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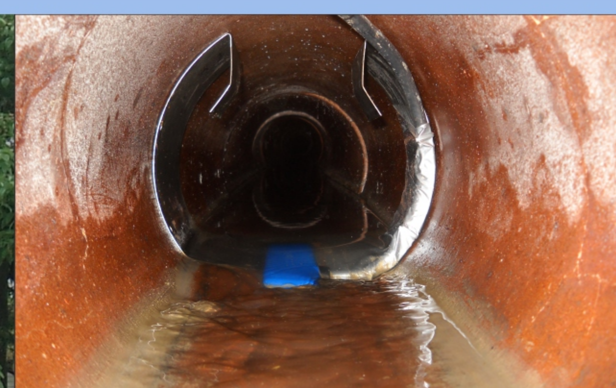
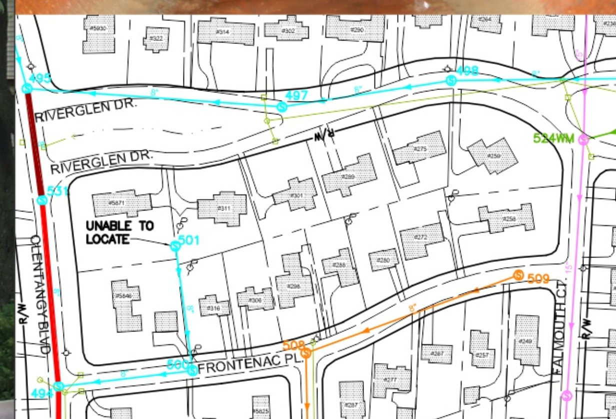
Sanitary Sewer System Evaluation Study

Riverlea, Ohio

January 2012





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1. Executive Summary

The Ohio Environmental Protection Agency (OEPA) is requiring local communities that are tributary to the City of Columbus sanitary sewer system to complete a Sanitary Sewer Evaluation Survey (SSES) as part of a regional effort to reduce sanitary sewer overflows (SSOs) into the region's waterways and streams.

Columbus cannot fully comply with their consent order to eliminate SSOs unless satellite communities such as Riverlea identify and remove excessive clear water infiltration and inflow (I/I) from their sanitary sewers. This report completes a two year effort of field investigation and evaluation on the part of the village to thoroughly document the physical condition of the collection system, identify areas of non-compliance, and plan for improvements to the system that will both reduce downstream SSOs and provide for better maintenance of the system in the future.

1.1 Riverlea Profile

The Village of Riverlea is a small municipality covering approximately 94 acres, bounded on the west by the Olentangy River, on the north and east by the City of Worthington, and on the south by the City of Columbus. Development of Riverlea began in 1924 and was incorporated as a village in 1939. With approximately 221 occupied households, the current population estimate is 545 (2010 U.S. Census). Significant growth of the village is unlikely due to its landlocked position.

1.2 Historical Records

Village records kept since the OEPA Findings and Orders went into effect (February 2009) indicate two SSOs and one WIB (Water in Basement) to date. Both SSOs were associated with failures at the pumping station. Corrections at the pumping station are on-going including the recent addition of a telemetry and alarm system. The one reported WIB was a private property issue. None of these incidents point to capacity problems within the gravity collection system.

The City of Worthington is planning construction of a deep trunk sewer in the near future to replace the existing siphon located just south of the village. Completion of this sewer will allow Riverlea to construct a new outfall sewer, eliminating the pumping station altogether.

The findings and recommendations of the 1980 Riverlea SSES were also reviewed as part of this study, providing additional insight into the history of deficiencies found and repairs recommended for the collection system.

1.3 Mapping

The SSES work began with an update of the sanitary sewer collection system mapping. Information from existing paper atlas maps and as-built drawings was combined with detailed horizontal and vertical field survey data for each manhole. A computer-aided design (CAD) map was created and served as the base plan for many of the report figures. The field survey was also used to accurately determine pipe segment slopes for capacity calculations.

The updated mapping can also be useful when managing other utilities within the public rights-of-way since both horizontal and vertical positions of the manholes were determined.

1.4 Internal Inspection (CCTV)

Internal inspection of the village's existing sanitary sewer system was completed by Flowline, LLC from June 1 to June 11, 2010, during which approximately 12,100 lineal feet of sanitary sewer was cleaned and televised. Another 148 lineal feet of 8-inch pipe from MH 490 to the pump station was inspected on August 16, 2010. Remaining are 420 lineal feet of 12-inch sewer that was not cleaned and inspected due to access issues. The uninspected lines include 330 lineal feet of 12-inch pipe from MH 504 to MH 503 and 90 lineal feet of 12-inch pipe from MH 503 to MH 58, all located along the south corporation line of the village.

The complete manhole and closed circuit television (CCTV) internal inspection report is included in Appendix B. Structural repair and rehabilitation recommendations are based on the findings detailed in that report.

1.5 Flow and Rainfall Measurement

The village sanitary collection system can be divided into three tributary areas ranging in size from 12.2 acres to 44.8 acres. Data from the meters was used to evaluate the collection system's response to both wet-weather and finite storm events as well as to establish base flow conditions. Three flowmeters were maintained within the sanitary collection system from April 7 through August 3, 2011.

A rain gauge was also placed within the study area to better understand how rainfall impacts flow within the sanitary collection system. The rain gauge was located in the backyard at 5693 Olentangy Boulevard in the southwest corner of the village near the lift station. Five significant storm events were recorded from April 7 through August 3, 2011, with three of these storms being used for analysis of wet-weather pipe capacity and collection system I/I. The July 24, 2011 storm was the largest 24 hour storm event recorded at 1.63 inches.

1.6 Capacity and Flow Analysis

The Findings and Orders require two different hydraulic analyses of the sewer system. The first looks at the hydraulic capacity of the sewer and whether any deficiencies exist that could contribute to SSOs or WIBs. The second analyzes the affect rainfall has on flow volume within the collection system and whether that volume should be considered excessive. To satisfy the first requirement, sewer capacity was calculated based on diameter and slope for each pipe segment in the collection system. These capacities were then compared on a pipe-by-pipe basis against measured dry and peak wet-weather flows and against calculated design flows based on City of Columbus standards. The highest percentage of available capacity used within the system during peak wet-weather conditions was only 39 percent, indicating that the system has significant excess capacity with no deficiencies.

To evaluate the severity of rainfall-induced flows, comparisons were made using several industry guidelines to determine if the peak flows generated should be considered excessive, thus requiring remediation. Following is a summary of the analysis methods used:

1. Measured flows were compared to the City of Columbus Sanitary Sewer Design Manual criteria.
2. Measured flows were compared to the U.S. Environmental Protection Agency (USEPA) evaluation guidelines as found in the *1991 Sewer System Infrastructure Analysis and Rehabilitation* handbook.
3. Ratios were calculated for comparison to acceptable industry standards as follows:
    a. I/I volume to rainfall volume (Capture Ratio)
    b. Peak hourly flow to design average flow (Peaking Factor)

The results of the analysis show that wet-weather flows in the Olentangy (MH 490) and Southington/Dover Court (MH 505) subareas can be categorized as non-excessive, with average wet-weather peak flows reading below the City of Columbus design standards for new sewers and capture ratios and peaking factors in the low to moderate range. However, the Riverglen (MH 524) subarea is producing high peaking factors during wet weather indicating the presence of either a significant inflow source(s) or direct infiltration source(s). The Southington/Dover Court (MH 505) subarea, the largest of the three, shows some dry-weather ground water infiltration. Overall, the collection system should continue to perform well provided that the apparent I/I source upstream of MH 524 along Riverglen Drive is addressed.

1.7 Recommendations

No further SSES work, as set forth in the August 13, 2009 schedule approved by the OEPA, is recommended at this time for the Olentangy (MH 490) and Southington/Dover Court (MH 505) subareas. This recommendation is based on the following justifications:

1. No collection system SSOs or WIBs are occurring during wet-weather flow events.
2. The collection system has more than adequate hydraulic capacity to handle the measured wet-weather flows.
3. The collection system is properly designed when compared to local standards.
4. The wet-weather flows observed in the collection system were reasonable when compared to the stated benchmarks.

Since the Riverglen (MH 524) subarea exhibited large peaking factors for the wet-weather events measured in 2011, further investigation is in order. A likely source for this rainfall dependent infiltration and inflow (RDII) is the parallel storm and sanitary sewer arrangement located along Riverglen Drive. Smoke testing is recommended for the sanitary sewer to test for direct storm connections. Following the smoke testing, dye testing should be performed to determine the specific I/I pathways into the sanitary sewer. Dye testing on both public and private property may be warranted pending the outcome of the smoke testing. This field work will be performed in the summer of 2012 with the results submitted as an addendum to this report.

