4.0 I&I Assessment and Reduction Plan

4.1 Introduction

The City of Leavenworth, Kansas is under no mandatory requirement to develop an I&I Assessment and Reductions Plan; however the City understands the benefits of a structured comprehensive program for their wastewater utility. The City, with the assistance from TREKK Design Group, LLC (TREKK) has developed this I&I Assessment and Reduction Plan which presents procedures for identifying and cost-effectively reducing extraneous wet-weather induced wastewater flows within the City. This Plan also presents a recommended schedule for identifying and eliminating I&I sources by the year 2025.

4.2 Background

The City of Leavenworth operates and maintains an extensive wastewater management system that includes approximately 133 miles of sanitary sewer and one wastewater treatment facility. The collection system can be further separated into 5 sub-systems, SUB01, SUB02, SUB03, SUB04, and SUB05. Fort Leavenworth comprises approximately 1,892 acres of developed land located within Sub-systems SUB02 and SUB03.

The oldest parts of the City's wastewater system were constructed during the early 1900s and have been expanded over the years to accommodate residential, commercial, and industrial growth. Common construction materials included vitrified clay pipe with hot-poured jute joints and brick manholes.

The City completed a comprehensive Wastewater Master Plan in 2001 (Black & Veatch). Collection system flow monitoring determined that I&I is excessive, with peak wet to dry weather flows ranging between 2:1 and 15:1 at the monitoring sites. The master plan recommended that a sanitary sewer evaluation study (SSES) be conducted, beginning with sub-system SUB01 and established an initial budget of $460,000 to conduct this SSES. After discussing several options with City staff, it was decided that

before engaging in a comprehensive and long-term SSES in SUB01, a smaller scale "pilot" SSES would be conducted.

In April of 2002, Wade & Associates, Inc. completed the pilot study and submitted the pilot SSES report to the City. The pilot study area focused on a small mini-basin, located within SUB01, containing approximately 20,000 linear feet of sanitary sewer or 3% of the City's sanitary sewer collection system. This report identified excessive I&I in the pilot study area and recommended that a comprehensive long-term SSES be implemented in SUB01.

Wade & Associates, Inc. completed Phase I of the Wastewater Collection System I&I Study/SSES in September of 2003. Phase I of the SSES included flow monitoring of SUB01, which was sub-divided into 6 mini-basins. Seven flow monitors were placed at the outlet of each mini-basin, and one overflow line, for a 60-day monitoring period to establish preliminary I&I rates, mini-basin severity rankings, peak flow rates, and rainfall responses. Severity rankings were based on ratio of peak flow to dry weather flow. Mini-basins were then assigned a severity ranking and sorted from the most severe to the least severe. The SSES of SUB01 made the following recommendations:

- Pipeline Rehabilitation (I&I Reduction Program) – A total of 183 sanitary sewer line segments (approximately 46,300 ft) were targeted for rehabilitation to remove excessive I&I and restore structural integrity.
- Manhole Rehabilitation (I&I Reduction Program) –The final manhole rehabilitation schedule included 547 manholes with an estimated cost of $0.8 million. An additional 132 manholes were recommended to be repaired as part of the Pipeline Rehabilitation Program.
- Relief/Replacement Sewer Program (Capacity Improvements) – The study identified approximately $3.2 million of capital improvements to increase hydraulic capacity within the SUB01 system in order to accommodate and contain the 5-year, 60-minute design storm event. Improvements include approximately 9,700 linear feet of either pipe upsizing (replacement) or parallel sewer construction. These improvements also are necessary to

meet the 20-year planning period outlined in the 2001 Wastewater Master Plan.

- 4th Street Corridor Improvement Project (Capacity Improvements) – Wade & Associates, Inc. identified a separate project for the 4th Street Corridor Improvements. The project would remove several connections that currently exist between the storm and sanitary sewer systems. Under this project, approximately 2,300 feet of corridor improvements will include a new 15" sanitary sewer, replacement of the existing 41"x62" storm sewer with a new 60" conduit, and complete street historic restoration and reconstruction. Approximately $6.4 million was budgeted for the corridor improvements, of which $0.7 million was budgeted for the new sanitary sewer.
- Private-Sector I&I Reduction/Abatement Program (Optional Program) – The study recommended the removal of private-sector I&I through, 1.) the elimination of defective service laterals, 2.) disconnecting driveway drain, stairwell, and area drains, 3.) capping or repairing cleanouts, and 4.) disconnecting downspouts.

