# BENTONVILLE BASELINE SANITARY SEWER CAPACITY STUDY PART I

**Prepared for:**

City of Bentonville

Bentonville, Arkansas



Revised March 2025

Olsson Project No. 020-2321

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# TABLE OF CONTENTS



(Click to follow links)

# LIST OF FIGURES



(Click to follow links)

# LIST OF TABLES



(Click to follow links)

# APPENDICES

# ACRONYMS AND ABBREVIATIONS

AAF ........ Average Annual Flow
ARI ........ Average Recurrence Interval
CCTV ........ Closed-Circuit Television
DIP ........ Ductile Iron Pipe
DWF ........ Dry-Weather Flow
EPA ........ Environmental Protection Agency
EPS ........ Extended Period Simulation
GIS ........ Geographic Information System
GPM ........ Gallons per Minute
GPS ........ Global Positioning System
GWI ........ Groundwater Infiltration
IDM ........ Inch-Diameter-Mile
I/I ........ Inflow and Infiltration
LF ........ Linear Feet
MGD ........ Million Gallons per Day
MH ........ Manhole
NACA ........ Northwest Arkansas Conservation Authority
NOAA ........ National Oceanic and Atmospheric Administration
PVC ........ Polyvinyl Chloride Pipe
RDII ........ Rainfall Derived Inflow and Infiltration
RTK ........ Real Time Kinematic
SL-RAT ........ Sewer Line Rapid Assessment Tool
SSES ........ Sanitary Sewer Evaluation Study
SSO ........ Sanitary Sewer Overflows
SSOAP ........ Sanitary Sewer Overflow Analysis and Planning
SUH ........ Synthetic Unit Hydrographs
VCP ........ Vitrified Clay Pipe
WWF ........ Wet-Weather Flow
WRRF ........ Water Resource Recovery Facility
WWTF ........ Wastewater Treatment Facility

# EXECUTIVE SUMMARY

This report presents an analysis and evaluation of the impact of rainfall-derived inflow and infiltration (RDII) on the study area. The study area covers part of the City of Bentonville's sanitary sewer collection system, as shown in Figure 3, and includes McKisic, North (Shewmaker) and Town Branch basins which flow to the Bentonville Water Resource Recovery Facility (WRRF), and South Lift Station basin, which flows to the Northwest Arkansas Conservation Authority (NACA) Wastewater Treatment Facility (WWTF). The scope of this Part includes the evaluation of RDII in the study area, and the assessment of available capacity of the McKisic, North, and the South Lift Stations.

Flow and rainfall monitoring was conducted for about 9 months, and the study area was divided into 27 subbasins that were monitored individually. The US Environmental Protection Agency's (EPA's) Sanitary Sewer Overflow Analysis and Planning (SSOAP) Toolbox was used to analyze the flow and rainfall data. The SSOAP toolbox is used to generate model parameters, and develop flow hydrographs for the 1-, 2-, 5-, 10-, and 25-year design storms. Olsson developed a computerized hydraulic model that represents the trunk lines in the study area using InfoSewer by Autodesk. Parameters generated from the SSOAP analysis were used to calibrate the model using the historical flow and rainfall data collected as part of this study.

The calibrated model was then used to evaluate the system's response under various design storms, This evaluation achieves the following objectives:

- Quantify and rank the baseline RDII for each of the subbasins comprising the study area.
- Analyze RDII results and prioritize proposed RDII reduction and rehabilitation efforts.
- Provide recommendations for the City of Bentonville that prioritize Next Steps following the completion of Part I.

During this Part of the project, Autodesk acquired Innovyze, discontinued InfoSewer modeling software, and was replaced by InfoWorks ICM as the company's primary sewer modeling software. During Part II, the InfoSewer model was converted to InfoWorks ICM and recalibrated by Olsson using the 2023 flow and rainfall data, and the calibrated model was used to determine the level of service for the lift stations.

This Part I report discusses the results of the RDII evaluation and the desktop capacity evaluation of Lift Stations, presented in Appendix A, under the 1-, 2-, 5-, 10-, and 25-year rainfall events. The evaluation of the available gravity sewer capacities and detailed model results for the selected design storm are discussed in the Part II report.

# Results

The lift station capacity analysis performed using a set of design storms concluded that the McKisic and North Lift Stations have the capacity to provide a level of service of 5-year or greater, while the South Lift Station could only provide a level of service that is less than a 1-year.

Olsson compared the RDII contributions from each of the 27 subbasins and determined that the highest concentrations of RDII were in the Town Branch basin and the upper reaches of the McKisic basin. These subbasins correspond to some of the oldest and most densely populated areas in the City. In contrast, the Shewmaker basin and the southwestern area of the McKisic basin contributed relatively smaller amounts of RDII.

# Recommendations

Olsson's recommendations are detailed in Section 6, and summarized as follows:

- **Prioritized I/I Reduction Projects**
  Olsson has identified the subbasins that have the highest RDII rates, which can used to effectively guide the implementation of RDII reduction projects. These projects target removing I/I sources by repairing public and private sewer infrastructure.
  Olsson recommends that field investigations to be conducted by the City in order to identify potential I/I sources in streamway, public, and private infrastructures.
- **Lift Stations**
  The McKisic and North lift stations have adequate capacity to provide at least a 5-year level of service under current conditions. However, lift stations analysis should be included when analyzing the system under future growth scenarios.
  Immediate improvements to the South Lift Station are recommended in order to manage peak flows. Further analysis should also be included when analyzing the system under future growth scenarios.
- **Water Resource Recovery Facility**
  The WRRF currently has a peak hydraulic capacity of approximately 10 MGD, and has no onsite structure for storing excess flows. Estimated peak hourly rates range from 19.6 MGD for the 1-year storm to 29.7 MGD for the 25-year storm. Future improvements to the WRRF should take into consideration estimated volumes and peak hourly flow rates for current future conditions, and account for the projected population growth.
- **Future Scenario Modeling**
  The current level of service provided by the City does not meet the accepted benchmark of a 5-year design storm. Additionally, given the anticipated rate of rapid growth rate, Olsson recommends that the City proceed with evaluating the available capacity under future growth scenarios in conjunction with the evaluation of peak flow management alternatives,

which include a combination of I/I reduction, conveyance, and storage recommendations. Recommendations generated from these evaluation efforts should be incorporated in a capital improvements plan that evaluates the cost effectiveness of the recommended peak flow management projects.

# 1. INTRODUCTION

## 1.1 Purpose

The City of Bentonville's collection system surcharges during rainfall events because the presence of significant rainfall derived inflow and infiltration (RDII) that enters the system during these events, which is observed in collection systems around the country. RDII is defined as the rainfall induced flows that enter the sanitary sewer system during rainfall events in the form of inflow and infiltration (I/I). Inflow enters the system through direct connections, such as sump pumps and roof drains, while infiltration enters the system through defects in pipes and manholes. Typical RDII sources are shown on Figure 1. The amount of RDII that enters the system typically correlates with rainfall intensity and duration, ultimately resulting in pipes surcharging and manholes overflowing during large rainfall events.

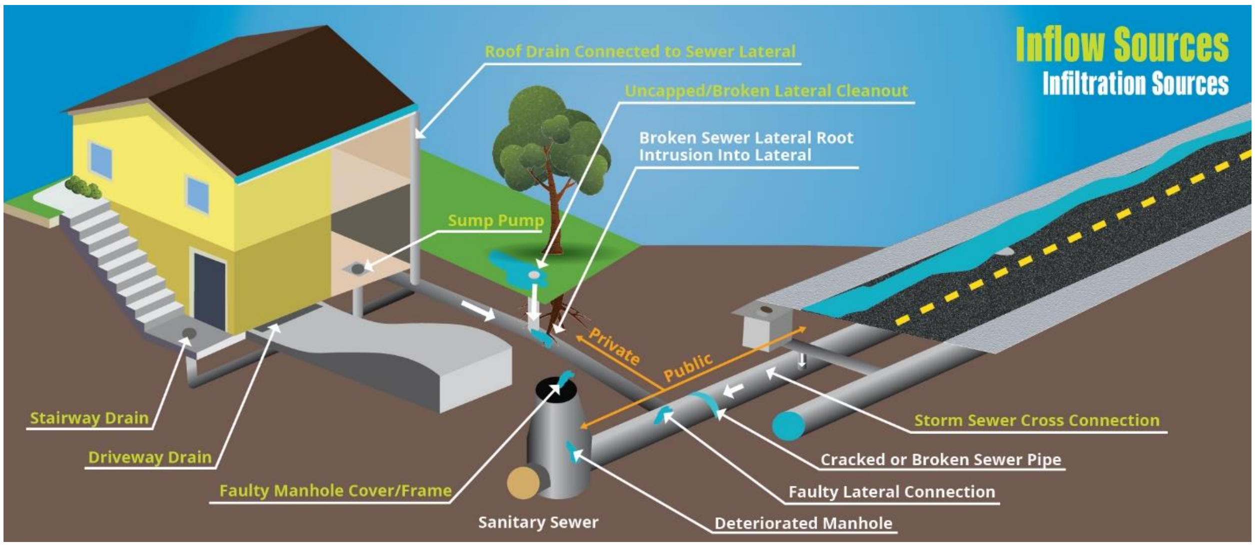


**Figure 1. Typical Sources of RDII**

This project, the Sewer Collection Analysis and Peak Flow Management Program, is comprised of two parts, detailed as follows:

- Part I:
  - TREKK and Olsson worked together to provide system-wide flow and rainfall monitoring of the collection system. TREKK monitored key areas beginning in September 2020 over approximately 284 calendar days. As data was received from monitoring, TREKK uploaded to the Waterspout platform, which was available to the City so they could remotely login and view data at all the flow and rainfall monitoring locations.

  - TREKK also performed field evaluations of existing manholes in the collection system and coordinated with the City regarding repairs.
  - As TREKK performed their monitoring and evaluations, Olsson evaluated the McKisic, North, and South Lift Stations.
  - Once all flow monitoring data and field evaluations were complete, Olsson analyzed the information and began capacity analysis and modeling.
  - This report summarizes the analysis and findings.
- Part II:
  - Olsson will establish a capacity baseline of the existing collection system and identify areas with deficient capacity.
  - Olsson will provide a calibrated hydraulic model, an analysis tool that will be used to evaluate proposed capacity improvements.
  - Once the baseline capacity for the current sewer system has been established based on results from Part I, TREKK, Olsson and the City staff will determine a systematic approach to reduce excessive I/I.
  - Olsson will develop and evaluate peak flow management improvement alternatives, then, develop public and private I/I reduction programs.
  - Olsson will model future scenarios, such a 5-year level of service and ultimate buildout projected flows and propose infrastructure improvements to convey the projected flows and enhance system performance.
  - Based on the analysis, Olsson will provide recommendations and develop a Capital Improvement Plan for the city.

Furthermore, the purpose of this Part I report is to summarize the analysis and findings as follows:

- Provide baseline data that quantifies and severity of existing RDII in each subbasin of the collection system.
- Provide ranking of each subbasin in terms of RDII severity, a metric that can be utilized to support the prioritization of RDII reduction and rehabilitation efforts.
- Provide prioritized recommendation of additional next steps.

## 1.2 Scope

In conjunction with subconsultant TREKK, Olsson provided system-wide rainfall and collection system flow monitoring services, which comprised of the following:

1. Developing a Flow and Rainfall Monitoring Plan to specify the number and locations of flow metering and rainfall gauging sites,
2. Utilizing the City's GIS/mapping information to divide the collection system into subbasins,
3. Assessing the suitability of each flow and rainfall monitoring site,
4. Providing and installing twenty-seven flow meters and eight rainfall recorders capable of 0.01-inch incremental measurements and a sampling rate no larger than 15 minutes,
5. Maintaining the flow meters and rainfall gauges during a 284-day monitoring period (client reduced from 365-day scope), through fourteen maintenance visits to each site,
6. Processing monitoring data following each maintenance visit and remove all flow monitors at the conclusion of the monitoring period,
7. Providing online access to data including depth, velocity, flow, rainfall, and digital camera pictures to allow Client to remotely view the collected flow and rainfall monitoring locations; and
8. Performing up to 535 manhole inspections and GPS survey.

Following the completion of the flow monitoring services, Olsson performed the following tasks, documented in this report:

1. Analyzing the collected flow and rainfall data and quantified RDII using the Environmental Protection Agency's (EPA's) Sanitary Sewer Overflow Analysis and Planning (SSOAP) Toolbox,
2. Utilizing existing GIS data and field data collected during of this project to develop a hydraulic model for the collection system using InfoSewer software by Autodesk,
3. Modeling the response of the existing system to rainfall events,
4. Developing synthetic unit hydrographs (SUH's) for various durations of design storms, including the 1-, 2-, 5-, 10- and 25-year return intervals, and, and simulating the system response under these design storms,
5. Evaluating the 3 major lift stations: McKisic, North, and South, and presented findings in a technical memorandum, which is presented in Appendix A, Lift Station Technical Memo,
6. Tabulating RDII results and related figures to summarize the analysis results; and
7. Developing recommendations for prioritizing rehabilitation efforts by subbasin and providing additional recommendation for the program development.

# 2. EXISTING COLLECTION SYSTEM

The City of Bentonville, located in Benton County in Northwest Arkansas, had an estimated population of 54,164 as of 2020. The city's collection system includes the assets listed in Table 1.

**Table 1. Bentonville Collection System Assets.**

| Area | Lift Stations | Force Main (LF) | Gravity Sewer Main (LF) | Manholes |
|---|---|---|---|---|
| Bentonville Collection System | 68 | 128,300 | 1,333,100 | 5,928 |

The City is served by two wastewater treatment facilities, and is comprised of two service areas, a northern and a southern service area as shown in Figure 2. Flows from the northern service area are treated at water resource recovery facility (WRRF), which is owned and operated by the City. Flows from the southern service areas are pumped to the Northwest Arkansas Conservation Authority (NACA) wastewater treatment facility (WWTF) as shown in Figure 2.

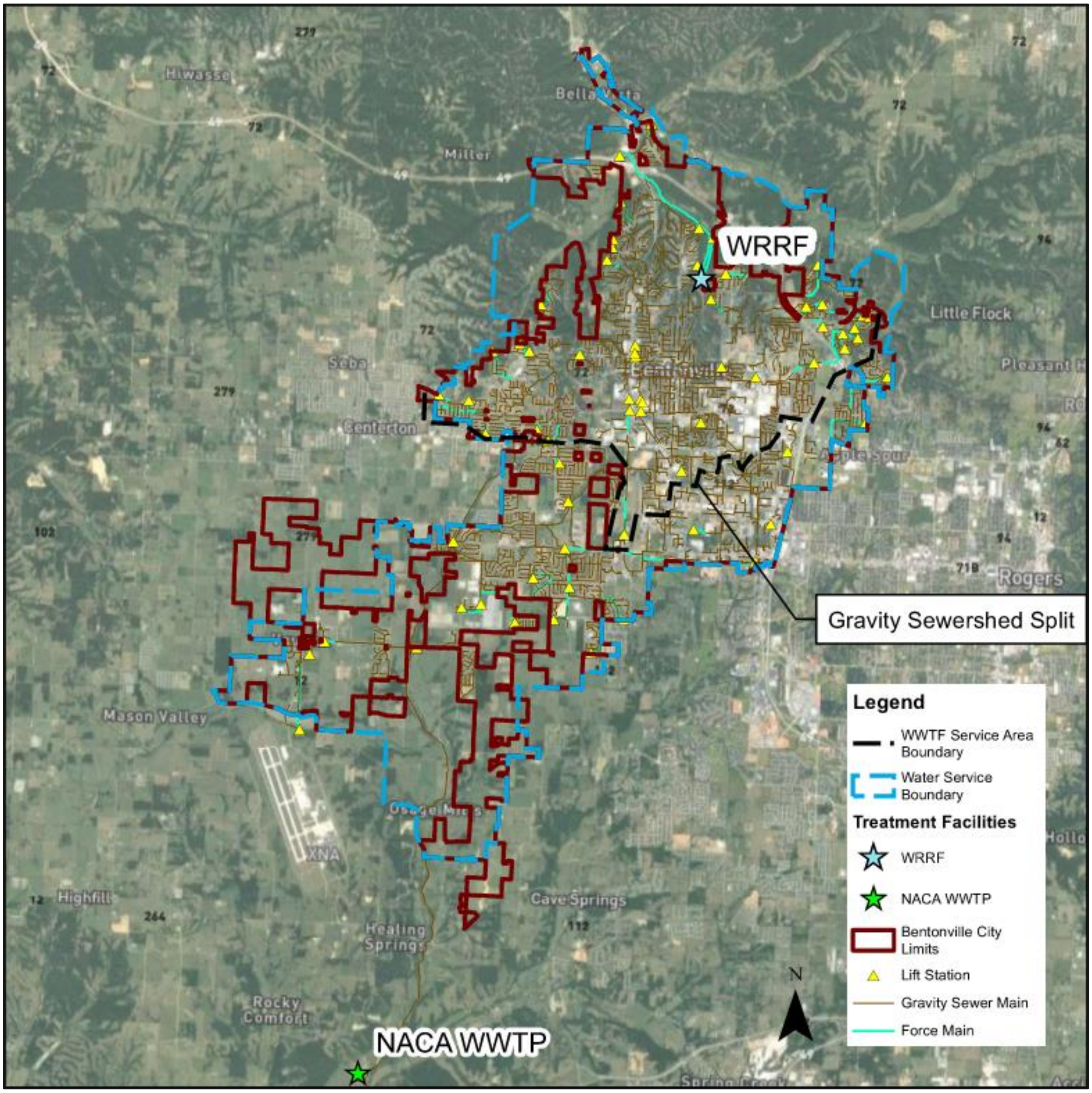


**Figure 2. City of Bentonville, Arkansas Collection System.**

The study area includes the McKisic, Town Branch, and Shewmaker basins, which constitute the entire service area of the Bentonville WRRF, and the South Lift Station basin, which is pumped to the NACA WWTF, as shown in Figure 3.

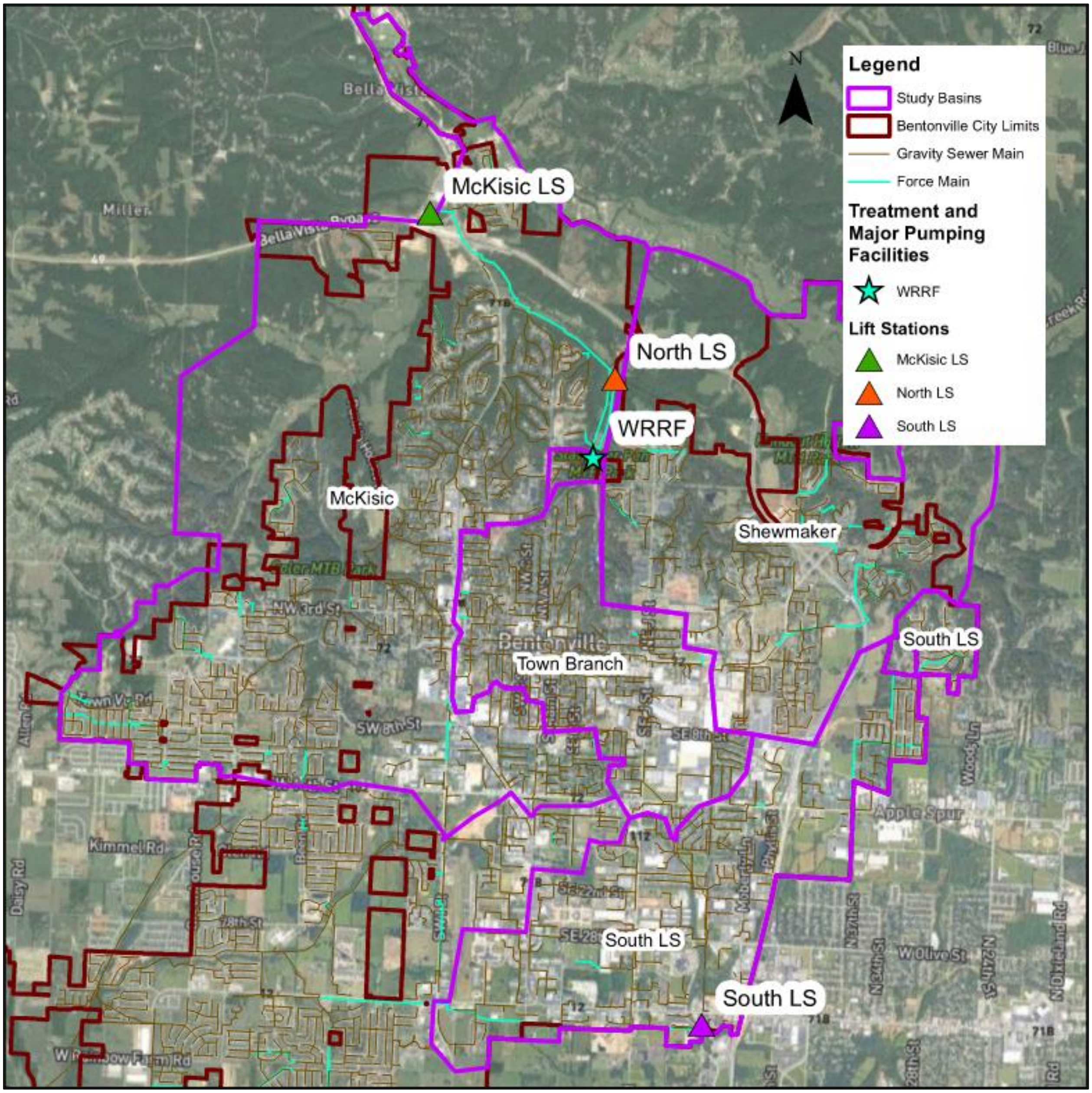


**Figure 3. Collection System Study Area.**

Assets within the study area are listed in Table 2, which shows that three of the basins drain into a major lift station, except the Town Branch basin which flows by gravity to Bentonville WRRF.

**Table 2. Study Area Assets.**

| Basin | Downstream Facility | Lift Stations | Force Mains (LF) | Gravity Mains (LF) | Manholes |
|---|---|---|---|---|---|
| McKisic | McKisic Lift Station | 25 | 44,400 | 449,600 | 2,062 |
| Town Branch | Gravity to WRRF | 7 | 1,300 | 197,500 | 732 |
| Shewmaker | North Lift Station | 13 | 21,600 | 161,500 | 796 |
| South Lift Station | South Lift Station | 5 | 26,000 | 209,100 | 816 |
| **Study Area Total** | **-** | **50** | **93,300** | **1,017,700** | **4,406** |

This study also included the evaluation of the city's three major lift stations, which are the McKisic, North, South lift stations, shown in Figure 3. A technical memorandum documenting the findings of this evaluation is provided in Appendix A, Lift Station Technical Memo.

As detailed later in this report, only the primary gravity mains, and primary lift stations and force mains were included in the hydraulic model for evaluation.

# 3. FLOW AND PRECIPITATION MONITORING

The study area was divided into 27 subbasins, as shown in Figure 4. These subbasins were individually metered, in order identify the characteristics of each subbasin, such as dry weather flows, dry weather diurnal patterns, and response to rainfall events.

Flow monitoring began September 10, 2020, for some sites, with all meters installed by September 25th, 2020. All meters were removed by July 6th, 2021.

## 3.1 Flow and Rainfall Monitoring Plan

In coordination with subconsultant TREKK, Olsson developed a Flow and Rainfall Monitoring Plan to monitor sewer flows and rainfall across the study area. Twenty-seven electronic flowmeters equipped with digital camera systems that measure both level and velocity were installed in sewer mains across the system.

These flow meters record the measured level and velocity of the wastewater flowing through a pipe and calculates the flow rate. Submerged pressure transducers were installed to measure the depth of flow by the hydrostatic pressure of the liquid above the transducers, collecting valuable depth data during surcharge conditions. Velocity was measured with continuous wave Doppler technology, in which a sensor transmits a continuous ultrasonic wave then measures the frequency shift of returned echoes reflected by air bubbles or particles in the flow.

The flow meters were strategically placed throughout the collection system to monitor each of the identified 27 subbasins, as illustrated in Figure 5. Each subbasin was named according to the basin it falls within.

A schematic of the flow meters and their relationship in each basin is shown in Figure 5, and schematically represents the metered subbasins shown in Figure 4. Flows into the McKisic Lift Station were mostly monitored by flow meters M1 and M2. Flows from the Town Branch basin were mostly monitored by flow meters TB1 and TB2. Flows from the Shewmaker basin were monitored by flow meter S1 immediately upstream of the North Lift Station. Flows to the South Lift Station were monitored by the SLS1 flow meter.

Eight rain gauges were strategically placed in portions of the collection system. The rain gauges were all tipping-bucket style and capable of recording rainfall in 0.01-inch measurements at 1-minute increments. Their locations were selected to account for the varying amounts of rainfall that fell within the sewer service area. The rain gauge locations are shown in Appendix B, Sewer Collection System Study Area Map, and are labeled as M1, M2, M3, M4, M5, S1, SLS1, and SLS2, according to the basin they are located within.