1.7.1 Structural Repairs and Pipe Rehabilitation

Based on the 2010 CCTV inspection, a number of structural repairs are recommended throughout the collection system as summarized in *Figure 7-1* (Tab 7). The first priority is an open cut replacement of 178 lineal feet of 8-inch sanitary sewer pipe located on Olentangy Boulevard in line with the Riverglen Ravine between MH 531 and MH 495. CCTV inspection of this section of sewer, located beneath a storm culvert, revealed a deep sag in the pipe that is restricting flow and creating the potential for backups. This repair should be scheduled and completed within the next three years and may temporarily disrupt traffic flow on Olentangy Boulevard. The estimated project cost including engineering and contingencies is $90,000.

Within the next four to eight years, and prior to any major street improvements, the remainder of the sanitary sewer leading from the pumping station upstream along Olentangy Boulevard to Riverglen Drive (approximately 1,950 lineal feet) should have full manhole-to-manhole cured-in-place-pipe (CIPP) lining installed at an estimated construction cost of $170,000. These 8-inch diameter pipe segments have multiple cracks and fractures distributed along most of their length. Some of the segments are also showing root intrusion. Since this is primarily a structural repair project and excessive I/I was not observed during televising, lining of sewer laterals is not recommended as part of this work. During future roadway replacement, the village should consider open cut replacement of the laterals to the right-of-way line as part of the roadway project.

Within the next six to ten years, fractured sewer pipe segments located between MH 518 and MH 519 near Riverglen Drive and between MH 514 and MH 515 along Southington Avenue near

Crescent Court should be spot repaired by open excavation. Pavement repair will only be required for the work on Southington. The cost of these repairs is estimated at $40,000.

The fourth priority for pipeline rehabilitation is the lining of 711 lineal feet of 8-inch sewer pipe running from MH 511 to MH 513 along Southington Avenue. In this case the pipe is structurally sound, but significant infiltration was observed entering the system in several locations. This observation is consistent with the flow monitoring results that showed elevated base flow rates, indicative of ground water infiltration. Since these pipes are structurally sound and peak flows are not excessive, this rehabilitation work may be deferred until the structural deficiencies above are addressed. The estimated construction cost is $140,000 and includes lateral lining.

1.7.2 Operation and Maintenance (O&M)

In addition to the normal inspection and cleaning activities involved with operation and maintenance of the collection system, a priority for Riverlea should be improved access for maintenance vehicles and personnel to the sewer sections connecting MH 504 to MH 503 and MH 503 to MH 58. This section of the collection system is located along the south corporation line and is overgrown with brush and some mature trees. The dense vegetation prohibited reasonable access during the 2010 CCTV inspection resulting in no condition assessment being completed for these segments. Emergency maintenance, especially during winter and early spring, would be nearly impossible.

Consideration should be given to establishing a 12 foot wide gravel drive from the end of Olentangy Boulevard, easterly along the village's south Corporation line over Manholes 504, 503 and 58 (tie-in point to Worthington). The estimated cost for the clearing, grading, and gravel surfacing needed is $35,000. Reviewing village sewer easement documents prior to initiating any construction activities is recommended to ensure that land clearing activities are permitted. Ideally, timing of this work should coincide with Worthington's schedule for construction of the new deep trunk sewer and the subsequent abandonment of the village's pumping station.

Likewise, to further improve access for cleaning and emergency service, nine off-street manholes with castings located below existing grade should be raised to ground surface at an estimated cost of $15,000.

1.7.3 Future Cleaning and Inspection Schedule

Based on review of the 2010 CCTV inspection, an ongoing cleaning and inspection program is proposed for the Riverlea collection system. Each line segment has been tagged with a recommended cleaning and inspection interval of 5 or 10 years. *Figure 7-2* (Tab 7) shows the recommended maintenance interval for each sewer segment. The following list summarizes the sewer footage and estimated cost included in each maintenance interval:

- 5-year: 4,000 lf of 8-inch pipe, 198 lf of 10-inch pipe ($12,000)
- 10-year: 4,503 lf of 8-inch pipe, 757 of 10-inch pipe ($15,000)

Recommended maintenance intervals can be lengthened or shortened based on future inspections.

Since the village collection system is not experiencing any wet-weather capacity issues or related overflows, scheduling of future temporary or permanent flow monitoring is not recommended. The financial resources saved can be used for recommended maintenance activities within the collection system and retirement of the pumping station once the new Worthington trunk sewer is available.

2. Introduction and Purpose

The OEPA and the City of Columbus entered into a Consent Order in 2002 that requires Columbus to properly operate and maintain its sewer system including elimination of any unpermitted discharges of sewage into local waterways. Columbus cannot fully comply with this Consent Order unless satellite communities such as Riverlea identify and remove excessive clear water I/I from their sanitary sewers. Subsequently, on February 11, 2009 the OEPA issued final Findings and Orders to the Village of Riverlea (*Appendix A*) requiring the village to:

- Provide adequate capacity to convey base and peak flows in each part of the sewer system.
- Take all feasible steps to stop SSOs and WIBs and mitigate the impact of SSOs and WIBs within the sewer system.
- Minimize excessive I/I.
- Provide notification to OEPA and to parties that have a reasonable potential for exposure to pollutants associated with any overflow event.
- Provide an Emergency Response Plan that identifies measures to protect public health and the environment in the event of an SSO.

To meet the requirements of the Consent Order, Riverlea has five years to perform an SSES of their entire sanitary sewer system (see approved schedule, Tab 2) and identify any improvements needed to eliminate excessive I/I. The SSES is required to:

- Identify sources and quantities of clear water I/I into the sanitary sewer system.
- Identify feasible, cost-effective actions to eliminate or minimize excessive I/I entering the system.
- Perform a physical survey of the sanitary sewer system.
- Develop and implement a flow-monitoring program.
- Provide estimates of peak flows associated with wet-weather conditions.
- Identify locations of any hydraulic deficiencies within the sanitary sewer system.
- Evaluate the usefulness of permanent flowmeters at connection points to the downstream sewers that are owned by a different entity (i.e. Columbus).
- Identify locations of structural deficiencies within the sanitary sewer system.
- Develop a phased schedule for remediation and actions identified in the SSES.

Following identification of sanitary sewer system deficiencies, alternatives with associated costs will be developed for both short-term and long-term actions required to eliminate these deficiencies. Recommendations will be developed along with proposed schedules for completion. The proposed actions will include both structural and hydraulic improvements as well as remediation of excessive I/I.

2.1 Project Approach

To minimize the magnitude and cost of field investigations for the SSES, the initial effort for this study focused on AutoCad mapping of the system, review of historical data related to maintenance and complaints, review of recent (2010) CCTV inspection reports of the sanitary sewer pipes, and recent (2011) flow monitoring of each of the three tributary areas served by village-maintained sewers. Analysis of this data has identified specific, limited subareas where I/I appears to be excessive.

Subareas that are not exhibiting hydraulic capacity issues such as WIBs and SSOs and have maintained acceptable wet-weather flows during testing will require “No Further Action.” This allows the village’s remaining resources to be focused on those specific areas exhibiting excessive I/I.

3. Existing Sewer System

The Village of Riverlea is a small municipality covering approximately 94 acres, bounded on the west by the Olentangy River, on the north and east by the City of Worthington, and on the south by the City of Columbus. Development of Riverlea began in 1924 and was incorporated as a village in 1939. With approximately 221 occupied households, the current population estimate is 545 (2010 U.S. Census). Significant growth of the village is unlikely due to its landlocked position.

The village owns and operates separate sanitary and storm sewer collection systems. Complete mapping of the sanitary sewer system is shown in *Figure 3-1* (Tab 3). All of Riverlea's sanitary sewage is indirectly discharged to the Columbus sanitary sewer system via two gravity connections to a City of Worthington sewer that passes through the village. Storm sewers from the village discharge directly to the Olentangy River through three outfalls.

3.1 Sanitary Sewers

Constructed in 1925, Riverlea's sanitary sewer gravity collection system is comprised of 12,670 lineal feet of vitrified clay pipe and 43 brick manholes as detailed in *Table 3-1*. The system discharges at two points along a 15-inch diameter trunk sewer that runs north to south through the village along a parallel alignment with Falmouth Court. This sewer was constructed by the City of Worthington prior to Riverlea incorporation and is not part of this study.

According to the 1980 Riverlea SSES report, the 15-inch trunk sewer provides an overflow at the intersection of Garden and Penny Drives for Worthington's sanitary sewers. However, recent inspection of the manhole at this intersection revealed reconfiguration of the piping, making the 15-inch sewer a continuous outfall for sanitary sewage flows from the Worthington system.

The Riverlea collection system is divided into three catchments or subareas. The first and smallest of these subareas includes approximately 12.2 acres of property located along Riverglen Drive east of Falmouth Court. The 8-inch Riverglen sewer serving this subarea discharges into the 15-inch Worthington sewer at Falmouth Court. The second and largest subarea, comprising approximately 44.8 acres, is tributary to the sewers located along Southington Avenue and Dover Court. This subarea discharges through a 10-inch sewer at the southeast corner of the village into the 15-inch Worthington sewer. The third subarea includes approximately 36.8 acres of property tributary to the 8-inch Olentangy Boulevard sewer and discharges into the pumping station located at the southwest corner of the village (*Figure 3-2*).

