered in the optimization because these pump stations currently contribute to the SWCC. If these stations remain in service, flow will continue to be directed to the SWCC. If these stations are rerouted to the NWCC, the combined flow will be removed from the SWCC, freeing up capacity there. PS48 has capacity to receive flow from PS44 and PS45 during dry weather events. However, the City chose to assume that wet weather flows will need to be stored at PS48 by 2040 due to downstream constraints within the NWCC. The City requested GBA and BV factor in the cost of storing the excess wet weather flow from PS44 and PS45 and the cost of a new gravity sewer from PS44 to PS48 when setting up the alternative in optimization. This alternative was built into the optimization algorithm as an "on/off", or binary, decision variable.

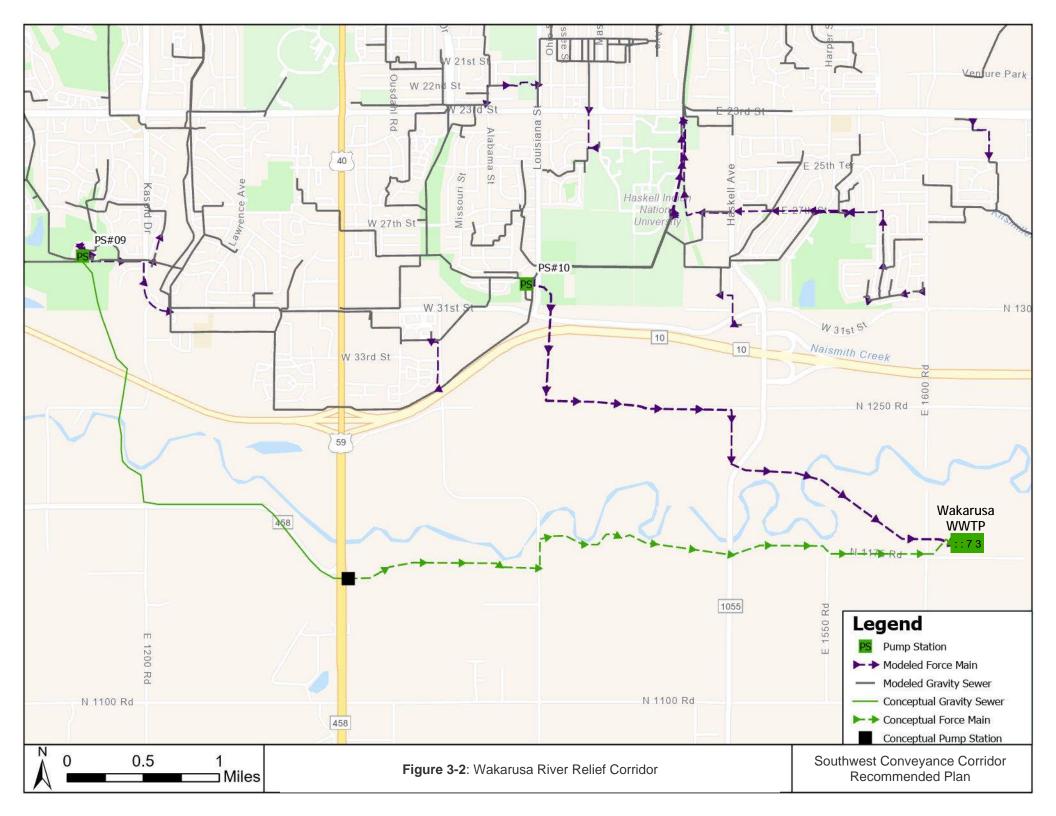
The preliminary route analyzed for the proposed PS 44 interceptor, as shown in Figure 3-1, travels north from PS44 and begins to run parallel to the existing gravity sewer from MH SW211219-001 to where it connects into the existing line at MH SW211219-004. This route paralleling the existing interceptor was chosen by the City due to uncertainty regarding financing implications and capacity impacts of connecting directly to the existing Baldwin Creek interceptor.



3.4.2 Wakarusa River Relief Corridor

The Wakarusa River Relief Corridor, shown in Figure 3-2, was conceptualized as an alternative to storing more at PS9 or upsizing interceptors between PS9 and PS10. This corridor would bypass the congested areas between PS9 and PS10 by rerouting flow from PS9 south, crossing the Wakarusa River and then pumping directly to the Wakarusa WWTP. The high-level conceptual alignment would take flow south by gravity from PS9 to a conceptual pump station south of the river, near US Highway 59. The pump station would then send flow east via force main to the Wakarusa WWTP. This alternative routing ties into the existing system just upstream of the PS9 wet well.

This alternative was previously considered as part of the initial Wakarusa WWTP siting and design study. When developing a conceptual alignment, the Engineer evaluated several possible routes to identify the most direct route. Alignment considerations included established wetlands, private property, K-10 and US Highway 59. Additionally, the gravity sewer would need to be deeper than 50 ft in some sections to extend under the Wakarusa River with adequate clearance between the top of the pipe and the bottom of the riverbed. The City and Engineer eventually chose a route that seemed least costly and least disruptive. It is important to note that this alternative would have the added benefit of extending City sewers south of the river.



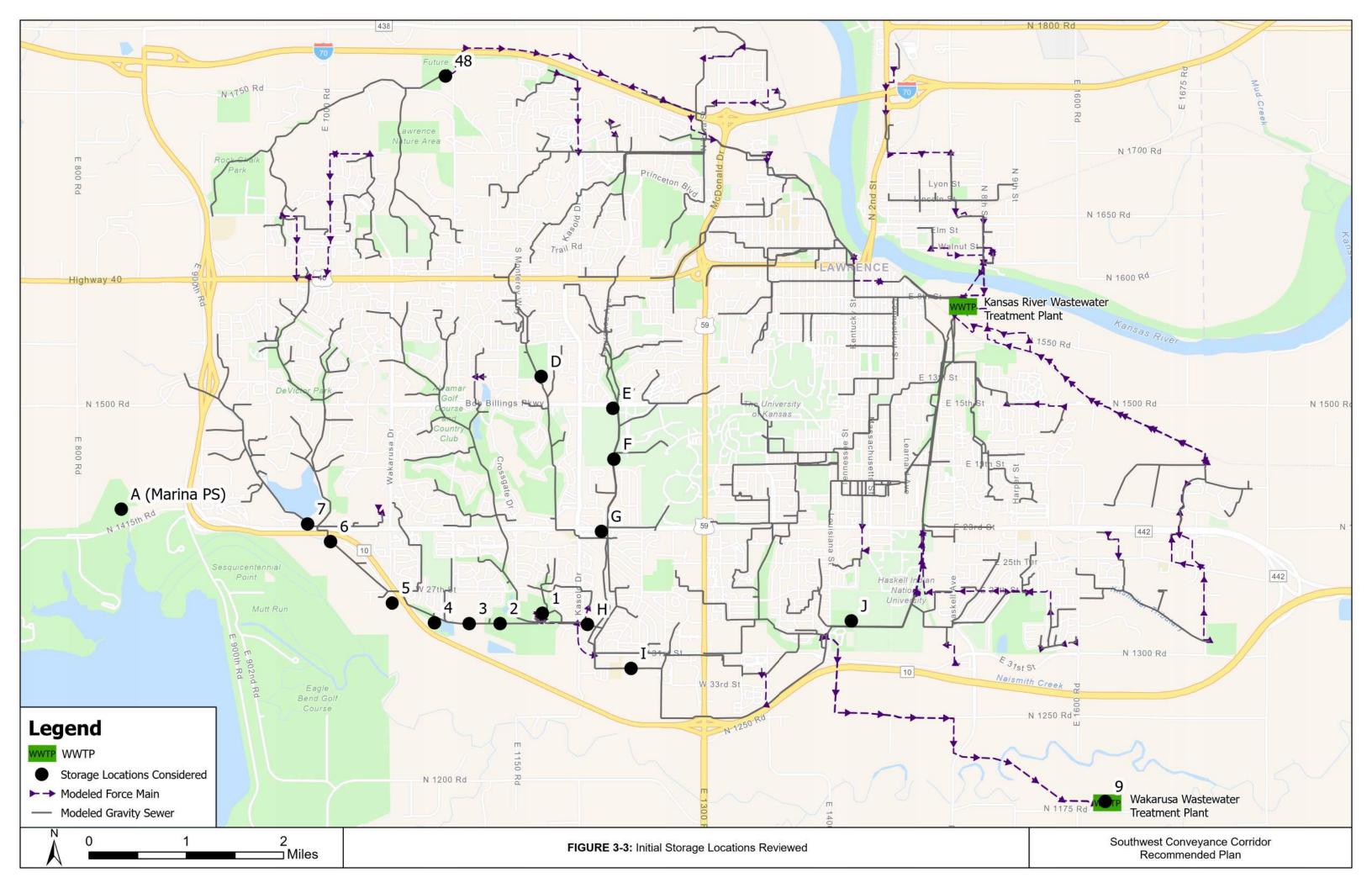
3.4.3 Diversion Structure Downstream of PS9

A conceptual diversion structure at the downstream end of the PS9 force main (MH NW141319-501) was chosen for evaluation in optimization. This structure would allow flow from PS9 to be directed away from the overloaded 36-inch interceptor along 31st Street and into the 24-inch K-10 interceptor that passes within 50-feet of the existing PS9 force main discharge point. This flow split would reduce capacity concerns in the 36-inch interceptor by leveraging the available capacity in the 24-inch interceptor.

3.5 Storage Alternatives

Alternative locations for storing wet weather flows were considered for optimization. PS9 currently has three storage basins (two uncovered and one covered) that can store a total of approximately 6.25 MG. The City and Engineer selected potential storage sites along SWCC interceptors where overloading may occur in 2040 conditions. Nine locations were initially identified at the October 2022 workshop. These sites were suggested based on a high-level review of sites with favorable conditions, such as being owned by the City or being distant from permanent residences. An additional ten locations were selected by the City and the Engineer in advance of the February 2023 workshop. These sites are considered to have strategic hydraulic influence on the system, both now and in 2040. The nineteen potential storage sites were then presented to the City stakeholders at the February 2023 workshop for feedback.

The numbered locations in Figure 3-3 were identified at the October 2022 workshop based on ideal site conditions, and the lettered locations were chosen in advance of the February 2023 workshop based on strategic influence on system hydraulics.



Three locations were immediately discarded during the February 2023 workshop based on City feedback. These locations were in places of higher risk, including a golf course, a previous landfill site, and residential backyards and possible preserved habitat. The remaining 16 storage locations were then compared and ranked based on the criteria provided below in Table 3-1.

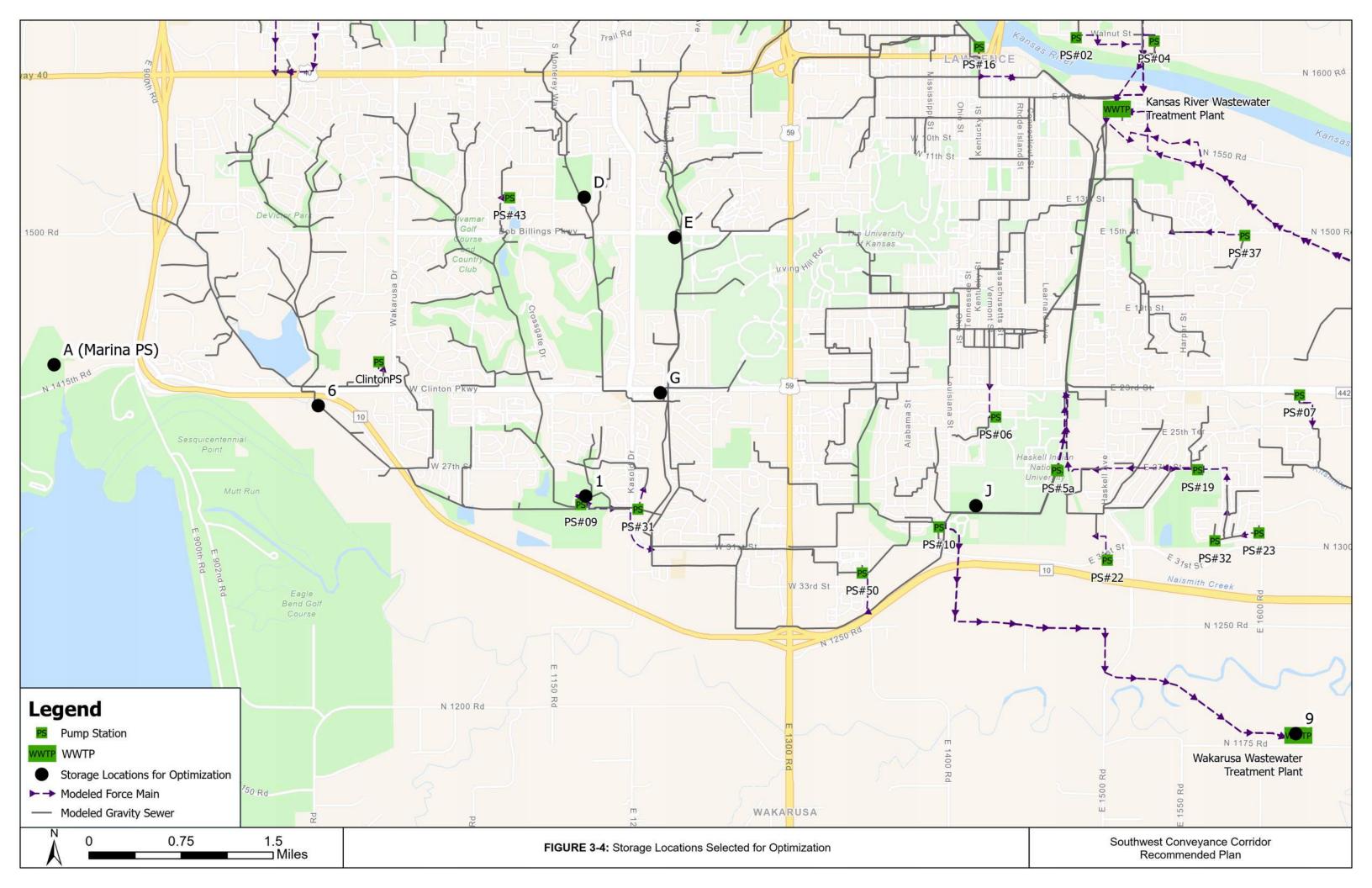
Oct. 2022 Sites Feb. 2023 Sites Criteria Weight New Site Number/Letter Α D Е F G Н J Uncovered City Owned Property Strategic Hydraulic Location No Floodway Constraints Proximity to Housing >750 ft Total Rank 11 | 11

Table 3-1: Storage Location Ranking Factors

The City chose to favor uncovered storage locations because they have been historically easier to maintain and safer to access than covered storage basins. City owned property was picked as an ideal characteristic due to availability of land. Flood way constraints were evaluated to ensure locations would not be inundated during wet weather events and regulatory hurdles could be avoided. A 750-foot or greater proximity to housing was favored to minimize nuisances to nearby homes. Strategic hydraulic location was more heavily weighted than other criteria, as these locations were expected to supply the most hydraulic relief to the system during 2040 wet weather conditions. A final list of the eight highest ranking locations were provided to the City for final approval for optimization in March 2023.