4.3 I&I Assessment

As previously mentioned, the City completed an SSES of SUB01 to identify and assess the extent of I&I in the sub-system system. The City should continue to conduct these assessments on the remaining sub-systems in the order of the I&I priority rankings established in the *Wastewater Master Plan* (B & V, 2001). Previous and future studies will generally follow the guidelines as established in the *Existing Sewer Evaluation & Rehabilitation* (WEF Manual of Practice FD-6) and ASCE Manual and Report on Engineering Practice (No. 62, 1994). The program may consist of these six (6) key components. They are summarized as follows:

- Administration
- Public Relations

- I&I Quantification (flow analysis)
- I&I Identification
- Cost-Effectiveness Analysis
- Final Recommendations and Implementation Plan

4.4 Administration

Progress meetings shall be regularly scheduled to review the project goals, objectives and schedule. Public hearings and Council meetings may be required to discuss the project and answer questions from the public and/or City. Field data shall be properly administered on a daily basis to ensure quality data to accurately evaluate the existing conditions and make proper recommendations.

4.5 Public Relations

During the data collection process, structures identified for inspection may be located in backyards on private property. In the event that these structures are inaccessible, a door notification will be left for the property owner. The notification will contain an explanation and the need to conduct the inspection along with a telephone number enabling residents to contact the City for more information and to schedule a convenient time to reschedule. Prior to smoke testing, notification to all property owners will be done by placement of door hangers on homes and businesses. The notice will include general information about the testing; including instructions to fill infrequently used plumbing traps with water and a tablespoon of cooking oil to prohibit smoke from entering buildings via service lines. Telephone numbers will be provided enabling residents to contact the City for more information or with any special needs and concerns they may have.

4.6 I&I Quantification

4.6.1 Flow Monitoring

Collection system flow monitoring will be conducted on the study basins by continuously and simultaneously measuring flows tributary to each basin. Monitoring will be conducted for a base period of 60-days during the spring or fall.

Flow meters capable of continuously recording flow depth and velocity measurements under free flow, surcharge, and reverse flow conditions will be employed. Data will be logged at 15-minute intervals.

The flow monitoring activities will include site hydraulic calibration measurements, installation of flow meters, weekly servicing of flow meters (including performance checks and collection of recorded data), as well as removal of flow meters. The flow monitoring process will be conducted using a two-person crew.

4.6.2 Rainfall Monitoring

Rainfall-monitoring activities will be performed concurrently with flow monitoring activities at multiple locations for a 60-day base period.

Rain gauges capable of continuously recording rainfall measurements to 0.01-inch will be used. Data will be logged at 15-minute intervals and the rain gauge electronic logger clock will be synchronized with the flow meter electronic logger clocks.

4.6.3 Flow Data Analysis

Flow and rainfall data collected will be analyzed to determine rates for the following:

- Average daily and peak hourly dry-weather flows
- Peak high groundwater infiltration flows
- Peak wet-weather inflow flows
- Peak wet-weather total flows

Dry weather flows will be determined from flow data collected during periods of dry weather and low groundwater. Infiltration will be determined from flow data collected during periods of dry-weather and high groundwater, as well as, additional data. Inflow will be determined from flow and rainfall data collected during wet-weather.

4.7 I&I Identification

4.7.1 Manhole Inspections

Manhole inspections will be conducted to identify I&I sources and structural/maintenance defects in the manholes. Manhole inspections will be accomplished using a two-person crew. Manholes less than 15 feet deep shall be inspected from the topside (Surface) using survey rods, digital cameras, mirrors and high powered spotlights. The inspections of manholes greater than 15 feet deep shall be accomplished by man entry into the manhole (Internal). Industry standard OSHA, NIOSH, OSDH and NASSCO confined space entry policies and practices shall be followed to ensure safe entry and egress of all confined spaces. Manholes may also be inspected from the topside utilizing zoom inspection cameras capable of recording video and photos. Cameras shall provide the adequate amount of light to ensure identification of all defects and suspect sources.