Table 3-1 - Sanitary Sewer Pipe		
Pipe Diameter	Estimated Length	Pipe Material
Inches	Lineal Feet	
4	650	Cast Iron (Force Main)
8	11,280	Vitrified Clay Pipe
10	970	Vitrified Clay Pipe
12	420	Vitrified Clay Pipe
43 Manholes constructed of Brick		

The duplex pumping station that receives the flow from the Olentangy Boulevard sewer is owned and operated by Riverlea. This station utilizes two submersible pumps operating at an average rate of 55 gpm each. A 4-inch cast iron force main carries the flow 650 feet to Manhole 504 located on the 10-inch Riverlea sewer running along the village's south corporation line. The pumping station receives flow from 36.8 of 93.8 total acres within the village (39%) which accounts for 47 of the 221 (21%) occupied homes. A high level overflow comprised of an 8-inch gravity sewer pipe connects the wet well to a storm sewer manhole located just west of the station. The manhole is part of an 18-inch gravity storm sewer that outlets directly into the Olentangy River at the southwest corner of the village.

Figure 3-2 - Pump Station, Looking West

The pump station is monitored 24 hours a day by an electronic telemetry and alarm system. This system alerts the designated first responders via telephone of any pump failures and/or high level alarms. The system also records pump operational data which is used to better manage station operation and track flow volume. Detailed information on station characteristics, operation, maintenance, and the alarm system is included under Tab 3.

3.1.1 Collection System Mapping Update

Proper evaluation of a sanitary sewer system requires an understanding of the manhole layout, manhole-to-manhole connectivity, pipe diameter, pipe material, invert depths, and top of casting (TOC) elevations. This information is necessary for updating existing mapping and analyzing system hydraulics, and is also useful for general management of all utilities within the public right of way.

The village previously had atlas level mapping of the collection system based on archival paper maps, miscellaneous field surveys, and as-built records. As part of the 2010 SSES, a field survey was performed using both global positioning and conventional surveying techniques. The casting elevation and horizontal position of each manhole was obtained based on the following control:

Instrument Used: Leica ATX1230+ GNSS GPS antenna with a Leica Controller running SmartWorx 7.53

Horizontal Datum: Grid coordinates, Ohio State Plane Coordinate System, South Zone, North American Datum (NAD) 83 (CORS96), GRS80 ellipsoid

Vertical Datum: North American Datum (NAVD88) (Geiod09) and is based on RTK Global Positioning System (GPS) observations utilizing the Ohio Department of Transportation (ODOT) Continuously Operating Reference Stations (CORS) and Virtual Reference Station (VRS) system.

Northing and Easting coordinates referenced in this report are based on a Grid Coordinate System

Inverts were obtained during manhole inspection. The existing mapping was updated in AutoCad format using the new horizontal and vertical information and is presented in *Figure 3-1* (Tab 3). The revised mapping has been used in the engineering analysis of the sanitary sewer system and serves as base mapping for the report figures.

3.2 Storm Sewers

The village-owned separate storm sewer system is comprised of approximately 1.5 miles of mostly vitrified clay pipe, 40 catch basins, and 10 manholes as detailed in *Table 3-2.* The system discharges directly into the Olentangy River through three outfalls. The outfalls are located west of the intersections of Riverglen Drive and Southington Avenue with Olentangy Boulevard, and at the southwest corner of the village. Riverlea is a regulated Municipal Separate Storm Sewer System (MS4) as currently permitted through the OEPA.

Table 3-2 - Storm Sewer Pipe		
Pipe Diameter	Estimated Length	Pipe Material
Inches	Lineal Feet	
12	2,797	Vitrified Clay Pipe
15	1,108	Vitrified Clay Pipe
18	1,786	Vitrified Clay Pipe
20	1,186	Vitrified Clay Pipe
24	822	Vitrified Clay Pipe
30	450	Vitrified Clay Pipe
50 Inlets and Manholes, 3 Outfalls		

3.3 System Operation

Due to its small size, the Village of Riverlea does not employ a staff for maintenance of the public infrastructure. A Street Commissioner is appointed by Council to review the condition of streets and sidewalks, sewer and water systems, and the parks. The Commissioner advises the council on action needed to maintain and repair infrastructure based on observation and resident input.

The Street Commissioner is designated as the first responder to calls regarding the sewer system including pumping station alarms, SSOs, and WIBs. The village contracts with sewer maintenance companies to unblock sewer pipes, perform point repairs, and clean-up any SSOs. The village maintains a general engineering services agreement with Burgess and Niple, Inc. to provide technical assistance on an as-needed basis when dealing with issues regarding infrastructure repair and regulation compliance.

3.4 Reported Overflows (SSOs and WIBs)

Village records kept since the OEPA Findings and Orders went into effect (February 2009) indicate two SSOs and one WIB (Water in Basement) to date. Both SSOs were associated with failures at the pumping station. Corrections at the pumping station are on-going, and the recent addition of a telemetry and alarm system has improved reaction time and increased the opportunity for preemptive action. The one reported WIB was a private property issue. None of these incidents point to capacity problems within the gravity collection system.

The City of Worthington is planning construction of a deep trunk sewer in the near future to replace the existing siphon located just south of the village. Completion of this sewer will allow Riverlea to construct a new outfall sewer, eliminating the pumping station altogether.

3.5 Sanitary Sewer Internal Inspection

Internal inspection of the village's existing sanitary sewer system by closed-circuit television (CCTV) was completed by Flowline, LLC from June 1 to June 11, 2010, during which approximately 12,100 lineal feet of sanitary sewer was cleaned and televised. Another 148 lineal feet of 8-inch pipe from MH 490 to the pump station was inspected on August 16, 2010. Remaining are 420 lineal feet of 12-inch sewer that was not cleaned and inspected due to access issues. The uninspected lines include 330 lineal feet of 12-inch pipe from MH 504 to MH 503 and 90 lineal feet of 12-inch pipe from MH 503 to MH 58, all located along the south corporation line of the village.

The televising equipment used for the internal pipe inspection ran *PipeTech* software that utilizes the Pipeline Assessment and Certification Program (PACP) uniform code established by the National Association of Sewer Service Companies (NASSCO). Once the sewers were coded by the equipment operator, the PipeTech software determined a composite structural, O&M, and overall grade for each manhole-to-manhole sewer segment. These composite scores were then used to evaluate the severity of defects and prioritize recommended repairs and maintenance activities.

The complete CCTV internal inspection report from 2010 is included in *Appendix B*. Structural repair and rehabilitation recommendations for this study are based on the findings detailed in that report.

3.5.1 Manhole Inspections

Inspections were completed on 41 of the 43 system manholes from ground level on May 18 through May 25, 2010 and on June 14, 2010 without confined space entry. Observations and measurements included invert depths, pipe location and material, wall construction and condition, lid and frame type and condition, infiltration through manhole walls, root intrusion, and mineral deposits. Nine of the manholes located in off-street areas had to be searched for with a metal detector. Eight of these were found, and seven were uncovered at depths from 1-inch to 1-foot below grade. Manhole 501 was never surface located and access to Manhole 517 was blocked by a fence. Both manholes were observed from below by CCTV.

All of the inspected manholes within the village appeared to be in good structural condition with no fracturing or cracking of manhole walls, missing brick, or significant mortar deterioration. However, seven of the manholes had signs of I/I entering near the bottom ranging from mineral deposits to groundwater flowing through the wall.

The complete manhole inspection report with analysis and detailed recommendations is included in *Appendix B*.

4. 1980 SSES

In April, 1980 John David Jones and Associates prepared an SSES report for the Village of Riverlea that included inspection of selected manholes in problem areas, smoke testing, flow metering, and recommendations for improvements.

4.1 Scope

The 1980 SSES was primarily an investigation into the cause of sewage back-ups in the basements of a number of village residents. A large rain event on September 13 and 14, 1979 produced 4.36 inches of rainfall. Water-In-Basements (WIBs) were reported as follows:

- Dover Court from Frontenac Place to Melbourne Place, along the west side of the street
- Falmouth Court and Frontenac Place, immediately east of intersection
- Southington Avenue and Westchester Court, immediately south and west of the intersection
- Beverly Place, mid-block on the south side
- Melbourne Place, at the eastern dead end

4.2 Findings and Recommendations (1980)

Following is a summary of the 1980 report findings and recommendations:

The primary factors affecting sewer performance were grouped into the following two categories:

1. Sources that contribute storm or ground water to the sanitary sewer system, thereby reducing capacity to convey sanitary flows.