Once the final set of locations were selected, an estimate of available surface area was found for each location using GIS analysis of Lawrence Parcel and FEMA floodway data. This provided the approximate surface area needed for optimization to size the potential storage basins. The optimization algorithm can size each basin depending on the amount of excess wet weather flow needing to be stored. The final locations chosen for optimization are shown in Figure 3-4.

^{*}Highlighted sites indicate they were selected as an optimized storage location.



3.6 Pumping Improvement Alternatives

3.6.1 Pump Station 9 (PS9)

There are two main options to handle the excess flow observed at PS9 during storm events: either increase the pump station capacity or add additional storage. Both options have disadvantages. Adding more pumping capacity at PS9 will likely require additional downstream system expansion to handle the additional flows, while adding more storage increases the recovery time of the system. Both options were considered in the optimization evaluation.

Using the 2040 conditions model, it was determined that a total pump station capacity of 15 MGD would be needed to avoid overflows with PS9's existing storage capacity. If PS9 pumping capacity remained at 9.28 MGD, additional storage would be needed. This additional storage would require more space for the new facilities, and the available space near PS9 was estimated at over 7 acres. It was assumed that the depth of the storage facilities would be similar to existing holding basins 2 and 3.

3.6.2 Pump Station 10 (PS10)

Currently, PS10 has a maximum discharge rate of 12.5 MGD. PS10 can either pump flows to the Wakarusa WWTP or allow flows to continue downstream to PS5 to be pumped to the Kansas River WWTP. As described in Chapter 2.7, PS5's maximum capacity was assumed to be limited to 15 MGD. Therefore, PS10 should allow no more flow be sent to PS5 than what PS5 is able to convey (15 MGD). Any flows in excess of PS5's 15 MGD capacity would need to be pumped to the Wakarusa WWTP via PS10.

There are four 200 HP pumps available at PS10, with three operating full time and one on reserve in the event of a failure. There is room for additional pumps within the facility, as the initial design accounted for future expansion to six pumps total. To meet the demands of 2040 population growth, PS10 will most likely need to expand its discharge capacity.

Three sequential expansion projects have been suggested to meet the required future pumping demand at PS10. These projects are anticipated to be completed in phases, as flow conditions require. The PS10 improvement projects evaluated are:

- Improvement Project 1 Add two additional 200 HP pumps, increasing the total capacity to 17 MGD.
- Improvement Project 2 Install six new 250 HP pumps in place of the existing 200 HP pumps, increasing the total capacity to 21 MGD.
- Improvement Project 3 Add an additional 30-inch force main to the existing force main corridor, increasing the total capacity to 26-28 MGD.

The assumption with these projects is that treatment and storage at Wakarusa WWTP would need to increase in tandem with PS10's discharge capacity. All three improvement projects rely on the installation of the second treatment train at Wakarusa WWTP.

3.6.3 Alternatives Not Selected (Lake Alvamar Pump Station)

The 2040 free-flow analysis showed that the inclusion of Marina watershed flows would overload the interceptors running along the west side of Lake Alvamar, assuming existing interceptor sizes. Solutions considered to address this overloading included construction of a pump station and force main to pump flow to the east side of Lake Alvamar where there is significant available capacity in the existing interceptors. A high-level analysis was performed to estimate the cost of installing a new pump station and force main to convey the Marina watershed flow to the east side of Lake Alvamar. This option was compared to the cost of upsizing the interceptors on the west side of Lake Alvamar. A high-level cost/benefit analysis showed that pumping flow to the east of Lake Alvamar would be cost prohibitive and would likely entail complicated property owner negotiations.

Another option considered to handle flow from the Marina watershed was pumping to the Baldwin Creek interceptor to the north, sending the Marina watershed flow to the NWCC instead of the SWCC. It was decided with the City that the significant distance and costs associated with a project of that scale made it unfeasible, and was thus excluded from consideration.

4 COST ASSUMPTIONS FOR OPTIMIZATION

In preparation for optimization, planning level improvement cost equations and tables were developed using historical cost sources, past project data, and EPA guidance documents. Cost estimates were also developed for improvement alternatives that were complex or unique to a specific location. The cost information was then used to automatically estimate costs of improvement projects with the Borg MOEA optimization engine during optimization model runs. Costs should be considered planning-level only and may not reflect costs of actual design and construction.

The Engineer used Engineering News-Record (ENR) Construction Cost Index (CCI) data for the Kansas City metropolitan area to adjust historical cost data for inflation to better reflect present-day worth. All cost equations used in optimization reflected December 2022 dollars (ENR CCI = 13276). This timeframe was chosen because when optimization analysis began in the first quarter of 2023, a basis of costs was needed to begin analysis. These cost values were later updated to reflect 2024 dollars in the recommended plan presented in Section 7.

4.1 General Cost Equations

The following cost equations were developed to represent lump sum costs for common improvement project categories and may not be representative of more unique situations. All cost equations include an additional 20% of construction costs to account for engineering design and easement acquisition. Another 20% of construction costs were also included to account for contingencies and unanticipated costs. In total, a factor of 1.4 was applied to construction costs to convert to an approximate capital cost that accounts for design, construction, and contingencies. The capital cost was considered more useful for capital planning and budgeting purposes. A summary of the cost equations are presented in Table 4-1 and described in more detail below.

Table 4-1: General Cost Equations for Optimization

Project Type	General Cost Equation	Units
Gravity Sewer	$y = b * m^x$ (<i>m</i> and <i>b</i> vary by depth)	y is \$/LF, x is diameter (inches)
Force Main	y = 32x	y is \$/LF, x is diameter (inches)
Covered Storage	$y = 3,916,000 * x^{0.803}$	y is \$, x is MG
Uncovered Storage	$y = 3,585,000 * x^{0.599}$	y is \$, x is MG
Pump Station	$y = 1,012,000 * (x^{0.78}) + 100,000$	y is \$, x is MGD

4.1.1 Gravity Sewer (Replacement)

Gravity sewer costs were considered in terms of new or replacement sewers. The City decided to assume replacement of existing sewer instead of parallel (or relief) sewers in situations where gravity sewer capacity increases were required during optimization. The cost estimates for replacement gravity sewer were represented in terms of a set of exponential cost equations with a dollar per linear foot unit rate. A different equation was developed for each possible depth of construction, rounded to the nearest 5 feet. A tabular representation of these cost equations is provided in Table 4-2.

Capital Cost of Gravity Sewer Replacement (\$/LF) **New Pipe** Construction Depth (ft) 10 15 25 35 40 20 30 Size (in) \$199 \$208 \$252 \$436 \$516 \$559 \$604 8 \$221 \$647 10 \$230 \$277 \$470 \$553 \$600 12 \$244 \$254 \$304 \$593 \$643 \$507 \$693 15 \$285 \$295 \$350 \$567 \$658 \$715 \$769 18 \$332 \$344 \$403 \$635 \$731 \$794 \$853 21 \$464 \$711 \$883 \$945 \$387 \$400 \$811 24 \$534 \$797 \$901 \$981 \$1,049 \$451 \$465 27 \$541 \$614 \$892 \$1,000 \$1,090 \$1,163 \$526 30 \$613 \$629 \$707 \$999 \$1,111 \$1,212 \$1,290 \$1,118 33 \$714 \$732 \$1,233 \$1,347 \$814 \$1,430 36 \$1,252 \$832 \$852 \$937 \$1,369 \$1,496 \$1,586 42 \$1,569 \$1,131 \$1,152 \$1,241 \$1,688 \$1,848 \$1,951 48 \$1,536 \$1,559 \$1,645 \$1,968 \$2,081 \$2,282 \$2,400 54 \$2,087 \$2,110 \$2,179 \$2,467 \$2,566 \$2,818 \$2,952 60 \$2,835 \$2,855 \$2,887 \$3,093 \$3,163 \$3,481 \$3,630

Table 4-2: Gravity Sewer Replacement Unit Costs

4.1.2 Force Main

Force main costs were represented with a linear equation in terms of a dollar per linear foot unit rate, assuming an approximate 5-foot construction depth. The cost equation was primarily developed using bid tab averages from recent force main and pump station construction bids in the Kansas City region. When compared to historical EPA cost guidance and other cost sources, the cost equation was considered conservative and more representative of costs for installing force main within more developed and congested corridors. The resulting cost equation is y = 32x, where x is the diameter of the force main in inches and y is the \$/LF.

4.1.3 Storage

Storage costs were represented with a power equation in terms of dollars per million gallons (MG) of storage volume. Two cost equations were developed – one to represent an uncovered concrete basin similar to what is currently installed at PS9, and another to represent a covered concrete basin. The uncovered storage equation was used for potential storage sites that were farther from permanent residences and heavy traffic and therefore had less risk of causing odor or nuisance complaints from the public. The covered storage equation was used for those potential storage sites that were closer to public use areas and/or permanent residences. A 15% factor was applied to the storage construction cost to account for present value of operations and maintenance of the storage tank, assuming approximately 10-20 uses per year over a 50-year lifespan.

Various sources were referenced when developing cost equations for storage volumes, including historical construction cost data, guidance documents developed by the EPA or other US cities, and quotes from tank manufacturers. One important data point that was compared against was the bid tab average from PS9's Holding Basin 3 construction in 2010.

The resulting cost equation is represented by $y = c * x^b$, where x is in MG and y is in dollars. For the covered storage equation, c = 3,916,000 and b = 0.803. For uncovered storage, c = 3,585,000 and b = 0.599.

4.1.4 Pump Station

Pump station costs were represented with a power equation in terms of dollars per million gallons per day (MGD) of pumping capacity. Historical pump station construction costs were primarily referenced when developing the cost equation for pumping costs. The resulting cost equation is represented by $y = c * (x^b) + z$, where x is in MGD, y is in dollars, b = 0.78, c = 1,012,000, and z = 100,000.

4.1.5 Inflow and Infiltration

I/I removal was excluded from optimization improvement alternatives due to the unpredictable and inconsistent manner in which I/I may be reduced after implementing mitigation efforts. The City has already budgeted for and begun implementing ongoing I/I reduction improvements throughout the system. Because the City desired a more predictable set of capital improvement costs focused on the SWCC, I/I reduction was excluded from consideration during optimization. The City will continue its ongoing efforts to reduce I/I throughout the system, which will have wide-ranging benefits.

4.2 Unique Project Costs

Some improvement alternatives considered during optimization represented unique, standalone projects that would not be well represented by the general cost equations presented above. Therefore, unique project costs were developed for each of the following improvement alternatives.

4.2.1 PS9 Capacity Upgrades

Black & Veatch conducted a Pump Station 9 condition assessment and provided an estimate to rehabilitate the pump station to maintain its existing capacity of 9.28 MGD. This estimated cost was assumed to be a fixed cost in optimization.

To increase the pump station capacity to 12 MGD, additional pumps can be added, but a new electrical room would need to be constructed for the additional electrical and control equipment. The cost to add pumps and build a new electrical room is incrementally less than building a new pump station so a cost was estimated to expand the capacity to 12 MGD. This cost was used for any capacity between 9.28 and 12 MGD as any flow within that range would require additional pumps. These costs are presented in Table 4-3.

Table 4-3: PS9 Estimated Costs Up to 12 MGD Capacity

Project	PS9 Capacity	Cost (Million Dollars)				
Rehabilitation	9.28	\$1.3				
Rehabilitation plus additional pumps	Up to 12	\$2.5				

Increasing the pump station capacity above 12 MGD would require additional facility space, pumps, and likely an additional force main. This cost is more than the expansion up to 12 MGD and was estimated to be similar to building a new pump station. The costs to expand PS9 capacity from 12 MGD up to 15 MGD are presented in Table 4-4, as provided and developed by BV.

Table 4-4: PS9 Estimated Costs Above 12 MGD Capacity

Capacity above 12	Unit Cost	Total PS9	Total Cost (Million
MGD	(\$/gpd)	Capacity (MGD)	Dollars)
0.25	1.66	12.25	\$2.8
0.5	1.5	12.5	\$3.2
1	1.33	13	\$3.7
1.5	1.25	13.5	\$4.2
2	1.2	14	\$4.8
2.5	1.05	14.5	\$5.0
3	0.85	15	\$5.5

4.2.2 PS10 Capacity Upgrades

To develop costs for various improvement options at PS10, the March 2014 *Pump Station No. 10 and Force Mains Design Memorandum* was used. This memorandum, developed during the design phase of PS10, described various phases of improvements that could be implemented at PS10 to increase its pumping capacity. The improvement projects considered during optimization are summarized in Table 4-5.