Each structural component of the manhole will be inspected and assigned a condition rating. An initial rehabilitation recommendation will also be provided by the inspectors during the inspection. Photographic records will be used to supplement and substantiate manhole inspection observations and recommendations. All manhole inspections will be recorded on City field forms and input into the City's information management system.

A field sketch of the plan view of the manhole will also be completed to verify sewer line configurations. An area photo as well as a topside photo, both north-facing, will be taken of each manhole with a digital camera. All area and topside photos are taken north-facing to ensure consistency and provide a standard point of reference for future

viewing. Field crews will utilize a white board to provide a media for manhole identification of area photos. This will facilitate the visual identification of the manhole when viewing the area photo without further investigation and provide another avenue of QA/QC checking for manhole inspection photos. Digital photographs will also be taken of selected I&I defects and other non-I&I related defects such as roots, debris, or structurally deteriorated steps. Each photo shall be uniquely annotated and attached to the specific inspection record, as specified herein.

Each field crew will carry metal detectors and probing rods to assist in locating manholes. If a manhole cannot be located, the manhole will be placed on a "Can Not Locate" list with a general map of the position for location services at a later time. If a manhole is found to be buried, the approximate location of the manhole will be identified in the field. New manholes found by field crews will be assigned a temporary manhole number consisting of the last known downstream manhole number followed by a T1, T2, T3…(0184-T1). If located on public sewer mains, these manholes will be inspected and location details for the manhole will be made on field maps.

4.7.2 Visual Pipe (Lamping) Inspections

Line lamping will be performed in conjunction with the manhole inspections to collect pipe sizes, rim-to-invert measurements and to observe the sewer line's structural condition and potential for leakage. Typically, up to 10-15 feet of incoming and outgoing pipes can be viewed from within a manhole utilizing digital cameras. Visual pipe inspections conducted utilizing zoom inspection cameras can typically increase sight distance to 50-100 ft in an 8" line, depending on how straight the line is.

Prioritization of the sewer lines for follow-up cleaning and CCTV inspections will be determined from sewer lines that exhibit structural and/or maintenance issues during line lamping and line segments that exhibited smoke during smoke testing activities indicating sources of I&I.

4.7.3 Smoke Testing

Smoke testing will be conducted on all line segments located within the City to identify inflow sources from both the public and private sector, to locate manholes not identified on the City's existing map, and to obtain a lineal footage of the sewer line segments for the system inventory. Each positively identified source is photographically documented, precisely located using GPS technology and referenced to allow for efficient repair. Suspect sources are identified for subsequent dyed-water testing.

Two (2) smoke blowers (rated at 6,211 cfm) using liquid smoke will be set-up on every other manhole to expedite the procedure. The high rated smoke blowers combined with the use of liquid smoke allow for continuous and constant smoke production while the field crew canvasses the areas over and adjacent to the lines and conduct a perimeter check of all buildings in close proximity for evidence of smoke.

Smoke testing activities will include a minimum of 48 hours advance notification to all residents within the study areas. Notification will be done by placement of door hangers on homes and businesses, including instructions to fill infrequently used plumbing traps with water and a tablespoon of cooking oil to prohibit smoke from entering buildings via service lines. Telephone numbers will be provided enabling residents to contact the City for more information or with any special needs and concerns they may have.

Photographic records will be used to supplement and substantiate smoke testing observations. Line segments exhibiting smoke from public sources other than manholes, will be included in the concurrent CCTV inspection program. All smoke testing inspections will be conducted using GPS cameras capable of recording defect information or by recording information on field forms.

4.7.4 Cleaning/CCTV Inspections

All of the line segments recommended for cleaning and CCTV inspections will be based on the results from visual pipe inspections and smoke testing programs. Necessary cleaning and root cutting will be performed prior to the television inspections. This allows

passage of the camera and offers the best view of the interior of the lines for evaluating structural conditions and identifying potential I&I sources.

It is anticipated that approximately 15% of sewers will be recommended for cleaning and CCTV as part of the I&I Assessment. All video records shall be recorded in electronic format and supplied to the City on CD's, DVD's, or on an external hard drive.

4.8 Cost-Effectiveness Analysis

All field information will be combined with additional treatment cost to conduct a cost-effectiveness analysis (CEA). The CEA will become the basis of establishing the optimal I&I reduction and sanitary sewer overflow (SSO) control plan for the basins included in the study. The CEA will, in essence, provide the City with a program that yields the "biggest bang for the buck".