2. Inadequate or restricted piping that reduces the system's capability to convey peak flows.

The location of identified problem areas and recommendations, by category, was as follows using the current sanitary sewer manhole numbering system:

1a. Two area drains located at the rear of the apartments at 5835 and 5841 High Street are connected to the sanitary sewer system and need to be removed. *(These two area drains have been disconnected.)*

1b. Cross-Infiltration from the storm sewer into the sanitary sewer near the south end of Olentangy Boulevard between Sanitary MH 490 and 491 needs to be corrected. (*No known record of this work being completed exists.)*

1c. Cross-connection or cross infiltration from the storm sewers into the sanitary sewers north of MH 524WM (Worthington Main) to the north corporation line and from MH 524WM to MH 524 along West Riverglen Drive needs to be corrected. (*No known record of this work being completed exists.)*

1d. Cross-connections (direct relief to storm sewer) in Worthington at the intersection of Garden and Pinney Drives and the intersection of Garden Drive and South Street need to be corrected. It was believed that flow from the storm sewer may be relieving into the sanitary sewers under certain conditions. (*Recent inspection of the manhole at the intersection of Garden and Pinney Drives revealed that storm sewers have been bulkheaded, making the 15-inch sewer a continuous outfall for sanitary sewage flows from the Worthington system*.)

1e. Problem of system-wide infiltration of ground water into sewers needs to be addressed. (*No known record of this work being completed exists.)*

2a. Possible blockage or restriction in the 12-inch sewer located along the south corporation line between MH504 and MH503 and between MH503 and MH58. (*No known record of this work being completed exists. Wooded surroundings make physical access to these structures difficult.)*

2b. Questionable capacity of the siphon located on the Worthington sewer just downstream of the Riverlea outfall connection due to possible restrictions caused by heavy debris. The 1980 SSES report indicates that the design capacity of the 16-inch siphon is adequate but blockages were revealed by inspection. *(Worthington is responsible for maintenance of the siphon and is planning to replace it in the near future by construction of a deep trunk sewer.)*

5. Sanitary Sewer Flow Monitoring

From April 7 through August 3, 2011, three Hach Sigma Model 910 flowmeters were installed and maintained in manholes located at the downstream ends of each of the three collection system subareas. The locations of the flowmeters are shown in *Figure 5-1* (Tab 5). The subareas were metered individually to provide the opportunity to narrow the focus of the SSES should one or more of these subareas exhibit non-excessive flows

During the flow monitoring period several dry- and wet-weather events were recorded. This chapter outlines the tools used to measure the flow and corresponding rainfall amounts, and associated ground water levels. The development of I/I estimates from the collected data will be covered in Chapter 6.

5.1 Flowmeter Installation and Downloads

The hydraulic conditions of a metering site are critical to collecting accurate flow data. Laminar flow is desirable for establishing accurate flow profile and velocity. Prior to flowmeter installation, manhole inspections and cleaning and televising of the collection system were performed in 2010 to verify pipe sizes, establish invert elevations, record flow depths, and evaluate the hydraulic conditions of potential flowmeter sites.

Flowmeter, rain gauge, and ground-water gauge installations were completed by a two-person crew from B&N on April 6 and 7, 2011. The flowmeters were set up to record flow in gallons per minute (GPM) at five-minute intervals, velocity in feet per second (FPS), and depth in inches. *Figure 5-2* shows the Hach Sigma 910 model used at each metering site. These flowmeters measure fluid depth using a combination pressure transducer and velocity sensor placed at the invert of the incoming sewer line. The velocity sensor uses Doppler waves to measure the velocity of suspended solids in the flow stream. The diagram in *Figure 5-3* illustrates a typical Sigma 910 flowmeter installation.

Figure 5-2 – Hach Sigma 910 Flowmeter

The flow meters were checked visually each week and the data downloaded onto a laptop computer. Less frequently, but as visual inspection warranted, a manhole entry was performed to recalibrate sensors and remove any obstructions or debris that may have collected. Standardized maintenance sheets were used to record readings from the flowmeters, noting any repairs or adjustments needed during the data downloads. *Figure 5-4* shows a typical maintenance sheet for this project. The complete set of maintenance records is included under Tab 5.

Overall, the flowmeters performed well throughout the program considering the frequent low depths and velocities experienced, particularly at Manholes 490 and 524.

Figure 5-3 – Flowmeter Installation

524 Riverglen Dr 8"							
Date	Time	Level (in.)	Flow (gpm)	Velocity (fps)	Velocity Signal Strength	Battery (v)	Maintenance Performed
4/7/2011	1:45 PM	--	--	--	--	--	Installed Meter
4/13/2011	8:39 AM	1.29	5.63	0.34	100	5.4	Measured velocity = 0.42 fps, depth confirmed, Ground Water = 3.5"
4/21/2011	2:12 PM	1.78	32.39	1.27	99	5.2	None
4/26/2011	11:11 AM	1.60	36.46	1.91	97	5.3	Ground Water = 4.0"
5/4/2011	8:44 AM	1.53	36.28	1.68	99	5.0	Depth confirmed, Ground Water = 4.0"
5/12/2011	8:00 AM	1.28	3.74	0.23	100	4.6	Change battery
5/19/2011	9:02 AM	1.01	2.29	0.20	100	5.7	Scrubbed sensor, confirmed depth, Ground Water = 0.0"
5/25/2011	12:23 PM	1.07	5.87	0.47	100	5.6	Depth confirmed, Ground Water = 1"
6/1/2011	1:14 PM	0.99	1.21	0.11	100	5.4	Ground Water = 0.0"
6/8/2011	2:01 PM	0.90	1.40	0.14	100	5.3	Ground Water = 0.0"
6/15/2011	12:44 PM	1.18	3.03	0.28	100	5.0	Ground Water = 0.0"
6/22/2011	12:40 PM	1.55	16.85	0.79	100	4.7	Change battery, Ground Water = 0.0"
6/29/2011	12:53 PM	1.47	4.76	0.24	100	5.4	Ground Water = 0.0"
7/6/2011	11:07 AM	1.38	1.78	0.10	96	5.2	Ground Water = 0.0"
7/13/2011	2:33 PM	1.06	1.88	0.15	98	5.0	Change battery, Ground Water = 0.0"
7/20/2011	10:55 AM	1.29	1.75	0.12	95	5.4	Ground Water = 0.0"
7/28/2011	8:41 AM	1.45	2.27	0.12	100	5.1	Changed depth to 1.1", Ground Water = 0.0"
8/3/2011	10:25 AM	--	--	--	--	--	Removed Meter

Figure 5-4 – Typical Flowmeter Maintenance and Download Sheet

5.2 Rain Gauge

On April 7, 2011, one automatic tipping bucket rain gauge was installed in the backyard at 5693 Olentangy Boulevard in the southwest corner of the village near the lift station. The site for the rain gauge was chosen based on separation from elevated obstructions and trees, protection from tampering, and close proximity to the sanitary collection system. Data collected from rain gauges provides the needed correlation between rainfall and the associated peaks in collection system flow.

Figure 5-5 shows the rain gauge model used on this project. As with the flowmeters, weekly downloading of the rain gauge to a laptop computer was performed to reduce the possibility of data loss and ensure accurate operation.

Figure 5-5 – Typical Rain Gauge

Table 5-1 provides a detailed description of the five most significant storm events recorded during the flow-monitoring program. The bold values represent the highest return intervals by duration listed in the last column. Three of the five storms (May 3, June 18, and July 24, 2011) were selected for use in the wet-weather analysis based on the volume and intensity of each event. The May 3, 2011 storm, with a 24-hour return interval of 3-months[1], was used for the system hydraulic capacity analysis since it provided the greatest runoff volume and storm duration for activation of typical public and private I/I sources.

Though none of the measured storms exhibited return intervals greater than 1-year, it is important to note that regular rainfall covered the central Ohio region throughout the year (2011) producing an annual rainfall record. April 2011 was the wettest April on record at Port Columbus registering over 7 inches, exceeding the previous record set back in 1893[2].

[1]*Rainfall Frequency Atlas of the Midwest,* Huff and Angel (Bulletin 71)
[2]*Rain Washes out 1893 April Record*, Jim Woods, Columbus Dispatch, April 29, 2011

Table 5-1 - Rain Gauge Data							
Date	Total Inches	Peak Rain by Duration					Return Interval / Duration (Bold) (Huff & Angel)
		30-Min	1-Hr	3-Hr	6-Hr	24-Hr	
19-Apr	1.23	0.20	0.28	0.57	0.89	**1.23**	2-month / 24 hr. storm
3-May	1.43	0.13	0.24	0.52	0.72	**1.43**	3-month / 24 hr. storm
23-May	1.19	0.23	0.34	0.59	0.96	**1.19**	2-month / 24 hr. storm
18-Jun	1.15	0.52	**0.73**	0.81	0.81	1.15	4-month / 1 hr. storm
24-Jul	1.63	**0.82**	0.85	0.87	1.08	1.63	1-year / 30 min. storm

5.3 Ground Water Gauges

Ground water gauges (sight glasses) were installed in MH 490 and MH 524 to establish ground water levels at the upper and lower ends of the collection system. Each gauge was placed low in the manhole near the bench by drilling completely through the manhole wall and fitting the hole with a ¼" watertight, nylon "barb." Plastic transparent tubing was attached to the nylon fitting and secured to the manhole wall extending upward towards the top of the manhole. The tubing was marked at one-foot intervals, and the water level observed and recorded on a weekly basis.