- Improvement Project 1, which is expected to increase the capacity of PS10 from 12.5 to 17 MGD, includes the addition of two new 200 HP pumps in the empty bays of the existing wet well.
- Improvement Project 2, which would increase the capacity of PS10 to 21 MGD, includes the addition of six new 250 HP pumps in place of the existing 200 HP pumps.
 The price of new 250 HP pumps was based on recent planning-level estimates from a regional pump vendor.
- Improvement Project 3, which would increase the capacity of PS10 to roughly 28 MGD, would involve the installation of a third 30-inch force main running parallel to the two existing force mains. To develop a capital cost, the force main cost equation was used assuming a length of pipe equal to the existing PS10 force main. An additional cost factor of 50%, specified by the City, was applied to account for unknown costs associated with crossing under K-10 and through the Baker Wetlands, as well as potential political opposition.

Project Resulting No. Description Capacity (MGD) Cost 2 New 200 HP Pumps 17 283,000.00 1 2 6 New 250 HP Pumps (Replace 200 HP Pumps) 21 \$ 1,843,000.00 3 30" Diameter Parallel Force Main 28 \$ 23,990,000.00

Table 4-5: Pump Station 10 Improvement Projects

Improvement Projects 1, 2, and 3 all rely on more treatment capacity than is currently available at Wakarusa WWTP. It is assumed that the treatment capacity at Wakarusa WWTP will increase in tandem with PS10's discharge capacity. However, the capacity at Wakarusa WWTP would be approximately 17 MGD with the second treatment train installed and operating. This treatment capacity would meet the maximum demands from Improvement Project 1 but not Improvement Projects 2 and 3. Any flow above 17 MGD would need to be stored at Wakarusa WWTP until wet weather peaks have subsided and treatment capacity is recovered.

4.2.3 Replacing PS44 and PS45 with Gravity Sewer to NWCC

Despite their service areas being located within the NWCC, PS44 and PS45 currently pump flow south into the SWCC. The improvement alternative to reroute PS44 and PS45 to the north by gravity was built into the optimization model as a decision variable resembling an "on/off" switch. The "on" option assumed rerouting of the two pump stations to the NWCC, while the "off" option assumed the two pump stations continue to pump into the SWCC. Rerouting the pump stations has an associated cost that the model must account for when evaluating the "on" option. Table 4-6 summarizes the associated costs of rerouting PS44 and PS45 to the north. PS45 has an existing gravity sewer route nearby the pump station, so it was assumed that connecting PS45 to the existing gravity main would be part of the decommissioning cost for the pump station.

ItemCostNotesGravity Sewer (PS44 to PS48)\$ 2,062,000.00Assumes ~6,8000 ft of 12" pipe, 20 ft depthStorage Tank at PS48\$ 2,895,000.00Assues storage of peak flows (0.7 MG)PS Decomissioning (20%)\$ 991,000.00Accounts for PS decommissioning/abandonmentTotal Capital Costs\$ 5,948,000.00Total O&M Savings\$ 5,252,000.00Present worth; assumes 27-r remaining useful lifeNet Cost\$ 696,000.00Capital Costs - O&M savings

Table 4-6: Net Cost of Rerouting PS44 and PS45

The costs associated with rerouting PS44 and PS45 include the cost of a new gravity sewer line from PS44 to PS48, following the route of the Baldwin Creek interceptor. Additionally, a storage basin (0.7 MG) is assumed to be required at PS48 to accommodate the increase in peak flows from PS44 and PS45 and to avoid capacity issues downstream of PS48 where there are known bottlenecks in the system. Sizing of sewers and storage was based on the 2040 free flow model flow rates. A cost factor of 20% was applied to account for costs to abandon the pump stations. Annual O&M cost for new sanitary sewers is assumed to be minimal.

The rerouting of PS44 and PS45 required consideration of cost savings from reduced O&M requirements at the two pump stations. Since the two pump stations would be removed from operation, the savings from the O&M of these two pump stations were considered by calculating a net cost. O&M savings were estimated using the Kansas City Water Services Department Overflow Control Program (OCP) cost manual and applying the Present Worth Equation to obtain present worth.

For the Present Worth Equation, the remaining useful life of both pump stations was assumed to be 27 years and the interest rate was assumed to be 7.5%. Pump Station 45 was built in 2000, and Pump Station 44 was built in 2004 according to GIS data. In total, Pump Station 45 has been in operation since 2000 (23 years) and has an expected useful

life of 50 years, leaving 27 years of useful life remaining. At the City's request, 27 years was chosen as the remaining useful life of both pump stations. For the sake of simplicity, it has been assumed that both pump stations have the same remaining useful life.

4.2.4 Wakarusa River Relief Corridor

There are four major components that make up the Wakarusa River Relief Corridor conceptual cost estimate. A cost breakdown of Gravity Sewer A (north of Wakarusa River), Gravity Sewer B (south of Wakarusa River), the Force Main, and the Pump Station are provided in Table 4-7.

	Gravity Sewer Diameter (in)	42
> 4	Length (ft)	4,400
Gravity Sewer A	Depth (ft)	15
Gra	Sewer Cost (\$/LF)	\$ 1,152
0 0	Subtotal - Gravity Sewer A	\$ 5,069,000
> m	Length (ft)	9,070
avit	Depth (ft)	35
Gravity Sewer B	Sewer Cost (\$/LF)	\$ 1,848
0)	Subtotal - Gravity Sewer B	\$ 16,761,000
2	Force Main Diameter (in)	20
Force Main	Force Main Length (ft)	17,860
N Z	Force Main Cost (\$/LF)	\$ 640
	Force Main Cost	\$ 11,430,000
	Pump Station	\$ 6,000,000
	Total cost	\$ 39,260,000

Table 4-7: Wakarusa River Relief Interceptor

Gravity Sewer A and B are split to accommodate the depth necessary to install a 42-inch interceptor sewer under the Wakarusa River. Gravity Sewer A spans roughly 4,400 feet between PS9 and the Wakarusa River. The gravity sewer drops significantly in depth at the Wakarusa River to accommodate the minimum clearance under the river. Gravity Sewer B spans roughly 9,070 feet, passing under the Wakarusa River and on to the pump station near the intersection of N 1200 Road and Highway 59. The Force Main from the pump station to the Wakarusa WWTP would span approximately 3.4 miles.

4.2.5 Diversion Structure Downstream of PS9

Connecting the PS9 force main discharge manhole to the 24-inch interceptor sewer located to the east would require approximately 100 ft of 15-inch RCP to the nearest manhole. The 24-inch interceptor sewer is approximately 5 feet higher than the 36-inch interceptor sewer, so the PS9 discharge will continue to flow by gravity as it does currently. But adding this connection will allow the sewer, when surcharged, to relieve itself to the 24-inch sewer. Since there are already receiving manholes, the cost to construct this connection was estimated to be minimal for optimization purposes (roughly \$100,000).

5 OPTIMIZATION FOR 2040 CONDITIONS

Chapters 2 through 4 describe the assumptions, setup, and selection of potential improvement projects for 2040 growth conditions. Chapter 5 describes the actual optimization process used to select improvement alternatives under 2040 growth conditions.

5.1 Optimization Using Borg Multiobjective Evolutionary Algorithm (Borg MOEA)

Optimization utilizes an algorithmic approach to evaluate many different combinations of projects (decision variables) and identify the set of projects that produces the best performance as measured by a set of defined criteria (objective functions). While there are different approaches to optimization, this evaluation used a Multiobjective Evolutionary Algorithm (MOEA) called Borg MOEA.

MOEAs, such as Borg MOEA, are a computationally efficient method to evaluate many different combinations of projects that are compared based on how well they accomplish a set of performance criteria. The optimization evaluation results are then used in the decision-making process to select the best set of projects for the planning horizon.

Conceptually, the optimization engine sends sets of projects, called decision variables, to the collection system simulation model. The outcomes – such as overflows, project cost, and surcharge locations – are returned so that the optimization engine can identify which sets of projects produce better outcomes. Each decision variable sent from the optimization engine is represented as a series of numbers that are translated and inserted into the simulation model to be solved, and the performance criteria (such as the system overflow volume and surcharge locations) are returned. This is accomplished with integration code developed in Python, which also calculates the cost of the improvement projects using the cost equations described in Chapter 4. The calculated costs are also returned to the optimization engine along with the performance criteria.

For the 2040 optimization, the base simulation model is the PCSWMM collection system model for the SWCC running the 10-year, 6-hour design storm and 2040 sewer loads. The optimization engine runs thousands of simulations to determine the best sets of improvement projects to meet the performance criteria described below in Chapter 5.2. The results of the optimization process are sets of improvement projects that are reviewed by the team and the City staff to determine the set of capital improvement projects that will best meet the selection criteria. Results of these optimization runs are described below in Chapter 5.3.

5.2 Optimization Criteria

The key hydraulic function of a collection system is to convey flow to the wastewater treatment facilities without overflowing, while remaining at a reasonable cost to ratepayers. The simulation model indicated that the 2040 loads will be more than the existing collection system can handle, which would result in system overflows. To reduce or eliminate overflows, the system can be upgraded to convey the extra flow or store the extra flow until it can be treated. For both of those options, there are many possible projects that could be constructed to handle the additional flow, but some of those options are more costly than others. To address both the capacity and cost objectives, two performance criteria were selected, the minimization of overflows and minimization of total project cost. Additionally, a third objective was also selected, the minimization of surcharging in portions of the SWCC.

5.2.1 Minimizing Overflows

Overflows in the SWCC consisted of flooded manholes and the overflow structure at PS9. In the optimization evaluation, the sum of all flooded volumes from those locations was treated as an objective function to be minimized. Therefore, lower total overflow volume was preferred, and the optimization algorithm selected sets of solutions that had the lowest total overflow volume with respect to the other objective functions.

5.2.2 Minimizing Cost

Each improvement project within the collection system has a cost that is calculated based on cost equations or unique project costs covered in Chapter 4. The sum of all improvement project costs was treated as an objective function to be minimized. Therefore, lower total improvement cost was preferred and the optimization algorithm selected sets of solutions that had the lowest total improvement cost with respect to the other objective functions.

5.2.3 Minimizing Surcharging

Surcharge was considered as a possible "penalty" to be used in optimization. However, it is very difficult to anticipate the impact of penalties on results and may produce unintended outcomes when included in optimization. As such, surcharge penalties were not included in the optimization, but rather as a third objective function to be minimized. A list was provided by the City identifying 48 manholes along interceptors upstream of PS9 where surcharging is at higher risk of causing sewer backups and overflows. A summary of the City-provided surcharge constraints is provided below in Table 5-1. For the third objective function, the total number of locations (manholes) where surcharging occurred for each solution was totaled and the optimization algorithm selected solutions that had the fewest number of surcharged locations with respect to the other objective functions.

Max. Surcharge Constraint	No. of MHs	Downstream- Most MH	Upstream-Most MH				
4 ft below rim	6	NW051319-029	SW321219-063				
5 ft below rim	29	SE091319-002	NW051319-028				
831 ft ⁽¹⁾	2	SE091319-500	SE091319-001				
829 ft ⁽²⁾	6	SE101319-150	SW101319-155				
1 ft below rim (3)	5	NW051319-037	NW051319-041				

Table 5-1: Surcharge Constraints Used In Optimization

Notes:

- 1) 831' avoids basement backups on Inverness Ct.
- 2) 829' avoids basement backups on Coneflower Ct.
- 3) This shallow 8" line was assumed to need upsizing.

5.3 Results of 2040 Optimization

Three separate rounds of optimization were run for 2040 growth conditions in the SWCC, and certain improvement alternatives were preferred across all three rounds.

5.3.1 2040 Optimization - Round 1

The first round of optimization included only two objectives: minimize overflow and minimize cost. During the first round of optimization, certain projects were favored over others. Optimization results generally favored:

- Upsizing gravity sewer at various locations
- Rerouting and abandoning PS44 and PS45
- Adding storage at PS9
- Storing at the conceptual Marina Watershed Pump Station
- Increasing the capacity of PS9 and PS10
- Installing a diversion structure downstream of PS9

The results from the first round of optimization did not favor the Wakarusa River Relief Corridor or storage at other locations besides PS9 or the conceptual Marina Watershed PS.

It is important to note that because the first round of optimization did not have an objective to minimize surcharge, many of the overloaded pipe segments upstream of PS9 were not upsized, leading to a higher HGL (surcharge). By allowing surcharge, these solutions were relying on in-system storage in the Yankee Tank Creek interceptors, creating a higher-risk scenario for backups and overflows.

5.3.2 2040 Optimization – Round 2

It was decided after reviewing initial results from the first round of optimization that another round would be necessary. The primary goals of running a second round of optimization with updated parameters included:

- Minimize Surcharging. A third objective was added to minimize surcharge along the interceptors upstream of PS9. This was meant to align optimization results more closely with typical design practices and reduce risk of basement backups in the area.
- Upsizing Gravity Sewer to Free-flow Diameter. This parameter would prohibit optimization from upsizing a pipe to an intermediate diameter between its existing capacity and 2040 free-flow capacity requirements. This was meant to align optimization results more closely with typical design practices.
- Finding a "zero" or "near-zero" overflow solution. The first round of optimization did
 not identify a near-zero overflow solution because not all pipe improvement
 decision variables were included due to concern for computation time
 requirements. It was decided that knowing the cost of a near-zero overflow solution
 would be useful for comparison purposes, particularly during discussions with
 regulatory agencies primarily interested in preventing overflows.

The results from the second round of optimization were very similar to the results of the first round of optimization. In order to investigate and present an alternative approach, a third round of optimization was run that focused on conveyance rather than storage.

5.3.3 2040 Optimization - Round 3

The third round of optimization used the same criteria as the second round, except that storage was only allowed at Wakarusa WWTP. The goal of this round was to identify solutions that would favor conveyance over storage and would take advantage of ample area adjacent to the Wakarusa WWTP for additional storage, if needed.