4.8.1 Establishing Source Flows and Costs

Utilizing the City's database with the populated physical information for the sanitary sewers investigated, data from all completed I&I source investigation inspection and testing activities will be used to calculate defect flow rates. A summary listing will then be completed. The listing will, for each specific I&I source, include the following:

- Source type (manhole defect, sewer line defect, etc.)
- Source category (public sector, private sector)
- Source status (confirmed, suspect)
- Number of such sources
- Source unit flow rate, based on five-year storm event
- Total five-year flow rate contributed by such sources
- Source unit repair cost
- Total repair cost for such sources
- Source cost/flow ratio (total repair cost divided by total five-year flow rate)

The final listing will be sorted in ascending order by source cost/flow ratio. Sources with low ratios are considered more cost-effective to repair than sources with higher ratios.

To balance the source flows, the I&I source summary listing will be used along with the peak infiltration and five-year inflow flow rates. Source unit flow rates will be calculated following the guidelines established in the *Existing Sewer Evaluation & Rehabilitation*, (WEF Manual of Practice FD-6).

A certain percentage of five-year I&I flow will be attributed to unidentified I&I sources. The unidentified sources would be those which investigations were unable to verify. These typically include building foundation drains, private service laterals, and other such sources for which smoke testing and inspection activities are not totally effective.

4.8.2 Capacity Analysis

The I&I data collected and the flow monitoring results will be evaluated and entered into the current hydraulic model. The model will be used to analyze 100% of the sanitary sewer system in targeted basins. Hydraulic models for each basin will be calibrated to storm event criteria that are established by the City and which meet the guidelines of proposed SSO policies or regulations.

The models will be used to identify additional capacity requirements, if necessary, to transport peak wet-weather flows for several levels of I&I reduction, beginning with 0%. The model will also determine the cost of relief sewers for each 10% increment of I&I reduction, based on residual I&I.

4.8.3 Treatment Analysis

Treatment cost data from City's WWTF will include both capital and operations and maintenance costs associated with normal daily and peak wet-weather flows. Unit, per gallon, rates will then be determined and applied to incremental levels of I&I

reduction beginning at the 0% I&I elimination level until a treatment cost curve is completed.

4.8.4 Cost-Effectiveness Analysis

The cost-effectiveness analysis compares costs associated with I&I source repair to costs associated with providing flow transportation and treatment for the extraneous flows. Combining the three cost curves, a composite cost curve can be developed based on present worth cost. The cost-effective level of I&I removal is that percentage associated with the minimum cost point on the curve.

4.9 Recommendations and Implementation Plan

The results of the studies should be provided in a clear and concise format summarizing the findings and recommendations for the field investigations and data analysis. The following information should be included in the final report:

- Executive Summary – highlighting all tasks performed, conclusions, recommendations and costs.
- Background Information – describing the previous problems, studies and rehabilitation work within the study area.
- Sewer Map – delineating subsystems, monitoring locations, sewer size, etc.
- Flow Monitoring Results – showing how dry weather and wet weather flows were determined and graphically comparing subsystem results.
- Field Data Analysis – tabulating the results of the field activities while quantifying I&I flows per source.
- Cost-effectiveness Analysis – graphically presenting the maximum amount of I&I that can be cost-effectively eliminated.
- Recommendations – listing the following recommended activities, including cost and schedule:
    - Prioritized manhole defect/rehabilitation schedule
    - Public sector inflow and infiltration reduction and elimination

- Private sector inflow and infiltration reduction and elimination
- Prioritized line rehabilitation schedule
- Routine maintenance recommendations

- Appendix B – including a complete bound copy of written inspection forms and a DVD containing scanned images of the inspection forms and digital inspection photos.

4.9.1 I&I Reduction

The I&I Reduction Plan to manage and control peak wastewater flows will consist of both public and private sector I&I elimination. Based on recommendations from the I&I Assessment Plan, I&I Reduction may be divided into the following five (5) parts including post rehabilitation flow monitoring:

- Priority 1 – Cost Effective Rehabilitation
- Priority 2 – Structural Rehabilitation
- Private I&I Abatement
- Preventative Maintenance
- Post-Rehabilitation Flow Monitoring

4.10 Priority 1 – Cost Effective Rehabilitation

Cost-effective rehabilitation is based on recommendations from the I&I Assessment plan and are those repairs that remove I&I and meet the lowest point on the CEA curve. Cost effective rehabilitation will consist of both manhole and pipeline rehabilitation.