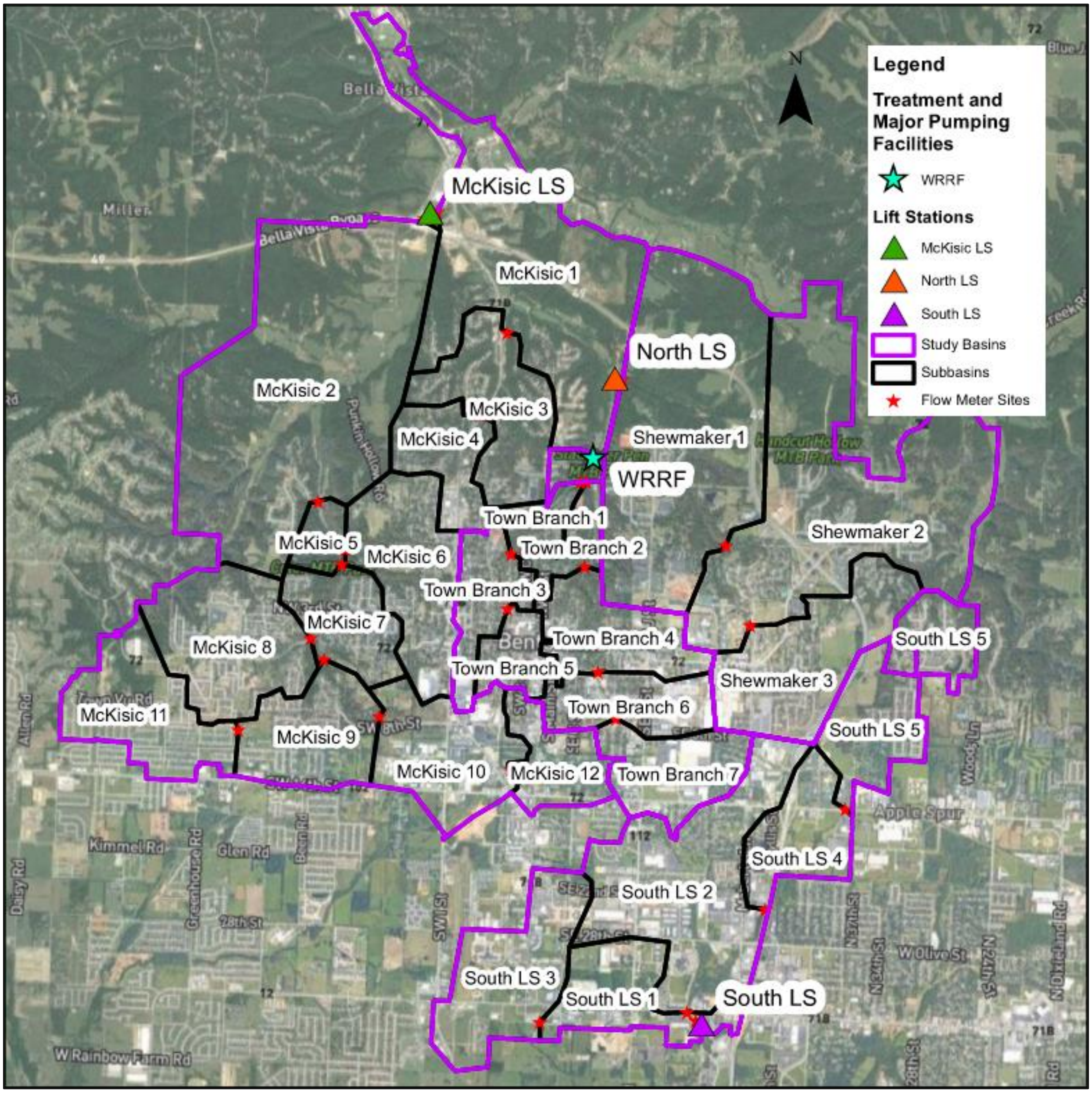


**Figure 4. Subbasin Locations**

**Table 3. Assets by Sewer Subbasins**

| Subbasin Short | No. of Manholes | No. of Service Connections | Total Length of Pipe (LF) |
|---|---|---|---|
| McKisic 1 | 258 | 411 | 46,667 |
| McKisic 2 | 35 | 69 | 8,687 |
| McKisic 3 | 275 | 517 | 49,368 |
| McKisic 4 | 176 | 353 | 36,865 |
| McKisic 5 | 52 | 110 | 11,423 |
| McKisic 6 | 221 | 569 | 44,479 |
| McKisic 7 | 111 | 302 | 20,906 |
| McKisic 8 | 213 | 729 | 46,653 |
| McKisic 9 | 144 | 758 | 33596 |
| McKisic 10 | 114 | 194 | 25,695 |
| McKisic 11 | 194 | 1041 | 45,416 |
| McKisic 12 | 313 | 810 | 72,531 |
| Shewmaker 1 | 73 | 433 | 32,651 |
| Shewmaker 2 | 322 | 752 | 68,157 |
| Shewmaker 3 | 252 | 649 | 51,752 |
| South LS 1 | 99 | 95 | 21,652 |
| South LS 2 | 333 | 572 | 84,874 |
| South LS 3 | 128 | 151 | 30,605 |
| South LS 4 | 57 | 49 | 13,757 |
| South LS 5 | 168 | 648 | 40,083 |
| Town Branch 1 | 26 | 88 | 6,120 |
| Town Branch 2 | 23 | 156 | 8,011 |
| Town Branch 3 | 130 | 476 | 31,697 |
| Town Branch 4 | 153 | 412 | 37,360 |
| Town Branch 5 | 56 | 284 | 18,913 |
| Town Branch 6 | 106 | 268 | 27,728 |
| Town Branch 7 | 137 | 389 | 34,864 |

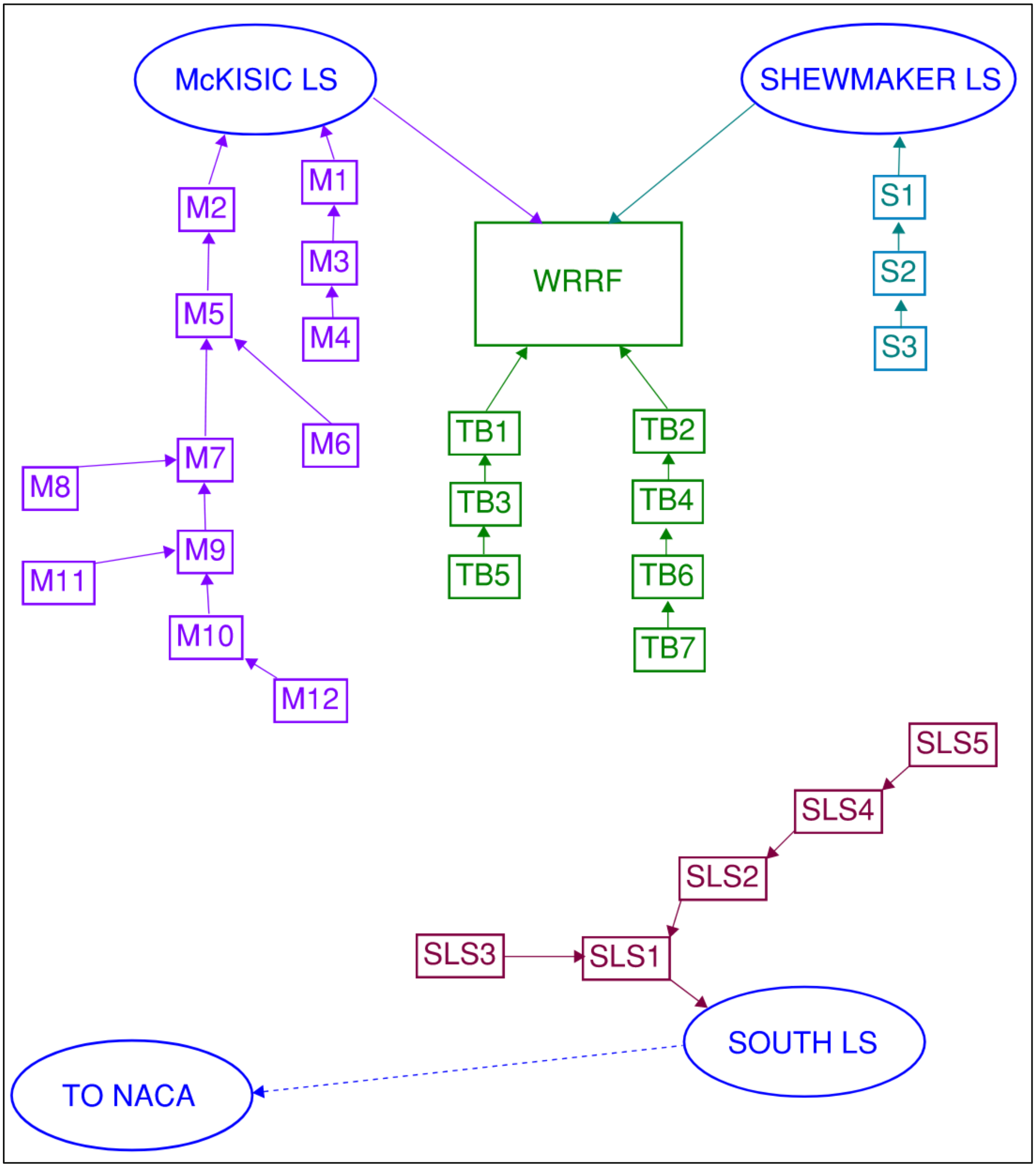


**Figure 5. Flow Monitoring Schematic**

## 3.2 Rainfall Monitoring Results

Olsson reviewed the rainfall data collected by the rain gauges, and selected distinct rain events. These rainfall events were then characterized by total rainfall depth and duration. Olsson used the following criteria to define and select distinct rain events:

- The total rainfall depth during the event was greater than 0.5 inches.
- The event had a duration of 30 minutes or longer.
- The event was preceded and succeeded by 12 hours without precipitation.

The National Oceanic and Atmospheric Administration (NOAA) precipitation frequency estimates tabulate the likelihood of rain events with a specific duration and depth that will occur within an average recurrence interval (ARI). The event distribution adopted for the analysis is discussed in Section 4.6. NOAA data for Bentonville are presented in Appendix C, NOAA Precipitation Frequency Estimates. This data is used to rank the selected rain events according to the NOAA classification. The estimated precipitation frequency for the selected rain events during the monitoring period is listed in Appendix D, Rainfall Frequency Estimates.

As a result of the spatial distribution of rainfall, the recorded rainfall data varies for each gauge. During the monitoring period, rain gauges recorded between 17 and 19 storms in fall/winter and 14 storms in spring, only counting the events that meet the criteria presented earlier.

Generally, the rainfall events that were recorded during fall/winter were below the State average rainfall, while the rainfall events that were recorded during spring were above State average rainfall, as shown in Figure 6. The average recorded rainfall in Figure 6 represent the average of the total monthly rainfall recorded by all the rain gauges.

Throughout the monitoring period, only two storm events exceed the 1-year ARI, as shown in Appendix D, Rainfall Frequency Estimates. The most significant rain event was recorded by rain gauge S1 on April 28, 2021, and had a duration of 26 hours and a depth of 6.07 inches. This event is equivalent to the NOAA precipitation frequency of 22 years. This implies that such a storm event has a 4.5-percent probability of occurring in any given year.

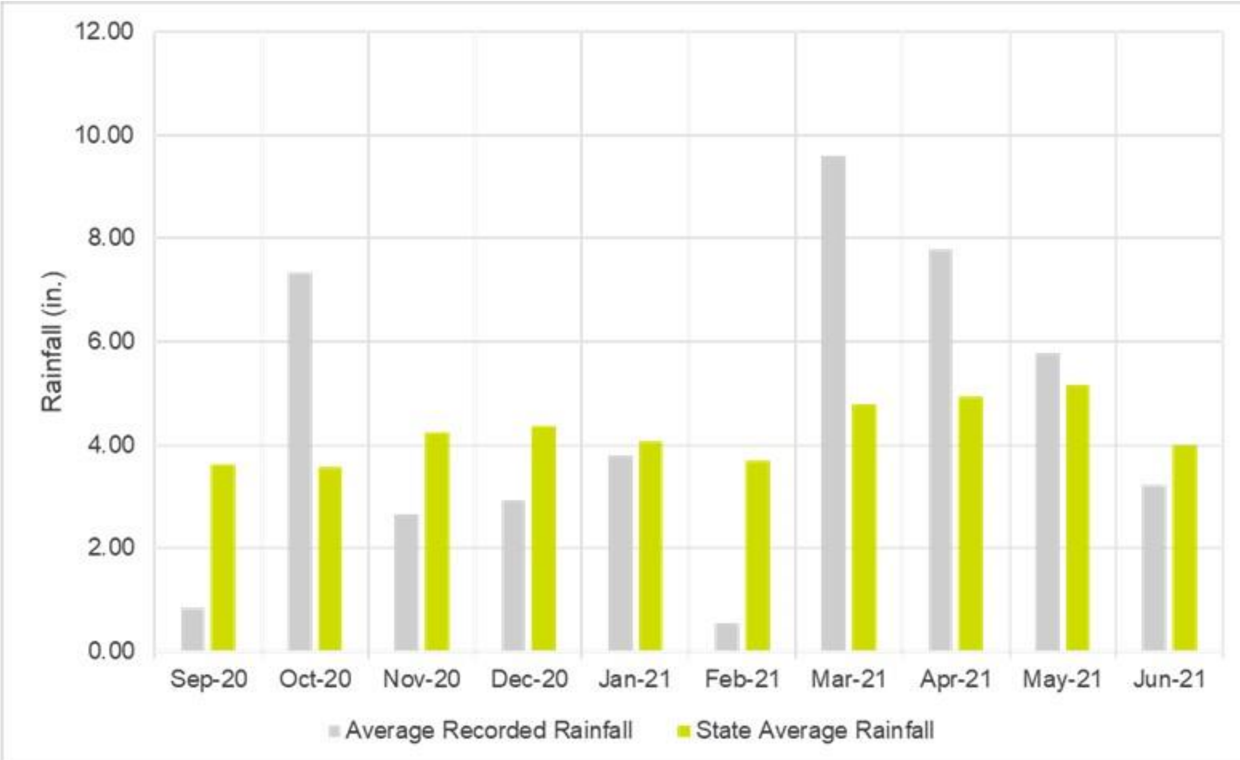


**Figure 6. Comparison of Average Recorded Rainfall in Bentonville and Arkansas State.**

Because of the spatial distribution of rainfall, Thiessen polygons were utilized to proportionally assign rainfall from rain gauges to individual subbasins. Theissen polygons were developed using the locations of the rain gauges, and it was assumed that rainfall recorded by each rain gauge was uniform over its Thiessen polygon. The percentage contributed by each rain gauge to a subbasin was calculated using the ratio of area within a polygon compared to the total subbasin area, as shown in Table 4.

**Table 4. Rain Gauge Contributions by Subbasin**

| Subbasin | Rain Gauge | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | M1 | M2 | M3 | M4 | M5 | S1 | SLS1 | SLS2 |
| McKisic 1 | 57.6% | 42.3% | --- | 0.1% | --- | --- | --- | --- |
| McKisic 2 | 38.2% | | --- | 61.8% | --- | --- | --- | --- |
| McKisic 3 | 4.5% | 91.5% | --- | 3.9% | --- | --- | --- | --- |
| McKisic 4 | --- | 44.9% | --- | 55.1% | --- | --- | --- | --- |
| McKisic 5 | --- | --- | --- | 99.6% | --- | --- | --- | --- |
| McKisic 6 | --- | --- | 34.8% | 65.1% | --- | --- | --- | --- |

**Table 4. Rain Gauge Contributions by Subbasin (Continued)**

| Flow Meter | Rain Gauge | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | M1 | M2 | M3 | M4 | M5 | S1 | SLS1 | SLS2 |
| McKisic 7 | --- | --- | 43.2% | 56.7% | --- | --- | --- | --- |
| McKisic 8 | --- | --- | 6.7% | 23.1% | 70.3% | --- | --- | --- |
| McKisic 9 | --- | --- | 70.5% | --- | 29.3% | --- | --- | --- |
| McKisic 10 | --- | --- | 99.0% | --- | --- | --- | --- | 1.0% |
| McKisic 11 | --- | --- | --- | --- | 100.0% | --- | --- | --- |
| McKisic 12 | --- | --- | 98.7% | --- | --- | 1.2% | --- | --- |
| Shewmaker 1 | --- | 23.8% | --- | --- | --- | 71.1% | 5.1% | --- |
| Shewmaker 2 | 1.4% | --- | --- | --- | --- | 96.2% | --- | 2.4% |
| Shewmaker 3 | --- | --- | --- | --- | --- | 82.0% | 18.1% | --- |
| South LS 1 | --- | --- | --- | --- | --- | --- | --- | 100.1% |
| South LS 2 | --- | --- | --- | --- | --- | 0.5% | 74.5% | 24.9% |
| South LS 3 | --- | --- | --- | --- | --- | --- | --- | 100.0% |
| South LS 4 | --- | --- | --- | --- | --- | --- | 100.0% | --- |
| South LS 5 | --- | --- | --- | --- | --- | --- | 100.0% | --- |
| Town Branch 1 | --- | 100.1% | --- | --- | --- | --- | --- | --- |
| Town Branch 2 | --- | 92.3% | 7.3% | --- | --- | --- | --- | --- |
| Town Branch 3 | --- | 10.7% | 77.7% | 11.6% | --- | --- | --- | --- |
| Town Branch 4 | --- | 5.9% | 28.5% | --- | --- | 65.6% | --- | --- |
| Town Branch 5 | --- | --- | 100.0% | --- | --- | --- | --- | --- |
| Town Branch 6 | --- | --- | 32.6% | --- | --- | 67.2% | --- | --- |
| Town Branch 7 | --- | --- | 3.4% | --- | --- | 77.1% | 19.4% | 0.2% |

When the flow data recorded by a flow meter was discarded for some reason, its subbasin was combined for analysis the downstream subbasin, as described in Section 4.2. Rain gauge contributions for the combined subbasins were recalculated accordingly.

## 3.3 Flow Monitoring Results

Figures depicting the flow rates recorded by each meter are provided in Appendix E, Flow Monitoring Results. For each flow meter, a contributing sewered area was calculated that excludes any large unsewered area, such as parks and greenspaces. The resulting sewer subbasin areas are important inputs for the subsequent analyses. Discussion of each basin is provided in Appendix E with the data.

# 4. RAINFALL-DERIVED INFLOW AND INFILTRATION ANALYSIS

Once flow and rainfall data were obtained at each location, Olsson analyzed the data to characterize the Rainfall Derived Inflow and Infiltration (RDII) entering the sanitary sewer system and provide necessary inputs for hydraulic capacity modeling.

## 4.1 SSOAP Toolbox Overview

Olsson analyzed the collected flow and rainfall data using the SSOAP Toolbox program to quantify RDII that occurred during the monitoring period. SSOAP assists users in utilizing the real time kinematic (RTK) method to calculate RDII and generate an RDII hydrograph using the flow and rainfall data for each subbasin. The RTK method is described in the EPA publication “Review of Sewer Design Criteria and RDII Prediction Methods (EPA/600/R-08/010)”.

These RTK hydrographs were then used within SSOAP to create hydrographs to estimate wet weather flows at each flow meter to represent the response from a subbasin. The hydrographs were generated for the 1-, 2-, 5-, 10-, and 25-year return interval rain events, as discussed in Section 4.6.

The RTK values obtained through SSOAP were used as inputs to the hydraulic model, further detailed in Section 5. The following steps were performed for each of the 27 flow meters:

1. Rainfall and flow data, and sewer service area were entered into SSOAP.
2. The data was evaluated using the Database Management Tool. The evaluation results, which included the generation of scatterplot graphs of the data, were discussed with TREKK to reconcile any discrepancies and verify the validity of the collected data.
3. The average dry-weather flow and significant wet-weather events (RDII events) were identified using the Dry Weather Flow (DWF) Analysis and Wet Weather Flow (WWF) Analysis tools.
4. A simulated RDII hydrograph was developed through decomposition of the observed RDII hydrograph generated by SSOAP for the selected RDII events. The decomposition process results in ‘R’, ‘T’, and ‘K’ values that represent the RDII response for each event in a sewer service area.
5. The accuracy of the simulated RDII hydrograph was evaluated using the Statistical Analysis tool.
6. A 24-hour rainfall distribution was created for 1-, 2-, 5-, 10-, and 25-year return interval rain events and the data were entered in SSOAP.

7. An RDII hydrograph was generated for each of the predicted return interval rain events. These hydrographs represent the flows that would result from a rain event of the same total rainfall and distribution as the design storms.
8. The RTK values determined within SSOAP were applied to the collection system model along with the dry-weather flow data to evaluate each subbasin’s reaction to rain events of varying intensity.

A detailed description of SSOAP is provided in the EPA report “Computer Tools for Sanitary Sewer System Capacity Analysis and Planning (EPA/600/R-07/11).”

## 4.2 Analysis Approach

Flow and rainfall data was collected for this project over an extended period to obtain sufficient data to characterize the RDII response in the study area.

The monitoring period began in September and ended in July for each meter. It is typical in collection systems for the measured dry weather flows to vary seasonally, which is a result of groundwater levels fluctuating over the seasons. Olsson noted that both flows through the system and rainfall patterns shifted on March 10th from a fall/winter pattern to a spring pattern. Therefore, Olsson analyzed the fall/winter period separately from the spring period.

Due to the layout of the system, several flow meters were installed downstream of other flow meters. In such cases, the downstream flow meter recorded cumulative flows from the area immediately upstream of the flow meter and all the metered areas upstream of the metered subbasin. Olsson isolated each of these flow meters by subtracting flow data recorded by the meters immediately upstream of each meter. The recorded flow data can be used for model calibration, as described in Section 5, but the flow should be isolated in order to analyze RDII generated in a subbasin.

A total of 10 flow meters were installed in upstream subbasins, and did not require flow isolation, while the remaining 17 meters required isolation of upstream data for analysis. Figure 7 shows an example of a subbasin requiring isolation due to its location, showing the raw flow data for the spring monitoring period for both the Town Branch 6 (TB6) and Town Branch 7 (TB7) flow meters. TB7 subbasin is most upstream, and flows through TB6 subbasin. Flow data recorded by meter TB6 represents the cumulative flows from both subbasins, and accordingly the flow rates recorded by the TB6 were generally greater than the TB7, as shown in Figure 7, indicating that meter TB6 was properly measuring the flow contributed both subbasins. For RDII analysis, Olsson isolated the flows for each subbasin as described above.

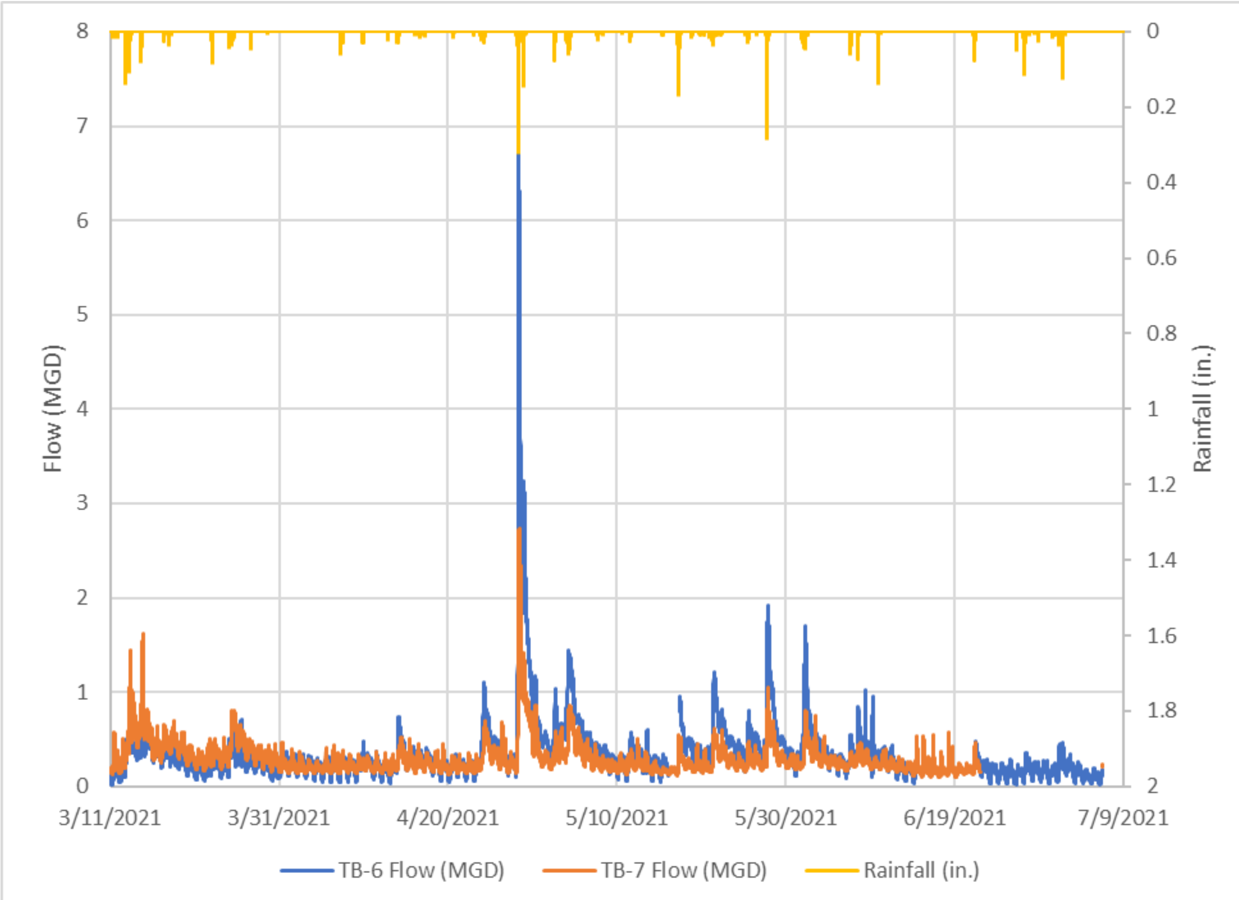


**Figure 7. Town Branch 6 and Town Branch 7 raw flow data.**

### 4.2.1 Fall/Winter Subbasin Isolation

Data for fall/winter, collected between September 23, 2020 and March 11, 2021, was analyzed for each meter. Preliminary isolation of dry weather flows could not be done successfully for 6 out of the 17 subbasins requiring isolation, because the upstream meters were recording higher flows that the downstream meters. Of the isolated subbasins, 4 out of 6 could be analyzed for their RDII response. Table 5 on the following page summarizes the results of preliminary subbasin isolation for the fall/winter monitoring period.

