Chapter 18

City of Poughkeepsie New York, Combined Sewer Overflow Monitoring Plan

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The City of Poughkeepsie, in southeast New York State, was founded in 1799 and, like many other older cities, it is largely served by a combined sewer system. The combined portion of the system serves a drainage area of approximately 788 acres (320 ha), with approximately 390,000 feet (118,900 m) of pipe, and it contains six combined sewer overflow structures (CSO's). The City of Poughkeepsie is located directly on the Hudson River and the discharges from its overflow structures enter the river or its tributaries. Because the Hudson River is used for so many purposes (navigation, water supply, irrigation, recreation, and fishing), water quality is of major importance to the entire region. In addition, the Hudson River is a crucial element in the areas' tourism industry and serves as a major international shipping lane.

During the 1970's and 1980's, the City of Poughkeepsie, prompted by new federal environmental regulations, completed several extensive

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Figure 18.1 City of Poughkeepsie schematic of SWMM model/combined sewers.

system that is a combined sewer. The combined system drains 788 acres (320 ha) of highly urbanized watershed. Included in this drainage area is approximately 390,000 feet (118,900 m) of pipe ranging from 8 inches to 48 inches (20 to 123 cm).

The City of Poughkeepsie's combined sewer system is complex with six interconnected overflow relief structures and is described as follows:

1. **Pine Street Pump Station:** The CSO is located immediately upstream of the Pine Street Pump Station on the bank of the Hudson River. The overflow consists of a side weir. Excess flow spills over the weir and flows through a 30 inch (77 cm) diameter pipe to the river. The capacity of the pump station is computed to be 6.5 MGD (284 liters/s), which is to be increased to 7.0 MGD (306 liters/s).
2. **Pine Street:** The Pine Street CSO is located upstream of the Pine Street Pump Station and at the downstream end of the Pine Street Trunk Sewer. This overflow consists of a side overflow weir in a maintenance hatch with a sliding orifice plate (the mechanism for operating the slide was not in place at the time of the inspection). Dry weather flow is directed through the orifice via a 10 inch (25 cm) high concrete curb. Flows in excess of 9.75 MGD (427 liters/s) overtop the curb and discharge into a 36 inch (92 cm) pipe into the Hudson River. This CSO serves the Pine Street and Riverview Boulevard basins.
3. **Fallkill Creek:** The Fallkill Creek CSO consists of a maintenance hatch in a concrete pipe bridge pier on the south bank of the Fallkill Creek. This maintenance hatch contains a 10 inch (25 cm) high wooden side overflow weir on a 24 inch (62 cm) diameter concrete pipe. The overflow pipe is a 15 inch (38 cm) diameter pipe that discharges directly into the Fallkill Creek. The CSO, which has a capacity of 20.1 MGD (879 liters/s), serves the Fallkill Basin and the Mill Street basin. Located just upstream of the Fallkill Creek CSO are the Mill Street and Albany Street CSOs.
4. **Mill Street:** The Mill Street CSO is at the base of the Mill Street Trunk Sewer in a maintenance hatch structure. The maintenance hatch contains a leaping weir on a 40 inch (103 cm) diameter brick sewer pipe and has a capacity of 13.6

MGD (595 liters/s). Dry weather flow drops into an 18 inch (46 cm) underflow line while excess flows are carried by a 42 inch (108 cm) diameter brick sewer discharging to the Hudson River. This CSO serves the Mill Street and Fallkill Basins, and discharges flow from the Albany Street CSO. A detail of this CSO is included as Figure 18.2.

5. **Riverview Boulevard:** The Riverview Boulevard CSO is located in a two-chambered maintenance hatch just upstream of the Pine Street Pump Station. This CSO, which has a capacity of 0.87 MGD (38 liters/s), consists of a diversion weir with a valve and float regulator that controls a gate beneath the two chambers. The float and gate were not in place at the time of the inspection. Flow is diverted by a 4 inch (10 cm) high concrete curb into a 36 inch (92 cm) bypass line to an outfall shared with the Pine Street CSO. The Riverview CSO serves the Church Street and Union Street Basins.
6. **Albany Street:** The Albany Street CSO is located in a maintenance hatch that contains a leaping weir on a 20 inch (51 cm) pipe. Flows in excess of 3.23 MGD (141 liters/s) discharge into a 20 inch (51 cm) overflow pipe which discharges to an outfall shared with the Mill Street CSO. The combined area served by the Albany Street CSO is very small due to separation projects previously completed by the City.