4.10.1 Manhole Rehabilitation

Cost-effective manhole rehabilitation may consist of the following methods which are focused on the top-end of the manhole where higher I&I flows are found:

- Replace Vented Covers Below Grade
- Raise Manhole to Grade

- Replace/Rehabilitate Frame Seal
- Replace/Rehabilitate Chimney

4.10.2 Pipeline Rehabilitation

Cost-effective pipeline rehabilitation may consist of the following methods which may include immediate structural repairs if discovered during the I&I Assessment phase:

- Point Repairs
- Full Line Replacement
- Full Line Rehabilitation
- Abandon/Realign Pipeline
- Disconnecting Direct Storm Connections
- Disconnecting Indirect Storm Connections

4.11 Priority 2 – Structural Rehabilitation

Additional defects that exhibit enough structural deterioration to possibly warrant rehabilitation but may not be classified as "cost-effective" are recommended for further evaluation and possible repair. Structural rehabilitation will also consist of both manhole and pipeline rehabilitation.

4.11.1 Manhole Rehabilitation

Structural manhole rehabilitation may consist of the following methods which may include additional top-end manhole repairs:

- Replace/Rehabilitate Frame Seal
- Replace/Rehabilitate Chimney
- Rehabilitate Cone and Wall
- Rehabilitate Bench and Invert
- Rehabilitate Pipe Seals
- Replace Manhole

4.11.2 Pipeline Rehabilitation

Structural pipeline rehabilitation may consist of the following methods:

- Point Repairs
- Full Line Replacement
- Full Line Rehabilitation
- Abandon/Realign Pipeline

4.12 Private I&I Abatement

Defects on private property may be significant contributors of excessive I&I to the collection system. Cost analysis from previous studies has shown that several sources of private-sector I&I, such as uncapped cleanouts, are cost-effective to remove. In addition, some of the sources of I&I on private property may be illegal connections according to current ordinances. The following illicit connections are required to be completed by the resident upon discovery:

- Uncapped Cleanouts
- Downspouts
- Foundation Drains
- Driveway Drains
- Basement Entry Drains

Defective service laterals identified during the I&I Assessment Plan are reported to the resident and are further recommended to be repaired by the resident. These defects are not considered as illicit connections and are currently not required to be repaired.

4.13 Preventative Maintenance

The City's current line cleaning and preventative maintenance program includes cleaning all sewer lines by ¼ section and a selected list of lines requiring monthly cleaning. The City's current preventative maintenance program includes cleaning approximately 150,000 feet of sewer a year. In addition, the City conducts monthly

maintenance on 30 line segments, representing approximately 10,566 feet of sewer. The *Sanitary Sewer Evaluation Study – SUB01* (Wade, 2005) identified 36 line segments, representing approximately 7,856 feet of sewer, as requiring routine maintenance. These 36 line segments should be included in City's current preventative maintenance list if maintenance records indicate they have been cleaned since the completion of the SSES.

4.14 Post Rehabilitation Flow Monitoring

As part of the I&I Reduction Plan and following the rehabilitation of individual study areas, post-rehabilitation flow monitoring will be conducted to measure the success of the program. Flow monitoring will be performed as previously described in the I&I Assessment Plan in the same locations prior to the rehabilitation. Flow data will then be compared to the pre-rehabilitation flow monitoring. Results will then be evaluated to determine the success of the rehabilitation program and if future rehabilitation methods should be altered.

4.15 Schedule

The *Wastewater Master Plan* (Black & Veatch, 2001) and the *Sanitary Sewer Evaluation Study – SUB01* (Wade, 2005) ranked sub-systems and mini-basins based on their peak inflow rates and were further prioritized for follow-up I&I elimination. The City has completed an I&I Assessment of sub-system SUB01 and subsequently I&I Reduction within the sub-system.