**Table 5. Fall/Winter Preliminary Subbasin Isolation Results**

| Subbasin | Preliminary Isolation Success | | Subbasin | Preliminary Isolation Success | |
|---|---|---|---|---|---|
| | DWF | RDII | | DWF | RDII |
| McKisic 1 | N | N | South Lift Station 1 | N | N |
| McKisic 2 | N | N | South Lift Station 2 | N | N |
| McKisic 3 | N | N | South Lift Station 3 | N/A | N/A |
| McKisic 4 | N/A | N/A | South Lift Station 4 | N | N |
| McKisic 5 | N | N | South Lift Station 5 | N/A | N/A |
| McKisic 6 | N/A | N/A | Town Branch 1 | Y | N |
| McKisic 7 | Y | N | Town Branch 2 | N | N |
| McKisic 8 | N/A | N/A | Town Branch 3 | Y | Y |
| McKisic 9 | Y | Y | Town Branch 4 | N | N |
| McKisic 10 | Y | Y | Town Branch 5 | N/A | N/A |
| McKisic 11 | N/A | N/A | Town Branch 6 | Y | Y |
| McKisic 12 | N/A | N/A | Town Branch 7 | N/A | N/A |
| Shewmaker 1 | N | N | | | |
| Shewmaker 2 | N | N | | | |
| Shewmaker 3 | N/A | N/A | | | |

Figure 8 shows an example of a successful subbasin isolation, where isolating flow data TB6 from TB7 resulted in generally positive flows for both dry weather and wet weather flows that could be analyzed. The notable exceptions are between October 22, 2020 and October 29, 2020 when flow meter TB6 dropped out and the end of the fall/winter monitoring period when the velocities at flow meter TB7 began increasing for an unknown reason.

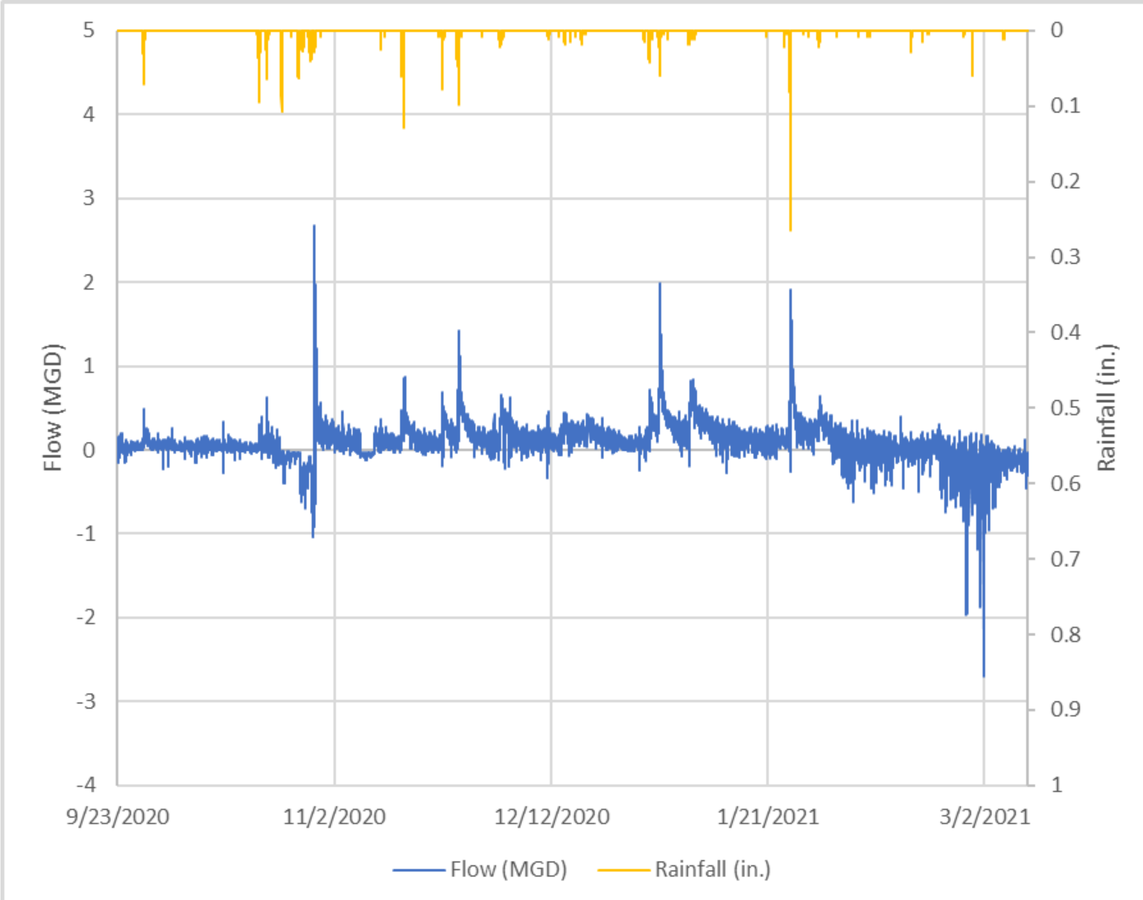


**Figure 8. Town Branch 6 flow data isolation from Town Branch 7.**

Discussed next are examples of the approach followed by Olsson's to resolve issues with flow isolation.

- McKisic 1 and 3

Isolating the McKisic 1 flow data from McKisic 3 resulted in the data shown in Figure 9 below. As shown, the flows recorded at McKisic 1 were generally slightly higher than recorded at McKisic 3 as indicated by the fact that the average flows in Figure 9 are greater than zero. The notable exception is the data from the storm on October 27, 2020 to January 1, 2021, during which time the velocity recorded by the McKisic 1 flow meter dropped out.

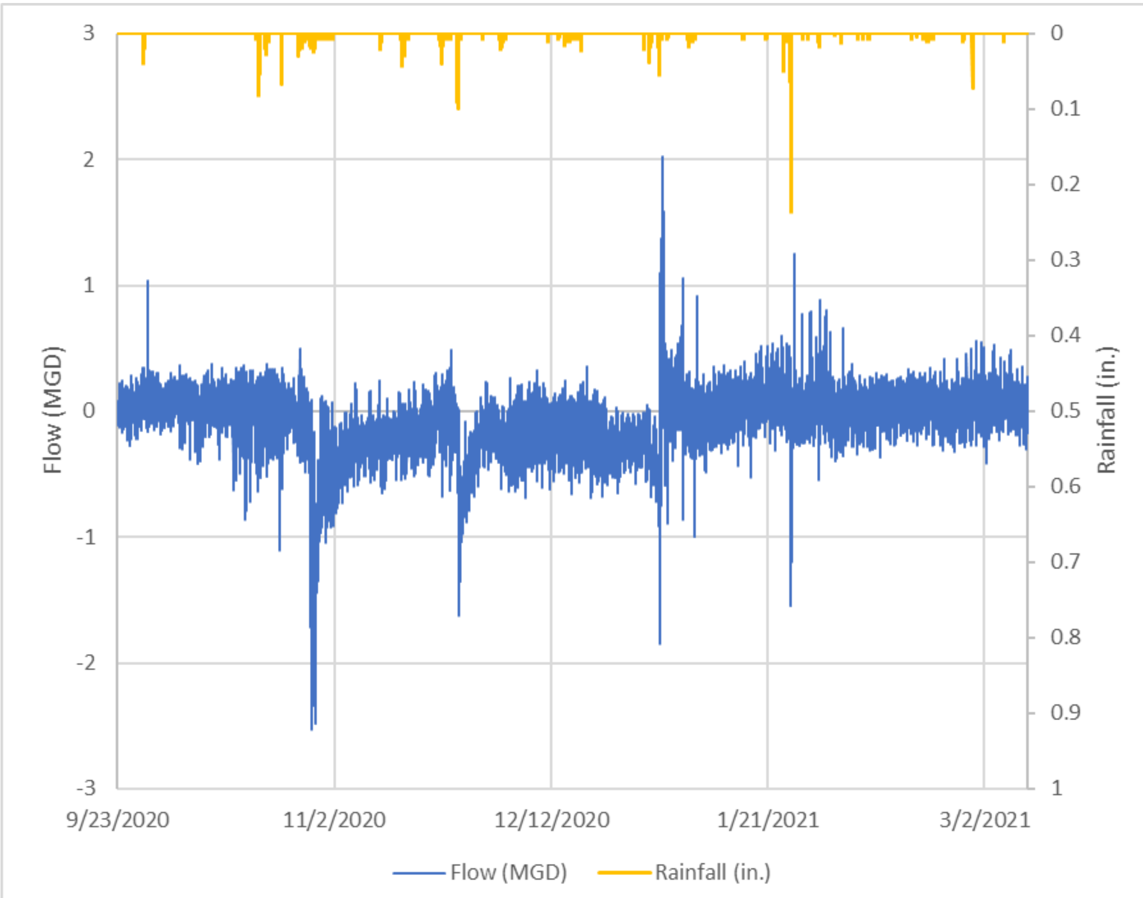


**Figure 9. McKisic 1 flow data isolation from McKisic 3.**

Olsson analyzed the McKisic 1 and McKisic 3 subbasins together by isolating the McKisic 1 flow data from McKisic 4, upstream of McKisic 4. In this way, Olsson was able to account for the RDII from both subbasins, which would not be possible by isolating McKisic 1 flow data from McKisic 3.

- McKisic 2

Isolation of the McKisic 2 flow data from McKisic 5 resulted in the data shown in Figure 10 below. As shown, the McKisic 2 flow meter readings were generally the same or lower than the McKisic 5 flow meter upstream. In discussion with the city, it was determined that the bar screen at the McKisic lift station was affecting the depth measurements at the McKisic 2 flow meter and impacting the flow readings.

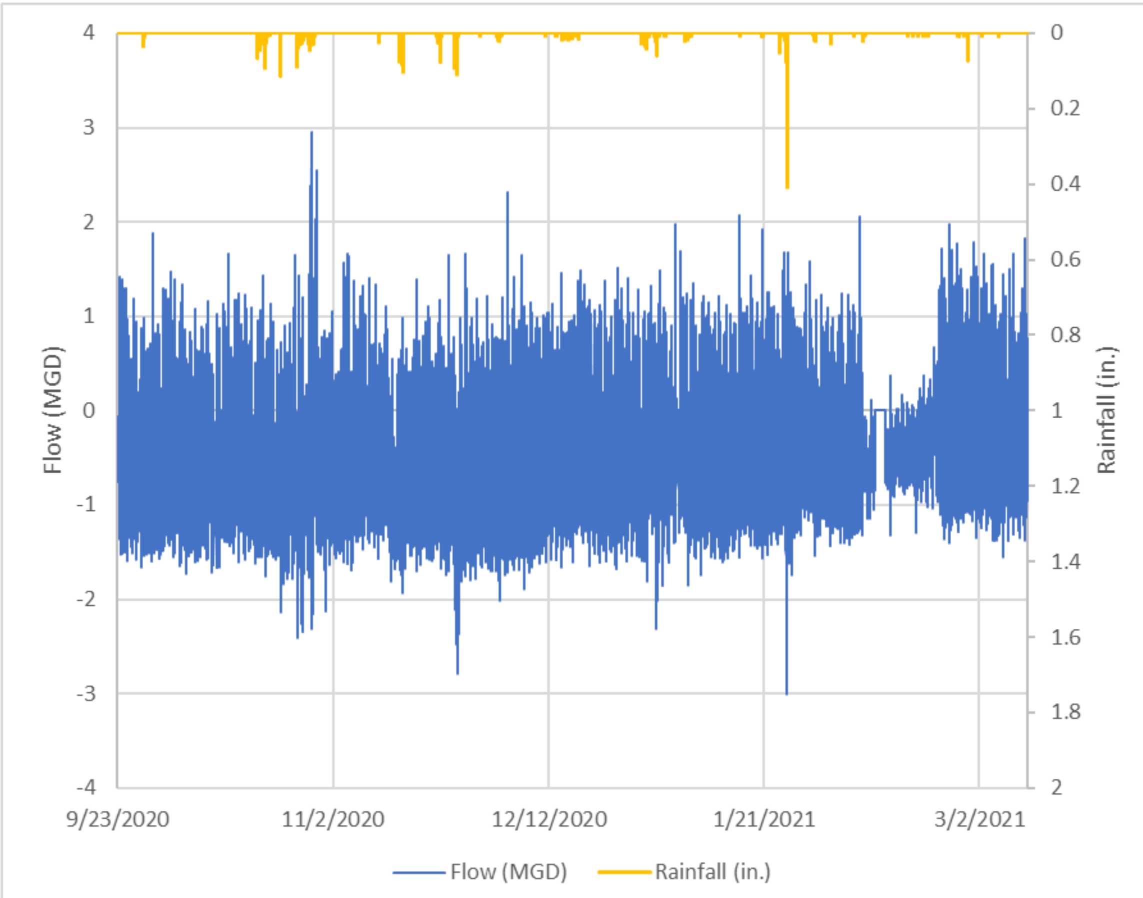


**Figure 10. McKisic 2 flow data isolation from McKisic 5.**

The isolated data from McKisic 2 could not be analyzed to determine either the dry weather flows or RDII flows.

- McKisic 5

Isolation of the McKisic 5 flow data from McKisic 6 and 7 resulted in the data shown in Figure 11 below. As shown, the McKisic 5 flow meter readings were generally the lower than the sum of the McKisic 6 and 7 flow measurements upstream.

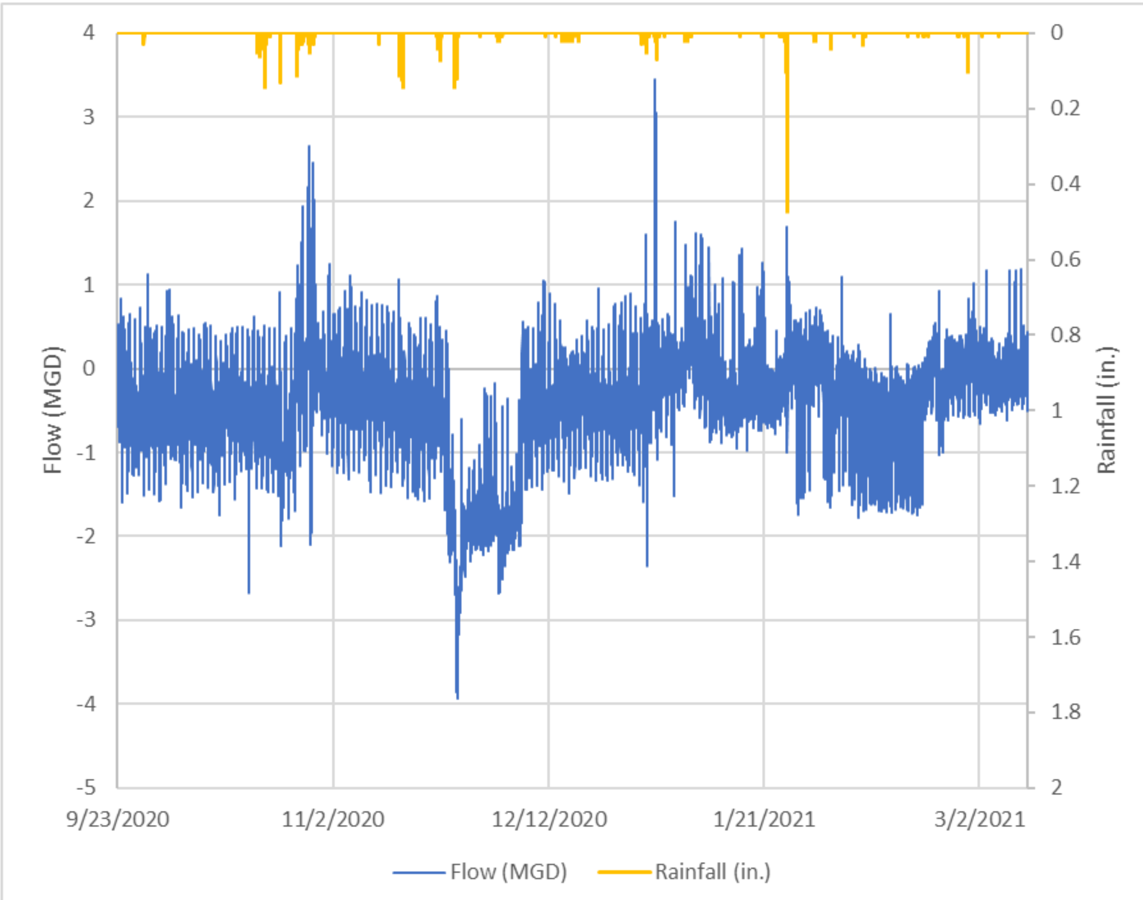


**Figure 11. McKisic 5 flow data isolation from McKisic 6 and 7.**

The isolated data from McKisic 5 could not be analyzed to determine either the dry weather flows or RDII flows.

- McKisic 7

Isolation of the McKisic 7 flow data from McKisic 8 and 9 resulted in the data shown in Figure 12 below. As shown, the McKisic 7 flow meter readings were generally higher than the sum of the McKisic 8 and 9 flow measurements upstream during dry weather. However, the wet weather flow rates recorded at McKisic 7 were generally lower, resulting in negative values.

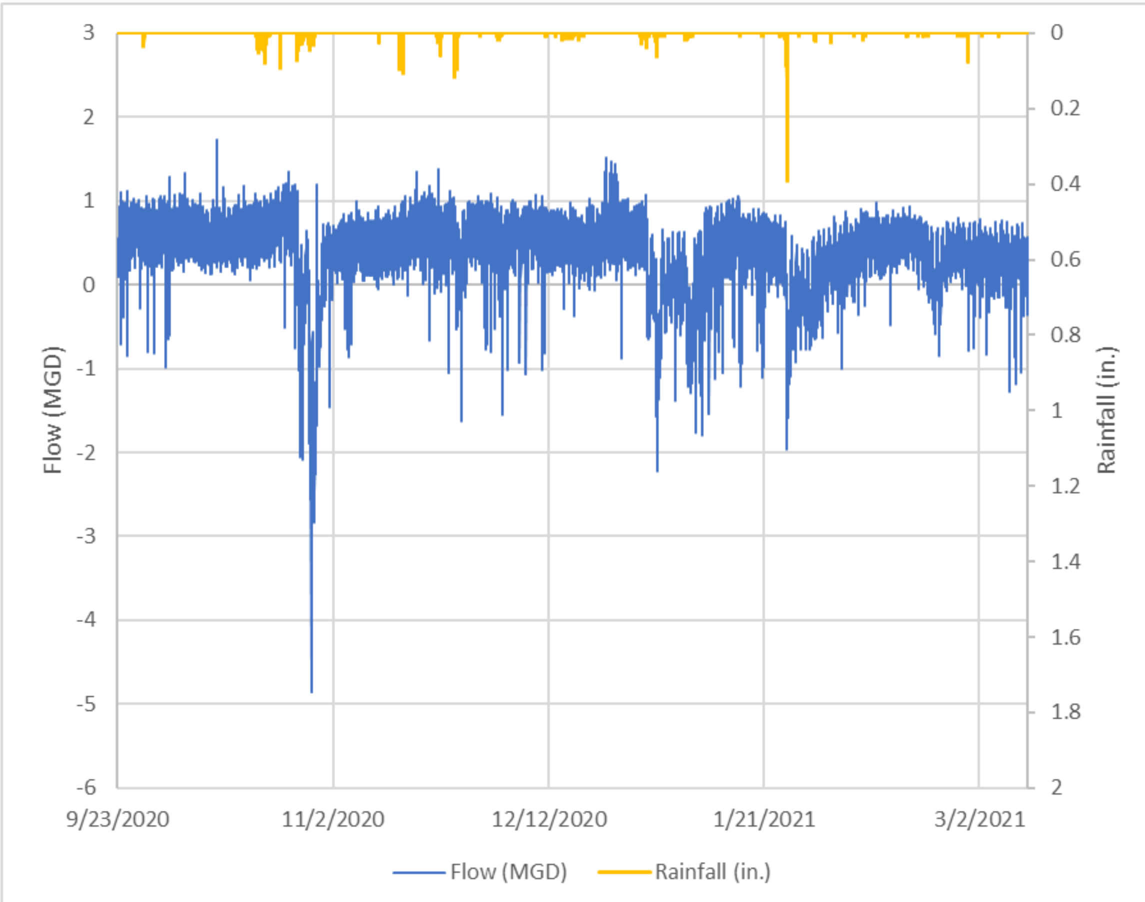


**Figure 12. McKisic 7 flow data isolation from McKisic 8 and 9.**

The isolated data from McKisic 7 was analyzed to determine dry weather flow rates but could not be analyzed to determine RDII responses.

- Shewmaker 1, 2, and 3

  Preliminary review of the flow data from the Shewmaker basin did not indicate a significant RDII response when compared to the McKisic, Town Branch, and South Lift Station basins. Isolation of the Shewmaker 1 flow data from Shewmaker 2 upstream resulted in the data shown in Figure 13 below. The average flow rates recorded at Shewmaker 1 were generally greater than recorded at Shewmaker 2 upstream, as indicated by the fact that the average isolated flow rate was positive. The RDII response from the isolated subbasin was more difficult to characterize, because peak RDII responses were generally no higher than the peak daily flows recorded the week before the October 28, 2020 storm event. In addition, negative flow rates at the beginning of each peak flow response made accurate analysis more difficult.

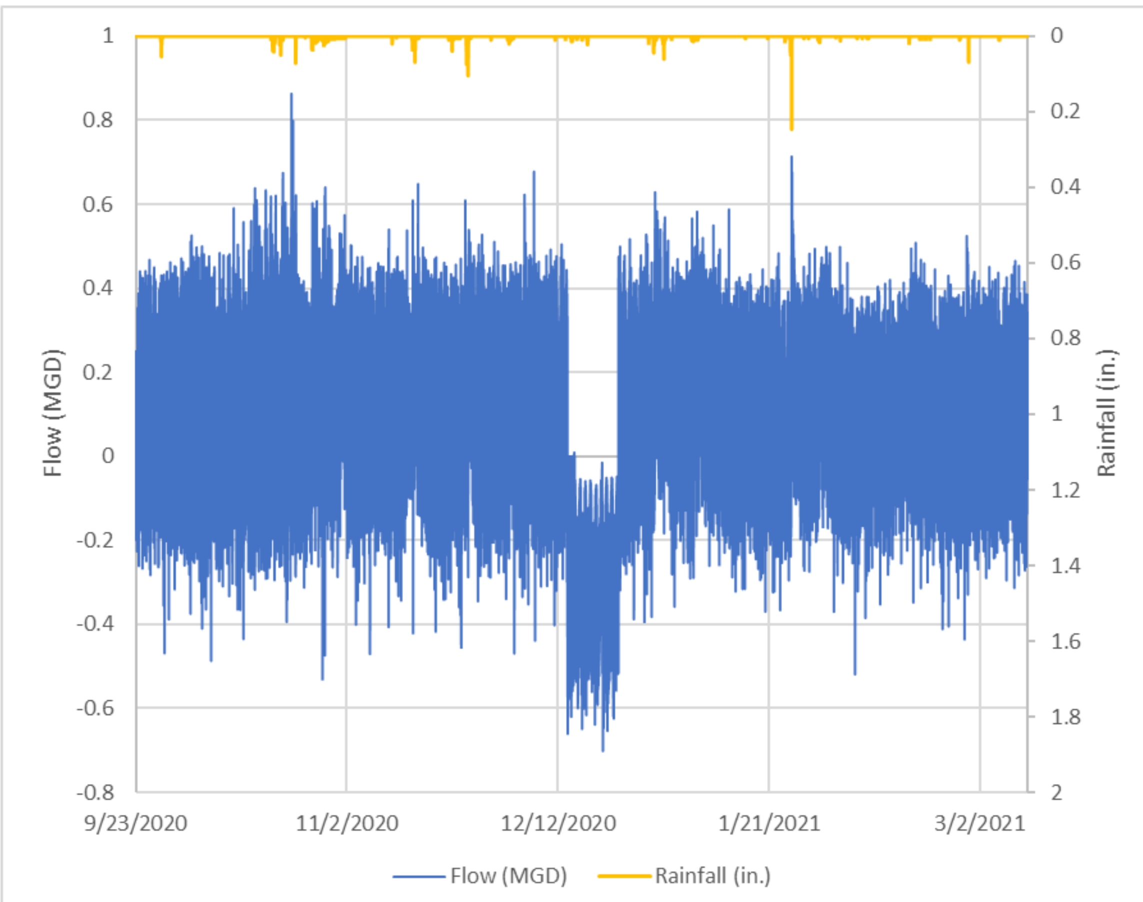


**Figure 13. Shewmaker 1 flow data isolated from Shewmaker 2.**

Isolation of the Shewmaker 2 flow data from Shewmaker 3 upstream resulted in the data shown in Figure 14 below. The average flow rates recorded at Shewmaker 2 were generally greater than recorded at Shewmaker 3 upstream, as indicated by the fact that the average isolated flow rate was positive. The isolated subbasin appeared to contribute insignificant amounts of RDII as evidenced by the lack of a significant flow response to rainfall in Figure 13.