The solutions from this round of optimization favored the Wakarusa River Relief Corridor projects (interceptor, pump station, and force main extending south of the Wakarusa River), but only a portion of flows to PS9 were diverted south through the Wakarusa River Relief line. The remaining flow would still be pumped and conveyed toward PS10, along the congested 31st Street corridor. This solution would not increase PS10's capacity, and no additional storage would be added at Wakarusa WWTP.

5.3.4 2040 Optimization – Conclusions

In general, the first two rounds of optimization favored a storage-focused approach to improvements in the SWCC. Storage at the conceptual Marina Watershed Pump Station and additional storage at PS9 were both included in the top solutions from the first two

rounds of optimization. Only during the third round of optimization, when storage was allowed only at Wakarusa WWTP, were more relief and conveyance improvements favored.

All rounds of optimization favored the following projects, referred to as "core" projects:

- Rerouting and abandoning PS44 and PS45
- Increasing the capacity of PS9
- Installing a diversion structure downstream of PS9

Workshops were held with key City staff on May 22 and May 26, 2023, to review the results of the three rounds of optimization. Three solution sets were presented at these workshops: a storage-focused solution, a conveyance-focused solution, and an "inbetween" approach that borrowed from the other solutions.

The primary differentiators for each presented solution are described below:

- Storage-Focus: includes additional storage of approximately 6 MG at PS9, and storage of approximately 2 MG at the conceptual Marina Watershed PS. This solution was favored during the first two rounds of optimization.
- Conveyance-Focus: focuses on upsizing pipes or adding relief, and does not include any additional storage in the system. This solution was identified during the third round of optimization.
- "In-between" Approach: includes approximately 8 MG of additional storage at PS9, and assumes extensive upsizing of Yankee Tank interceptors upstream of PS9. This solution was not identified by optimization but was a combination of optimized and unoptimized improvements. It was considered an "in-between" solution because it emphasizes conveyance to relieve the west side of the SWCC, and storage at PS9 to relieve the east side of the SWCC.

At the May 26, 2023, workshop, it was determined that the most critical decision remaining was whether the City would prefer storage improvements over conveyance improvements in two distinct sections of the SWCC: the west section (upstream of PS9) and the east section (PS9 and downstream). Despite optimization results showing storage improvements as being the most cost-effective solutions, there were pros and cons to implementing storage improvements that needed to be weighed before a decision could be made. The City requested a questionnaire be distributed to workshop attendees to collect feedback and consensus regarding preferred alternatives.

5.4 Selection of Preferred Alternatives

5.4.1 City Staff Questionnaire

After the Optimization Results Workshop was held, a questionnaire was distributed to key City staff to collect additional feedback regarding the improvement options for the SWCC. Respondents were not required to have attended previous SWCC-related workshops. In the questionnaire, respondents were asked for their opinions, preferences, and concerns regarding the proposed improvement options for the SWCC. Respondents were provided a memorandum containing key information, assumptions, maps, and tables to help them understand the options presented. Triple bottom line considerations were also listed in this memorandum. The memorandum provided to respondents is included as an Appendix to this technical memorandum. The results of this process were then confirmed with City staff to verify reliability of results and that the results were relevant to decision making.

Options presented to respondents in the questionnaire were grouped differently than those presented at the Optimization Results Workshop to isolate the West Section from the East Section of the SWCC. Core projects, however, remained the same as presented at the workshop. Core projects are those improvements that are considered necessary and are independent of other potential improvements. These projects include:

- 1. Abandoning PS44 and PS45 and rerouting to the NWCC
- 2. Improving capacity at PS9
- 3. Adding a diversion structure downstream of PS9

Not all the options presented in the questionnaire were favored by optimization. From the three rounds of optimization performed, the results generally favored:

- 1. Core projects (previously mentioned)
- 2. Adding more storage at PS9
- 3. Storing excess flows at the conceptual Marina Watershed Pump Station
- 4. Piecemeal upsizing of gravity sewer (including "telescoping" pipe sizes, where a larger pipe diameter is installed upstream of a smaller pipe diameter)

All options presented in the questionnaire focused on the primary corridor of the SWCC (Yankee Tank Interceptors, to PS9, to PS10, to Wakarusa WWTP). Improvements along the Quail Creek or Atchison Creek interceptors, for example, were excluded. Any necessary improvements in tributary watersheds (such as Quail Creek) will likely be split off as CIP projects separate from SWCC-focused improvements.

5.4.2 Results of City Staff Questionnaire

Eight City staff members responded to the questionnaire. Below summarizes key insights gathered from the respondents.

- Core Projects: There were no major concerns regarding these projects. However, some respondents did question how rerouting PS44 and PS45 might impact the NWCC and drive the need for storage at PS48 due to capacity limitations at PS16.
- West Section of the SWCC (Upstream of PS9)
 - Five respondents chose Option 1, which would involve storing excess wet weather flows at the future Marina Watershed Pump Station, along with less significant Yankee Tank Interceptor Relief and/or Upsizing.
 - Three respondents chose Option 2, which would assume no storage at the future Marina Watershed Pump Station, along with more significant Yankee Tank Interceptor Relief and/or Upsizing.
 - When asked about potential hurdles for either option, several respondents noted concerns about the ability to build a pump station and storage facility on U.S. Army Corps of Engineers (USACE) owned land.
- East Section of the SWCC (PS9 and Downstream)
 - Respondents were asked to rank the following options from Most Favored to Least Favored:
 - Option 1 Add More Storage at PS9 Facility.
 - Option 2 Wakarusa River Relief Interceptor and Pumping, which would involve building a new interceptor, pump station and force main to convey flows south of Wakarusa River from PS9 to Wakarusa WWTP).
 - Option 3 31st Street Corridor Relief/Upsizing, which would involve interceptor improvements from PS9 to PS10 within the existing corridor.
 - Option 1 (Add Storage at PS9) was ranked as the Most Favored option by six of the eight respondents, while Option 2 and 3 were ranked as Most Favored by only one respondent each. Option 3 was ranked as the Least Favored option by four of the eight respondents.
 - When asked about potential hurdles for any of the options, several respondents commented on Option 1, noting that floodplain and floodway may restrict the location and size of any new storage. Adding storage at PS9 may also be criticized by nearby homeowners for odor and nuisance concerns during site planning and zoning. Several noted how costly or disruptive Option 2 or 3 could become.

6 PRIORITIZATION OF PROJECTS

Prioritization of projects for the SWCC was determined based on 2030 and 2040 optimization and model runs, as well as the K-10 highway crossings and relocations to accommodate the K-10 Highway Expansion Project.

6.1 Selected Projects

Based on 2040 optimization results and City staff feedback, the following improvement alternatives were selected by the City and the Engineer for prioritization and phasing. The projects are generally listed in order of priority:

- Expand PS9 Pumping Capacity and Rehabilitate Facility
- Add Diversion Structure Downstream of PS9
- Replace PS44 and PS45 with Gravity Sewer to NWCC
- Add Storage at PS9
- Store at Future Marina Watershed Pump Station
- Gravity Sewer Improvements
 - Yankee Tank Creek Interceptors
 - Various Gravity Improvements Upstream of SWCC
- Expand PS10 Pumping Capacity

6.2 2030 Optimization

Optimization for 2030 growth conditions was run and analyzed to identify those improvements that need to be implemented by the 2030 planning horizon to meet anticipated capacity demands. This analysis provided a scenario between existing and 2040 planning horizon conditions that assisted in phasing of selected improvements. Findings from 2030 optimization were presented at a joint workshop held on August 25, 2023 with both the SWCC and K-10 utility crossings teams to prioritize and phase necessary projects.

Conclusions from 2030 optimization include:

- Expand PS9 Pumping Capacity: Increasing PS9's pumping capacity by 2030 growth conditions is critical. PS9's capacity is a known issue in present conditions, and 2030 optimization results confirm the urgent need for capacity expansion. Optimization predicted the capacity would need to be expanded from 9.3 MGD to 10.8 MGD by 2030.
- Add Diversion Structure Downstream of PS9: 2030 optimization confirmed the importance of the diversion structure downstream of PS9.
- Replace PS44 and PS45 with Gravity Sewer to NWCC: 2030 optimization confirmed the importance of replacing PS44 and PS45 with gravity sewer routed to the NWCC.

- Add Storage at PS9: Increasing PS9's storage capacity by 2030 growth conditions is also critical. Optimization showed a clear preference toward adding 4.5 MG of storage capacity at PS9 to accommodate the 10-year storm peak wet weather flows predicted during 2030 growth conditions. Similar to the 2040 optimization runs, this preference is likely influenced by the high cost of the alternative solution (upsizing interceptors downstream of PS9).
- Store at Future Marina Watershed Pump Station: Optimization showed approximately 0.25 MG of storage at the future Marina Watershed Pump Station being required to accommodate the 10-year storm peak wet weather flows by 2030 growth conditions. This suggests that when growth requires the Marina Watershed Pump Station, construction of storage needs to coincide with construction of the pump station facility itself.
- Gravity Sewer Improvements: Approximately 17% (20 of 117) of the gravity sewer improvements chosen during 2040 optimization were also chosen during 2030 optimization. This generally suggests that most gravity sewer improvements in the SWCC will not be needed until closer to 2040 growth conditions, assuming the optimized volumes of storage are utilized at the Future Marina Watershed Pump Station and at PS9.
- <u>Expand PS10 Capacity</u>: Optimization showed a slight increase (0.1 MGD) in capacity being required at PS10 by 2030 growth conditions.

6.3 Yankee Tank Interceptors

Optimization selected gravity sewer improvements on a segment-by-segment basis, preferring those pipe improvements that met the optimization objectives at the lowest cost. This process of selecting pipes for gravity sewer upsizing differs from traditional relief and replacement projects.

Traditional approaches involve sizing replacement pipes to avoid installing a larger diameter pipe upstream of a smaller diameter pipe. Traditional approaches also involve sizing replacement pipe so that the new pipe will no longer surcharge under design flow conditions. Neither of these criteria of traditional replacement pipe sizing is considered during optimization. Therefore, it is recommended that gravity sewer improvements selected by optimization be used as an indicator of gravity sewer bottlenecks that may be cost-effective to address, as opposed to using them as a basis for final design or sizing.

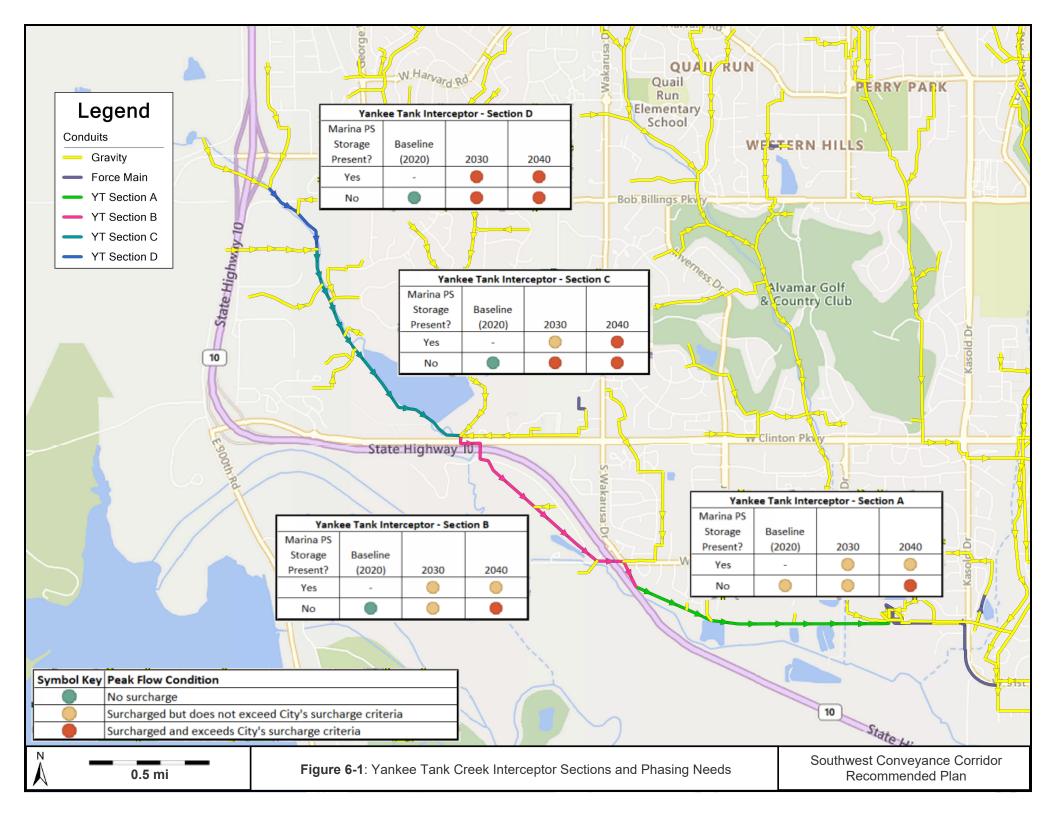
It is clear from 2030 and 2040 optimization that there are bottlenecks along the Yankee Tank Creek interceptors that will need to be addressed to reduce risk of backup and overflow. To better understand the extent of pipe replacement required using a traditional design approach, the Engineer performed model runs to determine which stretches of the Yankee Tank interceptors require upsizing and at what time horizon, as well as the appropriate pipe sizes to eliminate surcharge. Model runs of 2030 and 2040 growth conditions were performed, with two scenarios being modeled per time horizon. One scenario included storage at the future Marina PS, while the other scenario excluded any storage at the Marina PS.

The Yankee Tank interceptors were divided into four distinct sections to reflect more realistic extents of potential improvement projects, and those sections are shown in Figure 6-1. The necessity for improvements was then evaluated for each section, and findings are summarized in Table 6-1.