Figure 5-6 – Typical Ground Water Gauge

During April and May between 1 and 4 inches of ground water was recorded at MH 524, indicating that the water table elevation was high enough for ground water to enter the sanitary collection system through cracks in the pipe, poorly sealed joints, and leaky manholes. However, during June and July the gauge was dry, suggesting that the water table had receded below the sanitary collection system.

Measureable amounts of ground water were never observed in the gauge at MH 490 suggesting that the water table remained at a level below the collection system in that area for the duration of this study.

5.4 Flowmeter Data Analyses

Flowmeter and rain gauge data was processed weekly as collected. This involved creating summary tables of the previous week's rain events and flow hydrographs. The data was inspected to ensure that the meters were recording correctly. At the end of the four-month metering period, all of the collected data was analyzed to determine representative dry-weather and wet-weather flows. Following are details of the process used for determination of these flows. *Figure 5-7* shows a graphical representation of the sanitary sewer flow components of a typical hydrograph. The actual hydrographs for each metering location are included in *Appendix C and D*.

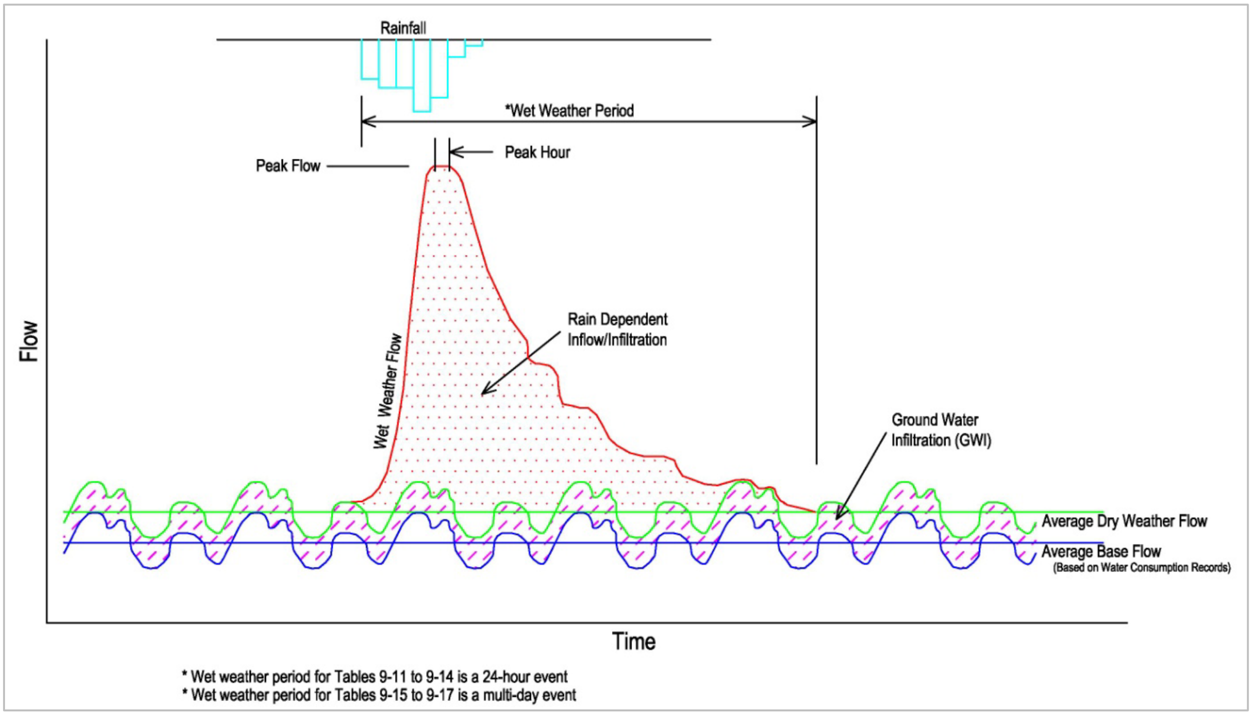

Figure 5-7 – Typical Wet-Weather Hydrograph

5.4.1 Base Sewage Flow

Base sewage flow is comprised of the sewage flows entering the collection system from residences, churches, office buildings, commercial buildings, or other structures having sanitary sewer service. Primarily generated through the use of toilets, showers, kitchen sinks, laundry machines, and floor drains, base sewage flow does not include any type of storm runoff or groundwater infiltration, including discharge from roof or yard drains. Base sewage flow was not estimated for this study.

5.4.2 Dry-Weather Flow Determination

Dry-weather flow is characterized by flow measured in the sanitary collection system during dry-weather periods with no direct influence from precipitation. Dry-weather flow is comprised of two parts; base sewage flow, as just described, and ground water infiltration (GWI) entering the collection system through cracked sewer pipes, leaky sewers joints, and defective manholes.

The dry-weather flow for Riverlea was determined from the collected flowmeter data. Because of the typical diurnal highs and lows that occur, an average daily flow was used for evaluation and comparison. Also, due to fluctuations in the ground water table throughout the study period and seasonal variations in residential water use patterns, three 24-hr dry-weather periods were averaged for use in the analysis. The three dry-weather periods were selected to represent the entire four months of the field study. *Tables 6-3* through 6-*5* detail the three dry-weather periods with the averages shown in *Table 6-6.* These tables are located in Section 6.3.1 Dry-Weather Flow.

5.4.3 Wet-Weather Flow Determination

Wet weather flow is characterized by flow measured in the sanitary collection system during wet-weather periods and is comprised of the base sewage flow, GWI, and RDII entering the collection system through cracked sewer pipes, leaky sewer joints, defective manholes, and other more direct sources such as leaky manhole lids, and illicit connections including catch basins, roof and yard drains, and foundation drains.

A wet-weather period is defined as beginning when precipitation commences and ending when metered flows return to near dry-weather levels. Again, because of the typical diurnal highs and lows that occur, an average daily RDII flow was used for evaluation and comparison. Also, due to fluctuations in the ground water table throughout the study period and antecedent moisture conditions, an average of three 24-hour wet-weather periods was used. These three periods differ in length due to the nature of the rain events contained within each respective period. Multiple rain events are included under one wet-weather period because the gaps between rain events were not long enough to allow the wet-weather flow to reach dry-weather flow levels before the next rain event occurred.

Tables 6-7 through *6-9* detail the three wet-weather periods with the averages shown in *Table 6-10*. These tables are located in Section 6.3.2 Wet-Weather Flow.

6. Excessive I/I Determination

A key component of the SSES, as required by the Directors Findings and Orders (DFOs), is the determination of the presence of excessive I/I within the Riverlea sanitary collection system and identification of potential deficiencies in hydraulic capacity. Removal of excessive I/I directly relates to the overall regional goal of eliminating SSOs downstream within the Columbus system.

This chapter looks at the hydraulics of the collection system based on measured flows and compares results with daily flow benchmarks established by the USEPA and City of Columbus Design Standards. Further analysis is presented comparing flow monitoring results from selected wet-weather events to other relevant I/I indicators.

6.1 Evaluation Methods

Wet-weather flows experienced during rainfall events are the result of extraneous clear water entering the sanitary collection system through both groundwater infiltration and direct inflow sources. Water from these wet-weather sources appears rapidly in sanitary sewers after the start of a rain event and can cause a sudden rise in flow rates. Direct inflow will diminish quickly following the event while infiltration rates diminish more gradually. Examples of I/I sources are as follows:

Inflow Sources

- Area drains directly connected to sanitary sewers or laterals.
- Roof downspouts directly connected to sanitary sewers or laterals.
- Storm drains directly connected to sanitary sewers.
- Low-lying, non-gasketed sanitary manhole lids with loose frames or vented lids that become submerged due to localized flooding during storm events.
- Sump pump discharges directly connected to sanitary sewers or laterals.
- Design Sewer Reliefs (DSRs) with no flap valves.

Infiltration Sources

- Aging sanitary and storm sewer pipe with deteriorated joints.
- Cracked or broken sections of sanitary sewer pipe.
- Gaps made by root intrusion into sanitary sewers or laterals.
- Foundation drain discharges into private sanitary laterals.
- Indirect stormwater infiltration from storm sewers crossing over or paralleling defective sanitary sewers
- Deteriorated wall joints and pipe penetrations in sanitary manholes.
- Faulty lateral connections.
- Pre-1972 plumbing practices and illegal plumbing practices after 1972.