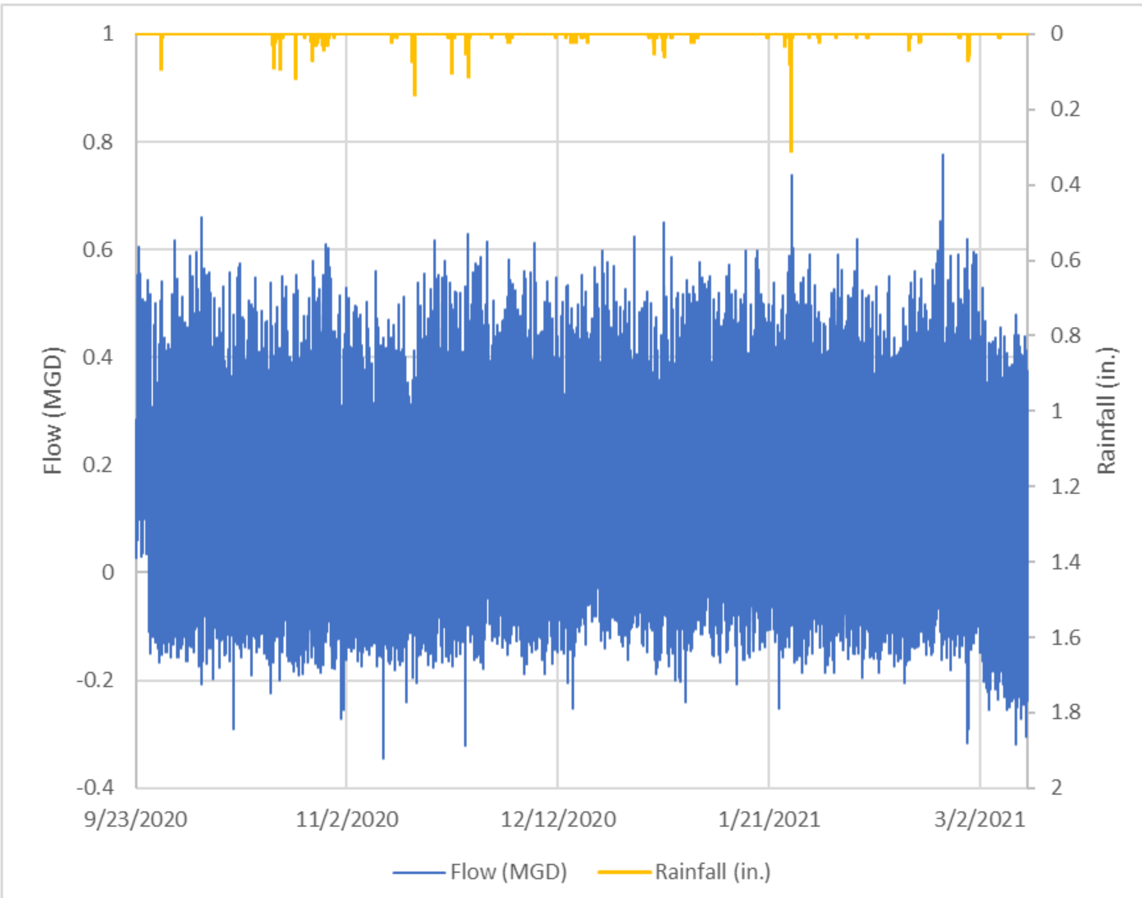


**Figure 14. Shewmaker 2 flow data isolated from Shewmaker 3.**

The RDII recorded within the Shewmaker basin generally was not concentrated in any of the three metered subbasins, so isolation did not improve the utility of RDII analysis. Olsson analyze the Shewmaker basin using only the data from the Shewmaker 1 flow meter to analyze more storms and eliminate error introduced by isolation.

- South Lift Station 3

The flow data collected by the South Lift Station 3 flow meter is shown in Figure 15 below. As shown, the dry weather flows recorded by the meter were generally inconsistent throughout the fall/winter monitoring period, making characterization of a typical dry weather flow pattern difficult. The RDII responses were similarly inconsistent. The RTK model of RDII characterization assumes that for a given subbasin, peak wastewater flow rates generally occur at a consistent amount of time after the peak rainfall (typically between 0.5 and 2 hours). However, the peak flow rates measured by the South Lift Station 3 flow meter did not occur at a consistent time interval after peak rainfall, making accurate characterization of RDII response times difficulty. The inconsistent data recorded by South Lift Station 3 also resulted in difficulty when isolating the South Lift Station 1 flow data.

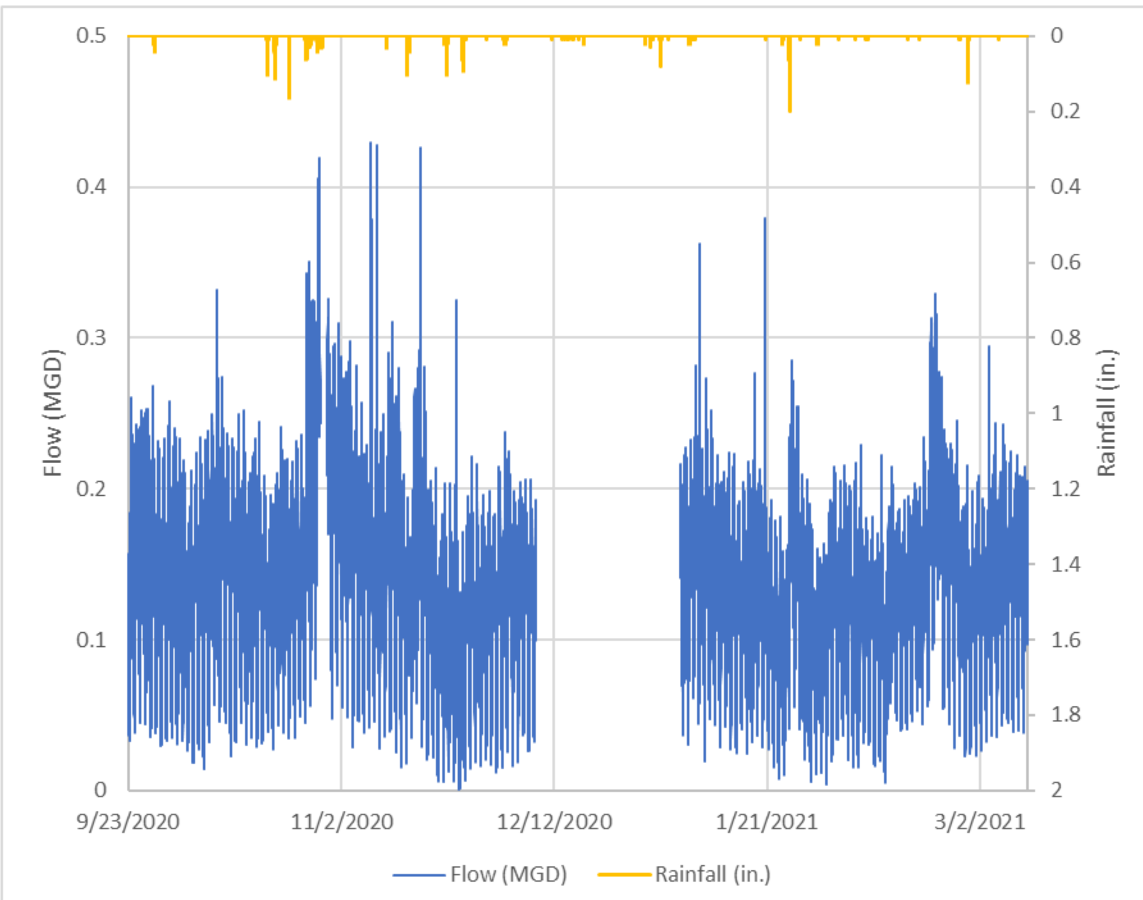


**Figure 15. South Lift Station 3 flow data.**

Olsson chose to analyze the South Lift Station 1 and 3 flow data together by isolating South Lift Station 1 from South Lift Station 4 in order to characterize the dry weather and RDII flows from both subbasins.

- South Lift Station 4 and 5

Isolation of the South Lift Station 4 flow data from South Lift Station 5 resulted in the data shown in Figure 16 below. As shown, the flow data pattern shifted after January 5, 2021, making the dry weather and RDII flow rates unclear. The meter did not record RDII responses to any of the calibration storms that could be analyzed for unknown reasons. Responses to the October 28, 2020 through October 31, 2020 rain events could not be analyzed, because the flow rates did not return to dry weather flow patterns between storms, which affected the generation of RTK values for each storm.

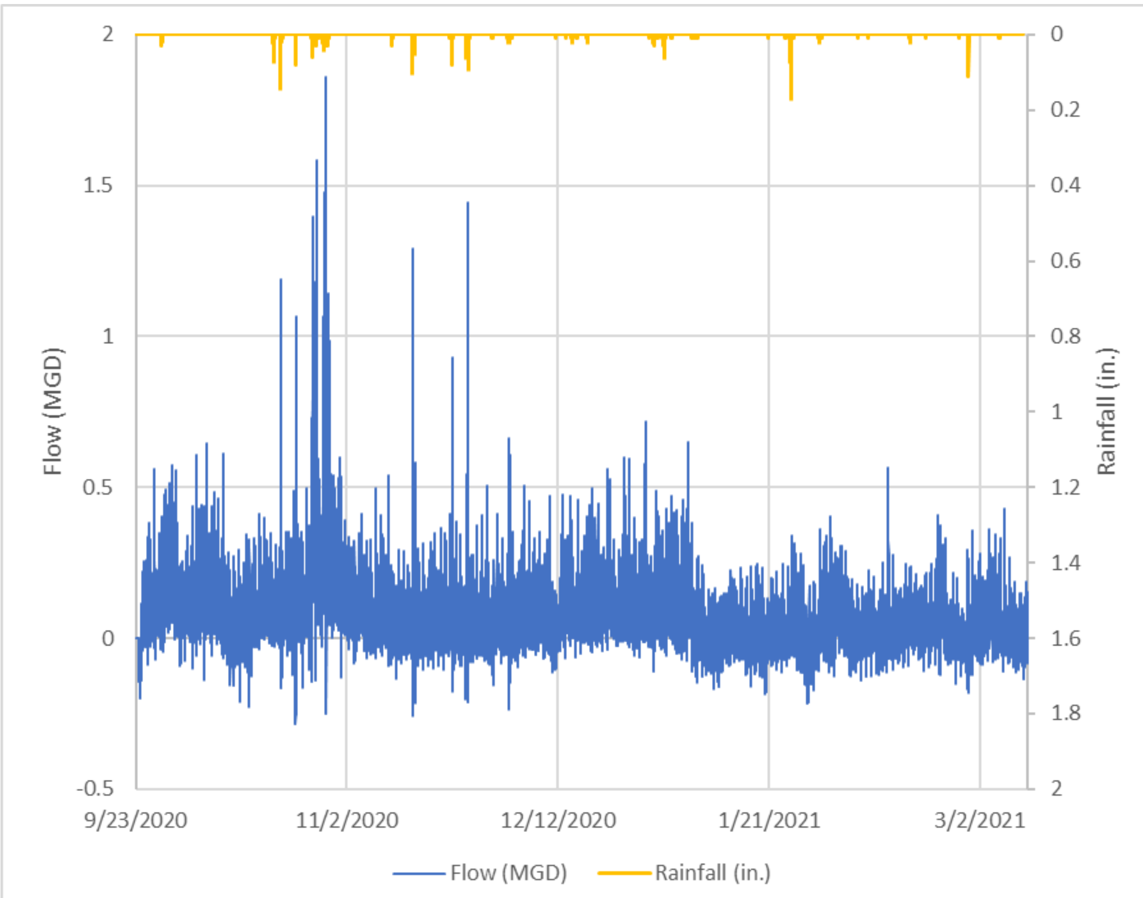


**Figure 16. South Lift Station 4 flow data isolated from South Lift Station 5.**

The flow data collected by the South Lift Station 5 flow meter is shown in Figure 17. As shown, the RDII responses recorded by the flow meter were inconsistent throughout the fall/winter monitoring period. The meter did not record RDII responses to any of the calibration storms. Responses to the October 28, 2020 through October 31, 2020 rain events could not be analyzed, because the flow rates did not return to dry weather flow patterns between storms, which affected the generation of RTK values for each storm.

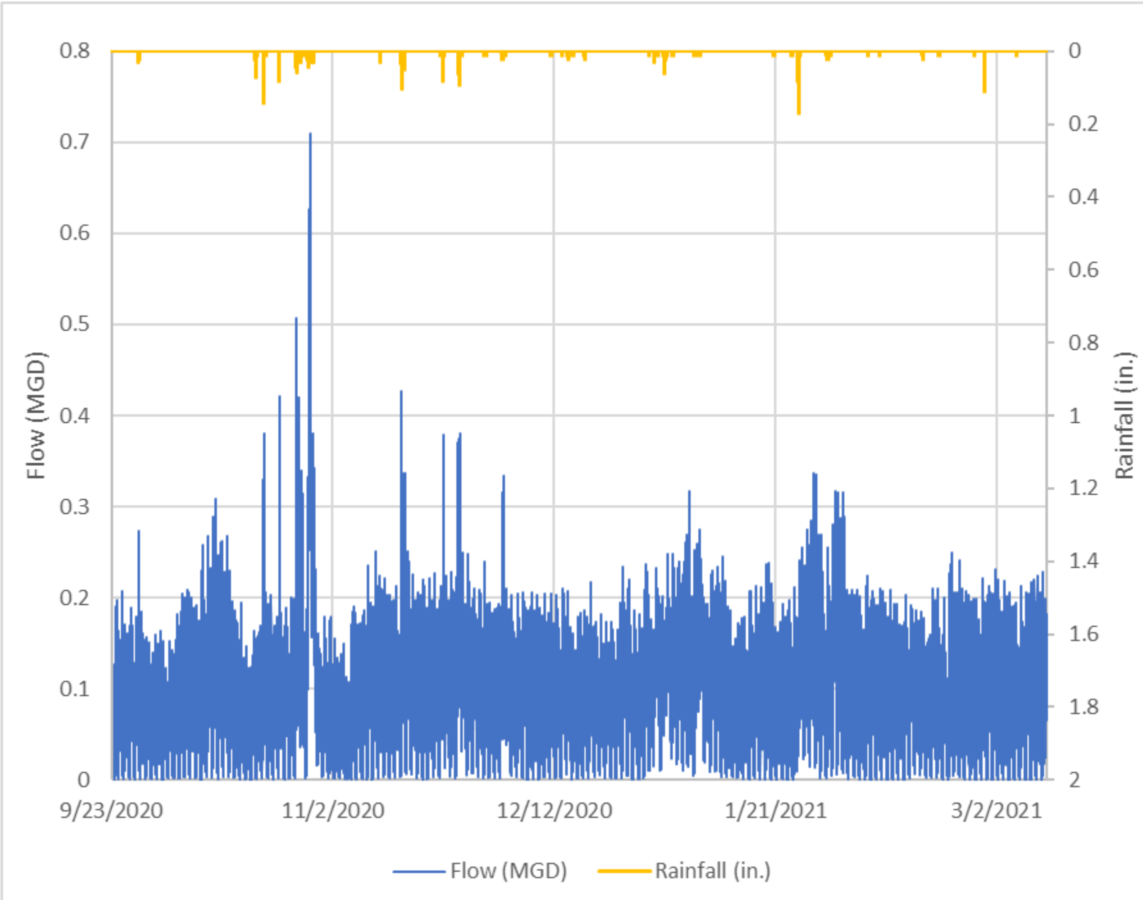


**Figure 17. South Lift Station 5 flow data.**

Due to the inconsistent data obtained from the South Lift Station 4 and 5 flow meters during the fall/winter monitoring periods, Olsson did not analyze the isolated subbasins. Rather, Olsson analyzed the South Lift Station 4 and 5 subbasins with the South Lift Station 2 subbasin to obtain dry weather and RDII flow patterns from all three subbasins.

- Town Branch 1

Isolation of the Town Branch 1 flow data from Town Branch 3 resulted in the data shown in Figure 18 below. As shown, the flow meter generally recorded the slightly higher flow rates as flow meter Town Branch 3 upstream. Isolation resulted in negative flow rates at the beginning of each significant RDII response throughout the monitoring period. The spikes in peak flow rate depicted in Figure 18 correspond to periods of surcharging within the manhole that subsided rapidly. Throughout the monitoring period, accumulation of debris on the meter affected flow readings such that the meter location was changed for the spring monitoring period.

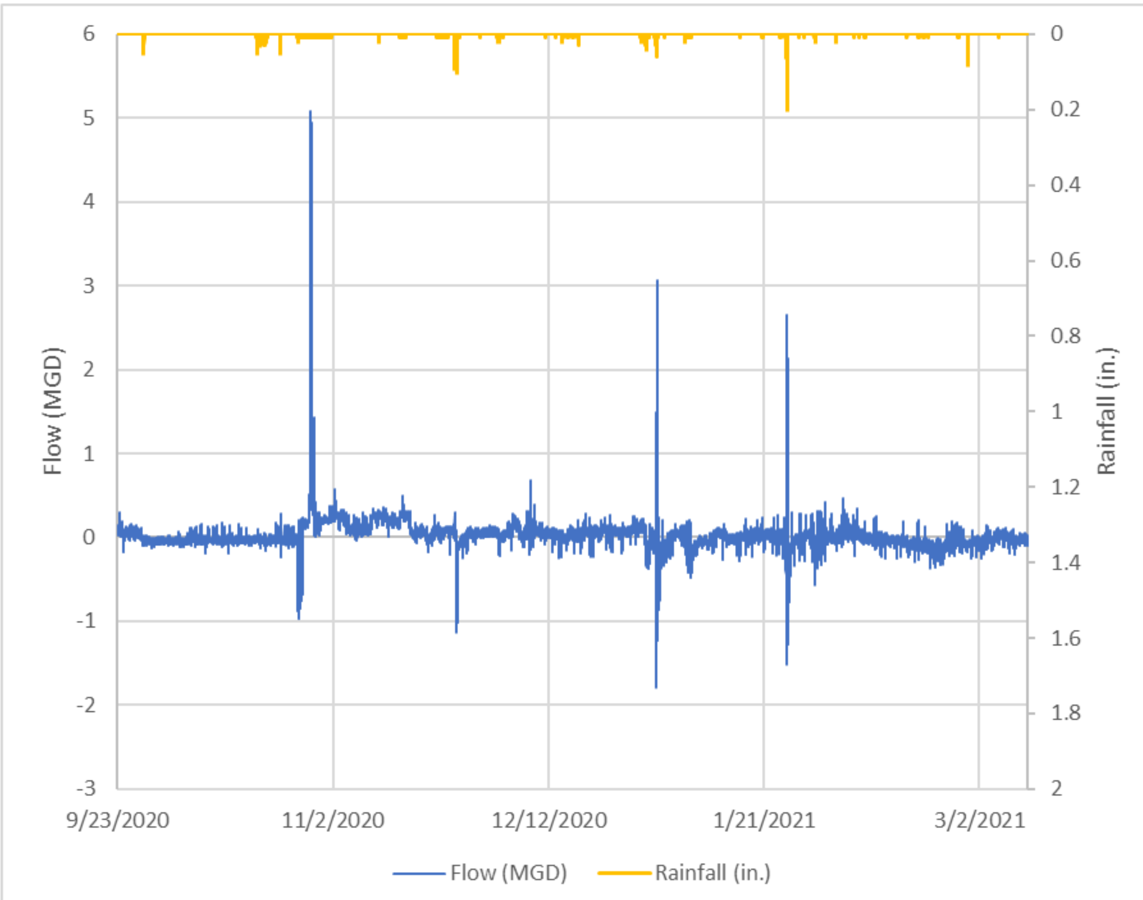


**Figure 18. Town Branch 1 flow data isolation from Town Branch 3.**

No RDII responses at Town Branch 1 could be analyzed due to the negative initial flow rates and the influence of surcharging on the flow recordings. However, Olsson was able to determine a dry weather flow pattern from the isolated flow data.

- Town Branch 4

Isolation of the Town Branch 4 flow data from Town Branch 6 resulted in the data shown in Figure 19 below. As shown, the flow meter generally recorded the slightly higher flow rates as flow meter Town Branch 6 upstream during dry weather periods. However, the isolation resulted in RDII responses that could not be analyzed. Additionally, isolation of Town Branch 2 from Town Branch 4 resulted in RDII responses at the Town Branch 2 flow meter that could not be accurately analyzed.

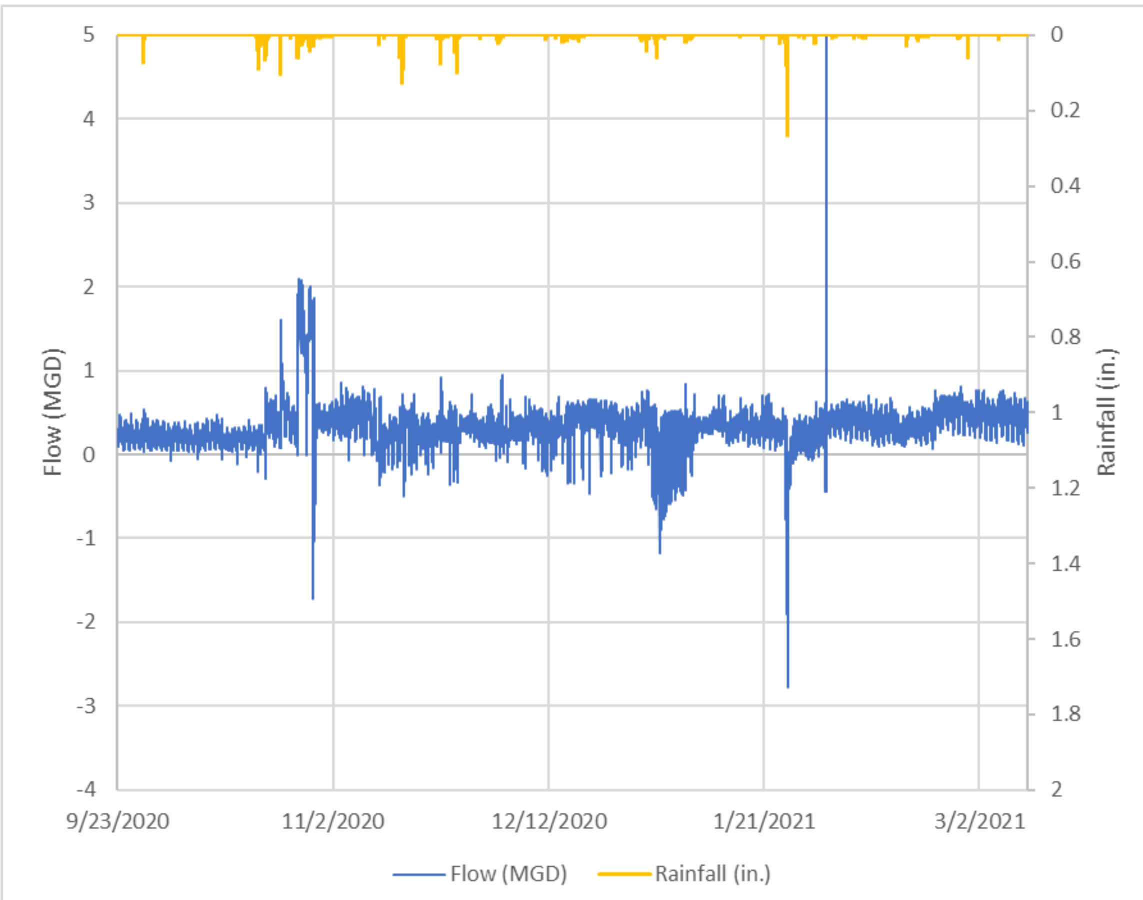


**Figure 19. Town Branch 4 flow data isolation from Town Branch 6.**

Olsson elected to analyze the Town Branch 2 and 4 subbasins together in order to best analyze the RDII flow rates from the subbasins.

## 4.2.2 Spring RDII Analysis

Data for the spring, collected between March 11, 2021 and the week July 4, 2021, was analyzed for each meter. Subbasin isolation was generally more successful during the spring monitoring period than in the fall/winter, where 10 out of the 17 subbasins requiring isolation could be analyzed without experiencing issues with the isolation. Of the isolated subbasins, 7 out of 10 could be analyzed for their RDII response. The results of preliminary subbasin isolation for the fall/winter monitoring period is summarized in Table 6.

**Table 6. Spring Preliminary Subbasin Isolation Results**

| Subbasin | Preliminary Isolation Success | | Subbasin | Preliminary Isolation Success | |
|---|---|---|---|---|---|
| | DWF | RDII | | DWF | RDII |
| McKisic 1 | N | N | South Lift Station 1 | Y | Y |
| McKisic 2 | N | N | South Lift Station 2 | Y | N |
| McKisic 3 | N | N | South Lift Station 3 | N/A | N/A |
| McKisic 4 | N/A | N/A | South Lift Station 4 | N | N |
| McKisic 5 | N | N | South Lift Station 5 | N/A | N/A |
| McKisic 6 | N/A | N/A | Town Branch 1 | Y | Y |
| McKisic 7 | Y | N | Town Branch 2 | Y | Y |
| McKisic 8 | N/A | N/A | Town Branch 3 | Y | Y |
| McKisic 9 | Y | Y | Town Branch 4 | Y | N |
| McKisic 10 | Y | Y | Town Branch 5 | N/A | N/A |
| McKisic 11 | N/A | N/A | Town Branch 6 | Y | Y |
| McKisic 12 | N/A | N/A | Town Branch 7 | N/A | N/A |
| Shewmaker 1 | N | N | | | |
| Shewmaker 2 | N | N | | | |
| Shewmaker 3 | N/A | N/A | | | |

Figure 20 below shows an example of a successful subbasin isolation, showing that isolating TB6 flow data from TB7 resulted in generally positive flows for both dry weather and wet weather flows that could be analyzed.