Table 6-1: Yankee Tank Creek Interceptor Phasing Needs

			orage ina PS	STORAGE at Marina PS					
Yankee Tank Section	Baseline (2020)	2030	2040	2030	2040				
Α									
В									
С									
D									
Symbol Key	Peak Flow Cond	lition:							
	No surcharge								
	Surcharged but does not exceed surcharge criteria								
	Surcharged and exceeds surcharge criteria								
Assumptions:									
PS44 and PS45 are decommissioned and flows are rerouted to NWCC by 2030.									
Additional storage at PS9 is on-line and available by 2030.									

The surcharge constraint criteria used to guide this analysis is the same criteria provided by the City for the third optimization objective described in Chapter 5.2. For a summary of those constraints, please see Table 5-1.



Conclusions from the capacity and phasing analysis of each section of the Yankee Tank Creek interceptors are summarized below:

- Section A: This downstream-most section of the Yankee Tank interceptors is surcharging under current conditions because PS9 is unable to keep up with large storm events such as the 10-year design storm, and additional storage is not yet available at PS9. This section may not require upsizing by 2040 growth conditions if Marina PS storage is able to reduce peak wet weather flows and the City accepts some surcharge (less than 829') in these sewers. City-provided surcharge criteria may be exceeded under the 10-year design storm scenario at 2040 growth conditions if Marina PS is unable to store excess wet weather flows, which could trigger the need for a project.
- Section B: This section is not surcharging under current conditions. This section may not require upsizing by 2040 growth conditions if Marina PS storage is able to reduce peak wet weather flows and the City accepts some surcharge in these sewers. City-provided surcharge criteria (maximum of 5' below MH rim) may be exceeded under the 10-year design storm scenario at 2040 growth conditions if Marina PS is unable to store excess wet weather flows, which could trigger the need for a project.
- <u>Section C</u>: This section will likely need an upsizing project, but the timing will be dictated by the presence of Marina PS storage and actual rates of growth west of K-10. Upsizing of Section C could be postponed until 2040 growth conditions if Marina PS is able to store peak wet weather flows, but modeling suggests that upsizing will be needed by 2030 growth conditions if there is no storage available at Marina PS.
- <u>Section D</u>: This section's capacity issues are not impacted by Marina PS storage. These 12-inch sewers will need to be upsized to adequately convey flows from 2030 growth conditions regardless of the presence of Marina PS storage.

Although the Yankee Tank interceptors were divided into the sections listed above for the purposes of this report, it is possible to combine or divide the interceptors into different sections at the time of project initiation and design. Actual project extents may differ from the sections listed above.

6.4 K-10 Highway Expansion

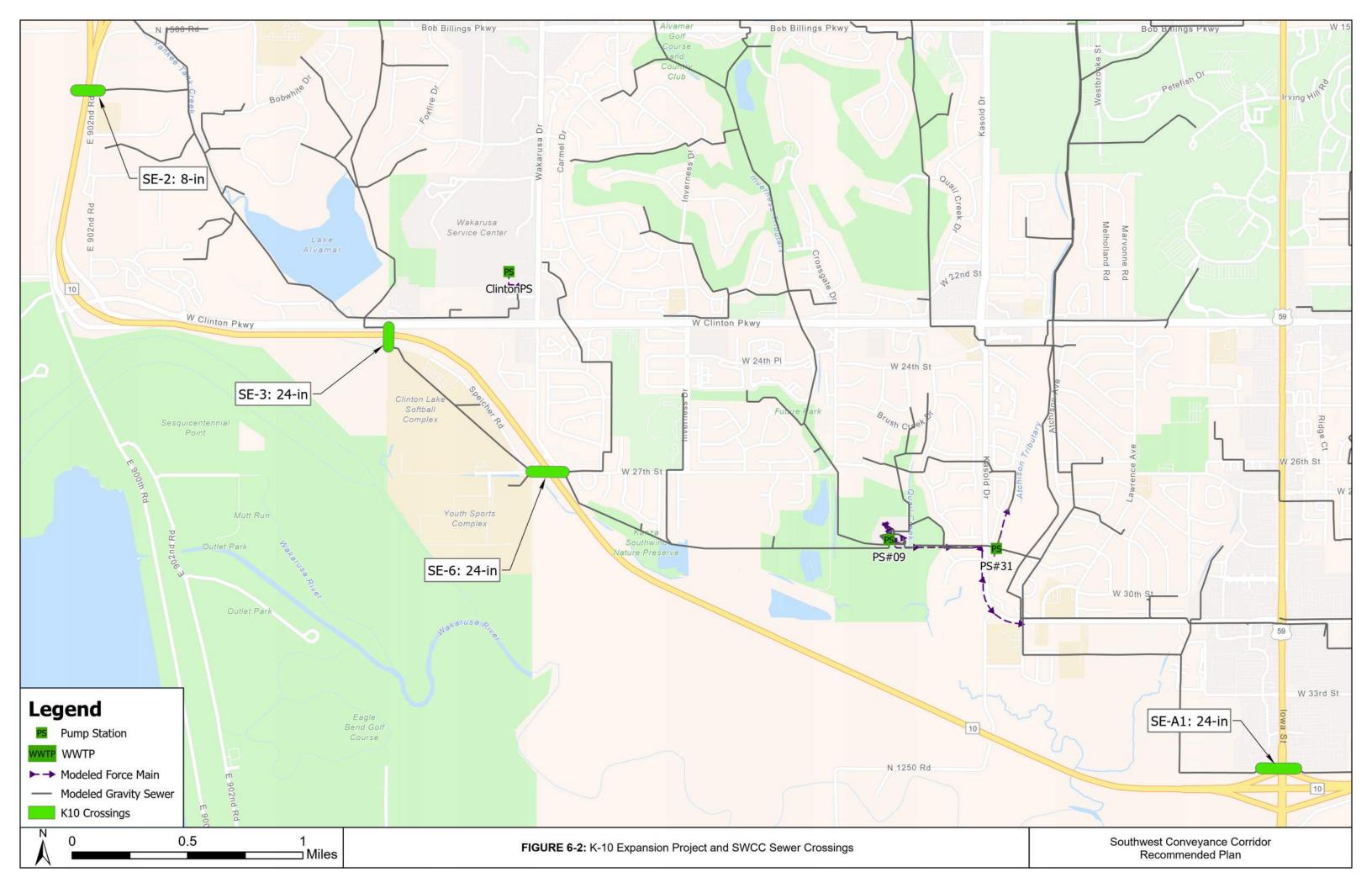
The K-10 highway expansion is a multi-phase Kansas Department of Transportation (KDOT) project to expand K-10 from a 2-lane highway to a 4-lane divided highway between K-10's intersections with US-59 and I-70. In preparation for the project, KDOT requested that the City of Lawrence relocate and plan for the City's existing and future water and sewer crossings impacted by the highway expansion. Due to the urgency and importance of the K-10 expansion project, the City is moving quickly to address any impacted crossings under a separate project (MS1-00001). Several of the impacted sanitary crossings are within the SWCC, and there are interdependencies between the SWCC improvements projects and the K-10 sanitary sewer crossings that must be considered when sizing and phasing SWCC improvements.

Due to the interdependent nature of the SWCC and K-10 utility crossing projects and CIP budgets, a joint workshop was held on August 25, 2023 to prioritize and phase necessary projects for the SWCC and K-10 utility crossings. One primary goal of the meeting was to determine how the City should address the Yankee Tank interceptor sewers crossing under K-10. Due to budget constraints and the urgent need to address sewer crossings impacted by the K-10 expansion project, the City determined that a portion of the fiscal year 2023 SWCC CIP budget would be allocated toward the K-10 utility crossings project. A list of priority projects and crossings and order of construction was determined during the workshop.

To date, four existing sanitary crossings along SWCC interceptors have been analyzed as part of the K-10 utility relocation project. Three of those crossings have been selected for design and construction. A brief description of each SWCC-related sanitary crossing is described below and shown on Figure 6-2. Crossing IDs were assigned as part of the K-10 utility relocation project.

- Crossing SE-2: Existing 8-inch, South of N 1500 Rd (Segment NW051319-041-NW051319-040): This crossing was selected for design and construction because it is in conflict with K-10 expansion and the Marina Watershed Pump Station is proposed to eventually pump to this crossing. To accommodate flows from the Marina Pump Station, the existing 8-inch sewers will need to be upsized from the relocated highway crossing to the existing 15-inch Yankee Tank Creek interceptor at MH 028. The City has chosen to be proactive and upsize the 8-inch sewers from MH 041 (currently west of K-10) to MH 028 (approximately 2,000 LF) while relocating the highway crossing to prepare for future growth west of K-10.
- Crossing SE-3: Existing 24-inch, South of Yankee Tank Lake Dam (Segment NW091319-502-NW091319-501): This crossing was not selected for design and construction because, while it does cross under K-10, it is not in conflict with K-10 expansion. The capacity of this pipe was also found to be adequate, at least through 2030 growth conditions. It was also determined that in the event this crossing needs to be upsized, trenchless boring could be performed at that time. For these reasons, the City decided to exclude this crossing from design and construction.
- Crossing SE-6: Existing 24-inch, 27th St Interchange (Segment NW091319-001-SE091319-034): This crossing was selected for design and construction because it is in conflict with K-10 expansion and is part of the Yankee Tank interceptors. To accommodate future flows, the existing 24-inch sewer crossing will need to be upsized. The City has chosen to be proactive and upsize this crossing now to accommodate flow during 2040 growth conditions assuming no storage at the future Marina Watershed Pump Station. Since storage at the Marina PS is not assured, the City chose to plan for the scenario in which there is no storage and design this crossing with larger diameter pipe in order to avoid costly upsizing or relief in the future.

• Crossing SE-A1: Existing 24-inch, US-59 Interchange (Segment NW131319-043-SW131319-048): This crossing was selected for design and construction because it is in conflict with pedestrian bridge improvements at the US-59 interchange. This crossing is downstream of PS9 and upstream of PS10, along the K-10 interceptor sewers. This crossing is planned to remain a 24-inch pipe.