The City plans to continue its ongoing commitment of improving the sanitary sewer collection system. This includes continuing the I&I Assessment in the remaining sub-systems, the rehabilitation of public sector defects, the elimination of illicit private sector defects, on-going sewer maintenance, and a post rehabilitation flow analysis to measure the success of the I&I Reduction Plan. *Table 4-1* presents the proposed schedule to complete the I&I Assessment and Reduction for the City's entire collection system by the year 2025:

Table 4-1
I&I Assessment and Reduction Plan

Basin	Pipe Footage (lf.)	Priority[1]	I&I Assessment Plan[2]					I&I Reduction Plan[3]		Cost Effective Work Completed[4]		
			Flow Monitored	CCTV Inspections	Smoke Testing	Manhole Inspections	Building Inspections	Priority 1 Cost-Effective Rehab	Priority 2 Structural Rehab	Point Repairs (each)	CIPP / Replace (lf)	Manhole Rehab (each)
SUB01-02	33,397	1	2003, 2017	2004	2003	2003	2014	2011 – 2012	2022 -2023	-	832	-
SUB01-05	61,491	2	2003, 2017	2004	2003	2003	2014	2012 – 2013	2022 -2023	-	-	-
SUB01-04	70,900	3	2003, 2017	2004	2003	2003	2014	2013 – 2014	2022 -2023	-	666	-
SUB01-01	31,593	4	2003, 2011	2004	2003	2003	2014	2014 – 2015	2022 -2023	-	396	-
SUB01-06	58,296	5	2003, 2017	2004	2003	2003	2003	2015 – 2016	2022 -2023	-	630	-
SUB01-03	69,702	6	2003, 2017	2004	2003	2003	2014	2016 – 2017	2022 -2023	-	932	-
SUB04	25,672	7	2000, 2011	2011	2011	2011	2011	2017 – 2018	2024 – 2025	-	-	-
SUB06	13,575	8	2000, 2011	2011	2011	2011	2011	2017 – 2018	2024 – 2025	-	-	-
SUB05	373,736	9	2000, 2011	2012	2012	2012	2012	2019	2024 – 2025	-	-	-
SUB02-03	40,781	10	2000, 2011	2013	2013	2013	2013	2020 – 2021	2024 – 2025	-	-	-
Totals:	**779,143**											

Note: 1. Priority based on flow monitoring results from *Sanitary Sewer Evaluation Survey Sub-System SUB0I* (Wade, November 2005) and *Wastewater Master Plan* (B&V, 2001).
2. I&I Assessment is year of completed or scheduled task.
3. I&I Reduction is year of completed or scheduled task.
4. Work Completed is units of work completed.

4.16. Recommendations

4.16.1 Introduction

This section discusses TREKK's recommended improvement plan for eliminating cost-effective I&I related defects and discusses additional flow monitoring to determine current peak wet weather flow in the collection system. As indicated in Section 7 of the *Sanitary Sewer Evaluation Study – SUB01* (Wade, 2005), all identified defects are not cost-effective to remove and it is virtually impossible to remove all flow from these defects. This recommended improvement plan entails removing identified defect flows from both public and private sectors up to the cost-effective level of 45%.

Implementation of this improvement plan will require the City to initiate a private sector I&I disconnect program. The ultimate success of this improvement plan for reducing wastewater surcharges and backups will depend largely upon the success of implementing this program. Partial implementation will not result in satisfactory reductions and transport of peak wet-weather-induced wastewater flows. Careful consideration must also be given to the desired schedule for improvements and method(s) of financing. All improvements recommended in this study will require varying degrees of involvement by the City.

4.17 Cost Effective Rehabilitation

The City has recently completed several I&I related rehabilitation projects identified in the *Sanitary Sewer Evaluation Study – SUB01* (Wade, 2005). These projects included the cured-in-place lining of twelve (12) VCP line segments, representing approximately 3,000 lf of sanitary sewer, and the replacement of one (1) VCP line segment, representing 455 lf of sanitary sewer. It is recommended that the City continue with its efforts to eliminate cost effective I&I from their collection system. TREKK has re-evaluated the recommendations from the *Sanitary Sewer Evaluation Study – SUB01* (Wade, 2005) and has developed a prioritized "plan of attack" for eliminating cost effective I&I from the system. SUB01 was identified as being Priority 1; this plan prioritized all mini-basins in SUB01 and includes eliminating public and private sector

defects on a mini-basin by mini-basin basis. Mini-basins were prioritized based on their severity of I&I (ratio of peak inflow to peak dry weather).