The best indicator of “excessive I/I” is the occurrence of WIBs and SSOs during periods of wet weather. In the absence of these direct physical indicators, as is the case in Riverlea, other criteria must be evaluated. The *1991 Sewer System Infrastructure Analysis and Rehabilitation Handbook* defines excessive I/I as exceeding 120 gpcd (80 gpcd base sewage flow and 40 gpcd infiltration) for dry-weather conditions and exceeding 275 gpcd during wet weather with no operational issues. In practice, these values are more representative of wastewater treatment plant flows and are based on national averages with unknown population density, undefined wet-weather events, and unknown pipe length per person served. These criteria may not accurately reflect the higher peaking factors inherent in smaller collection systems and subareas.

Due to the general nature of these criteria, other measurable, more site-specific parameters must also be evaluated to determine if I/I levels are truly excessive. One common tool is evaluation of collection system performance versus the local sewer design standard. For Riverlea this is the *City of Columbus Sanitary Sewer Design Manual*. Detailed hydraulic models can be economically built and calibrated with flow monitoring data for large collection systems, but because Riverlea’s collection system is small, a simplified spreadsheet model was constructed for this evaluation with capacity calculations made for each pipe segment based on the flow monitoring data.

Each sewer collection system has unique characteristics that affect its operation and efficiency. For this evaluation, Riverlea’s collection system has been characterized through gathering of the following information:

1. WIB reports – (Maintenance records)
2. SSO occurrences – (Maintenance records)
3. Flow monitoring of sanitary sewer pipes – (Measured flow April to August 2011)
4. Rain Events – (Measured flow April to August 2011)
5. Physical condition – (Observed with 2010 CCTV results and maintenance records)
6. Physical size and population of tributary areas.
7. Ground Water Levels.

Other system variables that can have an impact on the flow characteristics of sewers but were not measured as part of this study are as follows:

1. Antecedent moisture conditions.
2. Soil types.
3. Pipe material/Pipe Joint type integrity.
4. Other general climatic conditions such as snow melt and frozen ground.

6.2 System Hydraulic Capacity Analysis

The hydraulic capacity analysis has been performed to satisfy the orders outlined in the OEPA DFOs which state that the village must provide adequate capacity to convey base flows and peak flows for all parts of the sewer system and to identify locations of hydraulic deficiency within the sewer system that are causing or contributing to SSOs and WIBs (if applicable). All of the pipe segments within the Riverlea collection system have adequate capacity for the full range of flows measured as well as the theoretical design peak flows calculated from the City of Columbus Sanitary Sewer Design Manual.

Table 6-1 (Tab 6) lists each sewer segment with pertinent physical characteristics including the length, diameter, and slope used to determine full flow capacity. The physical characteristics of the sewer were obtained through a field survey of the collection system performed in 2010. Each sewershed subarea is represented in a separate table.

The method in which the measured dry-weather, measured wet-weather, and calculated design flows are applied to the sanitary collection system is based on a gallon per minute per linear foot (gpm/lf) flow. The flow determined at the metering location is divided by the total main line sewer footage represented in the tributary area upstream of the flowmeter. That gpm/lf flow is then evenly distributed over the piping system in that subarea based on the linear footage of each main line sewer segment. The flow is cumulative, so as you move downstream through the system in the calculation table, flow is added at the gpm/lf rate determined. Likewise, for simplicity of analysis, the total design flow calculated for each subarea area was also divided by the total footage in that subarea and evenly distributed over the pipe segments on a gpm/lf basis.

With the physical pipe data and subsequent mathematical capacity inventoried, the calculated design flow, total dry-weather flow, and peak wet-weather flow recorded by the flowmeters were directly compared to the calculated capacity of each pipe segment. For the purpose of this evaluation, 95-percent theoretical pipe capacity was used for the maximum flow permitted before flow restriction occurs. These calculations are tabulated in *Table 6-1* (Tab 6).

The calculations for "Pipe Flowing Full Capacity" within the hydraulic capacity spreadsheet are based on Manning's equation $Q = \frac{k}{n} * (A * R^{\frac{2}{3}} * S\text{^}(\frac{1}{2})$ where:

$$k = 1.486$$
$$n = 0.013$$
$$A = \pi r^2 \ (Area\ of\ a\ Circle)$$
$$R = \frac{A}{P} \ (Hydraulic\ Radius)$$
$$P = Wetted\ Perimeter$$
$$S = \frac{\Delta Elevation}{Segment} Length\ (Slope\ of\ line\ segment)$$

6.2.1 Dry-Weather Capacity

The purpose of the Dry-Weather Capacity Analysis is to identify any sewer segments that are experiencing reduced capacity due to ground water infiltration. Three separate metering periods were evaluated to account for varying soil and ground water conditions:

- May 2011, wet soil
- June 2011, moist soil
- July 2011, relatively dry soil

As seen in *Table 6-1* (Tab 6), the dry-weather hydraulic load on each of the three subareas is well within the as-built capacities of the piping systems. The Southington/Dover Court subarea (MH 505) exhibited the highest dry-weather flows with a maximum pipe capacity used of only 14% in pipe segment 505 to 504.

6.2.2 Design Flow Capacity

Since Riverlea is under contract with the City of Columbus for treatment of wastewater, Columbus sewer design standards are another appropriate benchmark for evaluating pipe capacity. The values shown in *Table 6-2* were generated using the Columbus design manual standards of 130 gpcd, a peaking factor of 3.5, and an infiltration allowance of 1.34 gpm/acre. These design flows are used in the hydraulic capacity analysis presented in *Table 6-1* (Tab 6) by distributing this flow evenly over the system on a gpm/lf basis. Comparison of the calculated flows to as-built pipe capacities indicates that each pipe segment falls well within the design parameters established by the Columbus manual, with a maximum flow to capacity ratio of 33 percent occurring in the Southington/Dover Court subarea pipe segment 505-504.

Table 6-2 - City of Columbus Design Peak Flow Calculation									
FM Area	Acres	Sewer Mile	Sewer LF	Total Population	Average Flow (GPM)	Peak Factor	Peak Hour Flow (GPM)	Infiltration Allowance (GPM)	Total Design Flow (GPM)
MH 490	36.8	0.67	3,524	116	10	3.50	37	50	86
MH 505	44.8	1.18	6,252	321	29	3.50	101	60	162
MH 524	12.2	0.26	1,372	81	7	3.50	26	16	42

6.2.3 Peak Wet-Weather Capacity

Peak hourly flows observed at each of the meters during the May 3, 2011 storm event were used to evaluate pipe capacity under peak wet-weather conditions. This 1.43 inch / 24-hour rainfall event represented a 3-month return frequency storm according to Huff and Angel, Bulletin 71, and fell on moist to wet ground based on the occurrence of several preceding storms. As with the total dry-weather flow and design flow, the wet-weather flow values, as metered, were distributed evenly by pipe length within the tributary area on a gpm/lf basis.

As seen in *Table 6-1*, the pipe segments in the Olentangy Boulevard subarea, metered at MH 490, fall well within as-built capacity, with the last pipe segment (MH 490 – PS) running at approximately 14% of theoretical capacity. The flows measured at MH 505 for the Southington/Dover Court subarea also fall well below as-built capacity, with a peak flow to capacity ratio of 39% in segment 505-504. And finally, the pipe segments in the Riverglen subarea that were metered at MH 524 again fall well within as-built capacity, with the last pipe segment (MH 524 – MH 524WM) also running at approximately 12% of theoretical capacity.

6.3 System Flow Evaluation

The Riverlea SSES incorporates both dry-weather and wet-weather flow analysis with an emphasis placed on wet-weather flow, since it has the greatest potential to create SSOs and WIBs. The determination of excessive flow in the collection system is based on comparison to the following:

1. City of Columbus Sanitary Sewer Design Manual criteria. The allowable design flows are calculated in *Table 6-2* (Design Peak Flow Calculation).
2. The EPA evaluation guidelines of 120 gpcd dry-weather flow and 275 gpcd wet-weather flow as found in the *1991 Handbook*.
3. Ratios used throughout the industry to characterize a collection system including:
    a. I/I volume to volume of rain (Capture Ratio)
    b. Peak hourly flow to design average flow (Typical Peaking Factor)

Since antecedent moisture conditions were not measured as part of this SSES and wet-weather defining rain events were not specified in the Director's Findings and Orders, multiple periods of wet- and dry-weather data have been selected to best represent the respective typical weather conditions, and multi-day averages developed to compensate for the immeasurable or undefined variables.

6.3.1 Dry-Weather Flow

Tables 6-3 through *6-6* compare the measured dry-weather flow for each sub-area on a gallon per capita per day basis to the USEPA Handbook value of 120 gpcd and the City of Columbus Design Manual value of 130 gpcd.