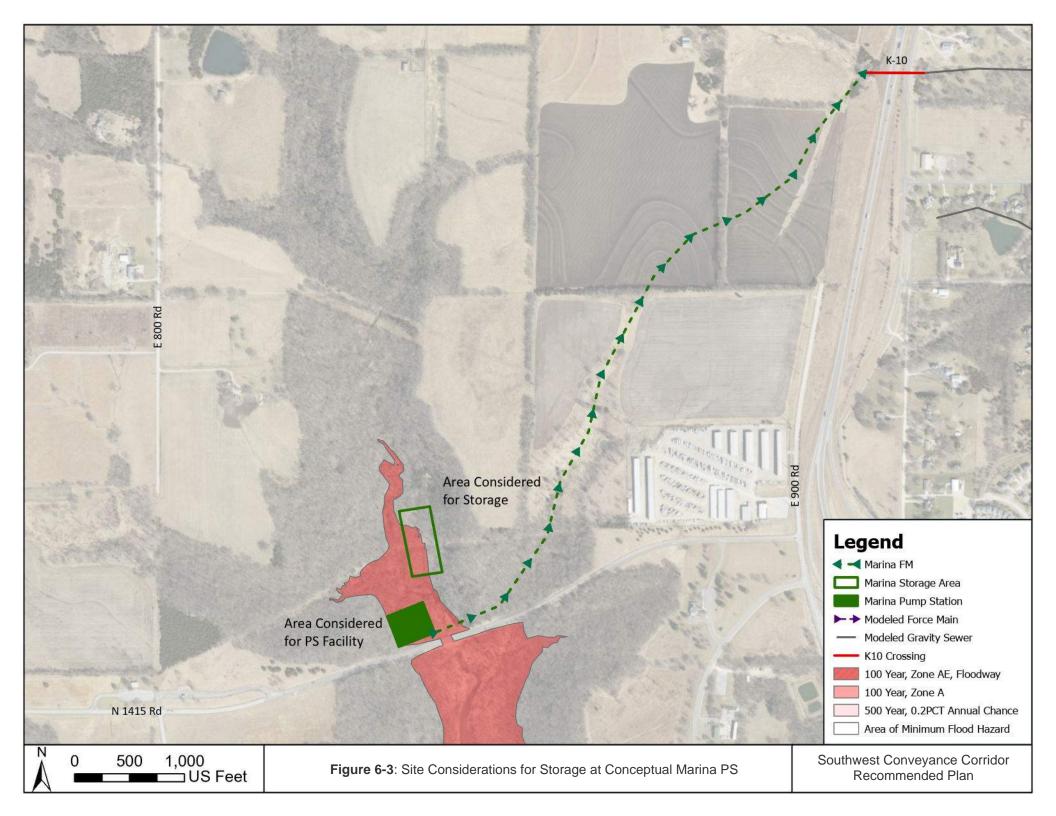
6.5 Storage Considerations

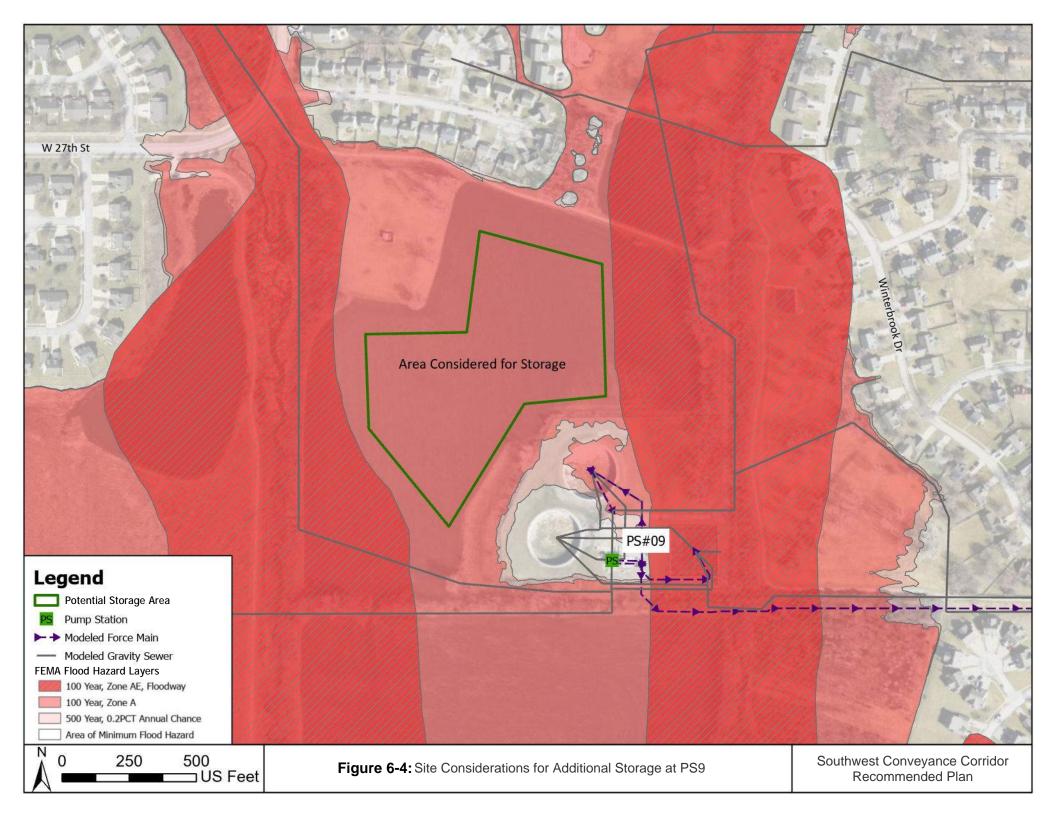
Although storage is being recommended to address wet weather capacity concerns at PS9 and the future Marina PS, there are risks and site-specific challenges to implementing these projects that must be considered. Early communication with the USACE and Kansas Department of Wildlife and Parks (KDWP) regarding feasibility of the Marina PS and storage project is highly recommended. Communication with the Lawrence Planning Department regarding expansion of storage at PS9 is underway. A pre-application meeting with the Planning Department was held on August 10, 2023 to discuss various zoning and planning considerations. If additional storage at PS9 is not possible, this will impact the plan significantly.

There are risks of unknowns for the storage project at the future Marina PS which could result in the Marina PS storage becoming impractical or unviable. The City has decided to pursue this option but with caution as they gather more information. Risks surrounding the viability of storage at Marina PS include but are not limited to:

- <u>Siting and Land Acquisition</u>: The preferred site for constructing the Marina PS and storage facility is on USACE-owned property roughly a quarter mile upstream of a finger of Clinton Lake, shown in Figure 6-3. The land is also within Clinton State Park, which is maintained by KDWP. There is currently no guarantee that USACE or KDWP will be obliging of the City acquiring this land for sanitary pumping and storage purposes.
- Regulatory Review and Permitting: There is the possibility of extra permitting and review required as the location potentially overlaps with state park grounds, wetlands, and floodplains. Further review of location data and survey will be required. KDHE may also require additional environmental review.
- <u>Potential Negative Public Opinion</u>: This location is upstream of the Clinton Lake Marina, which is a popular recreation area. The public will likely be concerned about possible impacts the additional storage could have on the Clinton Lake Marina site.

Maps of the conceptual storage locations at the Marina Watershed Pump Station and at PS9 are shown in Figure 6-3 and Figure 6-4, respectively.





7 SWCC IMPROVEMENTS PLAN AND PHASING

A phased improvements plan was developed for the SWCC system based on the results of the work previously presented.

7.1 Selected Improvements

Based on modeling, optimization results, and City staff feedback, the following improvement projects were selected by the City and the Engineer:

- 1. Plan for Storage at Future Marina Watershed Pump Station
- 2. Replace Existing K10 Sanitary Sewer Crossings
- 3. Expand PS9 Pumping Capacity
- 4. Add Diversion Structure Downstream of PS9
- 5. Replace PS44 and PS45 with Gravity Sewers to NWCC
- 6. Add Storage at PS9 (Phases 1, 2A or 2B)
- 7. Store at Marina Watershed Pump Station (Phase 1 and Phase 2)
- 8. Replace Yankee Tank Interceptors (Select Sections)
- 9. Expand PS10 Pumping Capacity
- 10. Gravity Sewer Improvements Throughout SWCC

A project description and justification are provided below. A summary table of projects with recommended phasing and capital costs is provided in Table 7-1. A summary of selected improvement projects is shown in Figure 7-1.

Trigger points have been included in Table 7-1 as applicable. Trigger points are provided in terms of average daily dry weather flows (ADDF) at strategic locations in the existing system. A trigger point is reached when the ADDF indicates that capacity improvements need to be conducted and that flows from growth have reached or are near the flow capacity of the system component. For improvements needed immediately, no trigger point was provided. The trigger point represents the existing ADDF plus the additional flows added by future growth conditions that exceed capacity, with a 75 percent buffer applied to provide the City time to commence improvements. It is recommended that the City monitor the ADDF at the trigger point manholes listed in Table 7-1 within the next 1-2 years to establish baseline ADDF flows. The "Current ADDF" flows listed in Table 7-1 are an approximation derived from the model, which was calibrated using flow meters that may not have been nearby the trigger point manhole locations. By establishing actual ADDF at the trigger point monitoring locations, the City will gain greater awareness of current flow conditions and ensure a more appropriate, fine-tuned trigger point monitoring program.

The following sections describe the projects and justification.

Subtotal, Scenario 2 (Storage at Marina PS) \$2.29M | \$2.79M | \$3.40M | \$4.96M | \$9.78M | \$4.25M | \$12.69M | \$40M

Table 7-1 Summary of Selected Improvements Phasing and Capital Costs

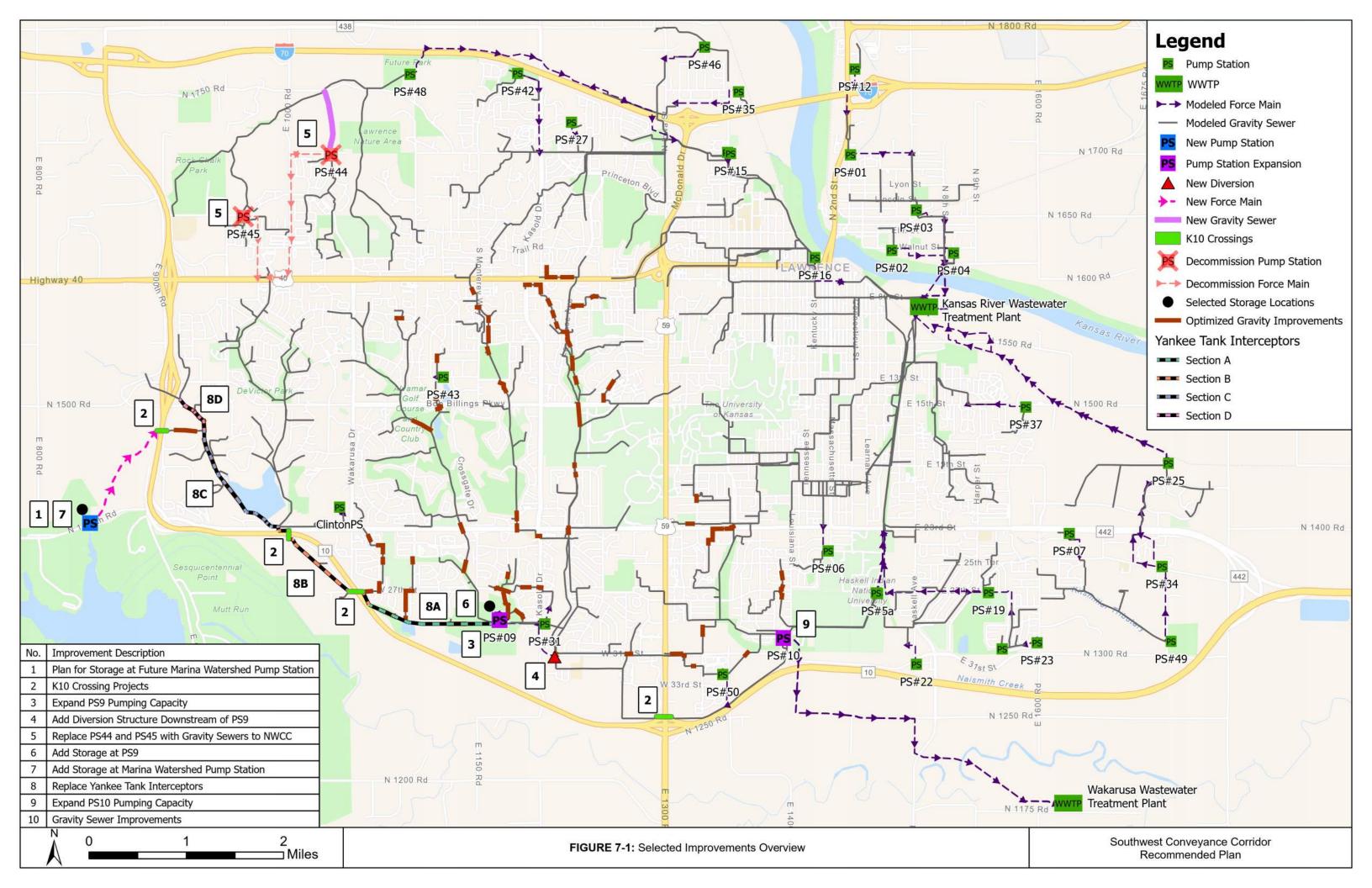
						SWCC	Capital Ir	nprovem	ents By	Year: Saı	mple Sch	edule ⁽⁵⁾				
No. Project	Projected Growth Condition ⁽¹⁾	Current ADDF (MGD)	ADDF Trigger (MGD) ⁽²⁾	ADDF Trigger Meter MH	2022 Conceptual OPCC ⁽³⁾	2024 OPCC +30% Conting. ⁽⁴⁾	Engr. & Survey (20%)	2024 Capital Cost Opinion	2025	2026	2027	2028	2029	2030	Period Ending 2040	
1 Plan for Storage at Future Marina PS ⁽⁶⁾	ASAP	-	-	-	-	-	-	-								l
2 K-10 Sanitary Crossings (3 Locations) ⁽⁶⁾	ASAP	-	-	-	-	-	=	-								i
3 Expand PS9 Pumping Capacity	ASAP	-	-	-	\$2.50M	\$3.46M	\$0.69M	\$4.15M	\$2.08M	\$2.08M						
4 Add Diversion Structure Downstream of PS9	ASAP	-	-	-	\$0.25M	\$0.35M	\$0.07M	\$0.42M	\$0.21M	\$0.21M						
5 Replace PS44 and PS45 with Gravity Sewer to NWCC	ASAP	-	-	-	\$1.80M	\$2.48M	\$0.50M	\$2.98M		\$0.50M	\$1.86M	\$0.62M				
6 Add Storage at PS9																
Phase 1 (4.5 MG)	2030	0.51 ⁽¹³⁾	0.89	SE101319-151	\$7.42M	\$10.24M	\$2.05M	\$12.29M			\$1.54M	\$3.07M	\$6.15M	\$1.54M		
Phase 2A (1.2 MG, <u>with</u> Marina PS Storage)	2040	0.51 ⁽¹³⁾	1.23	SE101319-151	\$3.42M	\$4.72M	\$0.94M	\$5.66M							\$5.66M	
Phase 2B (3.2 MG, without Marina PS Storage)	2040	0.51 ⁽¹³⁾	1.23	SE101319-151	\$6.08M	\$8.39M	\$1.68M	\$10.07M							\$10.07M	
7 Storage at Marina Watershed Pump Station ⁽⁷⁾																l
Phase 1 (0.25 MG)	2030	-	0.15	Marina PS	\$1.33M	\$1.85M	\$0.37M	\$2.22M				\$0.37M	\$1.39M	\$0.46M		l
Phase 2 (1.8 MG)	2040	-	0.36	Marina PS	\$4.25M	\$5.86M	\$1.17M	\$7.03M							\$7.03M	l
8 Replace Yankee Tank Creek Interceptors ⁽⁸⁾																
Section A ⁽⁹⁾	2040	0.51 ⁽¹³⁾	1.23	SE101319-151	\$7.50M	\$10.35M	\$2.07M	\$12.42M							\$12.42M	l
Section B ⁽⁹⁾	2040	0.40	1.14	NW091319-002	\$4.92M	\$6.79M	\$1.36M	\$8.15M							\$8.15M	l
Section C ⁽¹⁰⁾	2030	0.06	0.51	SE051319-015	\$2.75M	\$3.80M	\$0.76M	\$4.56M				\$0.76M	\$1.90M	\$1.90M		
Section D	2030	0.03	0.29	NW051319-029	\$0.50M	\$0.70M	\$0.14M	\$0.84M				\$0.14M	\$0.35M	\$0.35M		l
9 Expand PS10 Pumping Capacity ⁽¹¹⁾																ĺ
10 Gravity Improvements throughout SWCC ⁽¹²⁾																ĺ
Connected to No. Character at Martina DC					0.1.1		(A) O((N : DO)	CO. CO. A	#0.70M	φο 40N4	Φ4 F0N4	ΔO 40N4	Δ0.70M	A00 04N4	Tota
Scenario 1: No Storage at Marina PS					Subtot	ai, Scenario 1	(No Storage	at Marina PS)	\$2.29M	\$2.79M	\$3.40M	\$4.59M	\$8.40M	\$3.79M	\$30.64M	\$56I

Notes:

Scenario 2: Storage at Marina PS

- 1) Growth conditions were developed based on population projections provided by the City for years 2030 and 2040. Actual years at which growth conditions are realized may vary from the years shown here.
- 2) ADDF triggers are provided as means for evaluating the necessity of projects based on actual flows from growth. Triggers were estimated as 75% of modeled ADDF at year of concern to provide time for project implementation. Fine-tuning recommended.
- 3) 2022 OPCC estimates were developed using cost equations developed for SWCC optimization. They are representative of December 2022 dollars.
- 4) 2024 OPCC estimates have been adjusted using ENR CCI ratios. They are representative of February 2024 dollars. 30% contingency is applied because of the conceptual nature of the cost equations.
- 5) This is an example schedule of project costs based on 2030-2040 growth projections provided by City. Actual timing/necessity of projects should be evaluated based on actual growth and flow triggers, which may vary from schedule provided.
- 6) No costs are provided because these are subject to change depending on scope and necessity of external factors.
- 7) This is representative of storage costs only. Costs of pump station, force main, and gravity sewers to serve the Marina Watershed are excluded.
- 8) Yankee Tank Interceptor trigger points conservatively assume there is no storage at the Marina PS.
- 9) Section A and B of the Yankee Tank interceptors exceed surcharge criteria set by City for optimization at 2040 growth conditions IF Marina PS is unable to store. Upsizing of Sections A and B may be postponed beyond 2040 if Marina PS is able to store.
- 10) Section C of the Yankee Tank interceptors is assumed to be needed by 2030 based on the scenario with NO storage at Marina PS. Upsizing of Section C may be postponed to 2040 growth conditions if Marina PS is able to store.
- 11) PS10 expansion is anticipated to be addressed as part of Wakarusa WWTP expansion and is not included in costs presented here.
- 12) Gravity improvements upstream of SWCC (not on Yankee Tank interceptors) are addressed as part of Task 6.
- 13) In the calibrated model, ADDF is estimated at 0.51 MGD at MH SE101319-151. However, 2016 flow metering (not used in model calibration) suggests actual ADDF could be higher. Metering is recommended to establish baseline ADDF.

