9.0 DATA ANALYSIS FOR INFLOW AND INFILTRATION

This Chapter presents the following:

- Summary and review of inflow estimates based on conditions observed in the Priority Catchment areas during the SSES field work activities; and,
- Summary and review of infiltration estimates based on conditions observed in the priority catchment areas during the SSES field work activities.

9.1 SUMMARY AND REVIEW OF INFLOW

Inflow sources in the Priority Catchment Areas 1, 3, and 4 were identified and verified based on the results of the house to house surveys, smoke testing and dye testing. The complete results and locations for each inflow source in each area from the house to house surveys, smoke testing, and dye testing were previously presented in Chapters 5, 6 and 7, respectively.

9.1.1 Methodology to Estimate Inflow Calculations Contributing to the System from the Inflow Source

The Rational Equation was used to determine peak discharge entering into the sewer system as identified during smoke testing and dye testing. The Rational Equation is **Q = ciA**, where:

Q = Peak Inflow Rate (gpd)
c = Rational method runoff coefficient
i = Rainfall intensity (inches/hr)
A = Drainage area (square feet)

The runoff coefficient (c) and the drainage area (A) were determined in the field during the smoke testing and dye testing. The runoff coefficient is typically a function of the soil type and slope of the drainage area surrounding the inflow source. For this analysis, a runoff coefficient of 0.9 was used for impervious surfaces (asphalt and rooftops) and a coefficient of 0.3 was used for previous surfaces (grass and native soils). All inflow estimates are based upon a storm with a maximum hourly intensity of 1.00 inches per hour. This intensity is approximately the peak intensity of a 1-year, 6-hour storm event.

To estimate the inflow contribution to the sanitary sewer from connected sump pumps, a standard average flow per pump range of 1 to 5 gallons per minute (gpm) or 1,440 to 7,200 (gpd) was used to estimate the total contribution of the sump pumps to the sanitary system. Since the State of Rhode Island does not have standards or guidelines for such estimates, the estimated flow has been calculated based on the standard flow value suggested by the Massachusetts Department of Environmental Protection in the 1993 publication "*Guidelines for Performing Infiltration/Inflow Analysis and Sewer System Evaluation Survey.'*

9.1.2 House to House Survey

As part of the house to house survey, ADS Environmental Services (ADS) attempted to survey approximately 1,300 buildings, both commercial and residential, to identify sources of inflow to the sanitary sewer including rain leaders, roof and yard drains, and sump pumps. Sump pumps piped directly to the sanitary sewer were noted. Rain leaders, roof and yard drains, and sump pumps with no obvious discharge were selected for smoke and dye testing to verify the discharge location of the potential inflow source.

Based on the methodology presented in Section 9.1.1, the estimated inflow contribution from sump pumps connected to the sanitary sewer is between 276,480 and 1,382, 400 gpd based on flow contributions for each of the Priority Catchment areas as follows:

- Catchment Area 1 – 95,040 to 475,200 gpd, 66 sump pumps
- Catchment Area 3 – 80,640 to 403,200 gpd, 56 sump pumps
- Catchment Area 4 – 100,800 to 504,000 gpd, 70 sump pumps

Based on the 192 sump pumps discharging inflow to the sanitary sewer, slower drain down (system recovery) periods should be expected similar to those observed in the Phase I Part 1 flow metering. The elevated flows in the system for several days after a moderate to heavy wet weather event are substantiated by the number of sump pumps observed in the house to house surveys.

9.1.3 Smoke Testing

ADS preformed smoke testing on the sanitary sewer system throughout the Priority Catchment Areas 1, 3, and 4. The smoke testing was performed during low flow periods using the methods outlined previously in Chapter 6. Smoke was observed emanating from connected roof leaders and catch basins and documented, photographed, and an approximate drainage area was estimated. Structures or fixtures emitting heavy volumes of smoke are considered to be directly connected to the sanitary sewer, while structures or fixtures emitting light smoke are considered to be connected indirectly to the sanitary sewer. Direct connections are typically piped directly to the sanitary sewer, while indirect connections may include brick off pipe connections that are leaking, leaking joints or sanitary sewer and storm drain cross connection, where the amount of inflow could not be determined. Direct connections were estimated using the rational method outlined above. The smoke testing confirmed 91 connections to the sanitary sewer contributing approximately 2,500,965 gallons per day (gpd) to the sanitary sewer. The estimated inflow contribution from each of the Priority Catchments is as follows:

- Catchment Area 1 – 1,121,836 gpd
- Catchment Area 3 – 234,595 gpd
- Catchment Area 4 – 1,144,534 gpd

9.1.4 Dye Testing

ADS performed dye testing of rain leaders to verify potential sources of inflow to the sanitary sewer system in each of the Priority Catchment areas using the procedures outlined in Chapter 7. Once the potential inflow source was confirmed, the inflow was estimated using the methodology above. ADS performed 409 dye tests in the priority catchment areas of which 139 sources were confirmed to be connected to the sanitary sewer system. These 139 confirmed inflow sources had an effective drainage area of approximately 116,071 square feet (sf) and are estimated to contribute approximately 1,723,000 gallons per day (gpd) of inflow. The estimated inflow contribution from each of the priority catchments is as follows:

- Catchment Area 1 – 843,768 gpd, 47 connections
- Catchment Area 3 – 481,917 gpd, 49 connections
- Catchment Area 4 – 396,513 gpd, 43 connections

9.1.5 Summary of Inflow

Table 9.1 presents the summary of estimated inflow from the SSES activities in Priority Catchment Areas 1, 3, and 4. As noted in the previous sections, dye testing and investigation of indirect inflow sources identified in the smoke testing investigation are on going as of the writing of this report and may increase the number of confirmed inflow sources.