18.3 Model Development

18.3.1 Model Selection

To develop the CSO monitoring plan, two fundamental approaches were evaluated to report overflows. One option was to install traditional permanent flow monitoring equipment on each of the CSOs. The data obtained from these flow meters, in combination with the rainfall data, could then be used to report system response (overflow volume). The major benefit of this approach is that overflows are measured and the uncertainty of a computer-generated estimate is eliminated. The problems with this approach are: the cost and difficulties associated with installing and maintaining permanent flow monitoring equipment; and the fact that this approach would not allow the City to estimate overflow volume for hypothetical rainfall events.

OVERFLOW DESCRIPTION: This is A Leaping Weir Overflow Manhole. The Downstream Weir Plate Has Been Removed.

Figure 18.2 Detail of Mill Street overflow.

The second approach evaluated, which was the eventually selected approach, was to quantify the CSO discharges, by use of a computer model. The model would:

1. Satisfy the requirements of the permit by allowing the City to report overflow events using only local rainfall data.
2. Eliminate the need for manual or automated flow monitoring at each CSO discharge point.
3. Provide a sophisticated planning tool that would allow the evaluation of future control strategies or permit requirements.

Once the decision was made to use a computer model to compute overflows, an appropriate model had to be selected. The major criteria for selection of the model would be its acceptance by the regulating authority, NYSDEC. Other criteria for selection included the ability to expand the model for future evaluation of water quality impacts, the ability to perform both continuous and single-event simulations, and the ability to easily evaluate flow regulators or overflow structures.

Two models were investigated for use with the Poughkeepsie project. These models were the Stormwater Management Model (SWMM), developed by the United States Environmental Protection Agency (USEPA) and the Storage Treatment Overflow Runoff Model (STORM) developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers. The SWMM model was selected for this project mainly because of its acceptance by the NYSDEC. The SWMM model was able to meet all other selection criteria and permit conditions.

18.3.2 System Definition

A first step in the development of the SWMM model is the definition of both the limits of the system that would be modeled and the limits of the respective drainage areas. As previously described, the total combined system of the City serves approximately 788 acres (320 ha). The project budget dictated that every conduit in the combined system could not be modeled. An attempt to model the entire system at once would exceed the 200 element limit in the usual distribution of the SWMM program. Moreover, modeling every conduit and maintenance hatch in the system would not significantly alter the results of the model when compared to a model that contained only the major trunk sewers and critical points within the system.

To create an accurate model that would meet the goals of the project, the system was discretized. The system was defined by accurately detailing the six overflow structures, identifying the major trunk sewers, identifying all tributary areas (subcatchments), examining land use to identify major contributors or large sources of flow, and evaluating key or critical points within the system such as major changes in slope, pipe size, or pipe configuration. In addition, the system was further defined by placing nodes at key intersection points within the system for ease in future expansion of the model.

18.3.3 Data Collection

To develop the SWMM model, a significant amount of information was required for accurate calibration. “As-built” information on the City’s system was readily available from the City Engineer, which facilitated construction of the model without exhaustive field survey or investigations. The City Engineer also provided a number of technical reports concerning inflow/infiltration, and pre-treatment programs that helped minimize efforts in establishing base flow and I/I for the existing system. The City was also able to provide 200-scale topographic mapping that was used in determining drainage areas.

The largest effort in collecting data was obtaining flow information for calibration of the model. An extensive monitoring program was required to insure that sufficient data would be available for calibration. Both the inflow pipe and the overflow pipe had to be monitored to obtain base flow and overflow quantities. Utility Pipeline Services Inc., of Auburn, New Hampshire was retained to install and maintain metering equipment. The metering equipment consisted of Marsh-McBirney dual sensor meters; one sensor simultaneously recorded the velocity and depth of flow and the second recorded depth of flow only. The flow and depth data were stored in digital format and were uploaded in the field using a lap-top computer. The meters were checked weekly for proper operation. Calibration measurements for depth of flow and velocity were taken during each observation. To obtain rainfall data, an electronic tipping bucket-type rainfall gage was installed at the City’s sewage treatment plant to record precipitation during the metering period. Based on a review of historical rainfall data from surrounding existing gages, it was concluded that one rain gage would be representative of the rainfall for the entire watershed.

Continuous monitoring was performed from May 21 to June 22, 1993. All data were recorded and summarized by 15-minute intervals for each sewer main line and overflow. The data were assembled and summarized in report form as follows:

- minimum flow (MGD)
- peak flow (MGD)
- total daily flow (MG)
- total rain (inches)
- peak rain intensity (inches/hour)

To supplement the flow data and assist in model calibration, additional flow measurements were obtained in upstream areas of the system. These measurements were taken to aid in accurate distribution of the base flow identified by the metering data (and reports) in upstream branches of the main trunk sewers. These data were obtained by manually measuring the depth of flow in key maintenance hatches and later computing the pipe flow based on the hydraulics of the pipe. While this type of measurement is not as accurate as the flow monitoring described earlier, it provided a useful tool to verify assumptions made with base flow distribution.