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7.1.1 Project 1 – Plan for at Future Marina Watershed Pump Station

Storage at the conceptual Marina Watershed Pump Station is recommended as growth dictates. By 2040 growth conditions, the storage basin would provide up to 2 MG of storage at the conceptual Marina Watershed Pump Station. Because availability of land for this storage basin cannot be confirmed at this time, it is recommended that downstream capacity improvements potentially impacted by this pump station be sized assuming no storage is feasible, at least until details are confirmed. Future steps will be to acquire land for the facility, if determined feasible.

Justification. Based on optimization results and feedback from City staff, pursuing wet weather storage at the conceptual Marina Watershed PS is the preferred approach for addressing future capacity concerns in the Yankee Tank interceptors upstream of PS9. There are risks and site-specific challenges to implementing this project, so early communication with the USACE and KDWP regarding feasibility of the project is highly recommended.

7.1.2 Project 2 – Replace Existing K10 Sanitary Sewer Crossings

The City is in the process of relocating and resizing three existing sanitary sewer crossings under K-10 and US-59 as part of Project MS1-00001: SE-2, SE-6, and SE-A1. The crossings were previously shown in Figure 6-2. Because feasibility of storage at the future Marina Watershed Pump Station cannot be confirmed at this time, SE-2 and SE-6 will be sized to accommodate 2040 growth condition flows assuming no storage is feasible at the Marina Watershed PS.

Justification. Due to the urgency of schedule and sensitive timing of the K-10 Expansion project, the City is moving quickly to address these crossings. The location of these crossings affects the SWCC sewer improvement projects. There are interdependencies between the SWCC improvements projects and the sanitary sewer crossings impacted by the K-10 expansion project that must be considered when sizing and phasing SWCC improvements. Therefore, these crossings and associated SWCC improvements are documented here and included in the SWCC Improvements Plan.

7.1.3 Project 3 – Expand PS9 Pumping Capacity

PS9 capacity will be increased by adding a new pump to an empty bay of the existing wet well at PS9 and replacing the impellers of the existing dry weather pumps. The location of PS9 is shown in Figure 6-4. The pump station will also be rehabilitated to extend its useful life. Expansion of storage basins for the PS9 system has been identified as an additional project and should be considered during the design of the improvements to PS9 for spatial, operational and hydraulic reasons.

Justification. Based on optimization results, it was identified that increasing PS9's pumping capacity is essential for meeting near-term and long-term capacity needs in the SWCC. PS9 is critical to the operational success of the SWCC, and it has failed to keep pace with large, back-to-back storm events that have occurred in recent years. Rehabilitation of the pump station facility will also be included in this project to extend its useful life and address condition concerns noted during the PS9 condition assessment. For more information regarding the PS9 condition assessment, refer to the technical memorandum titled "Pump Station 9 Condition Assessment" by Black & Veatch.

7.1.4 Project 4 – Add Diversion Structure Downstream of PS9

A diversion structure will be added at or near manhole NW141319-501, which is downstream of PS9's existing force main discharge. The diversion will strategically split flow between the existing 36-inch interceptor along 31st Street and the 24-inch K-10 interceptor.

Justification. It was determined during optimization that by adding a diversion structure downstream of PS9, flow could be split between the existing 36-inch interceptor along 31st Street and the 24-inch K-10 interceptor that passes within 50-feet of the existing PS9 force main discharge point. This flow split would reduce capacity concerns in the 36-inch interceptor by leveraging the available capacity in the 24-inch interceptor. This project would be relatively low-cost compared to other improvements selected for the SWCC and would reduce the need for more expensive interceptor relief projects downstream of PS9.

7.1.5 Project 5 - Replace PS44 and PS45 with Gravity Sewers to NWCC

As part of this project, PS44 and PS45 would be decommissioned, and gravity sewers would be built to convey flows to the existing Baldwin Creek interceptors in the NWCC. The proposed location of the gravity line and current locations of PS44 and PS45 are shown in Figure 3-1. After further modeling analysis, it was determined that the existing gravity sewer from MH SW211219-001 to PS48 has sufficient capacity to accommodate the extra flow from PS44. Therefore, rather than having the proposed PS44 gravity line run parallel to the existing interceptor, the proposed line is recommended to connect at MH SW211219-001. PS48 is a key pump station for the NWCC system and is key to future growth northwest of existing city limits. A storage basin may be required in a future phase of this project as growth dictates, but this is not included as part of the SWCC CIP.

Justification. This project was chosen because it would increase capacity in the SWCC by rerouting these two pump stations to the NWCC. This project would also eliminate two pump stations, thereby reducing the operations and maintenance costs of keeping the pump stations in service. Based on modeling results, the Baldwin Creek interceptor and PS48 have available capacity to receive flows from PS44 and PS45 under current conditions. However, it was assumed that wet weather flows will need to be stored at PS48

by 2040 due to downstream constraints in the NWCC, most notably at PS16. Therefore, it is recommended the City continue to monitor flows at PS48 and along the NWCC to prepare for the eventual need for storage at PS48.

By 2040, estimated peak flows during the design storm (10-year, 6-hour) from the PS44 sewers will be approximately 1 MGD and peak flows from the PS45 sewers will be approximately 0.6 MGD. In total, an estimated 1.6 MGD of peak flow during 2040 conditions will be rerouted away from the SWCC and conveyed to PS48 in the NWCC. It was assumed that peak wet weather flows in excess of PS48's existing capacity of 6 MGD would need to be stored. Based on modeling of the design storm event, PS48 could experience peaks of up to 6.9 MGD by 2040, which may require storage to accommodate.

7.1.6 Project 6 - Add Storage at PS9

Phase 1 (2030 Growth Conditions): Approximately 4.5 MG of additional storage will be constructed at PS9 to accommodate peak wet weather flows by 2030 growth conditions.

Phase 2A and 2B (2040 Growth Conditions): Phase 2A and 2B are alternate recommendations which are dependent on whether storage is constructed at the Marina Watershed PS. If the Marina PS storage is constructed, option 2A will be recommended. Option 2B will be recommended if the Marina PS storage is not constructed.

- Phase 2A: An additional 1.2 MG of storage will be added at PS9.
- Phase 2B: An additional 3.2 MG of storage will be added at PS9.

Justification. Based on optimization results and feedback from City staff, increasing wet weather storage capacity at PS9 is considered the most cost effective and adaptable approach for addressing capacity concerns downstream of PS9. This option was significantly less expensive than the Wakarusa River relief corridor and the 31st Street corridor alternatives. This option is also more adaptable in terms of sizing and phasing of storage capacity expansion. Growth projections represent a best approximation of future conditions. However, actual growth and capacity demands may vary from projections, and storage expansion could be implemented in separate phases to better align with real-time flow measurements and capacity needs.

7.1.7 Project 7 – Store at Marina Pump Station (Phase 1 and Phase 2)

As previously discussed in Chapter 6, the feasibility of storage at the future Marina Watershed Pump Station cannot be confirmed until property agreements are in place. If property agreements are successful, then two stages of storage would be the cost-effective approach to serve anticipated growth areas west of K-10. A conceptual location for the storage facilities is shown in Figure 6-3.

- Phase 1 (2030 Growth Conditions) Install 0.25 MG of storage at the future
 Marina Pump Station site to accommodate 2030 growth conditions.
- Phase 2 (2040 Growth Conditions) Install an additional 1.8 MG of storage at the future Marina Pump Station site to accommodate 2040 growth conditions.

Justification. Storage at the conceptual Marina Watershed Pump Station was found to be the most cost-effective approach to maintain level of service requirements for the downstream SWCC system. Costly improvements along the Yankee Tank Interceptors can either be avoided or delayed by storing peak flows at the Marina PS. This was the preferred approach based on City feedback.

7.1.8 Project 8 – Replace Yankee Tank Interceptors (Phase 1, 2, 3, and 4)

As previously discussed in Chapter 6, the extent and timing of replacement of the Yankee Tank Interceptors is dependent on actual growth conditions and the viability of storage at the Marina Pump Station. Sections A, B, C and D of the Yankee Tank Interceptor were previously shown in Figure 6-1. The potential projects are described by Section below:

- Section D This upstream-most section requires relief by 2030 growth conditions regardless of whether storage is feasible at the Marina Pump Station. This project would consist of approximately 1,800 feet of replacement sewer, upsizing from a 12 inch to an 18 inch.
- Section C This section will require relief, but the timing and sizing is dependent on the Marina Pump Station storage. This project will consist of upsizing approximately 5,500 feet of 15–21 inch diameter pipe to 27-30 inch diameter pipe by either 2030 or 2040 growth conditions, depending on whether the Marina PS storage does or does not get built.
- Section B This section will likely not require relief unless the Marina Pump Station storage is not built. This project would consist of upsizing approximately 5,600 feet of 24-27 inch diameter pipe to 36-48 inch diameter pipe by 2040 growth conditions.
- Section A This downstream-most section will likely not require relief unless the
 Marina Pump Station storage is not built. This project would consist of upsizing

approximately 5,800 feet of 27-30 inch diameter pipe to 48 inch diameter pipe by 2040 growth conditions.

Justification. The Yankee Tank Interceptor is directly downstream of a significant portion of the anticipated growth west of K-10. Providing a versatile plan for relief or replacement of this interceptor is key to the success of the SWCC improvements.

7.1.9 Project 9 – Expand PS10 Pumping Capacity

Justification. Based on optimization results, it was identified that increasing PS10's pumping capacity will be necessary for increasing flow delivery to the Wakarusa WWTP. It was assumed that this project would be implemented as part of a larger capacity upgrade project at the Wakarusa WWTP, so CIP budget for the SWCC will not be used to fund this project.

7.1.10 Project 10 – Gravity Sewer Improvements Throughout SWCC

Justification. Although storage is recommended (at PS9 and the conceptual Marina Watershed PS) as the primary method for addressing downstream capacity concerns, there are gravity sewer improvements scattered throughout the interceptors upstream of the SWCC that will be required to meet 2040 capacity demands. These projects would likely be funded separately, outside of the SWCC CIP budget.

APPENDIX

Memorandum: Southwest Conveyance Corridor (SWCC) Improvements Questionnaire, June 2023

Technical Memorandum GBA and BV



MEMORANDUM

To: City of Lawrence, KS

From: GBA and Black & Veatch (BV)

Date: 6/23/23

Subject: Southwest Conveyance Corridor (SWCC) Improvements Questionnaire

<u>Purpose</u>: Provide important context and information for City staff stakeholders to give feedback and preferences regarding the SWCC improvement options.

Background:

- The Optimization Results Workshop for the SWCC Improvements Project was split into two parts and held on May 22 and May 26.
- During the May 26 workshop, GBA and BV presented three top solutions developed after three
 rounds of optimization assuming 2040 growth conditions: a storage-focused solution, a
 conveyance-focused solution, and a solution that was a combination of the other two solutions.
- Core Projects: All three of the top solutions presented on May 26 included, as a baseline:
 - 1) rerouting PS44 and PS45 to the north
 - 2) improving capacity at PS9 and PS10 (note: capacities varied between options)
 - 3) adding a diversion structure downstream of PS9
- It was decided after the workshop that a questionnaire be distributed to collect City staff feedback regarding the top solutions/alternatives. Using this feedback, the SWCC project team will choose the best path forward for Lawrence's SWCC.

IMPORTANT:

- For the questionnaire, the top three solutions presented at the May 26 workshop have been reorganized and simplified to isolate the two primary decisions remaining: 1) choosing the best option for the West Section of the SWCC and 2) choosing the best option for the East Section of the SWCC.
- Not all the options in the questionnaire were favored by optimization. From the three rounds of optimization performed, optimization generally favored:
 - The core projects mentioned above (rerouting PS44 and PS45, etc.)
 - Adding storage at PS9 and the conceptual Marina Watershed Pump Station



- Piecemeal upsizing of gravity sewer (including telescoping pipe sizes, where a larger pipe diameter is installed upstream of a smaller pipe diameter)
- All options presented in the questionnaire for feedback will be phased. Options were developed assuming 2040 growth conditions, so not all projects will need to be funded and implemented immediately.
- All options presented in the questionnaire focus on the primary corridor of the SWCC (Yankee
 Tank Interceptors, to PS9, to PS10, to Wakarusa WWTP). Improvements along the Quail Creek
 or Atchison Creek interceptors, for example, have been excluded. Any necessary improvements
 in tributary watersheds (such as Quail Creek) will likely be split off as CIP projects separate from
 the SWCC-focused improvements.