Table 6-3 Dry-Weather Flow Evaluation
May 12, 2011

Flow Meter	Flow Meter Trib Area (Acres)	Estimated Flow Meter Population (2010 Census)	Measured Daily Dry Weather Flow (gpcd)	Above EPA Allowable Dry Weather Flow (120 gpcd)	Above City of Columbus Allowable Base Flow (130 gpcd)
MH 490	36.8	116	137	17	7
MH 505	44.8	321	319	199	189
MH 524	12.2	81	71	-49	-59

Table 6-4 Dry-Weather Flow Evaluation
June 14, 2011

Flow Meter	Flow Meter Trib Area (Acres)	Estimated Flow Meter Population (2010 Census)	Measured Daily Dry Weather Flow (gpcd)	Above EPA Allowable Dry Weather Flow (120 gpcd)	Above City of Columbus Allowable Base Flow (130 gpcd)
MH 490	36.8	116	37	-83	-93
MH 505	44.8	321	121	1	-9
MH 524	12.2	81	35	-85	-95

Table 6-5 Dry-Weather Flow Evaluation July 14, 2011					
Flow Meter	Flow Meter Trib Area (Acres)	Estimated Flow Meter Population (2010 Census)	Measured Daily Dry Weather Flow (gpcd)	Above EPA Allowable Dry Weather Flow (120 gpcd)	Above City of Columbus Allowable Base Flow (130 gpcd)
MH 490	36.8	116	50	-70	-80
MH 505	44.8	321	94	-26	-36
MH 524	12.2	81	35	-85	-95

Table 6-6 Dry-Weather Flow Evaluation Dry-Weather Average					
Flow Meter	Flow Meter Trib Area (Acres)	Estimated Flow Meter Population (2010 Census)	Measured Daily Dry Weather Flow (gpcd)	Above EPA Allowable Dry Weather Flow (120 gpcd)	Above City of Columbus Allowable Base Flow (130 gpcd)
MH 490	36.8	116	75	-45	-55
MH 505	44.8	321	178	58	48
MH 524	12.2	81	47	-73	-83

The Olentangy (MH 490) and the Riverglen (MH 524) subareas are below both the EPA and City of Columbus Design Manual standards for the average of the dry-weather flow events, with the Southington/Dover Court (MH 505) subarea reporting slightly above. The dry-weather flows appear to trend downward over the study period suggesting that ground water and soil moisture levels are dropping in late summer to early fall as is normally expected in central Ohio. The corresponding dropping flow values point to the presence of some dry-weather infiltration, most notably in the subarea metered at MH 505 (Southington/Dover Court).

The ground water gauge located in MH 524 (Riverglen) recorded head readings of up to 4-inches above the pipe crown in April and May while the gauge at MH 490 (Olentangy) recorded no ground water above the pipe crown throughout the monitoring period. It would appear from this data, that when elevated ground water is present, minimal head is being applied to the collection system piping. Because 2011 was the wettest year on record in Columbus, it is likely that normal moisture conditions would produce across the board flows within both the USEPA and City of Columbus dry-weather flow values.

6.3.2 Wet-Weather Flow

The purpose of measuring and evaluating peak wet-weather flow in sanitary sewers is to identify not only those portions of the collection system where capacities are being exceeded, thus contributing to WIBs and SSOs, but to identify and isolate sources of excessive I/I to facilitate removal and reduce the load on downstream piping and treatment facilities.

This section of the report focuses on the comparison of measured wet-weather flows to a variety of industry flow guidelines and I/I ratios. Because each tributary area has unique characteristics, a variety of comparisons are made to evaluate the existence of excessive I/I in each of the three collection system subareas.

Tables 6-7 through *6-9* are based on three selected 24-hour, wet-weather events used in the I/I analysis for this report, and *Table 6-10* shows the average of the three events.

Table 6-7 Wet-Weather Flow Evaluation						
May 3, 2011 1.44-inches of rain in 24-hrs.						
Flow Meter	Flow Meter Trib Area (Acres)	Estimated Flow Meter Population (2010 Census)	Measured Daily Wet Weather Flow (gpcd)	Above EPA Allowable Wet Weather Flow of 275 gpcd (gpcd)	Measured Peak Hourly Flow (gpm)	Above City of Columbus Allowable Peak Design Flow - Based on Actual Population (130gpcd*pop*3.5)/1440+ 1.346gpm/acre (gpm)
MH 490	36.8	116	385	110	40	-46
MH 505	44.8	321	764	489	195	33
MH 524	12.2	81	938	663	91	49

Table 6-8 Wet-Weather Flow Evaluation						
June 18, 2011 1.15-inches of rain in 24-hrs						
Flow Meter	Flow Meter Trib Area (Acres)	Estimated Flow Meter Population (2010 Census)	Measured Daily Wet Weather Flow (gpcd)	Above EPA Allowable Wet Weather Flow of 275 gpcd (gpcd)	Measured Peak Hourly Flow (gpm)	Above City of Columbus Allowable Peak Design Flow - Based on Actual Population (130gpcd*pop*3.5)/1440+ 1.346gpm/acre (gpm)
MH 490	36.8	116	87	-188	24	-62
MH 505	44.8	321	247	-28	149	-13
MH 524	12.2	81	283	8	88	46

Table 6-9 Wet-Weather Flow Evaluation						
July 24, 2011 1.63 inches of rain in 24-hrs						
Flow Meter	Flow Meter Trib Area (Acres)	Estimated Flow Meter Population (2010 Census)	Measured Daily Wet Weather Flow (gpcd)	Above EPA Allowable Wet Weather Flow of 275 gpcd (gpcd)	Measured Peak Hourly Flow (gpm)	Above City of Columbus Allowable Peak Design Flow - Based on Actual Population (130gpcd*pop*3.5)/1440+ 1.346gpm/acre (gpm)
MH 490	36.8	116	112	-163	29	-57
MH 505	44.8	321	247	-28	106	-56
MH 524	12.2	81	177	-98	73	31

Table 6-10 Wet-Weather Flow Evaluation						
Wet Weather Average						
Flow Meter	Flow Meter Trib Area (Acres)	Estimated Flow Meter Population (2010 Census)	Measured Daily Wet Weather Flow (gpcd)	Above EPA Allowable Wet Weather Flow of 275 gpcd (gpcd)	Measured Peak Hourly Flow (gpm)	Above City of Columbus Allowable Peak Design Flow - Based on Actual Population (130gpcd*pop*3.5)/1440+ 1.346gpm/acre (gpm)
MH 490	36.8	116	195	-80	24	-55
MH 505	44.8	321	419	144	149	-12
MH 524	12.2	81	466	191	88	42

The subarea tributary to MH 490 (Olentangy) is below both the USEPA and City of Columbus Design Manual standards for the average of the wet-weather flow events. The Southington/Dover Court subarea (MH 505) is reporting above the EPA Handbook values but below the City of Columbus Design values. The subarea tributary to MH 524 (Riverglen) has average wet-weather flows above both the USEPA Handbook and City of Columbus Design Standards. Overall, the measured flow values in each subarea vary consistently with the measured rainfall throughout the monitoring period.

The excess wet-weather flows seen in the Riverglen subarea (MH 524) are indicative of inflow and/or direct infiltration. Review of the sewer system mapping for this subarea reveals a parallel storm and sanitary sewer pipe arrangement along most of Riverglen Drive that, from past experience, is a likely source of infiltration from the storm sewer over to the sanitary sewer and into sanitary sewer laterals where crossing beneath the storm sewer. Further investigation of this flowmeter area is warranted.

6.3.3 Discussion of Findings Compared to I/I Ratios

Two additional parameters useful for evaluating the presence of excessive wet-weather flow in a collection system and common to the industry are Capture Ratio and Peaking Factor. These ratios are evaluated here for three different multi-day wet-weather periods, accounting for seasonal variations in ground water, soil moisture, and water consumption. These evaluations are presented in *Tables 6-11* through *6-13* showing the following results:

- **RDII volume to volume of rain (Capture Ratio).** Capture ratios are a measure of the amount of rainfall volume from a given storm that is being captured by the sanitary sewer system. This ratio is calculated by determining the RDII (total flow during the rain event minus the average dry-weather flow) and dividing by the total rainfall volume. Generally, capture ratios of 0 – 0.05 are considered indicative of low RDII, values of 0.06 to 0.1 are an indication of moderate RDII, and values greater than 0.1 are considered indicative of high RDII:

    - MH 490 - Max 0.02, Min 0.01, Ave 0.01. Indication of low RDII.
    - MH 505 - Max 0.20, Min 0.02, Ave 0.09. Indication of moderate RDII.
    - MH 524 - Max, 0.28, Min 0.02, Ave 0.13 Indication of high RDII.

- **Peak hourly wet-weather flow to average dry-weather flow (Peaking Factor).** Peaking factors are a measure of the percent increase in total flow through a collection system caused by a rainfall event. This factor is calculated by dividing the wet-weather peak hour flow by the average dry-weather hourly flow. Generally, peaking factors of 0-6 are considered indicative of low RDII, values of 6.1-10 indicate moderate RDII, and values greater than 10 are considered indicative of high RDII:

    - MH 490 - Max 8.60, Min 3.90, Ave 6.01. Indication of low to moderate RDII.
    - MH 505 - Max 6.56, Min 3.27, Ave 4.76. Indication of low RDII.
    - MH 524 - Max, 41.50, Min 14.52, Ave 30.75. Indication of high RDII and possible inflow or direct infiltration source.