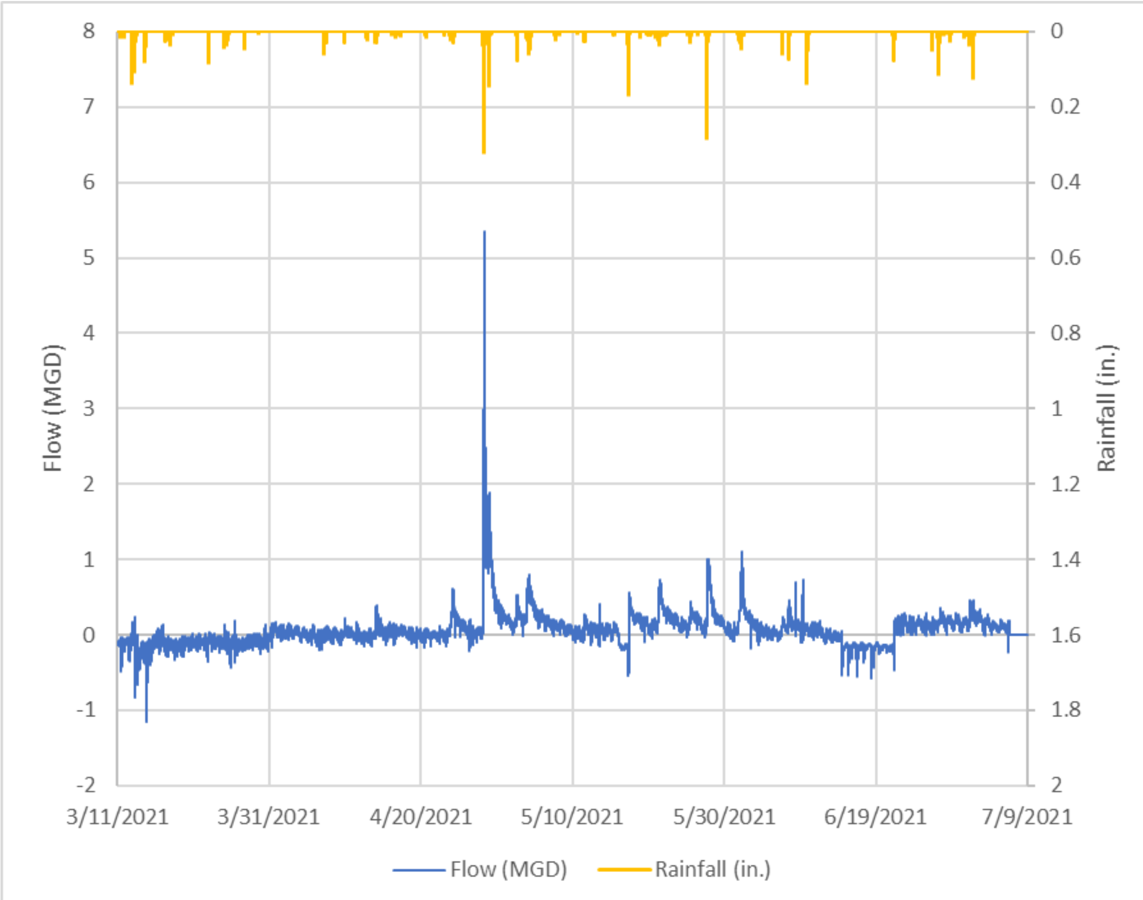


**Figure 20. Town Branch 6 flow data isolation from Town Branch 7.**

Discussed next are examples of the approach followed by Olsson's to resolve issues with flow isolation.

- McKisic 1 and 3

  Isolating the McKisic 1 flow data from McKisic 3 resulted in the data shown in Figure 21 below. Similar to the fall/winter monitoring period, the McKisic 1 flow meter recorded generally more dry weather and RDII flows, although peak flows following isolation were negative, which made RDII analysis of the isolated data impossible.

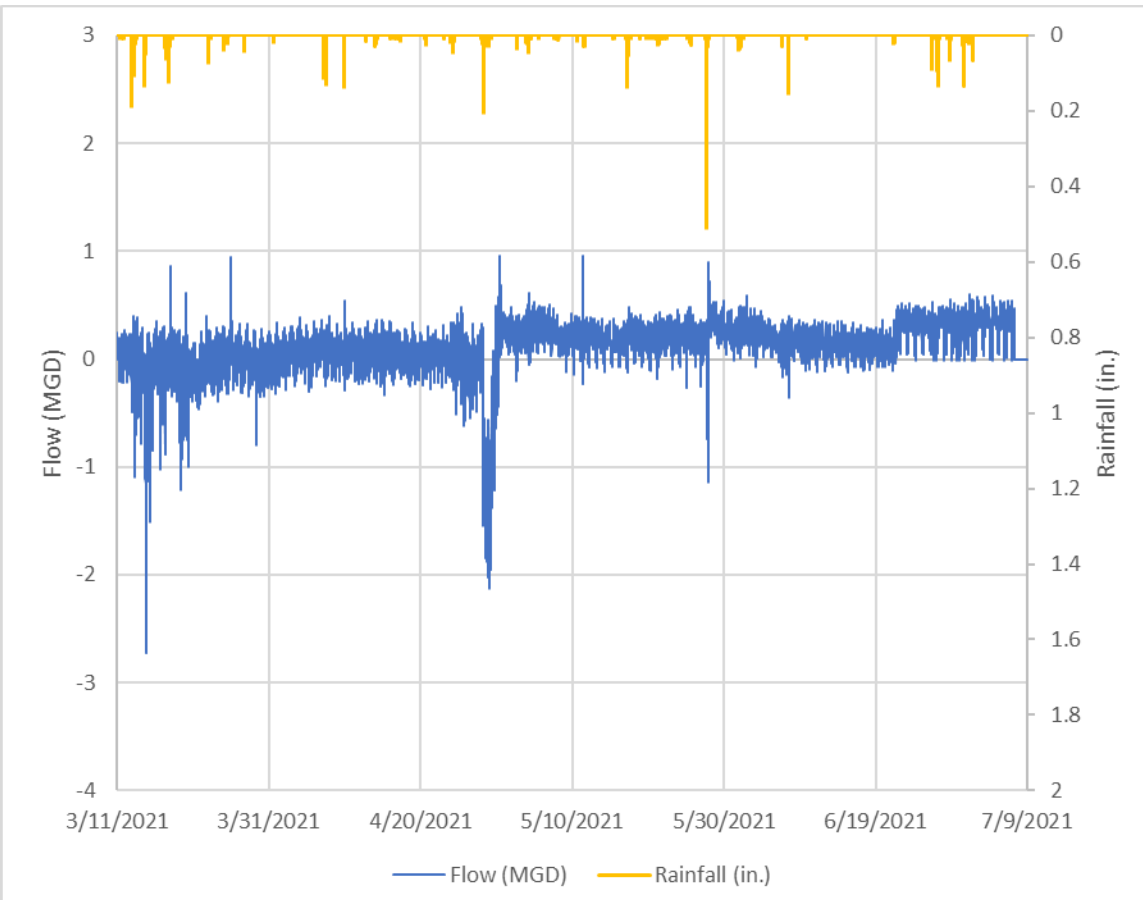


**Figure 21. McKisic 1 flow data isolation from McKisic 3.**

As in the fall/winter monitoring period, Olsson analyzed the McKisic 1 and McKisic 3 subbasins together by isolating the McKisic 1 flow data from McKisic 4, upstream of McKisic 4.

- McKisic 2

As noted previously, the meter site for the McKisic 2 flow meter was affected by operation of the bar screen at the McKisic lift Station. Isolation of the McKisic 2 flow data from McKisic 5 resulted in the data shown in Figure 22 below. As in the fall/winter monitoring period, the McKisic 2 flow meter readings were generally the same or lower than the McKisic 5 flow meter upstream.

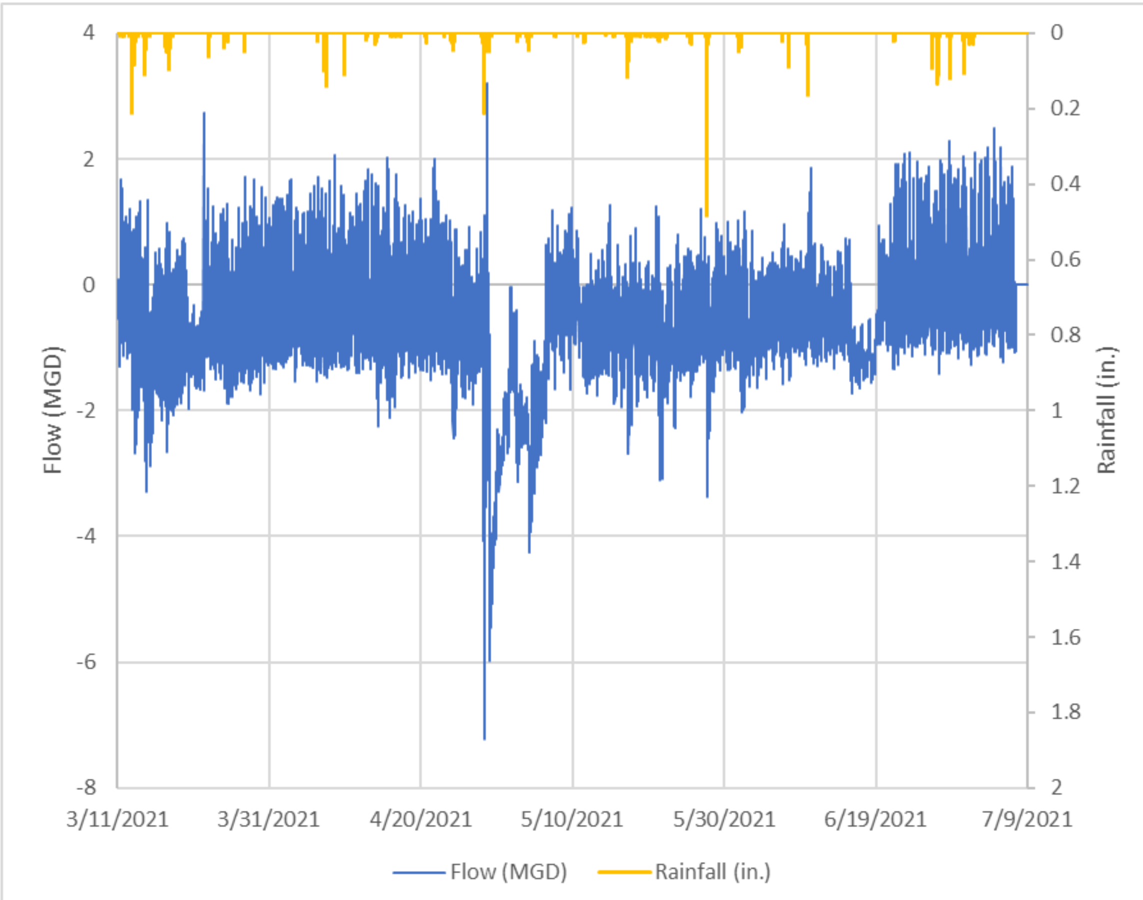


**Figure 22. McKisic 2 flow data isolation from McKisic 5.**

The isolated data from McKisic 2 could not be analyzed to determine either the dry weather flows or RDII flows.

- McKisic 5

Isolation of the McKisic 5 flow data from McKisic 6 and 7 resulted in the data shown in Figure 23 below. As shown, the McKisic 5 flow meter readings were generally lower than the sum of the McKisic 6 and 7 flow measurements upstream during dry weather. However, during wet weather periods, the flow meter recorded higher flows, indicating an RDII response.

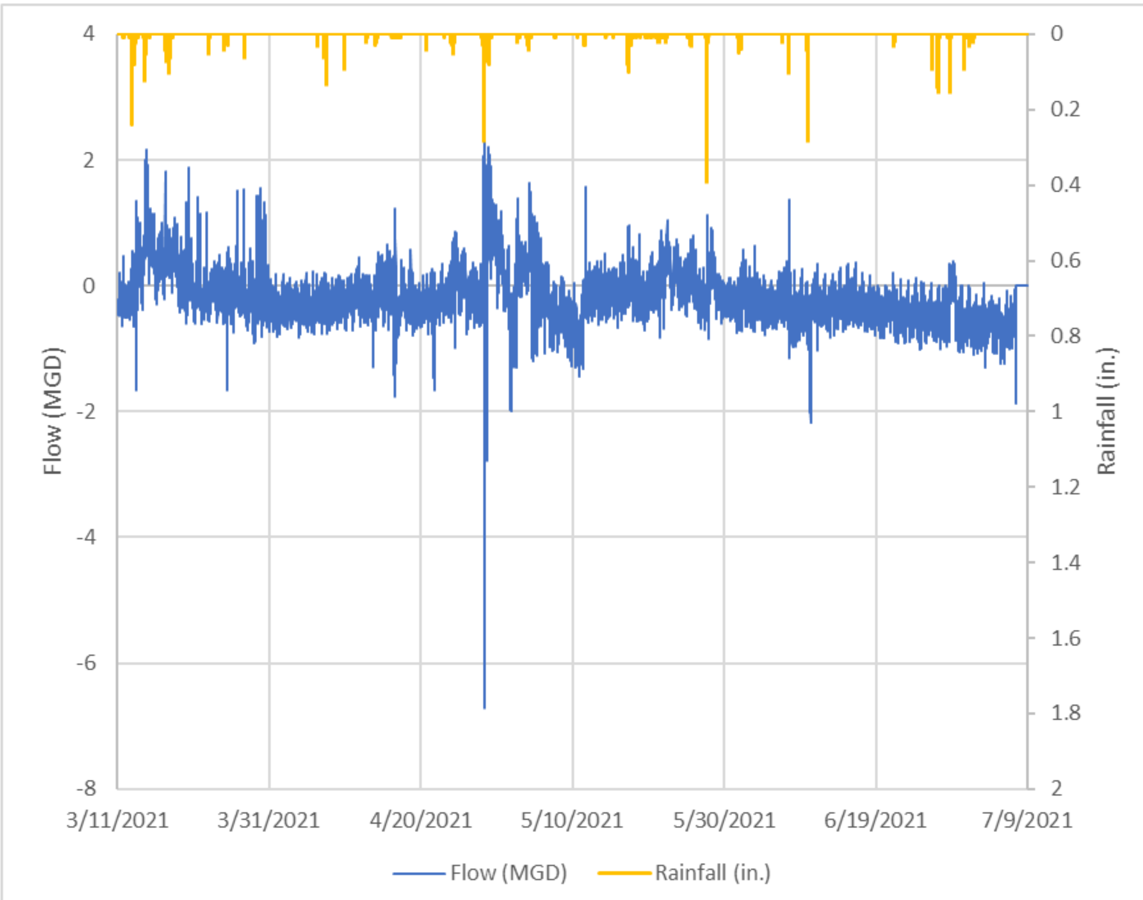


**Figure 23. McKisic 5 flow data isolation from McKisic 6 and 7.**

The isolated data from McKisic 5 was analyzed for its RDII response but could not be analyzed to determine the dry weather flows.

- McKisic 7

Isolation of the McKisic 7 flow data from McKisic 8 and 9 resulted in the data shown in Figure 24 below. As shown, the McKisic 7 flow meter readings were generally higher than the sum of the McKisic 8 and 9 flow measurements upstream during dry weather. However, during wet weather periods, the isolated flow meter did not record RDII flows.

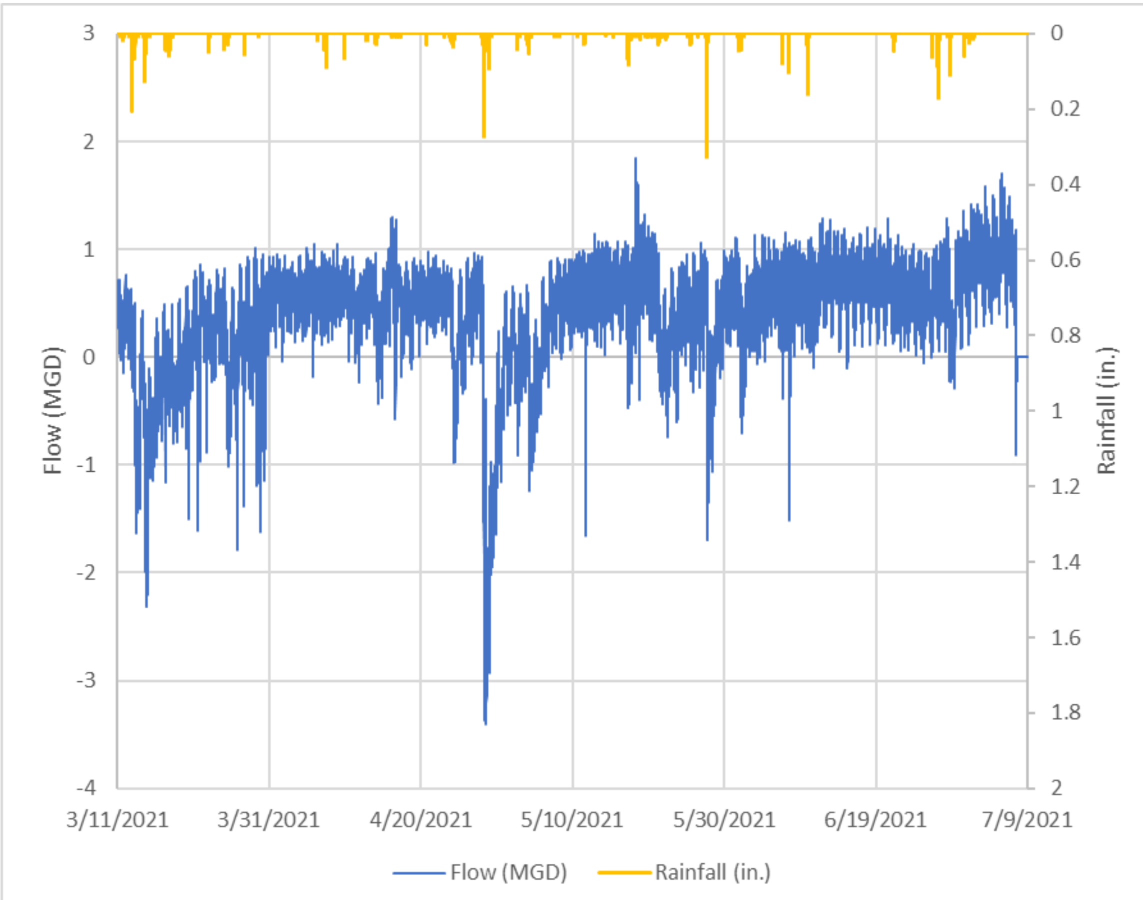


**Figure 24. McKisic 7 flow data isolation from McKisic 8 and 9.**

The isolated data from McKisic 7 was analyzed for dry weather flows but could not be analyzed to determine an RDII response.

- Shewmaker 1, 2, and 3

  Isolation of the Shewmaker 1 flow data from Shewmaker 2 upstream resulted in the data shown in Figure 25 below. The average flow rates recorded at Shewmaker 1 were generally greater than recorded at Shewmaker 2 upstream, as indicated by the fact that the average isolated flow rate was positive. Throughout the spring monitoring period, only the April 28, 2021 storm showed significant RDII for the isolated Shewmaker 1 subbasin. Analysis of that storm was made more difficult by the negative flow rates at the beginning of the wet weather period.

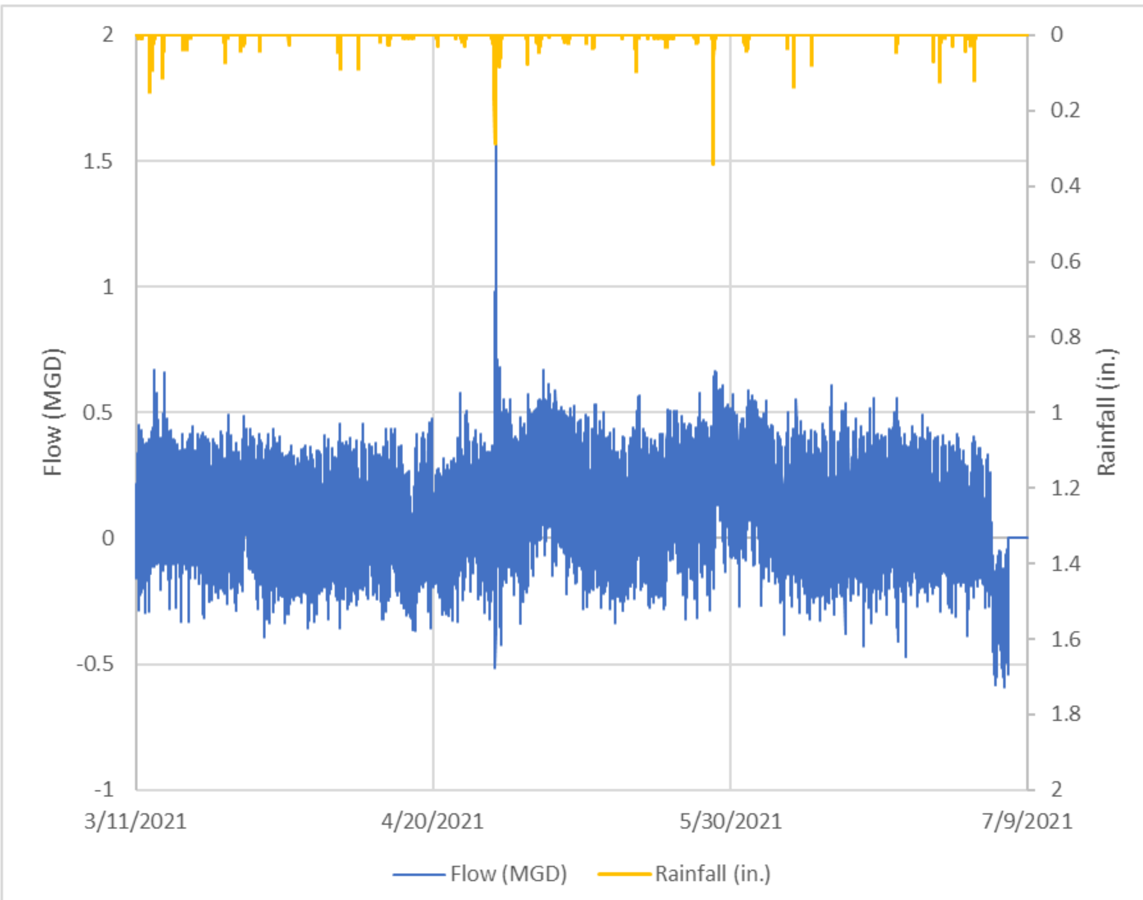


**Figure 25. Shewmaker 1 flow data isolation from Shewmaker 2.**

Isolation of the Shewmaker 2 flow data from Shewmaker 3 upstream resulted in the data shown in Figure 26 below. The average flow rates recorded at Shewmaker 2 were generally greater than recorded at Shewmaker 3 upstream, as indicated by the fact that the average isolated flow rate was positive. The isolated subbasin appeared to contribute insignificant amounts of RDII with the notable exception of the April 28, 2021 storm, which contributed significant RDII flows.

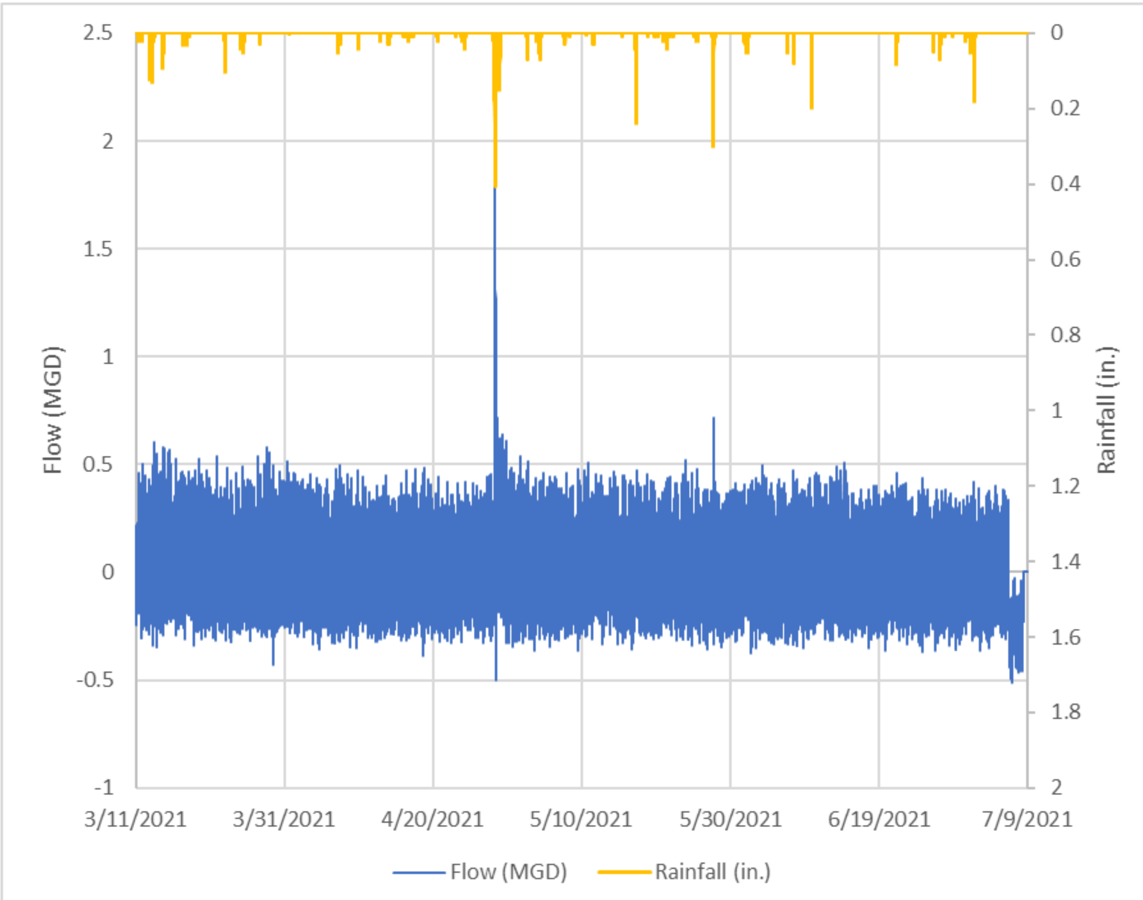


**Figure 26. Shewmaker 2 flow data isolation from Shewmaker 3.**

As in the fall/winter monitoring period, the RDII recorded within the Shewmaker basin generally was not concentrated in any of the three metered subbasins, so isolation did not improve the utility of RDII analysis. Olsson analyzed the Shewmaker basin using only the data from the Shewmaker 1 flow meter in order to analyze both the April 28, 2021 storm and the May 27, 2021 storm.