18.3.4 Model Structure and Calibration

For this simulation, two computational blocks of the SWMM program version 1 by Haestad Methods (stated to be USEPA version 4.0) were used. The hydrologic computations were performed using the RUNOFF Block. Routing of the various storms through the system was performed using the TRANSPORT Block. The TRANSPORT Block was chosen over the Extended Transport Block (EXTRAN) so that the model would have the ability to be expanded later to simulate water quality. Based on conversations with City personnel who were most familiar with the system, there were no known capacity problems, and therefore the need to model pressure flow was not a high priority in selection of the model. The most important criterion the model had to meet was to accurately represent the six overflow structures. Five of the structures were various types of weirs. These weirs were best modeled as a flow divider (Type 21) using the dry weather transfer capacity of the structure as the undiverted flow. The dry weather transfer capacity for the structures was obtained from previous technical reports completed for the City. The capacity of these structures was also computed based on information

gathered during the field investigation phase of the project. When the computed capacities were checked against the previously reported capacities, some adjustment was needed.

The sixth overflow device was a spillway pipe at a pumping station. The dry weather transfer capacity of this device was ultimately controlled by the capacity of the pumps within the station. Therefore, this device was modeled as a flow divider with the transfer capacity of the pumps as the undiverted flow.

Before model calibration could be completed, there were several elements within the SWMM program that required attention. Adjustments were made to the model to overcome the following:

1. *RUNOFF Block Scratch Files* - The program manual suggests that the NSCRAT(1) is always required for the RUNOFF Block. When this file was assigned on the MM line, the program indicated an error in reading precipitation data on the NSCRAT(1) file. When the file assignment was changed to NSCRAT(2) the program would operate normally.
2. *Units! Units! Units!* - Overland slopes within the RUNOFF Block are expressed in feet/foot, while pipe slopes within the TRANSPORT Block are expressed as a percent. When entering data into the program, it is imperative that the proper units be used. This has been a common problem in practice. It would appear that if units were consistent between blocks, errors such as this would be reduced.

Once a representative model was developed, it was calibrated to the metered overflows. The model calibration was an iterative process that was completed in a careful and methodical fashion. It was particularly important to avoid adjusting control variables to values that are outside their expected ranges. Typically, if adjustments of this nature are needed, it is a signal that the model is flawed, and some system parameter has been ill-defined.

The Poughkeepsie model was calibrated by adjusting some drainage basin characteristics within the RUNOFF Block. Parameters adjusted were:

- available depression storage (final values range from 0.35 in (0.9 cm) to 0.65 in (1.67 cm))
- Manning's n for overland areas (final values ranged from 0.35 to 0.45)
- the percent of effective impervious area (final values ranged from 40% to 60%)

- the effective width of the subcatchment area (final values ranged from 740 ft (225 m) to 1036 ft (316 m))

The above variables were chosen for model calibration because typically these variables are assumed, and modification of such would not change any known physical parameters of the watershed. The model was calibrated to the total volume discharged at each overflow. Volume was used as the basis for calibration because it is the only result from the model that will be reported. Upon review of all monitoring data, a rainfall event that occurred on May 31, 1993 was used for the calibration. This event was chosen because it produced the most significant amount of rainfall (0.5 in (1.28 cm)) and the greatest volume of overflow. Although it would be desirable to calibrate the model with additional rainfall data at varying intensities, the limited data collected during the monitoring period prevented such an effort. A summary of the calibration results is given in Table 18.1.

During the calibration process, a problem with the monitoring data for the Pine Street overflow became evident. The depth recorder installed in the structure was subjected to an intermittent vacuum due to

Table 18.1
Model calibration results.

CSO Structure	Measured Overflow (mg)	Predicted Overflow (mg)
Mill Street	0.004	0.005
Riverview Blvd.	0.06	0.05
Albany Street	0	0
Fallkill Creek	0	0
Pine Street	0.13	0.35
Pine Street Pump Station	0.55	0.62

shallow flow depth and high velocity. The vacuum caused the monitor to report flows less than actually occurred. This underestimation became evident when calibrating the model at the overflow immediately downstream of the CSO, the Pine Street Pump Station. The Pine Street Pump Station CSO was calibrated to within 11% of the measured flow, while the computed overflow at Pine Street CSO upstream was much higher than

measured.