TABLE 9.1
SUMMARY OF ESTIMATED INFLOW
PRIORITY CATCHMENTS 1, 3, and 4

Catchment Area	House to House Survey (gpd)	Smoke Testing (gpd)	Dye Testing (gpd)	Total Estimated Inflow (gpd)
1	95,040 - 475,200	1,121,836	843,768	**2,060,644 - 2,440,804**
3	80,640 - 403,200	234,595	481,917	**797,152 – 1,119,712**
4	100,800 - 504,000	1,144,534	396,513	**1,641,847 – 2,045,047**
Estimated Inflow (gpd)	**276,480 - 1,382,400**	**2,500,965**	**1,722,198**	**4,499,643 – 5,605,563**

Notes:

1. Dye flooding of indirectly connected catch basins, investigation of other indirect connections, and additional rain leaders is part of a separate study which will result in increased estimates for inflow.

9.2 SUMMARY AND REVIEW OF INFILTRATION

Infiltration sources in the Priority Catchment Areas 3, 4, and 7 were identified and verified using flow isolation and CCTV Inspection and internal manhole inspections. The complete results and locations for each infiltration source in each area of flow isolation and CCTV inspection and the manhole inspections were previously presented in Chapters 3 and 4, respectively.

9.2.1 Flow Isolation

ADS performed flow isolation in all pipe segments to identify locations for CCTV inspection within infiltration Priority Catchment Areas, 3, 4, and 7. Using the methods outlined in Chapter 3, ADS measured infiltration flow in pipes under 18 inches in diameter and visually estimated infiltration flow in larger pipes. An infiltration flow rate of 106,560 gpd was measured and/or observed originating in the priority areas. The measured infiltration contribution from each of the infiltration catchment areas is as follows:

- Catchment Area 3 – 41,616 gpd
- Catchment Area 4 – 44,208 gpd
- Catchment Area 7 – 20,736 gpd

9.2.2 Manhole Inspections

ADS performed internal manhole inspections in both inflow and infiltration Priority Catchment Areas 1, 3, 4, and 7 and observed minimal infiltration flow using the method outlined in Chapter 4. Though surcharge evidence and potential infiltration sources were observed, the total infiltration in the infiltration priority areas 3, 4, and 7 totaled 4 locations contributing only 2,592 gpd. An additional 3,312 gpd was observed at 2 locations in inflow Priority Catchment Area 1, which results in a total infiltration of 5,904 gpd. The observed infiltration contribution from each of the infiltration catchment areas is as follows:

- Catchment Area 1 – 3,312 gpd
- Catchment Area 3 – 288 gpd
- Catchment Area 4 – 1,584 gpd
- Catchment Area 7 – 720 gpd

9.2.3 Summary of Infiltration

Table 9.2 presents the summary of estimated infiltration observed in the SSES field work activities.

TABLE 9.2
SUMMARY OF ESTIMATED INFILTRATION
PRIORITY CATCHMENTS 1, 3, 4, and 7

Catchment Area	Flow Isolation (gpd)	Manhole Inspections (gpd)	Total Infiltration (gpd)
1	0	3,312	**3,312**
3	41,616	288	**41,904**
4	44,208	1,584	**45,792**
7	20,736	720	**21,456**
Total Estimated Inflow (gpd)	**106,560**	**5,904**	**112,464**

9.3 SUMMARY OF ESTIMATED INFILTRATION AND INFLOW

A summary of the estimated infiltration and inflow is presented in Table 9.3. The majority of the extraneous flows observed in the SSES field program appear to generally be a result of inflow entering the sanitary sewer.

TABLE 9.3
SUMMARY OF ESTIMATED INFILTRATION AND INFLOW
PRIORITY CATCHMENTS 1, 3, 4, and 7

Catchment Area	Inflow (gpd)	Infiltration (gpd)	Total Estimated Extraneous Flow (gpd)
1	**2,060,644 - 2,440,804**	3,312	**2,063,956 – 2,444,116**
3	**797,152 – 1,119,712**	41,904	**839,056 – 1,161,616**
4	**1,641,847 – 2,045,047**	45,792	**1,687,639 – 2,090,839**
7	Not Measured	21,456	**21,456**
Total Estimated Infiltration/Inflow (gpd)	**4,499,643 – 5,605,563**	**112,463**	**4,612,107 – 5,718,027**

The 4.6 to 5.7 million gallons per day of extraneous flow in Priority Catchments 1, 3, 4, and 7 represents a target value for future efforts to remove this flow from the system. While it is not likely that all of the extraneous flow can be eliminated, it is reasonable to estimate that a meaningful reduction in inflow, especially, can be achieved. If only 30% to 50% of this extraneous flow can be eliminated, the number and volume of combined sewer overflows could approach a reduction greater than 50%.