Improvement Options Requiring Feedback:

Respondents will be asked to rank and provide feedback on the following options in the questionnaire.

Decision A - West Section of SWCC

Extent:

- Upstream End: Sewers crossing K10, in vicinity of Bob Billings Pkwy & K10 Interchange
- Downstream End: PS9

Improvement Options:

- Option 1 Store at Future Marina Pump Station + Less Significant Yankee Tank Interceptor Relief/Upsizing
 - a. Assumptions/Considerations:
 - Kansas State Parks will cooperate and allow the City to build uncovered storage on or near Clinton Lake State Park land.
 - ii. Yankee Tank Interceptor crossings under K10 may be in conflict with K10's upcoming expansion. If, for example, the sanitary crossing near 27th St needs to be relocated, there could be significant work required along the interceptors. It may be in the City's best interest to take advantage of any conflicts and upsize sewers at that time. This option avoids upsizing gravity sewers however, and may not be as cost-effective in the event of a conflict.
 - iii. The gravity sewer improvements preferred by optimization were piecemeal and included some telescoping of pipe sizes (larger pipe upstream of smaller pipe). Therefore, actual design of gravity improvements could be more significant than what's shown in the highlighted maps below.

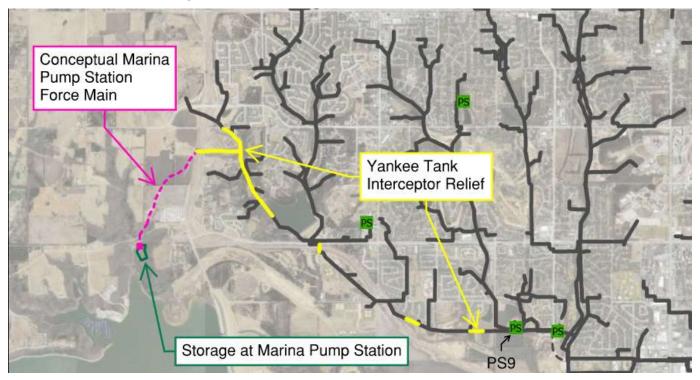


2. Option 2 – Do Not Store at Future Marina Pump Station + More Significant Yankee Tank Interceptor Relief/Upsizing:

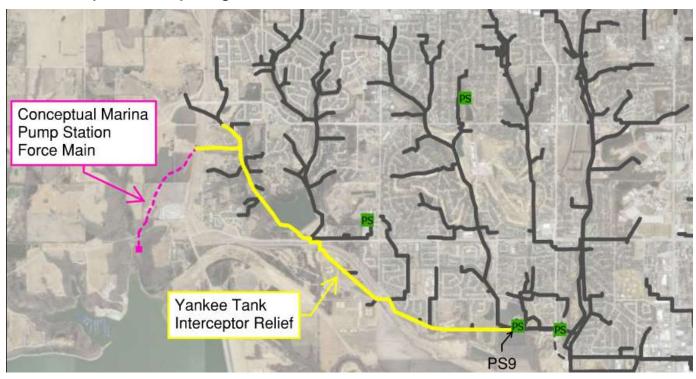
- a. Assumptions/Considerations:
 - i. This option would increase the size of improvements selected for the East (downstream) section of the SWCC.
 - ii. This option could take advantage of any work required to relocate sanitary sewer crossings underneath K10 in the event of a conflict.
 - iii. This option would involve sizing sewers to handle 2040 peak flows without the need for upstream storage, though upstream storage could still be implemented beyond 2040 if necessary.
 - iv. This option would avoid telescoping of sewer sizes along the Yankee Tank Interceptor.



Decision A – <u>Option 1</u>: Store at Future Marina Pump Station and Less Significant Yankee Tank Interceptor Relief/Upsizing



Decision A – <u>Option 2</u>: Do Not Store at Future Marina Pump Station and More Significant Yankee Tank Interceptor Relief/Upsizing





Decision B - East Section of SWCC

Extent:

Upstream End: PS9

Downstream End: Wakarusa WWTP

Improvement Options:

Option 1 – Add Storage at PS9

a. Description: Build additional storage at PS9, thereby reducing the extent of conveyance upgrades downstream of PS9.

b. Assumptions/Considerations:

- This option would likely require additional storage to be built closer to homes north of PS9, potentially within 500 feet of the nearest home at 3705 Crossgate Terrace. (See figure below)
- ii. There is floodway surrounding the PS9 site to the east and west. Therefore, it will likely be most feasible to locate any additional storage on the property owned by the City to the north and west of PS9.

2. Option 2 - Wakarusa River Relief Interceptor and Pumping

- a. Description: Build new interceptor, pump station and force main to convey flows south of Wakarusa River from PS9 to Wakarusa WWTP.
- b. Assumptions/Considerations:
 - i. The primary benefit of this option is the opportunity to provide sewer service south of the Wakarusa River.
 - ii. During optimization, an optimized solution was identified that would require both the Wakarusa River Relief Interceptor and significant upsizing of sewers along the 31st Street Corridor. This optimized solution was not favored by the City during the May 26 workshop, because it did not avoid work along 31st Street as it was expected to and was sized smaller than expected. To find a solution that avoided work along 31st Street and was sized more realistically, the Wakarusa River Relief Interceptor needed to be sized significantly larger than the optimized solution, and additional storage would be required. This revised option is what is presented in the questionnaire.
 - iii. To avoid upsizing pipe along 31st St corridor, storage must be added either at PS9 or Wakarusa WWTP. It was assumed storage would be added at Wakarusa WWTP for comparison purposes.



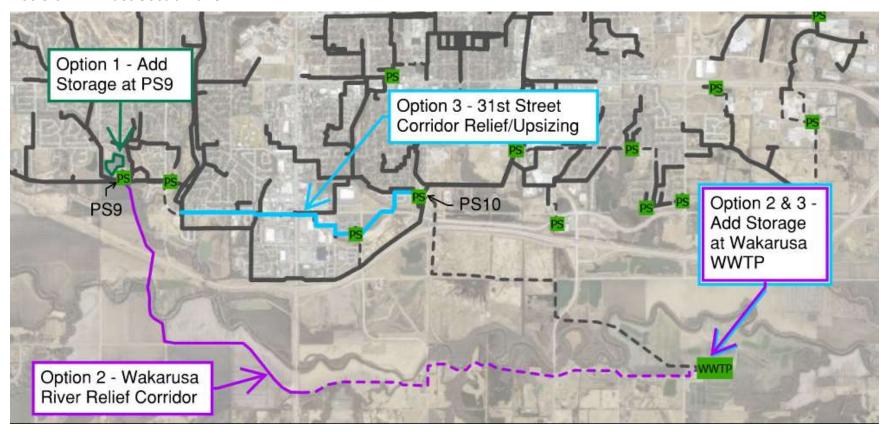
iv. Any additional storage at Wakarusa WWTP is assumed to be feasible within existing City-owned land. It is also assumed that no major floodway permitting conflicts would be encountered during design or construction of additional storage footprint.

3. Option 3 – 31st Street Corridor Relief/Upsizing

- Description: Relief/upsizing of existing sewers from PS9 to PS10 within existing interceptor corridor.
- b. Assumptions/Considerations:
 - This option assumes that the existing interceptor corridor between PS9 and PS10 would be used to upsize or parallel new interceptor for relief and capacity improvements.
 - ii. Significant disruption to traffic is anticipated along the 31st Street corridor during construction.
 - iii. This solution requires additional storage at Wakarusa WWTP, similar to Option 2.
 - iv. Any additional storage at Wakarusa WWTP is assumed to be feasible within existing City-owned land. It is also assumed that no major floodway permitting conflicts would be encountered during design or construction of additional storage footprint.



Decision B - East Section of SWCC





Decision B - Option 1: Add Storage at PS9

The blue box below represents a conceptual footprint of where additional storage at PS9 could be built in order to avoid nearby floodway. The nearest homes are located 500 feet or less to the north of this conceptual footprint.





Summary of Improvements and Costs for Each Option

		West Section of SWCC			East Section of SWCC					
Category	Units	Option 1	Option 2		Option 1	Option 2	Option 3			
Short Description		Store at Marina	Do Not Store at		Additional Storage	Wakarusa River	31st St Corridor			
•	-	PS	Marina PS		at PS9	Relief Corridor	Relief/Upsizing			
Favored by Optimization ⁽¹⁾	-	Yes	No		Yes	No	No			
Overflow Volume ⁽²⁾	MG	0.1	0		0	0 0.3				
Number of Overflows	count	1	0	0 2		2	0			
Surcharge Violations ⁽³⁾	count	0	0		-	-	-			
Storage Locations (Added)	-	Marina PS	None		PS9	Waka. WWTP ⁽⁷⁾	Waka. WWTP			
Storage Volume	MG	2.0	None		5.7 - 7.7 ⁽⁶⁾	4.5	4.5			
Storage Cost	\$M	6.2	None		10.2 - 12 ⁽⁶⁾	12.9	12.9			
PS9 New Capacity ⁽⁴⁾	MGD	-	-		10.9	11.2	14.25			
PS9 Cost	\$M	-	-		1.5	1.5	3.8			
PS10 New Capacity ⁽⁴⁾	MGD	-	-		12.6	13.25	16.25			
PS10 Cost	\$M	-	-		0.3	0.3	0.3			
Wakarusa River Relief Interceptor	\$M	-	-		0	32.4	0			
Gravity Relief/Upsizing Cost	\$M	3.7	12.5		0.3	0	21.8			
Total Cost of Option	\$M	9.9	12.5		12.3 - 14.1 ⁽⁶⁾	47.1	38.8			
Core SWCC Projects ⁽⁴⁾										
Reroute PS44 and PS45 North ⁽⁵⁾	\$M	5.9	5.9		-	-	-			
Diversion Downstream of PS9	\$M	-	-		0.1	0.1	0.1			
Total Cost Including Core Projects	\$M	15.8	18.4		12.4 - 14.2 ⁽⁶⁾	47.2	38.9			

Notes:

- 1. Options "favored" by optimization are those that achieved a significant reduction in overflows at the lowest cost.
- 2. This summary table is representative of the SWCC only (Yankee Tank interceptors to Wakarusa WWTP). Costs and overflows associated with tributary interceptors (e.g., Quail Creek) are not included.
- 3. During optimization, surcharge criteria were included as an objective only along the Yankee Tank interceptors, upstream of PS9.
- 4. PS9 and PS10 improvements, although considered "core" projects to the SWCC, are variable depending on the selected option. They are considered part of the East Section of the SWCC.
- 5. It is assumed PS48 will eventually require storage, especially if PS44 and 45 are rerouted north. An estimated cost of storing peak flows from PS44 and 45 at PS48 is included in the cost presented.
- 6. Storage volume and cost at PS9 is dependent on the option selected for the West Section of the SWCC. The lower volume and cost is associated with Option 1 (Storage at Marina PS), while the higher is associated with Option 2.
- 7. Option 2, East SWCC: To avoid upsizing pipe along 31st St corridor, storage must be added either at PS9 or Wakarusa WWTP. It was assumed storage would be added at Wakarusa WWTP for comparison purposes.



Comparison of Options Using Triple Bottom Line Considerations (Financial, Social, Environmental)

		West Section	on of SWCC	East Section of SWCC			
		Option 1	Option 2	Option 1	Option 2	Option 3	
	Considerations	Store at Marina PS	Do Not Store at Marina PS	Additional Storage at PS9		31st St Corridor Relief/Upsizing	
General	Least Cost	✓	X	✓	Х	X	
	No Overflows Predicted (10-yr 6-hr Design Storm Model)	X	✓	✓	Х	✓	
	Favored By Optimization	>	X	✓	X	X	
	Favored By SWCC Project Team (subject to change)	X	✓	√	X	X	
	Takes Advantage of Potential K10 Crossing Conflicts	X	✓	n/a	n/a	n/a	
	Reduces Peak Loads on Downstream System	✓	X	✓	X	X	
	Provides Sewer Service to Currently Unserved Areas	X	X	X	✓	X	
Triple Bottom Line ⁽¹⁾	Least Maintenance & Workload Added	X	✓	X	X	✓	
	Least Operational Complexity & Risk	X	✓	X	X	✓	
	Most Adaptable to Growth (phasing, deferred cost)	>	X	✓	X	X	
	Least Land Acquisition & Siting Risk	X	✓	X	X	√	
	Least Disruption from Construction	>	X	✓	X	X	
	Least Ongoing Nuisance (noise, odor, traffic, visibility)	X	✓	X	X	✓	
	Least Safety Concerns (City staff & public)	X	✓	X	X	✓	
	Smallest Carbon Footprint (cement, energy, site, etc.) ⁽²⁾	X	✓	Х	X	√	
	Least Scrutiny from Public Expected ⁽³⁾	X	✓	Х	X	✓	
	Least Scrutiny from Regulators Expected ⁽³⁾	X	✓	Х	X	✓	

Notes:

- 1. The Triple Bottom Line (financial, social, environmental) considerations and comparisons presented here are not exhaustive and are meant to be a rough guide.
- 2. It is assumed that options requiring new facilities (storage and/or pumping) would have a larger carbon footprint than options involving gravity sewer upsizing only.
- 3. It is assumed that options leveraging existing sewer easement and relieving existing infrastructure may be least scrutinized/criticized by the public and regulators.