- South Lift Station 2

Isolation of the South Lift Station 2 flow data from South Lift Station 4 upstream resulted in the data shown in Figure 27 below. The average flow rates recorded at South Lift Station 2 were generally greater than recorded at South Lift Station 4 upstream, as indicated by the fact that the average isolated flow rate was positive. However, the peak RDII flow rates after nearly all storm events were negative, making analysis of the isolated subbasin impossible.

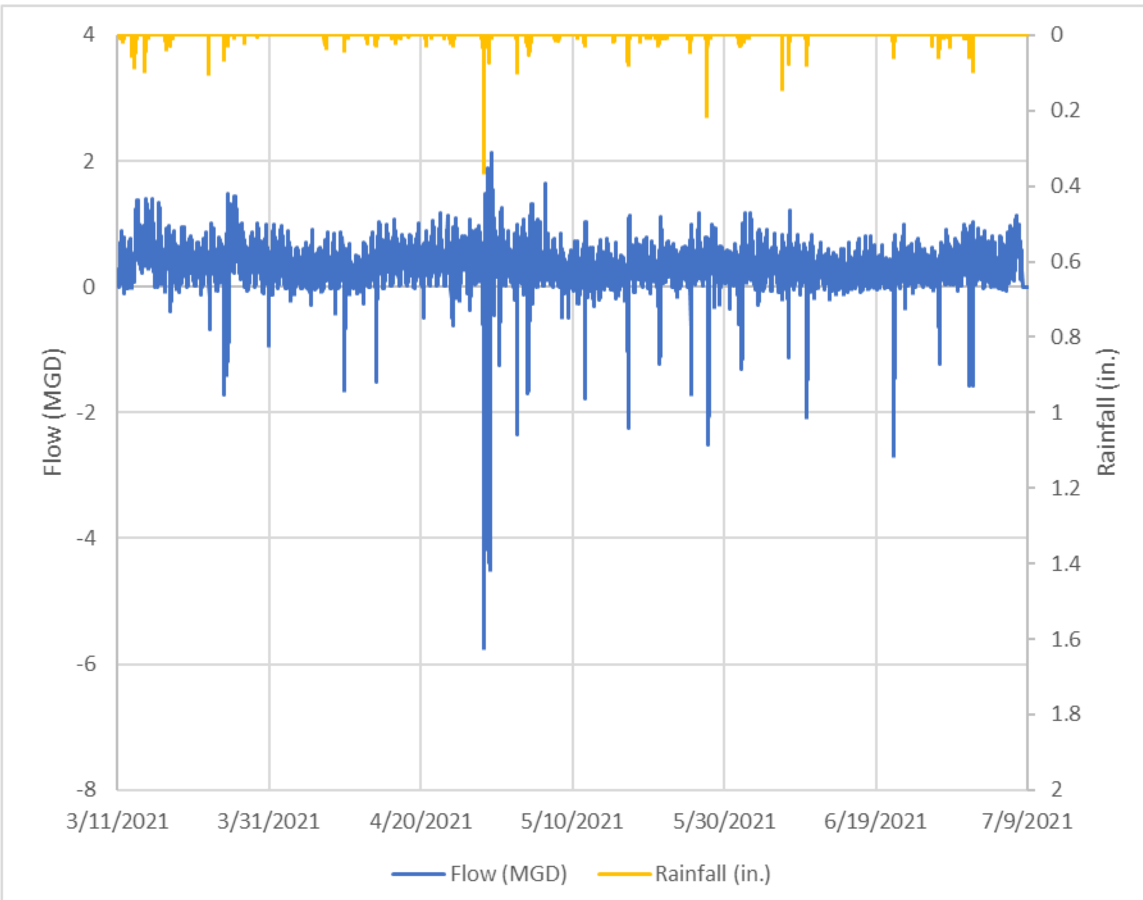


**Figure 27. South Lift Station 2 flow data isolation from South Lift Station 4.**

Olsson was able to analyze the dry weather flow contributed by the South Lift Station 2 subbasin but could not analyze the RDII response.

- South Lift Station 4 and 5

Isolation of the South Lift Station 4 flow data from South Lift Station 5 upstream resulted in the data shown in Figure 28 below. The average flow rates recorded at South Lift Station 4 were generally greater than recorded at South Lift Station 5 upstream, as indicated by the fact that the average isolated flow rate was positive. The total RDII after isolation was generally positive, although the isolation resulted in negative values at the beginning of most wet weather periods as shown.

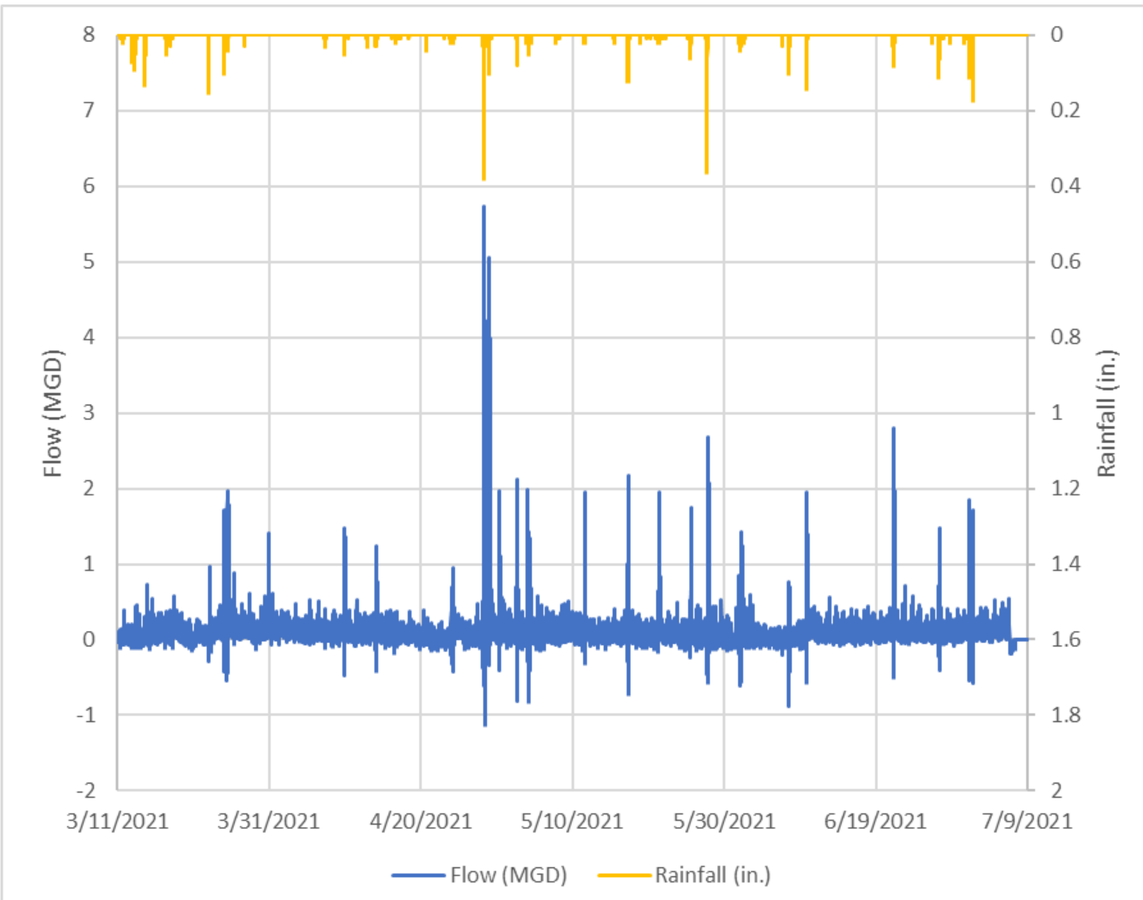


**Figure 28. South Lift Station 2 flow data isolation from South Lift Station 4.**

The South Lift Station 5 flow meter also surcharged frequently throughout the spring monitoring period, which reduced the number of storms that could be analyzed. During significant surcharge events, the flow data could not generally be analyzed using SSOAP. Figure 29 below shows the depth data recorded by the South Lift Station 5 flow meter throughout the spring monitoring period. As shown, the manhole surcharged during most storm events with a depth greater than 0.50 inches such that these storms could be analyzed accurately. Note that the meter did not record any overflows.

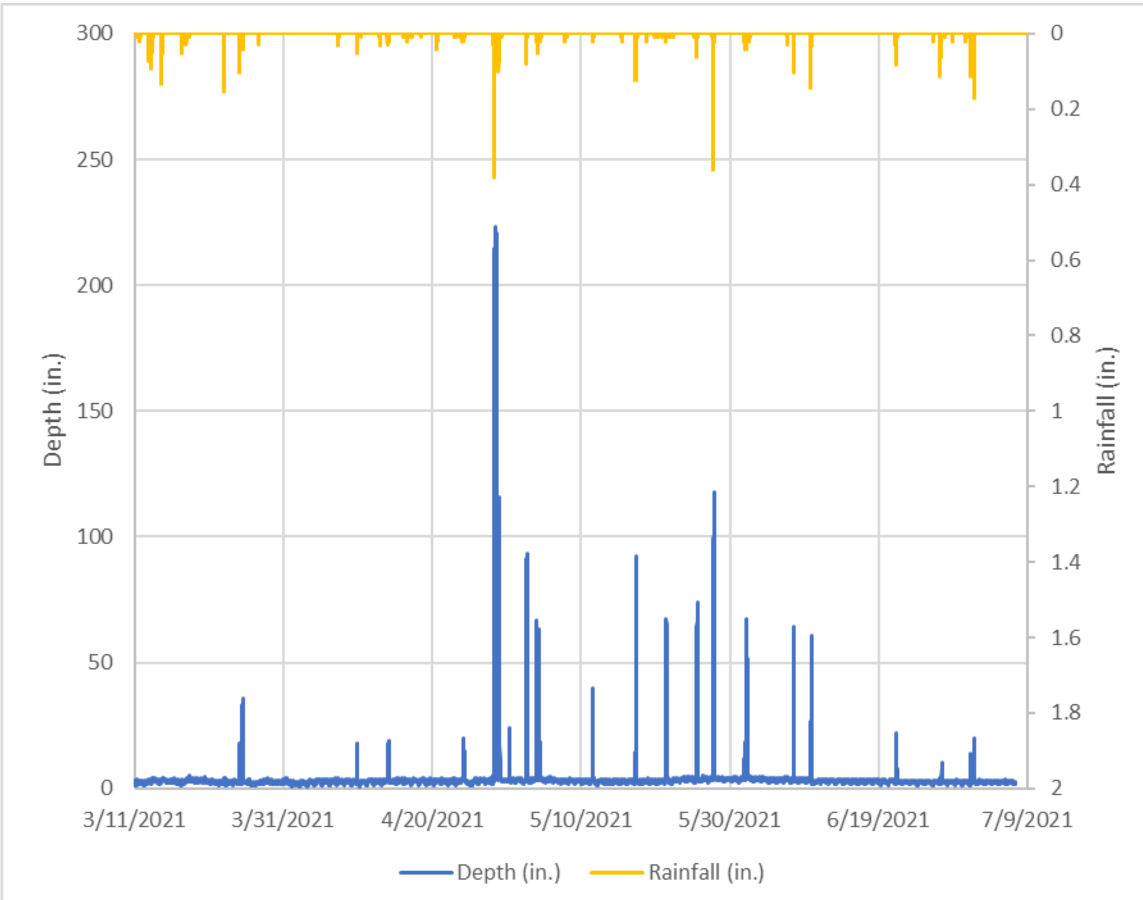


**Figure 29. South Lift Station 5 depth data.**

Olsson found that accurate characterization of the RDII from the South Lift Station 5 subbasin was difficult due to the frequent, significant surcharging during the monitoring period. In addition, isolation of the South Lift Station 4 flow data resulted in negative flows during RDII responses such that RDII analysis accuracy would suffer. Therefore, Olsson elected to analyze the South Lift Station 4 and 5 subbasins together using only the South Lift Station 4 flow data. In this way, Olsson was able to more accurately characterize the significant RDII present in both subbasins.

- Town Branch 4

Isolation of the Town Branch 4 flow data from Town Branch 6 upstream resulted in the data shown in Figure 30 below. The average flow rates recorded at Town Branch 4 were generally greater than recorded at Town Branch 6 upstream, as indicated by the fact that the average isolated flow rate was positive. However, the peak RDII flow rates after nearly all storm events were negative, making analysis of the isolated subbasin impossible.

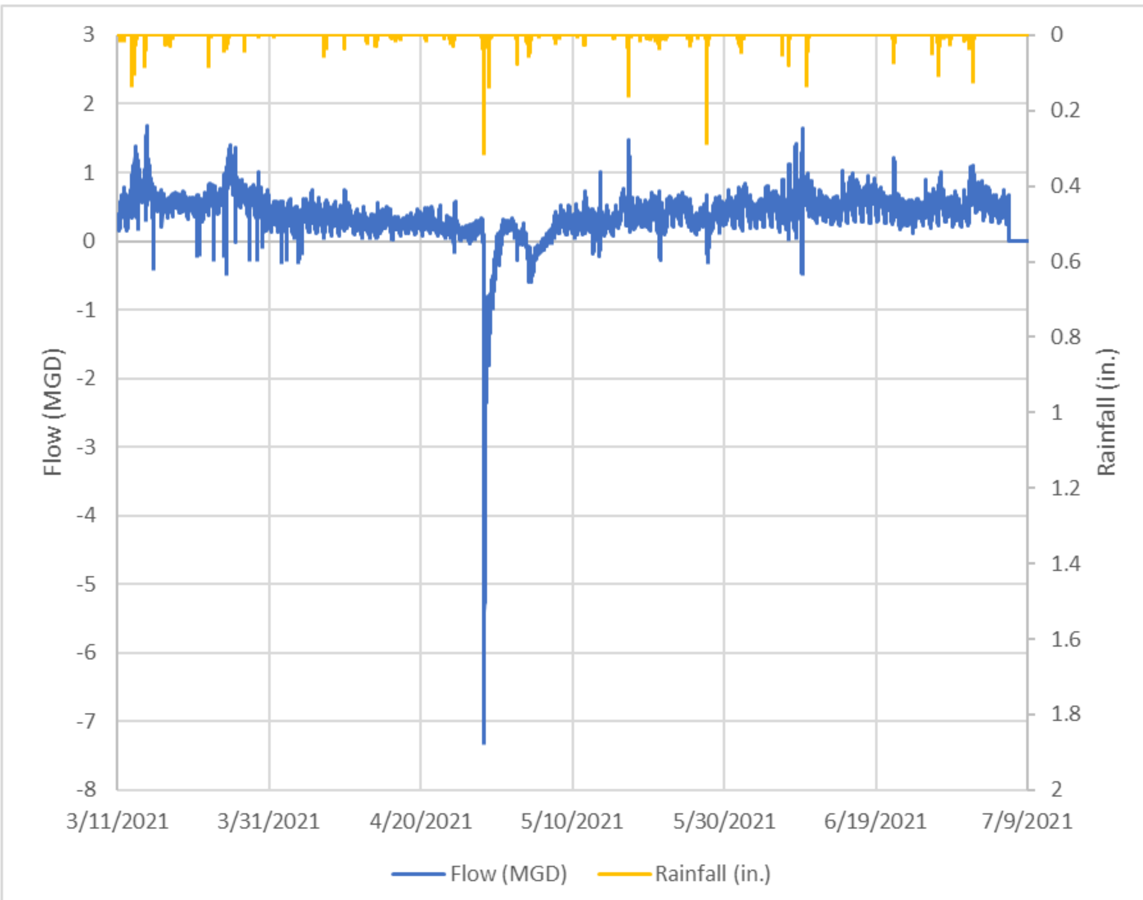


**Figure 30. Town Branch 4 flow data isolation from Town Branch 6.**

Olsson was able to analyze the dry weather flow contributed by the Town Branch 4 subbasin but could not analyze the RDII response.

## 4.3 Dry Weather Flow Analysis

SSOAP's DWF Analysis Tool provides an Automatic DWF Determination function that selects days that experienced dry weather flow conditions based on parameters set by the user. SSOAP identifies dry weather weekdays separately from dry weather weekend days, and the user manually reviews and modifies the selections. Dry weather weekdays and weekend days are analyzed separately because flow rates can vary significantly between the two. In industrial or commercial areas, flow rates can decrease during the weekends when businesses are closed. In residential areas, flow rates can increase during weekends when residents who work away from home during the week are home.

For this project, the following parameters were selected to define a dry weather day:

- No missing data.
- No rain during the seven preceding days.
- The minimum, maximum, and average flow must be within one standard deviation of the same values for the entire set of days.

For each meter, SSOAP averaged the dry-weather weekday flows and the dry-weather weekend flows to create a 24-hour DWF diurnal hydrograph for an average weekday and for an average weekend day. The results of this analysis are summarized for each flow meter in Appendix F, Dry Weather Flow Statistics.

## 4.4 Wet Weather Flow Analysis

SSOAP's WWF Analysis Tool provides an Automatic RDII Event Identification function that selects RDII events based on the parameters set by the user. For this project, the parameters were an event duration of at least 6 hours and rainfall volume of at least 0.5 inches. The RDII events measured by each flow meter are summarized in Appendix G. Events were then manually added or removed by the user.

## 4.5 RDII Decomposition and Unit Hydrograph Development

The SSOAP toolbox automatically performs hydrograph decomposition by separating the observed flows recorded by the flow meters into their DWF and RDII components. This information is provided in the RDII Graph in the toolbox.

SSOAP was used to further decompose the RDII flows by applying the RTK curve-fitting method to develop SUH parameters from the observed RDII hydrographs. This process involves fitting three triangular unit hydrographs to the observed RDII hydrograph for each rain event. The first triangle generally includes the most rapidly occurring inflow, the second includes both inflow and infiltration, and the third includes infiltration occurring after the rain event ends. Each of the three-unit hydrographs are represented by three variables: 'R' is the fraction of rainfall volume entering the sewer system as RDII during and immediately after a rainfall event, ‘T’ is the time for RDII to peak, and ‘K’ is the ratio of time of recession to ‘T’.

The three triangular hydrographs are created through a trial-and-error process. For each rain event, the user inputs R, T, and K values into SSOAP for each of the three triangular hydrographs and adjusts the values until the outline of the simulated RDII hydrograph closely resembles the observed RDII curve. The SSOAP toolbox automatically combines the three triangular unit hydrographs to create a simulated RDII hydrograph for each rain event.

SSOAP provides statistical tools to analyze how closely the simulated RDII hydrographs resemble the observed RDII hydrographs. These tools were used to refine the hydrographs, and the statistical results are provided in Appendix H, Statistical Rainfall-Derived Inflow/Infiltration Analysis.

## 4.6 Design Storm Development

In Part I of this study, the existing sewer collection system was analyzed using design storms of various frequency. Design rainfall depths were derived from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 for 1-, 2-, 5-, 10-, and 25-year return interval rain events for the City of Bentonville. A return interval year is directly related to the frequency a storm is likely to occur. For example, a 10-year storm has a 1 in 10 or 10% probability of happening in any given year. The 24-hour rainfall amounts are as follows:

- 1-year design storm: 3.36-inches
- 2-year design storm: 3.79-inches
- 5-year design storm: 4.53-inches
- 10-year design storm: 5.19-inches
- 25-year design storm: 6.16-inches

Olsson distributed the statistical rainfall event over a 24-hour period using the Natural Resources Conservation Service (NRCS) synthetic storm Type II hyetograph, formerly known as the Soil Conservation Service (SCS). Figure 31 illustrates the 5-year, 24-hour design storm hyetograph used in the model.

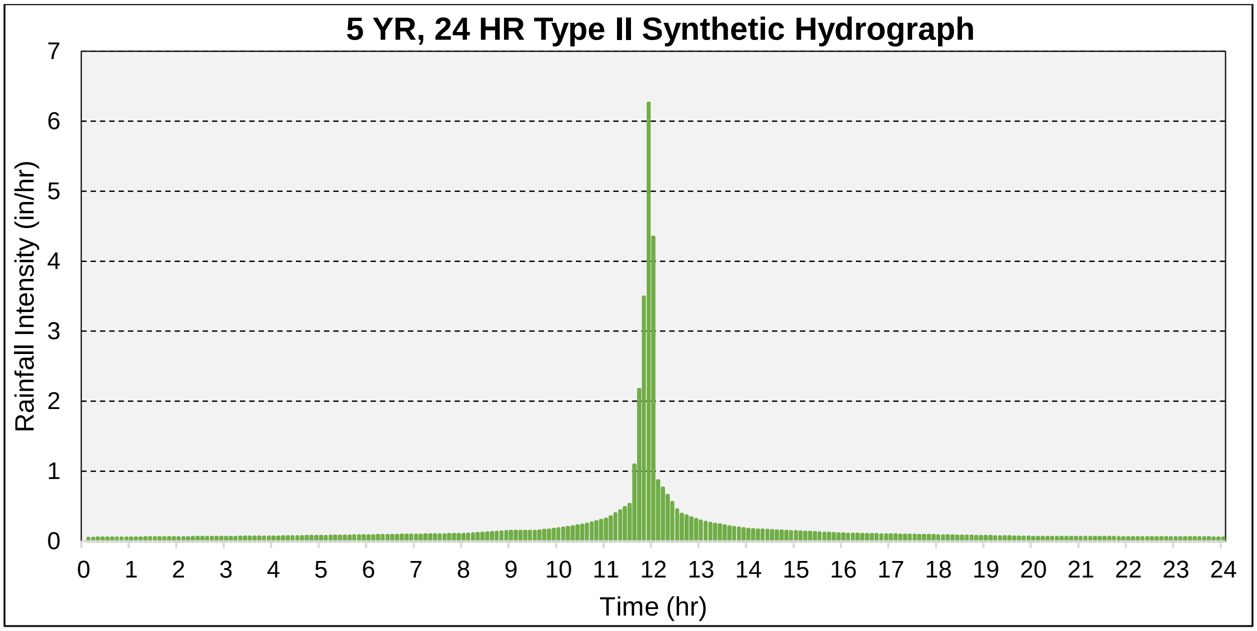


**Figure 31. 5YR-24HR Type II Synthetic Hydrograph.**

## 4.7 Synthetic Unit Hydrograph Generation

Synthetic unit hydrographs, SUHs, represent the flow that would pass through each flow meter at varying intensity rainfall events. The SUHs were created by averaging the RTK values used to develop the simulated RDII hydrographs to create a single set of RTK values. These were then applied to the 1-, 2-, 5-, 10-, and 25-year design events to generate SUH for each design storm representing flows passing through each meter.

## 4.8 Chronic Infiltration

Chronic infiltration, also referred to as groundwater infiltration, is that flow which is consistently observed during dry weather periods that cannot be attributed to typical wastewater sources. Sewer defects located in or near perennial waterways or below the groundwater table could potentially contribute to the infiltration entering the system during dry weather conditions. Olsson estimated chronic infiltration flow rates by subtracting winter average water usage (based on water billing records) within a basin from the dry weather flows determined using the EPA SSOAP toolbox. Winter average water usage records within each subbasin were averaged over the months of December, January, and February such that water usage records did not include irrigation water that would not enter the sanitary sewer system.

The exhibits in Appendix I, Subbasin Dry Weather Flow Comparison, show the subbasin winter average water usage records, fall/winter dry weather flows from SSOAP analysis, and spring dry weather flows from SSOAP analysis. The city's flow data from the magnetic flow meter on the McKisic lift station force main and the Parshall flume at the influent to the City's WRRF are included for comparison. The dry weather flows shown follow the modeling approach discussed in Section 4.3.

As shown, the calculated dry weather flows for each subbasin generally increased from the fall/winter monitoring period to the spring monitoring period, indicating a potential increase in chronic infiltration in the spring. During the fall/winter monitoring period, 9 subbasins had suspected chronic infiltration flow rates greater than 0.05 MGD. During the spring monitoring period, 13 subbasins had suspected chronic infiltration flow rates greater than 0.05 MGD.

The cumulative dry weather flow rates were generally higher than the flow rates recorded by the City's magnetic flow meter and the Parshall flume at the WRRF. This discrepancy could be attributed to error in the winter average water records or the error propagated by summing dry weather flows from each subbasin.

The tables in Appendix J, Subbasin Inflow/Infiltration Rankings Table, include the estimated chronic infiltration rates for each modeled subbasin and the corresponding rankings. Subbasins with negative estimated chronic infiltration flow rates were not ranked and the negative values were attributed to error from measurement and calculations. As shown, the McKisic 7 subbasin had the highest estimated chronic infiltration flow rates during both the fall/winter and spring monitoring periods. The McKisic 10, Town Branch 4, and South Lift Station 1 subbasins generally recorded higher estimated chronic infiltration flow rates during both monitoring periods as well. The Town Branch 7 subbasin was unique in that the estimated chronic infiltration increased between the fall/winter and spring monitoring periods, potentially indicating that higher average groundwater levels during the spring period contributed to increased infiltration flow rates.

Olsson combined the fall/winter and spring estimated chronic infiltration flow rates for each subbasin to create overall basin rankings presented in Table 7 on the following page. Subbasins are ranked such that the subbasin ranked 1 is the subbasin with the highest estimated chronic infiltration flow rate, the subbasin ranked 2 is the subbasins with the next highest estimated chronic infiltration flow rate, and so on. Subbasins for which no chronic infiltration was estimated in either the fall/winter or spring monitoring periods are not listed.