Table 6-11- I/I Ratios During Wet Weather Period 5/1/11 - 5/7/11

Flow Meter Area	Area	Rainfall	Wet-Weather Time Period	Total Volume of Rain	DWF During Period	Wet Weather Flow	Peak Hour WWF	Peak Hour RDII	Total RDII	Ratio Total RDII / Vol. Rain	Peaking Factor
	(ac)	(in.)	(days)	(gal)	(gal)	(gal)	(gal)	(gal)	(gal)		
MH 490	36.8	2.07	6.00	2,068,638	88,904	130,350	2,407	1,790	41,446	0.02	3.90
MH 505	44.8	2.07	6.00	2,518,342	513,638	1,021,311	11,669	8,102	507,673	0.20	3.27
MH 524	12.2	2.07	6.00	685,798	54,127	242,893	5,459	5,083	188,766	0.28	14.52

Dry weather flow based on metering from 5/8/2011 thru 5/13/2011

Table 6-12- I/I Ratios During Wet Weather Period 6/17/2011 - 6/21/2011

Flow Meter Area	Area	Rainfall	Wet-Weather Time Period	Total Volume of Rain	DWF During Period	Wet Weather Flow	Peak Hour WWF	Peak Hour RDII	Total RDII	Ratio Total RDII / Vol. Rain	Peaking Factor
	(ac)	(in.)	(days)	(gal)	(gal)	(gal)	(gal)	(gal)	(gal)		
MH 490	36.8	1.52	4.00	1,519,000	25,204	36,268	1,455	1,192	11,064	0.01	5.54
MH 505	44.8	1.52	4.00	1,849,217	170,730	267,770	11,669	8,978	97,040	0.05	6.56
MH 524	12.2	1.52	4.00	503,581	13,982	62,090	5,277	5,131	48,108	0.10	36.23

Dry weather flow based on metering from 6/12/2011 thru 6/15/2011

Table 6-13- I/I Ratios During Wet Weather Period 7/23/2011 - 7/25/2011											
Flow Meter Area	Area (ac)	Rainfall (in.)	Wet-Weather Time Period (days)	Total Volume of Rain (gal)	DWF During Period (gal)	Wet Weather Flow (gal)	Peak Hour WWF (gal)	Peak Hour RDII (gal)	Total RDII (gal)	Ratio Total RDII / Vol. Rain	Peaking Factor
MH 490	36.8	1.64	1.22	1,638,921	5,831	14,597	1,720	1,520	8,766	0.01	8.60
MH 505	44.8	1.64	1.22	1,995,208	41,700	90,676	6,365	8,978	48,976	0.02	4.45
MH 524	12.2	1.64	1.22	543,338	3,068	15,477	4,366	4,261	12,409	0.02	41.50
Dry weather flow based on metering from 7/13/2011 and 7/14/2011											

6.3.4 Summary

Though the flow characteristics of Riverlea's sanitary sewers reflect those of an older collection system, wet-weather flows in the Olentangy (MH 490) and Southington/Dover Court (MH 505) subareas can be categorized as non-excessive based on the analysis. However, the Riverglen (MH 524) subarea is producing high peaking factors during wet-weather indicating the presence of either a significant inflow source(s) or direct infiltration source(s). The Southington/Dover Court (MH 505) subarea, the largest of the three, appears to have ground water infiltration that is most evident in the dry-weather hydrograph from 5/8/2011 thru 5/16/2011 (Appendix C).

Overall, the collection system should continue to perform well with mitigation of the apparent RDII source located upstream of MH 524 along Riverglen Drive.

7. Recommendations

7.1 Further SSES Work

No further SSES work, as set forth in the August 13, 2009 schedule approved by the Ohio EPA, is recommended at this time for the Olentangy (MH 490) and Southington/Dover Court (MH 505) subareas. This recommendation is based on the following justifications:

1. No collection system SSOs or WIBs are occurring during wet-weather flow events.
2. The collection system has more than adequate hydraulic capacity to handle the measured wet-weather flows.
3. The collection system is properly designed when compared to local standards.
4. The wet-weather flows observed in the collection system were reasonable when compared to the stated benchmarks.

However, the Riverglen (MH 524) subarea exhibited large peaking factors for the wet-weather events measured in 2011. A likely source for this RDII is the parallel storm and sanitary sewer arrangement located along Riverglen Drive. Smoke testing is recommended for the sanitary sewer to test for direct storm connections. Following the smoke testing, dye testing should be performed to determine the specific I/I pathways into the sanitary sewer. Dye testing on both public and private property may be warranted pending the outcome of the smoke testing. The field work will be performed in the summer of 2012, with the results submitted as an addendum to this report.

7.2 Structural Repairs

Based on the 2010 CCTV inspection, a number of structural repairs are recommended throughout the collection system as summarized in *Figure 7-1* (Tab 7). The first priority is an open cut replacement of 178 lineal feet of 8-inch sanitary sewer pipe located on Olentangy Boulevard in line with the Riverglen Ravine between MH 531 and MH 495. CCTV inspection of this section of sewer, located beneath a storm culvert, revealed a deep sag in the pipe that is restricting flow and creating the potential for backups. This repair should be scheduled and completed within the next three years and may temporarily disrupt traffic flow on Olentangy Boulevard. The estimated project cost including engineering and contingencies is $90,000.

Within the next four to eight years, and prior to any major street improvements, the remainder of the sanitary sewer leading from the pumping station upstream along Olentangy Boulevard to Riverglen Drive (approximately 1,950 lineal feet) should have full manhole-to-manhole CIPP lining installed at an estimated construction cost of $170,000. These 8-inch diameter pipe segments have multiple cracks and fractures distributed along most of their length. Some of the segments are also showing root intrusion. Since this is primarily a structural repair project and excessive I/I was not observed during televising, lining of sewer laterals is not recommended as part of this work. During future roadway replacement, the village should consider open cut replacement of the laterals to the right-of-way line as part of the roadway project.

Within the next six to ten years, fractured sewer pipe segments located between MH 518 and MH 519 near Riverglen Drive and MH 514 and MH 515 along Southington Avenue near Crescent Court should be spot repaired by open excavation. Pavement repair will only be required for the work on Southington. The cost of these repairs is estimated at $40,000.

The fourth priority for pipeline rehabilitation is the lining of 711 lineal feet of 8-inch sewer pipe running from MH 511 to MH 513 along Southington Avenue. In this case the pipe is structurally sound but significant infiltration was observed entering the system in several locations. This observation is consistent with the flow monitoring results that showed elevated base flow rates, indicative of ground water infiltration. Since these pipes are structurally sound and peak flows are not excessive, this rehabilitation work may be deferred until the structural deficiencies above are addressed. The estimated construction cost is $140,000 and includes lateral lining.

7.3 Operation and Maintenance (O&M)

In addition to the normal inspection and cleaning activities involved with operations and maintenance of the collection system, a priority for Riverlea should be improved access for maintenance vehicles and personnel to the sewer sections connecting MH 504 to MH 503 and MH 503 to MH 58. This section of the collection system is located along the south corporation line and is overgrown with brush and some mature trees. The dense vegetation prohibited reasonable access during the 2010 CCTV inspection resulting in no condition assessment being completed for these segments. Emergency maintenance, especially during winter and early spring, would be nearly impossible. Consideration should be given to establishing a 12 -foot wide gravel drive from the end of Olentangy Boulevard easterly along the villages south Corporation line over Manholes 504, 503, and 58 (tie-in point to Worthington). The estimated cost for the clearing, grading, and gravel surfacing needed is $35,000. Reviewing village sewer easement documents prior to initiating any construction activities is recommended to ensure that land clearing activities are permitted. Ideally, timing of this work should coincide with Worthington’s schedule for construction of the new deep trunk sewer and the subsequent abandonment of the village’s pumping station.

Likewise, to further improve access for cleaning and emergency service, nine off-street manholes with castings located below existing grade should be raised to ground surface at an estimated cost of $15,000.

7.3.1 Future Cleaning and Inspection Schedule

Based on review of the 2010 CCTV inspection, an ongoing cleaning and inspection program is proposed for the Riverlea collection system. Each line segment has been tagged with a recommended cleaning and inspection interval of 5 or 10 years. *Figure 7-2* (Tab 7) shows the recommended maintenance interval for each sewer segment. The following list summarizes the sewer footage included in each maintenance interval:

- 5-year: 4,000 lf of 8-inch pipe, 198 lf of 10-inch pipe ($12,000)
- 10-year: 4,503 lf of 8-inch pipe, 757 of 10-inch pipe ($15,000)

Recommended maintenance intervals can be lengthened or shortened based on future inspections.

Since the village collection system is not experiencing any wet-weather capacity issues or related overflows, scheduling of future temporary or permanent flow monitoring is not recommended. The financial resources saved can be used for recommended maintenance activities within the collection system and retirement of the pumping station once the new Worthington trunk sewer is available.