The total estimated cost to perform the recommended Priority 1 improvements to Sub-System 01 is approximately $4,042,000. This cost includes improvements to the public and private sector infrastructures. Partial implementation of this improvement plan will not result in satisfactory reductions in peak wet-weather-induced wastewater flows. *Table 4-2* summarizes the recommended improvement tasks and provides a cost estimate for each task. The specific improvements to each mini-basin are discussed further in the appendices.

4.18 Flow Monitoring

The previous collection system flow monitoring was conducted as part of the *Wastewater Master Plan* (Black & Veatch, 2001). The collection system flow monitoring data is over 10 years old and may not accurately represent current flows in the system. The Average Daily Dry Weather Flow (ADDF) recorded at the WWTP during the 2000 flow monitoring period between April 11th and June 26th of 2000 was 3.940 mgd. The ADDF recorded at the WWTP between April 11th and June 26th of 2009, minus wet weather days, was 4.775 mgd. This correlates to an increase in ADDF of 21% over a nine year period. It should also be noted that during this same time period the City's population decreased from 35,420 (2000 census) to 35,081 (2009 census estimate). This dramatic increase in dry weather flow, with no population increase, could be an indication of the steady deterioration of the collection system. This deterioration could account for the higher ADDF due to an increase in the amount of groundwater entering the system. Current flow monitoring data should be collected and compared with the previous data to determine actual changes in the ADDF and peak wet weather flow rates.

It is recommended that temporary flow monitors be installed to re-monitor flows at the outlet of each sub-system for a minimum of 60 days to determine the peak wet weather flow going to the WWTP. An extension to the monitoring period may be necessary if insufficient wet or dry weather events are recorded during the monitoring

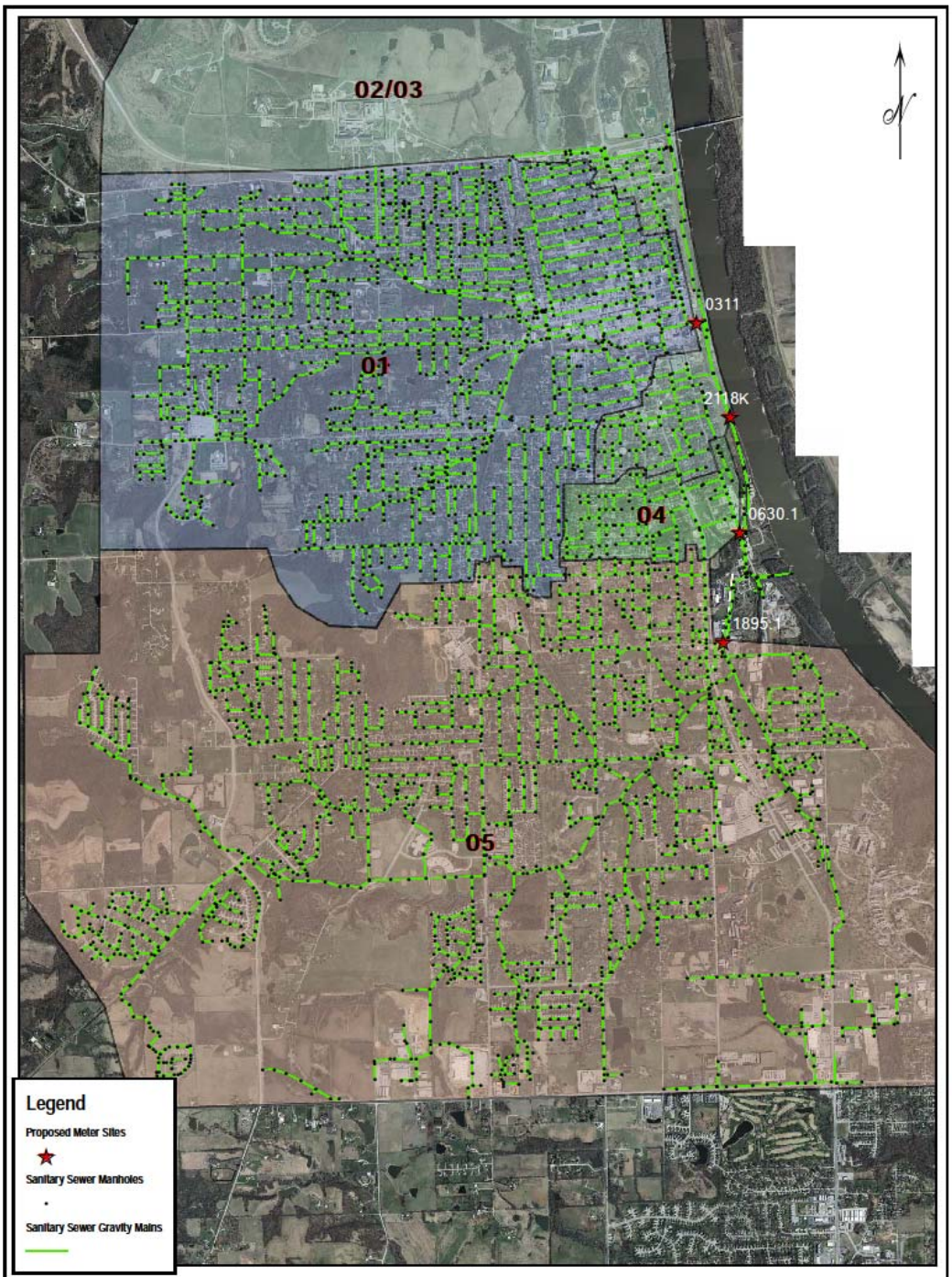
period. It is recommended that at least five (5) flow meters be installed to isolate the collection system. Meters should be re-installed in the same locations as previously installed during the *Wastewater Master Plan* (Black & Veatch, 2001). In addition to installing flow meters, two (2) temporary rain gauges should be installed to correlate peak sewer flows to total rainfall and peak rainfall intensity. *Table 4-2* summarizes the estimated cost associated with conducting the collection system flow monitoring. Figure 1 shows proposed meter locations and the general system layout.