**Table 7. Overall Modeled Subbasin Estimated Chronic Infiltration Rankings.**

| Modeled Subbasin | Overall Chronic Infiltration Ranking |
|---|---|
| M7 | 1 |
| TB4 | 2 |
| SLS1 | 3 |
| M10 | 4 |
| SLS2 | 5 |
| M6 | 6 |
| SLS3 | 7 |
| M1 & M3 | 8 |
| TB7 | 9 |
| TB6 | 10 |
| TB1 | 11 |
| SLS4 | 12 |
| M9 | 13 |
| S1, S2, & S3 | 14 |
| TB2 | 15 |
| TB3 | 15 |
| M11 | 16 |
| TB5 | 17 |
| M4 | 18 |

Figure 32 on the following page includes a color-coded list of subbasins color coded according to their chronic infiltration ranking.

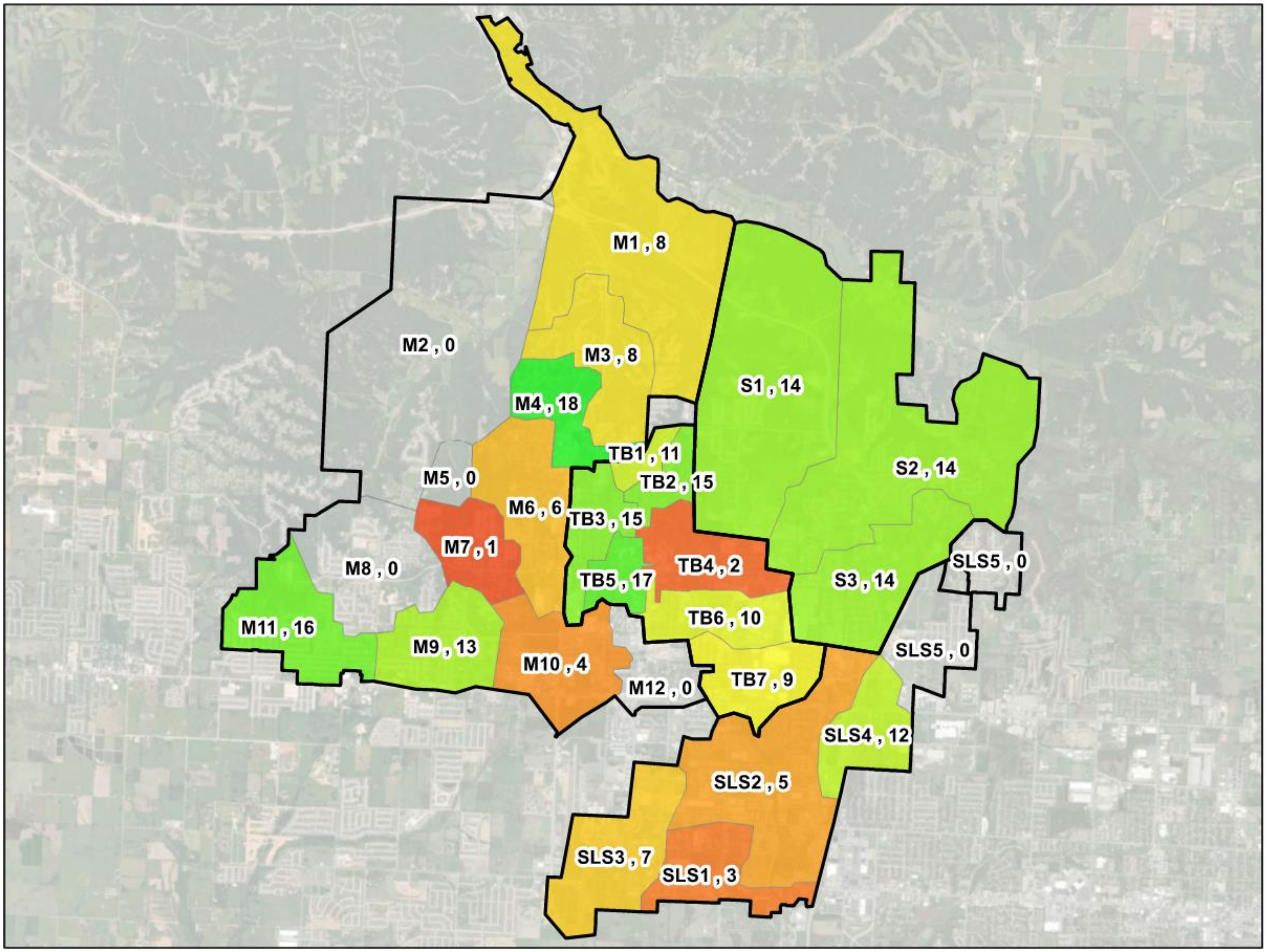


**Figure 32. Subbasin Chronic Infiltration Rankings.**

## 4.9 Peak RDII Flow Rates

Using the peak RDII flow rates obtained from the SSOAP analysis described in Section 4.4, Olsson compared the subbasins to identify the primary sources of peak flow rates experienced throughout the City's collection system. Subbasins were ranked from highest priority (one) to lowest priority (varied) in each category below.

First, Olsson ranked each modeled subbasin based on its peak RDII flow contribution. Higher peak RDII flow rates in a subbasin may imply that the basin has the greatest theoretical potential for RDII reduction, subject to the feasibility of source investigation and repairs. Additionally, Olsson considered peak RDII flow an important parameter because subbasins with higher peak RDII flow rates have greater impacts on downstream sewer, pump station, and treatment capacities.

Olsson then ranked each modeled subbasin based on the peaking factor, which was calculated by dividing the peak flow rate (the sum of the average dry weather flow rate and the peak RDII flow rate) by the average dry weather flow rate. Ranking by peaking factors served to normalize the relative RDII contribution from each subbasin such that subbasins could be compared more directly. The higher the peaking factor, the greater the likelihood that economically feasible RDII reduction can be obtained.

Next, Olsson ranked each subbasin using the peak flow rate per manhole and linear foot of pipe within each subbasin. These two parameters also serve to normalize peak RDII flow contributions from each subbasin. Both parameters might imply a greater average density of RDII sources in a subbasin. In addition, both parameters have implications for the potential cost effectiveness of typical RDII investigations such as manhole inspections, Closed Circuit Television (CCTV) inspection of sewer mains, and smoke testing, which are typically bid on a per manhole or per linear foot of pipe basis. Generally, where a subbasin has a higher peak RDII flow rate per manhole and per linear foot of pipe, it is more likely that a greater number of RDII sources can be identified at the same cost as a subbasin with a lower peak RDII flow rate per manhole and per linear foot of pipe.

Finally, Olsson ranked each subbasin using the peak flow rate per inch-diameter-mile (IDM). The IDM is a parameter recommended for consideration by the US EPA for comparing subbasins' RDII potential. The IDM is obtained by multiplying the diameter of each pipe segment, and adding the IDM for all pipe segments within a subbasin. This parameter is intended to further normalize RDII within subbasins by comparing not only the length of pipe but the primary pipe diameter within each subbasin. Thus, if one compared subbasins with equal peak RDII flow rates, the subbasin with the higher peak RDII flow rate per IDM would have either smaller pipes, less pipe, or both. In the case of smaller diameter pipes, repairs are generally less expensive to implement. In the case of subbasins containing less pipe, RDII source investigations would be less expensive as discussed above. Regardless, subbasins with higher peak RDII flow rates per IDM might reasonably be expected to be the most cost effective subbasins in which to implement RDII reduction programs.

Note that the above discussion is intended to be general in nature and cannot account for unknown RDII sources within each subbasin. The tables in Appendix J, Subbasin Inflow/Infiltration Rankings Table, include the RDII parameters considered by Olsson and their respective rankings. Appendix K, Subbasin Inflow/Infiltration Rankings Maps, includes maps of the subbasins color-coded by the rankings described above.

Using these preliminary rankings, Olsson calculated a composite score by combining the subbasin rankings across the five parameters described above. The composite score for each subbasin was calculated using the following equation:

*Composite Score* **=** *(Peak RDII Flow Rate Rank) (Weighting Factor)* +
*(Peaking Factor Rank) (Weighting Factor)* +
*(Peak RDII Flow Rate per Manhole Rank) (Weighting Factor)* +
*(Peak RDII Flow Rate per Linear Foot of Pipe Rank) (Weighting Factor)* +
*(Peak RDII Flow Rate per IDM Rank) (Weighting Factor)*

Olsson weighted each parameter equally as shown in Table 8.

**Table 8. Composite Subbasin Score Weighting Factors.**

| Rank | Weighting Factor |
|---|---|
| Peak RDII Flow Rate | 0.2 |
| Peaking Factor | 0.2 |
| Peak RDII Flow Rate per Manhole | 0.2 |
| Peak RDII Flow Rate per Linear Foot of Pipe | 0.2 |
| Peak RDII Flow Rate per IDM | 0.2 |

Olsson then ranked each subbasin using the composite score to develop composite ranks for each subbasin during the fall/winter and spring monitoring periods. Olsson combined these composite rankings to create the overall basin rankings presented in Table 9.

**Table 9. Overall Modeled Subbasin Peak RDII Rankings**

| Modeled Subbasin | Overall Peak RDII Ranking |
|---|---|
| M12 | 1 |
| TB2 | 2 |
| TB5 | 3 |
| TB6 | 4 |
| TB4 | 5 |
| M10 | 6 |
| TB3 | 7 |
| SLS4 & SLS5 | 8 |
| M4 | 9 |
| TB7 | 10 |
| M9 | 11 |
| M6 | 12 |
| SLS1 | 13 |
| M1 & M3 | 14 |
| M5 | 15 |
| M8 | 16 |
| M11 | 17 |
| TB1 | 18 |
| SLS3 | 19 |
| SLS2 | 20 |
| S1, S2, & S3 | 21 |

The highest ranked subbasins listed in Table 9 reflect subbasins with the highest likelihood of containing a relatively concentrated number of RDII sources. Figure 33 on the following page shows a map of the subbasins color coded according to their overall RDII rank.

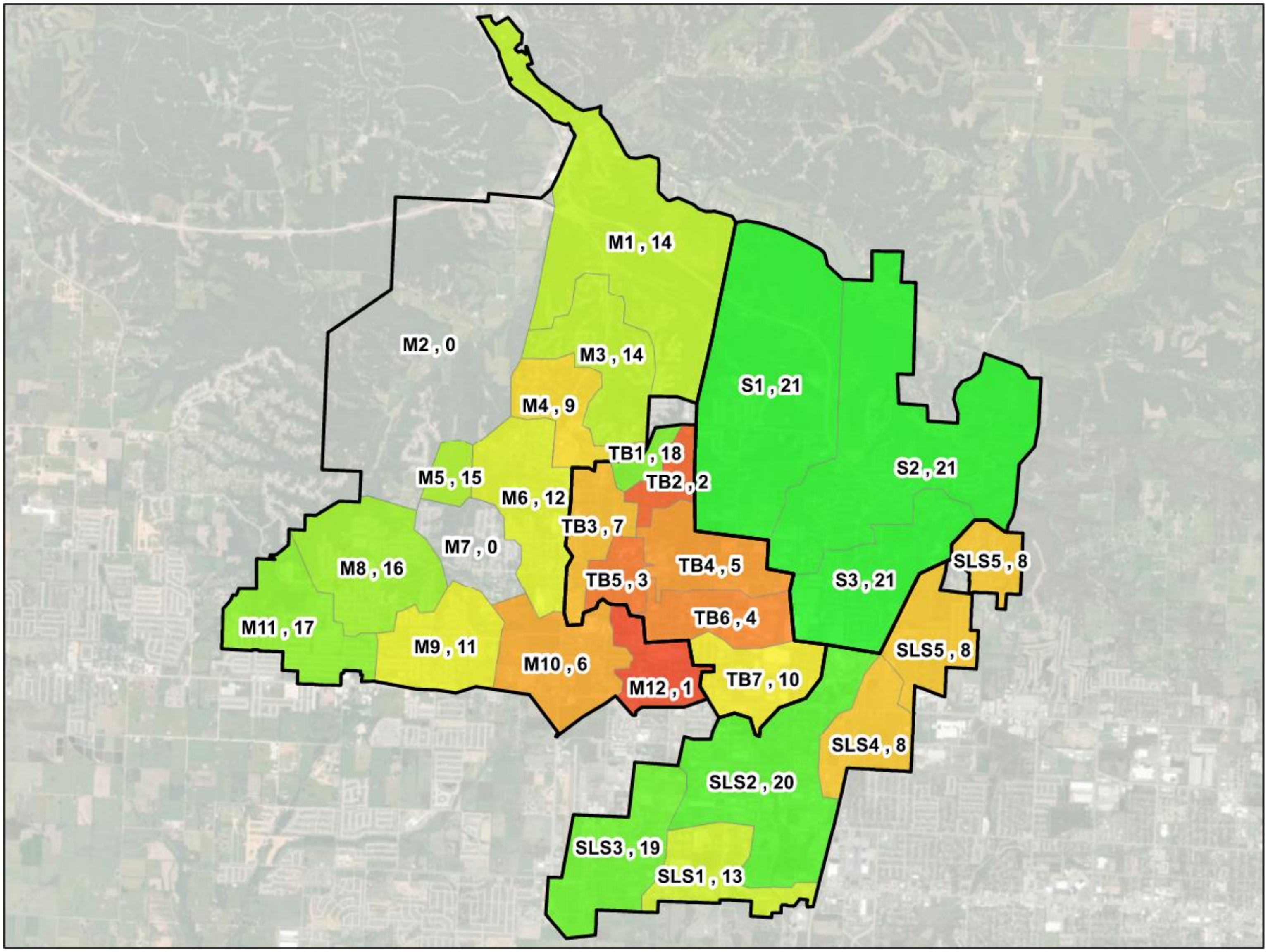


**Figure 33. Combined Subbasin Peak RDII Flow Rate Rankings.**

# 5. EXISTING COLLECTION SYSTEM MODELING

The City’s collection system hydraulic model was developed as a skeletal model that includes the primary gravity sewer mains, primary lift stations and force mains. The primary lift stations included in the model as McKisic and North lift station which discharge into the Bentonville WRRF, and South lift station which discharges to NACA.

The model was initially developed using InfoSewer software by Innovyze. InfoSewer was later discontinued, after Innovyze was acquired by Autodesk. During Part II, the InfoSewer model was converted to InfoWorks ICM and recalibrated by Olsson using 2023 flow and rainfall data. This Part I report discusses the RDII and Lift Station capacity evaluation results in the context of the InfoSewer model and the 1-, 2-, 5-, 10-, and 25-year rainfall events. Gravity sewer capacities and detailed model results for the selected design storm are discussed in the Part II report.

## 5.1 Hydraulic Model Development

The City’s Online GIS portal and plans of record were the primary source of information related to the modeled gravity sewers, manholes, lift stations and force mains. TREKK conducted manholes inspections to verify pipe inverts and manhole rim elevations.

Data from City’s GIS layers was imported to build the model, which was then updated to reflect provided by TREKK that include rim elevations, and pipe inverts and sizes. Pump information for each of the lift stations was also added to the model using data provided by the City as described in Lift Station Technical Memo included in Appendix A. A Manning’s coefficient of 0.013 was used for all modeled gravity pipes, regardless of the material.

The model allows for the analysis of the impact each subbasin on the system performance under various flow conditions. This will allow for the prioritization of rehabilitation efforts by subbasin. The modeled trunk lines consist of approximately 124,900-feet of gravity sewers, ranging in diameter between 8 and 30-inch, 553 manholes, and the McKisic, North and South lift stations and force mains. The extent of the modeled gravity sewers and force mains is shown on Figure 34.

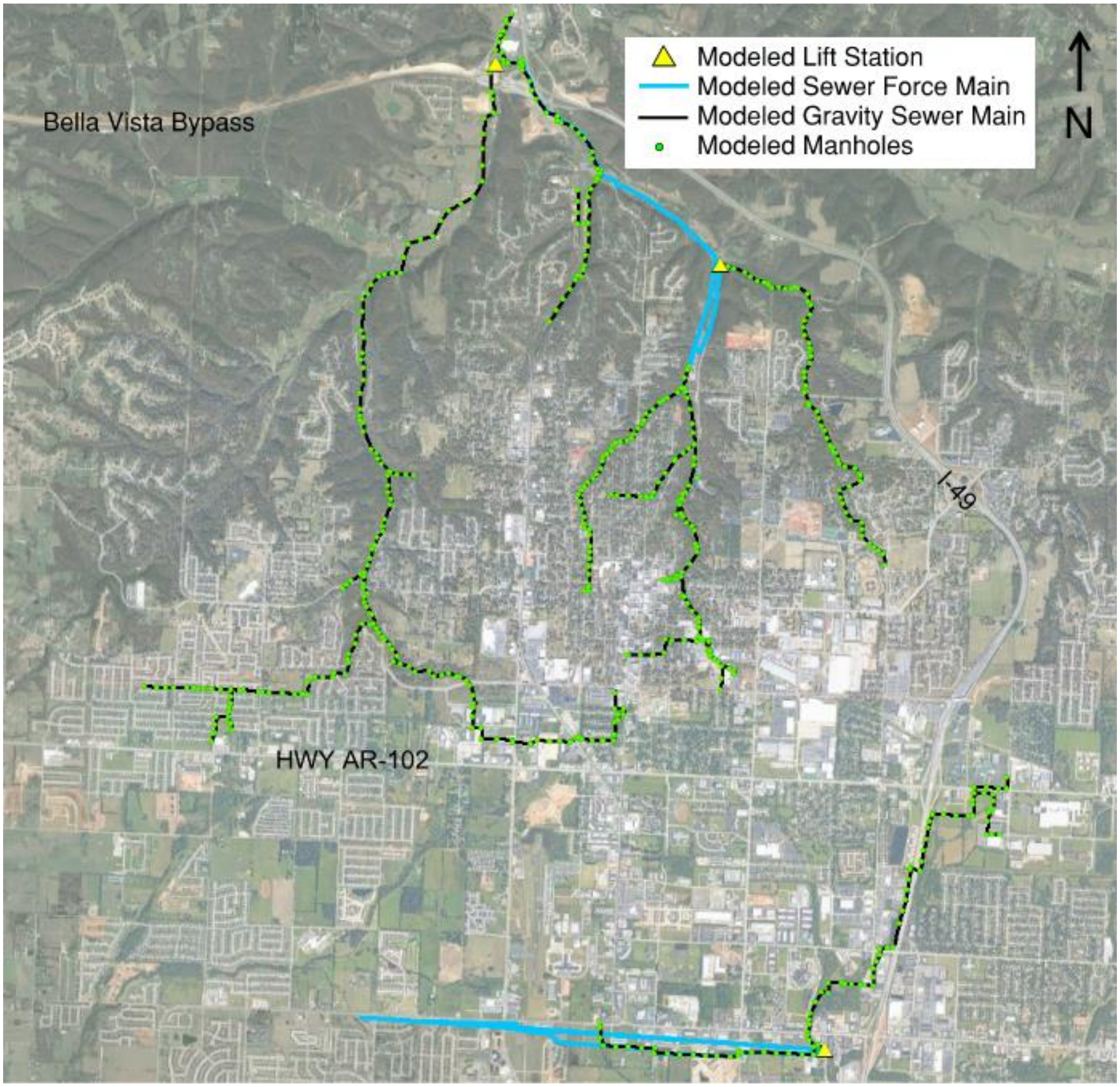


**Figure 34. Modeled Gravity Main, Lift Stations, and Force Mains**

## 5.2 Dry Weather Flow Modeling

After the sewer system model was created, several scenarios were developed. Two scenarios were created for dry weather analysis, which is representative of the city's base flow, with one using the average winter water usage (Dec-Feb) provided by the City and the other using SSOAP's DWF Analysis Tool. Both DWF scenarios were evaluated and used in determining potential groundwater induced Dry-Weather infiltration, also known as Chronic Infiltration. Further information regarding Chronic Infiltration is presented in Section 4.8.

The City provided water usage records for the 2020-2021 winter, in which the usage (in gpm) was assigned to the user's address. Along with the addresses, each of the users had a code that of whether the address is connected to the city's sewer system. In theory, water usage provides a representation of what the flow would be in the wastewater collection system under dry conditions with no I/I present. Winter water usage was selected for analysis to reduce error from non-sewered water usage such as irrigation systems, pools or other miscellaneous use. Once the water usage data was reduced to the winter usage (Dec-Feb) and sewer customers identified, the records were spatially geocoded on the map. For example, Figure 35 shows the water/sewer users in the McKisic 11 subbasin, represented by the purple points.

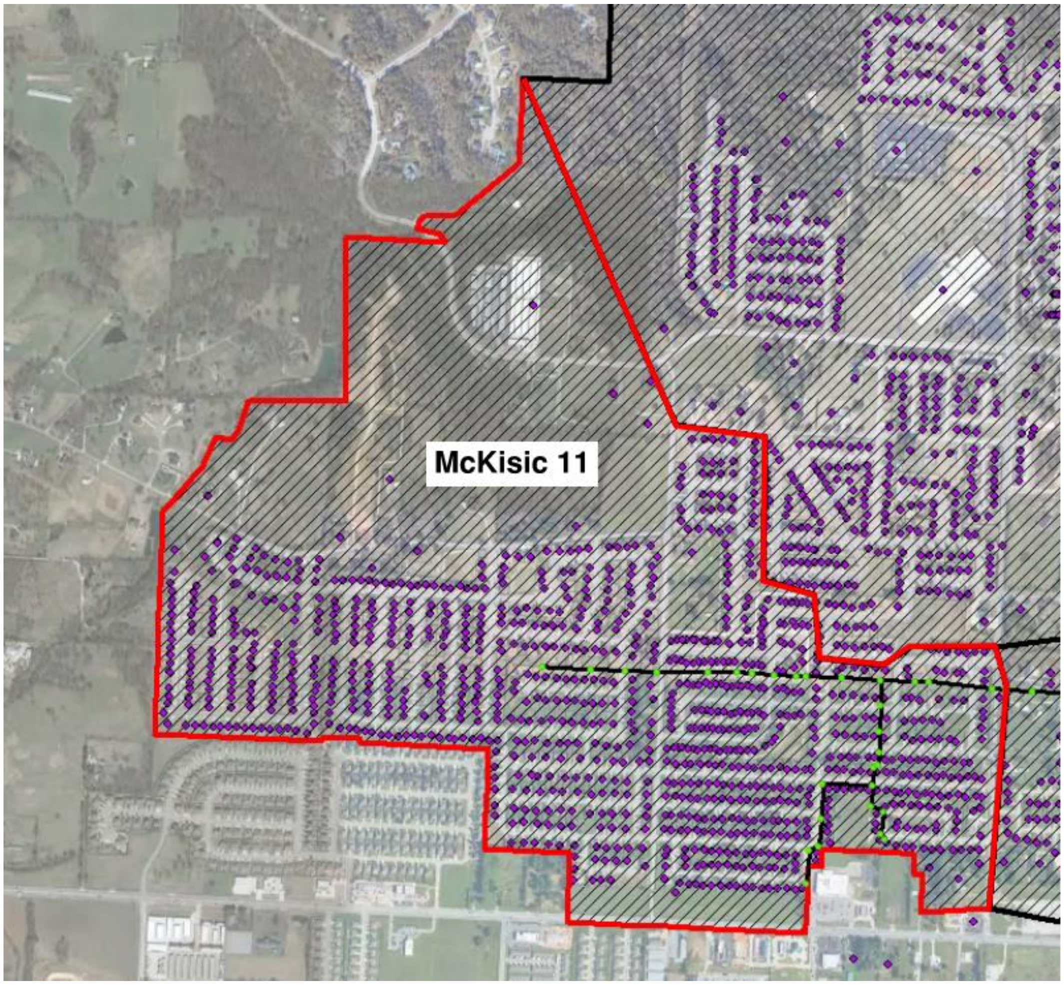


**Figure 35. Users Within the McKisic 11 Subbasin**

Each water record was assigned to the modeled manhole that it drains to, providing the dry weather loading for each of the modeled manholes, which allows the model to accurately represents dry weather distribution.

Once the dry weather flows were assigned to individual manholes, flows were then assigned to each subbasin for the two scenarios discussed earlier. The first scenario used only the water usage values, representing flow the sewer would experience if only water used by the city's users entered the system. The second scenario used SSOAP derived flows, representing more accurately what the sewer system experiences (water usage + any dry weather flow infiltration or other sources).

While InfoWorks ICM only supports dynamic modeling, InfoSewer had the option to run steady-state hydraulic. The discussion related to steady-state analysis presented here is not going to be replicated in Part II, where InfoWorks ICM is used to model the system. Similarly, InfoSewer can run extended period simulations (EPS), which is similar to the standard dynamic simulations in InfoWorks ICM. The reference to EPS simulations is limited to discussing results from InfoSewer in Part I.

Both scenarios were evaluated using a steady-state analysis. Steady-state analysis provides a simulation of the hydraulic response of the system. In a steady-state analysis, all flows are assumed to accumulate in the system and discharge only at the outlets. This means that even if a pipe has a flow beyond its maximum capacity, the flow is still carried downstream, including the flow through pumps and force mains. The transition between gravity flow and pressurized flow is accounted for by assuming that all flows are transported through each force main, subject to the upstream hydraulic capacities.

In summary, the water usage provided by the City was used to allocate flows in each modeled subbasin. Two DWF scenarios were run, one with only water usage flows and another with SSOAP derived DWF. Comparison of the two aids in the evaluation of chronic infiltration during dry weather periods.

## 5.3 Wet Weather Flow Modeling

Wet weather extended period simulation (EPS) scenarios were created using the InfoSewer model for the 1-, 2-, 5-, 10-, and 25-year rainfall events (also referred to as “design storms"), to represent for and analyze peak flows during a predefined set of design storms. The purpose of developing design storm scenarios is to evaluate the system’s performance and available capacity to convey predicted RDII through different components of the collection system under various design storms. Each of the WWF scenarios was evaluated using an EPS analysis.