Another problem with the monitoring data was encountered when calibrating the Albany Street overflow. During the monitoring period, a blockage developed in the main-line pipe immediately downstream of the CSO, which caused the flow recorder to report overflows during an eight-day period in which only two very small rain events occurred that should not have caused an overflow. The model on the other hand computes that only a small volume of overflow will pass through the CSO device and will overflow only during large storm events. The results of the model do conflict with the measured data that reported overflow occurring because of minimal rainfall. Fortunately the Albany street CSO serves a very small drainage area (less than 3 acres (1.2 ha)) in which the area characteristics can easily be verified based on mapping and observation.

Of the four CSO devices which overflowed during the calibration rainfall event, three were calibrated to within 2% to 11% of the measured flow. Because of the identified monitoring problems, neither the Pine Street CSO nor the Albany Street CSO could be calibrated without over-adjusting the calibration parameters and affecting the performance of the downstream CSOs. Based on the relatively good calibration of the other CSOs, it was decided that additional metering would not likely provide better data, and therefore was not recommended. The model was assumed to provide acceptable data for all of the overflows.

18.4 SWMM Model Simulations

18.4.1 24-Hour Storm Events

Conditions of Poughkeepsie's SPDES permit required reporting the volume of overflow for a series of hypothetical storm events. These events were the 1, 5, 10, 25, and 100 year storms. Rainfall data for these specific storms did not exist and, therefore, it was necessary to simulate these storms by a synthetic sequence of events. The first step in the simulation was to generate synthetic hyetographs for input to the RUN-OFF Block of the model. The total amount of rainfall used to develop these hyetographs were taken from TP 40, Rainfall Frequency Atlas of the United States, (U.S. Department of Commerce, 1961). To develop hyetographs from the total rainfall amounts in TP 40, the rain had to be distributed over a specific storm duration so as to represent the storm of

rainfall distribution curves published in TR 55, Urban Hydrology for Small Watersheds (U.S. Department of Agriculture, 1986). The synthetic rainfall distribution curve contained in Appendix B of TR 55 identifies what fraction of the 24-hour rainfall event will occur in a particular time interval. Tables 18.2, 18.3, and 18.4 summarize the distribution process.

Table 18.2
24 hour rainfall events.

Recurrence Interval (yr)	Rainfall Amount (in)
1	30
5	45
10	55
25	60
50	70
100	80

Table 18.3
Cumulative mass rainfall.

Time (hr)	Unit Dist.	Recurrence Interval (yr)					
		1	5	10	25	50	100
0	0	0	0	0	0	0	0
3	0.02	0.06	0.09	0.11	0.12	0.14	0.16
6	0.06	0.18	0.27	0.33	0.36	0.42	0.48
9	0.13	0.38	0.56	0.69	0.75	0.88	1.0
12	0.38	1.13	1.70	2.07	2.26	2.64	3.02
15	0.83	2.47	3.71	4.53	4.94	5.77	6.59
18	0.89	2.66	3.98	4.87	5.31	6.20	7.08
21	0.97	2.91	4.37	5.34	5.82	6.79	7.76
24	1.0	3.0	4.5	5.5	6.0	7.0	8.0

Table 18.4
Hyetographs.

Time (hr)	Unit Dist.	Recurrence Interval (yr)					
		1	5	10	25	50	100
0	0	0	0	0	0	0	0
3	0.02	0.06	0.09	0.11	0.12	0.14	0.16
6	0.04	0.12	0.18	0.22	0.24	0.28	0.32
9	0.66	0.20	0.29	0.36	0.39	0.46	0.52
12	0.25	0.76	1.13	1.39	1.51	1.76	2.02
15	0.45	1.34	2.01	2.46	2.68	3.13	3.58
18	0.06	0.18	0.27	0.34	0.37	0.43	0.49
21	0.09	0.26	0.38	0.47	0.51	0.56	0.68
24	0.03	0.09	0.14	0.17	0.18	0.21	0.24

Once the hyetographs were developed, the calibrated SWMM model was run for each of the hypothetical storm events. The results (volume of overflow as a function of rainfall amount) were plotted for each of the six overflow structures. A sample of the 24-Hour Storm Event Graph appears as Figure 18.3. These graphs were generated using LOTUS 123, and submitted to the NYSDEC for approval within the combined sewer overflow monitoring plan.