Table 4-2
Recommended Improvement Cost Summary

Priority	Description of Improvements	Cost Estimate ($)
Study Area Improvements		
1-1	**Mini-Basin 01-02 Improvements**	
	Manhole Rehabilitation Program	26,000
	Private-Sector I&I Abatement Program	82,000
	Pipeline Rehabilitation Program	213,000
	Sub-Total:	**321,000**
1-2	**Mini-Basin 01-05 Improvements**	
	Manhole Rehabilitation Program	124,000
	Private-Sector I&I Abatement Program	30,000
	Pipeline Rehabilitation Program	281,000
	Sub-Total:	**435,000**
1-3	**Mini-Basin 01-04 Improvements**	
	Manhole Rehabilitation Program	49,000
	Private-Sector I&I Abatement Program	42,000
	Pipeline Rehabilitation Program	709,000
	Sub-Total:	**800,000**
1-4	**Mini-Basin 01-01 Improvements**	
	Manhole Rehabilitation Program	78,000
	Private-Sector I&I Abatement Program	20,000
	Pipeline Rehabilitation Program	525,000
	Sub-Total:	**623,000**

Table 4-2
Recommended Improvement Cost Summary

Priority	Description of Improvements	Cost Estimate ($)
1-5	**Mini-Basin 01-06 Improvements**	
	Manhole Rehabilitation Program	170,000
	Private-Sector I&I Abatement Program	7,000
	Pipeline Rehabilitation Program	368,000
	Sub-Total:	**545,000**
1-6	**Mini-Basin 01-03 Improvements**	
	Manhole Rehabilitation Program	47,000
	Private-Sector I&I Abatement Program	50,000
	Pipeline Rehabilitation Program	1,221,000
	Sub-Total:	**1,318,000**
Sub-Total:		**4,042,000**
Additional Investigation Work		
1-1	**Sub-System Flow and Rainfall Monitoring**	
	Site Assessment and Install (5 meters)	2,000
	Flow Monitoring (5 meter sites, 60-days)	18,000
	Flow Data Analysis (5 meter sites)	8,000
	Rain Fall Monitoring (2 sites, 60-days)	1,000
Sub-Total:		**29,000**
Total Cost:		**4,063,000**



City of Leavenworth, Kansas I&I Assessment and Reduction Plan Trekk Project No. 10-066	Figure 1 Proposed Meter Sites & General System Layout	TREKK