Historical rainfall data is used to calibrate the hydraulic model. A total of seven rainfall events that occurred during the flow monitoring period were selected to be used in the model for calibration purposes. Three occurred in the summer-fall 2020 (11/24/20, 12/31/20, 1/24/20), four in winter-spring 2021 (4/28/21, 5/17/21, 5/27/21, 5/31/21). The April 28th storm was noteworthy, as it represented a 5 to 10-year storm across the city’s collection system.

SUHs derived using SSOAP were brought into the model, along with the actual recorded rainfall for each recorded storm. Model outputs were then compared to the actual recorded flow at each of the monitoring locations, and additionally compared to records provided by the City at the WRRF and the McKisic force main. This process was iterative as adjustments were made to both the model and the SSOAP derived SUHs for each individual subbasin to produce an accurate representation of the collection system response during precipitation periods.

The major sewer components include the gravity sewer entering the Dogwood (south) and Turner (east) sides of the McKisic lift station, the lines entering the North and South lift stations, and the east and west sides of Town Branch entering the WRRF. It is important to note that the only storage facility that was represented in the model is located at McKisic lift station.

The existing WRRF is rated to treat 4 MGD and from discussions with staff, and according to records, can pass a peak flow of 10 MGD during wet weather. To limit the flow at the WRRF operators utilize the storage located at McKisic, 4 MG total storage, during storm events to reduce the peak flow reaching the WRRF and maintain it below 10 MGD.

The table below shows the total peak hourly flow to the WRRF from the McKisic, Shewmaker and Town Branch subbasins for each of the design storms, along with the calculated volume of wastewater that would need to be diverted to storage in order to keep the peak flow to the WRRF below 10 MGD. The results presented in Table 10 and Table 11 are based on design storms with the NRSC (SCS) distribution, presented in Section 4.6, and using the InfoWorks ICM hydraulic model recalibrated in Part II.

**Table 10. Wastewater Influent at WRRF**

| Wastewater Influent at WRRF | | |
|---|---|---|
| **Design Storm** | **Estimated Peak Hourly Flow Rate (MGD)** | **Storage utilized to limit flow to <10 MGD at WRRF (MG)** |
| 1-yr Storm (3.36", 24-hr) | 17.72 | 0.15 |
| 2-yr Storm (3.79", 24-hr) | 18.68 | 0.24 |
| 5-yr Storm (4.53", 24-hr) | 20.03 | 0.45 |
| 10-yr Storm (5.19", 24-hr) | 20.92 | 0.68 |
| 25-yr Storm (6.16", 24-hr) | 21.55 | 1.01 |

For each of the modeled lift stations, the level of service, firm capacity and peak hourly flows for each design storm is shown in Table 11. The lift station (including storage) is highlighted in red where the level of service cannot be met. See Appendix A, Lift Station Technical Memo, for a more detailed analysis of the lift stations.

**Table 11. Lift Station Level of Service**

| Lift Station Level of Service | | | | | | |
|---|---|---|---|---|---|---|
| | Design Storm Peak Hour Flow (gpm) | | | | | |
| **Lift Station** | **Firm Capacity (gpm)** | **1-yr Storm** (3.36", 24-hr) | **2-yr Storm** (3.79", 24-hr) | **5-yr Storm** (4.53", 24-hr) | **10-yr Storm** (5.19", 24-hr) | **25-yr Storm** (6.16", 24-hr) |
| McKisic LS (Dogwood - south side) | 4,800 | 3,310 | 3,653 | 4,221 | 5,337 | 4,650 |
| McKisic LS (Turner - east side) | 1,030 | 1,462 | 1,605 | 1,804 | 1,925 | 2,114 |
| North LS (Shewmaker) | 2,200 | 1,557 | 1,577 | 1,579 | 1,580 | 1,580 |
| South LS | 2,400 | 2,719 | 2,827 | 2,901 | 2,905 | 3,100 |

While peak flows at McKisic LS (Dogwood south side) exceed its firm capacity beginning at the 10-year storm recurrence, the existing 4 MG of storage is sufficient to attenuate system wide flows to the WRRF for any recurrence interval.

McKisic LS (turner east side) has a firm 3 pump capacity of 1,030 gpm at low wetwell level 1120.00 (6 ft above floor elevation of 1014.00). From analysis of the gravity sewer, the lowest manhole has a rim elevation of approximately 1037.00. If the Turner wetwell is allowed to fill to elevation 1033.00, leaving 4 feet for freeboard and line losses, the firm 3 pump capacity improves to 1,875 gpm. If all 4 pumps are operating, the pump rate with wetwell elevation of 1033.00 is estimated to be 2,500 gpm.

In summary, McKisic (Dogwood south side) and North lift stations meet or exceed a 5-year design storm rating, while McKisic (Turner east side) and the South lift station have insufficient capacity for a 1-year design storm rating. Improvements to the South and McKisic (Turner east side) lift stations are required to meet current peak flows, while upgrades to the McKisic (Dogwood south side) and North lift stations may be required in the future as the City continues to expand and peak flows increase.

# 6. RECOMMENDATIONS

As stated previously, this engineering report summarizes the initial field data collection, analysis and baseline capacity modeling efforts considered Part I of the overall Sewer Collection Analysis and Peak Flow Management Program project for the City of Bentonville. Recommendations summarized below include prioritized I/I reduction projects in public, private and streamway infrastructure; lift station improvements; and completion of Part II - Peak Flow Improvement Alternatives and Part III - Modeling/Evaluation of Future Collection System Scenarios.

## 6.1 Prioritized I/I Reduction Recommendations

In addition to providing model inputs for planning purposes, the analysis described in Section 4 provides an indication of which subbasins allow the most I/I into the City's sanitary sewer system. Independent of the modeled sewer capacities, Olsson analyzed the results of Section 4 to identify subbasins which may be candidates for future I/I removal projects. These projects can be implemented by the City as time and budget allow to reduce peak flow rates throughout the City's collection system.

Based on the analysis of flow and rainfall monitoring, Olsson has prioritized basins with the highest I/I contributions so the City can implement I/I reduction projects most cost effectively. Olsson considered both the chronic infiltration contribution described in Section 4.8 and peak RDII flow rates described in Section 4.9 to produce these recommendations.

Independent of any future sewer main capacity improvements necessary based on modeling, Olsson recommends that the City begin I/I reduction projects to identify and repair I/I sources within public infrastructure (defects in manholes and sewer mains) as well as private infrastructure (such as defective plumbing or illicit plumbing connections).

## 6.2 Streamway Infrastructure

Section 4.8 describes Olsson's methodology for estimating chronic infiltration within each subbasin and ranking the subbasins. Chronic infiltration may enter the sanitary sewer system through several sources, but typically assets in or near streamways or low-lying areas with inadequate drainage are considered to be at the greatest risk. As a preliminary investigation, Olsson recommends that the City perform above grade inspections of trunk sewers to identify any exposed pipe or defective manholes in or near streamways or chronically wet areas. In addition, the City should make note of any sinkholes above sewer mains or manholes in areas that do not drain or drain toward the manhole. Once these assets have been identified, Olsson recommends that the City further investigate through manhole inspections and/or CCTV inspections of sewer mains where infiltration sources are suspected.

Olsson recommends that the City perform these investigations in the order listed in Table 7. Depending upon the progress of the public I/I investigations, the City may choose to perform these investigations earlier or include them in the scope of public I/I investigations. Upon identification of defects, Olsson recommends that the City perform repairs as soon as possible either on a case-by-case basis or as part of a larger repair program.

## 6.3 Public I/I Reduction

Olsson recommends that the City complete Sanitary Sewer Evaluation Studies (SSES) to locate potential I/I sources by subbasin in the priority indicated in Table 12 and as shown in Figure 36. These investigations should include comprehensive manhole inspections and smoke testing with selected follow-up dye testing and Closed-Circuit (CCTV) inspection of sewer mains. Tests/inspections may be performed by the City or contractors depending upon City staffing, budget, and timeline. As phases of the SSES program and future I/I reduction projects are implement, the City should evaluate the effectiveness of each program and adjust the pace and scope of future project phases as needed.

The results of SSES activities in an area will provide the City the necessary data to identify and prioritize sources removal repairs for implementation. Repair implementation can include a combination of capital rehabilitation projects and “find and fix” programs for public sources, such as manhole lining or trenchless pipe segment rehabilitation. “Find and fix” programs can include a combination of in-house staff and term-and-supply contracts with outside contractors. The SSES should include a data management system for test/inspection data including a prioritized listing of recommended repairs and potentially assistance with implementation programming.

**Table 12. Public I/I Source Investigation Prioritization.**

| Priority | Timeline | Subbasins | Area (Acres) | Length of Pipe (LF) | Number of Manholes |
|---|---|---|---|---|---|
| High | 1 to 2 Years | TB2 | 141 | 13,900 | 45 |
| | | TB3 | 262 | 33,300 | 133 |
| | | TB4 | 384 | 45,600 | 184 |
| | | TB5 | 155 | 20,900 | 63 |
| | | TB6 | 316 | 35,300 | 125 |
| | | M10 | 512 | 33,000 | 132 |
| | | M12 | 259 | 34,000 | 140 |
| | | **Total** | **2,029** | **216,000** | **822** |
| Medium | 3 to 5 Years | M1 | 1,433 | 49,700 | 260 |
| | | M3 | 494 | 51,500 | 271 |
| | | M4 | 314 | 38,200 | 180 |
| | | M6 | 544 | 44,000 | 213 |
| | | M9 | 432 | 41,100 | 178 |
| | | TB7 | 351 | 38,300 | 137 |
| | | SLS1 | 358 | 27,000 | 109 |
| | | SLS4 | 334 | 22,600 | 86 |
| | | SLS5 | 526 | 38,300 | 151 |
| | | **Total** | **4,786** | **350,700** | **1,585** |
| Low | 5 to 10 Years | M2 | 1,992 | 33,200 | 122 |
| | | M5 | 107 | 2,500 | 11 |
| | | M7 | 319 | 24,400 | 125 |
| | | M8 | 614 | 45,900 | 205 |
| | | M11 | 506 | 52,100 | 225 |
| | | S1 | 1,523 | 41,900 | 225 |
| | | S2 | 1,677 | 70,800 | 324 |
| | | S3 | 637 | 48,700 | 247 |
| | | SLS2 | 982 | 90,400 | 346 |
| | | SLS3 | 552 | 30,800 | 124 |
| | | **Total** | **8,909** | **440,700** | **1,954** |

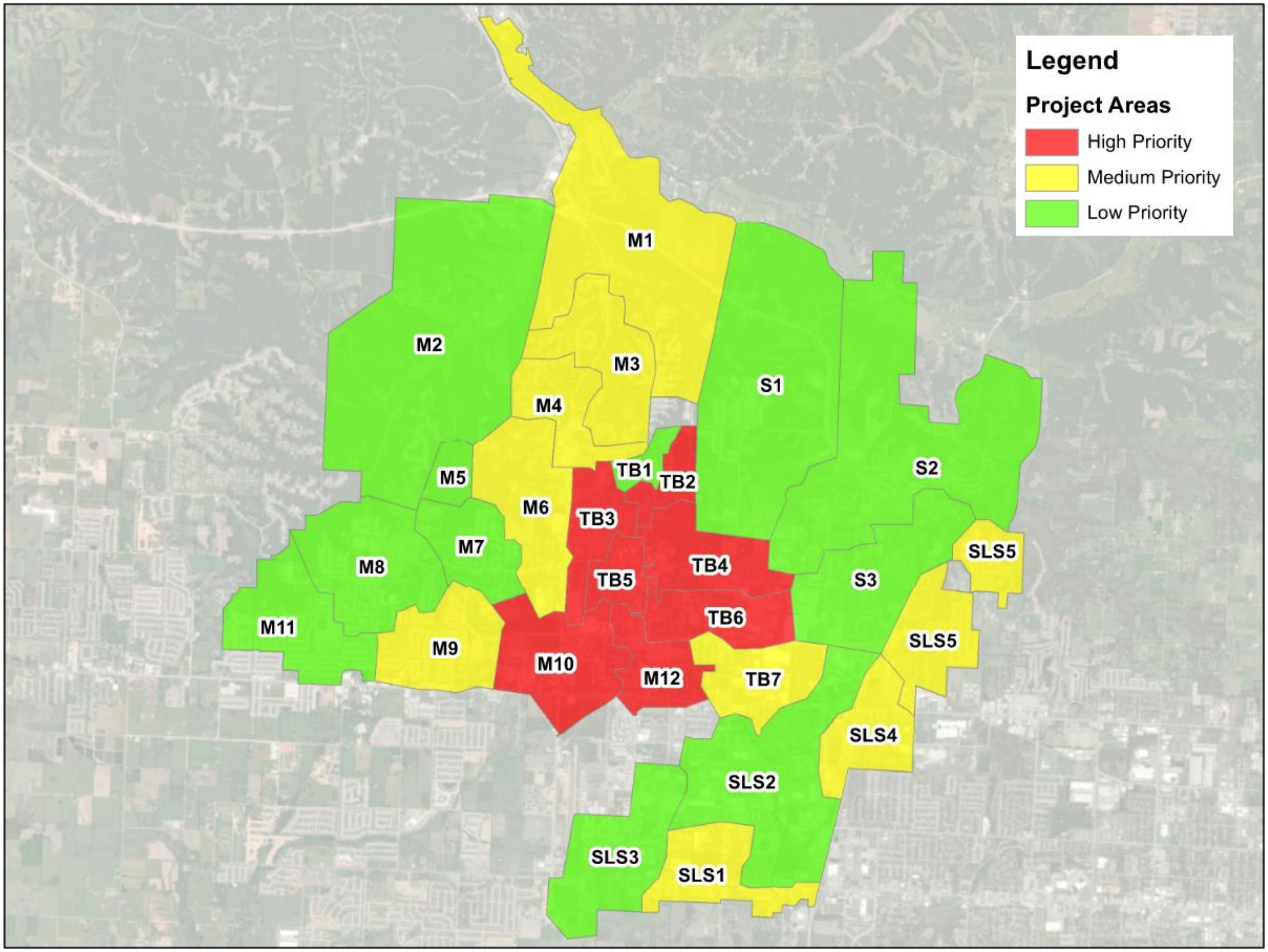


**Figure 36. Prioritized Public I/I Reduction Project Areas.**

Olsson's estimated cost for I/I source investigations is shown in Table 13.

**Table 13. Public I/I Source Investigation Project Cost Estimates.**

| Item Description | Quantity | Unit | Unit Cost | Extension |
|---|---|---|---|---|
| **High Priority I/I Source Investigation** | | | | |
| Smoke Testing | 216,000 | LF | $-.65 | $140,400 |
| Acoustic Sounding (SL-RAT) | 216,000 | LF | $-.35 | $75,600 |
| Manhole Inspections | 822 | EA | $175 | $143,850 |
| CCTV | 21,600 | LF | $3.25 | $70,200 |
| **Subtotal Estimated Investigation Costs** | | | | $430,050 |
| **Contingency (25%)** | | | | $108,000 |
| **Engineering and Administration (15%)** | | | | $81,000 |
| **Total Estimated Project Cost** | | | | $619,050 |
| | | | | |
| **Medium Priority I/I Source Investigation** | | | | |
| Smoke Testing | 351,000 | LF | $-.65 | $228,150 |
| Acoustic Sounding (SL-RAT) | 351,000 | LF | $-.35 | $122,850 |
| Manhole Inspections | 1,585 | EA | $175 | $277,375 |
| CCTV | 35,100 | LF | $3.25 | $114,075 |
| **Subtotal Estimated Investigation Costs** | | | | $742,450 |
| **Contingency (25%)** | | | | $186,000 |
| **Engineering and Administration (15%)** | | | | $139,000 |
| **Total Estimated Project Cost** | | | | $1,067,450 |
| | | | | |
| **Low Priority I/I Source Investigation** | | | | |
| Smoke Testing | 452,000 | LF | $-.65 | $293,800 |
| Acoustic Sounding (SL-RAT) | 452,000 | LF | $-.35 | $158,200 |
| Manhole Inspections | 1,999 | EA | $175 | $349,825 |
| CCTV | 45,200 | LF | $3.25 | $146,900 |
| **Subtotal Estimated Investigation Costs** | | | | $948,725 |
| **Contingency (25%)** | | | | $237,000 |
| **Engineering and Administration (15%)** | | | | $178,000 |
| **Total Estimated Project Cost** | | | | $1,363,725 |

The cost estimates above assume the use of outside contractor(s), with cleaning and CCTV inspection of 10 percent of the sewer mains located within each subbasin. Additional CCTV inspection may be necessary as the actual percentage of sewer mains requiring CCTV inspection should be based on a combination of manhole inspection observations; smoke and dye testing findings; pipe material, location, and backup report; and/or acoustic sounding.

## 6.4 Private I/I Reduction

Sources of I/I within private infrastructure can be a significant contributor to peak flow rates within a subbasin and are typically less costly to remove than public sources per unit of flow removed. Typical sources include downspouts, uncapped cleanouts, driveway/area drains, sumps pumps, and others as discussed in Section 1.1. Private sources are typically identified through internal and external building evaluations combined with the results of smoke/dye testing that can be performed as part of public source SSES or a private I/I program. Removal and disconnection of private sources should be completed by trained/licensed plumbers and inspected for conformance to City standards to improve durability of source repairs.

Because of the nature and location of private I/I sources, the inherent cost-effectiveness of private I/I reduction, and the benefit to all customers, Olsson recommends the City establish a voluntary and City-funded Private I/I Program that includes a public outreach/education element to improve participation. In establishing such a program, the City should establish and refine the program’s objectives, standards, construction details, policies, and processes. The City may involve assistance from Olsson and/or outside consultant(s) or contractor(s) for program development and implementation. As a minimum, the City should review their Sewer Use Ordinance and other policies and revise as necessary, before beginning.

An initial phase of private source I/I removal should focus on three of the highest priority subbasins in terms of overall peak RDII ranking from Section 4.9, specifically Town Branch 5, Town Branch 6, and McKisic 12 subbasins as shown in Figure 37.

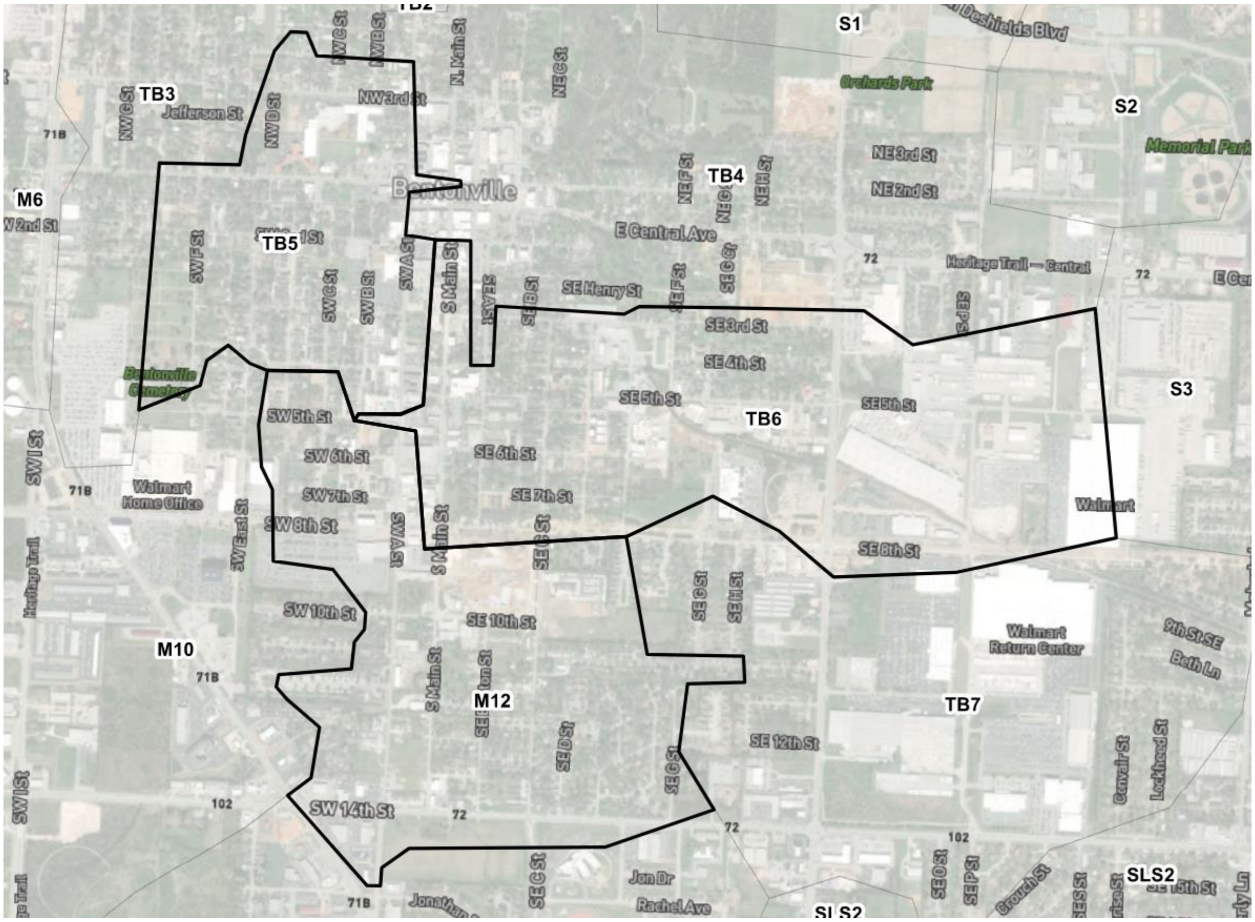


**Figure 37. Initial Private I/I Reduction Project Areas.**

In addition to their high RDII ranking, these three subbasins are located in the southern half of the downtown core area of the City, which is comprised of older construction areas undergoing significant redevelopment and increased density. These subbasins cover approximately 730 acres and are also included within the high priority public I/I reduction projects described in the previous section. Table 14 below lists the number of residential and non-residential parcels in these areas.

**Table 14. Potential Private I/I Reduction Project Area Parcel Counts.**

| Parcel Type | Parcels | | | |
|---|---|---|---|---|
| | M12 | TB5 | TB6 | Total |
| Residential* | 324 | 301 | 265 | 890 |
| Non-Residential* | 116 | 93 | 155 | 364 |
| **Total** | | | | **1,254** |

* *Residential parcels include parcels categorized as single-family and multi-family residential parcels. Non-residential parcels include the remaining parcels within each subbasin.*

Olsson's estimated cost for private I/I source investigations is shown in Table 15 below.

**Table 15. Private I/I Source Investigation Project Cost Estimate.**

| Item Description | Quantity | Unit | Unit Cost | Extension |
|---|---|---|---|---|
| Residential Building Evaluation | 890 | EA | $300.00 | $267,000 |
| Non-Residential Building Evaluation | 364 | EA | $450.00 | $163,800 |
| **Subtotal Estimated Investigation Costs** | | | | $430,800 |
| **Contingency (25%)** | | | | $108,000 |
| **Engineering and Administration (15%)** | | | | $81,000 |
| **Total Estimated Project Cost** | | | | **$619,800** |

These cost estimates assume that the City has implemented smoke testing within the Town Branch 5, Town Branch 6, and McKisic 12 subbasins as part of the high priority public I/I investigation discussed in the previous section. The costs listed above assume that all investigation work is performed by outside contractors.

## 6.5 Lift Station Recommendations

Currently, the McKisic Lift Station has adequate capacity to convey existing flows from a 5-year design storm. The North Lift Station can provide a 25-year design storm level of service, while the South Lift Station capacity is less than a 1-year design storm. The City's desired level of service may vary depending upon factors described elsewhere in this report. To increase the level of service from the South Lift Station, there are several strategies recommended to ensure the lift station meets City requirements outlined below.

One opportunity, which is further discussed in this document, is to reduce the peak flow being conveyed to the South Lift Station utilizing a I/I reduction program. Typically, I/I reduction programs set target reduction on the order of 10% to 30%. Since a reduction of this amount would not reduce peak flows below the rated firm capacity of the station, lift station improvements are anticipated in the future. These improvements can vary from:

1) Extraneous Flow Holding Basin (EFHB) – a wet weather storage basin could be constructed to hold back excessive volume of flow for a particular design storm. Additional study for siting and sizing the basin will be required to determine the best outcome for the City.

2) Wet-Weather Pump Station – a wet-weather force main, wetwell and associated pumping equipment could be constructed adjacent to the South Lift Station.

Additional siting study and economic analysis will be required to determine design flow and head conditions, wetwell sizing and other key considerations.

To increase the level of service from the South Lift Station a combination of I/I reduction, storage and/or pumping capacity will likely be required. Olsson recommends that peak flow improvement alternative analysis be performed, as discussed below, to determine the most cost-effective approach that takes into consideration population growth.

## 6.6 Part II: Peak Flow Improvement Alternative Analysis

Based on findings of baseline capacity modeling for existing conditions in Section 5, the current level of service for much of the gravity portion of the collection system is less than a 1-year design storm, which is well below the recommended 5-year design storm level of service. However, the Shewmaker basin that flows to the North lift station is at a 25-year level of service.

Considering this and the potential for high rate of growth in the city of Bentonville, Olsson recommends that the City proceed directly with future scenario modeling, which will also include any peak flow management measures to address minor existing capacity and protection level deficiencies.

## 6.7 Part III: Future Scenario Modeling

In addition to the public and private I/I reduction recommendations stated previously, Olsson recommends applying growth projections to the sanitary sewer model to predict future flows and develop a comprehensive peak flow management approach. The creation of the future model scenarios would allow for the identification of future needs, evaluation of alternatives, and cost analysis of alternatives. Alternatives to evaluate would include the three points of a cost-effective peak management program including I/I reduction, conveyance improvement and storage. The capital improvement plan resulting from the future model analysis would likely be a balanced blend of the three alternatives to provide the most cost-effective program.

# BENTONVILLE BASELINE SANITARY SEWER CAPACITY STUDY - PART I

Bentonville, Arkansas

Revised March 2025

Olsson Project No. 020-23210