18.4.2 Estimating Curves

As previously stated, the primary purpose for development of the SWMM model was to enable the City to compute overflows to meet the reporting requirements of the permit. To accomplish this, a series of CSO estimating curves was developed for each of the six overflow structures. A sample curve is given in Figure 18.4. Use of the curve to estimate overflow volume requires only knowledge of the total amount of rainfall for a storm event, and the peak intensity. This information was obtained from the electronic rain gage installed at the City's sewage treatment facility.

Figure 18.3
Mill Street 24 hour storm CSO curve.

To develop the estimating curves, the SWMM model was used with historical rainfall data. The necessary rainfall data was obtained from the Northeast Regional Climate Center (NRCC) at Cornell University, in Ithaca, New York. The NRCC maintains a gaging station data base and provided historical hourly precipitation data from 1970 to 1992 for the USGS gage in the City. The data were examined and storms with varying peak-hour-intensities, durations and rainfall amounts were selected for input to the SWMM model. The storms simulated by the model ranged in peak-hour-intensity from 0.10 inches/hour to 1.6 inches/hour (7.14 to 114 liters/(s-ha)), and ranged in volume from 0.7 inches to 6.8 inches (50 - 486 liters/(s-ha)). Thirty-one storms were simulated by the calibrated model to develop data for the CSO estimating curves.

After completion of the SWMM simulations the volume of overflow computed by the model was plotted as a function of peak-hour-intensity and volume of rainfall. For 31 SWMM simulations and three variables that had to be represented graphically for each overflow device, a significant amount of time-consuming interpolation had to be completed.

Figure 18.4 Mill Street CSO estimating curve.

DATE OF EVENT	PRECIPITATION DATA			CSO DATA			WWTP Flow (MG)
	Total Precipitation (inches)	Peak Hourly Intensity (inches/hr)	Total Duration (hours)	CSO	Estimated Volume (MG)	Estimated Duration (hours)	
			START: END: DURATION:	1			
				2			
				3			
				4			
				5			
				6			
			START: END: DURATION:	1			
				2			
				3			
				4			
				5			
				6			
			START: END: DURATION:	1			
				2			
				3			
				4			
				5			
				6			
			START: END: DURATION:	1			
				2			
				3			
				4			
				5			
				6			
			START: END: DURATION:	1			
				2			
				3			
				4			
				5			
				6			

CSO DESIGNATIONS: 1 - Pine Street Pump Station
 2 - Pine Street
 3 - Falkill Creek

4 - Mill Street
 5 - Riverview Boulevard
 6 - Albany Street

Figure 18.5 CSO operating report.

To efficiently generate the estimating curves, the graphs were plotted using the DCA (David C. Arnold) module of Autocad Version 12. Although DCA is not typically used for this purpose, it has the ability to deal with the three variables (overflow, peak intensity, and volume). DCA created the estimating curves in the same way it constructs a digital terrain model (DTM). In creating a DTM the program uses two horizontal coordinates and a vertical elevation as the three variables. DCA was particularly useful in reducing error that would have resulted by manually estimating the curve lines.

With the use of the SWMM-generated CSO estimating curves, the number of combined sewer overflow events for the month and the corresponding volume of each overflow can be recorded by the City's wastewater treatment plant operator. Recording of this information along with the appropriate rainfall data will be manually entered on the CSO Operating Reports shown in Figure 18.5. Once a year, the CSO operating reports will be transmitted to the NYSDEC to satisfy conditions of the City's SPDES permit.

18.5 Conclusions

Development of a computer model to compute CSO discharges is a reasonable, cost-effective alternative to installation of permanent flow monitoring equipment, when system conditions are favorable. In some instances, combined sewer/storm systems may be too complex or possess unique characteristics where a model would not produce accurate results. In these instances the installation of permanent flow monitoring equipment may be the best solution for reporting overflows.

Computer modeling requires a limited amount of system monitoring data for calibration. Careful evaluation of the monitoring data is imperative to ensure that the data accurately represents the existing system. The SWMM model developed for the City of Poughkeepsie provided reasonable computations for CSO discharges because it was calibrated to observed system response. However, as identified in the report, the successful application of this model required investigation during the calibration process. If these situations had not been addressed, the accuracy in the CSO computations would be questionable.

Poughkeepsie's CSO Monitoring Plan, using the SWMM model to report CSO discharges was approved by the NYSDEC in November 1993. The tools developed from the model will allow the City to comply

with the major reporting requirements of their SPDES permit with a minimal commitment of resources. Furthermore, the CSO estimating curves can be used by personnel with no specialized training on computer modeling. The calibrated SWMM model will also serve as a basis for evaluation of future projects involving their combined sewer/storm system.

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