# 3 Section Three – Collection System Model Development

## 3.1 Combined Sewer System Model Development and Calibration

### 3.1.1 Introduction

This subsection discusses the development of the calibrated combined sewer system (CSS) computer model. The model simulates runoff from the CSO service areas and then routes the flow through the major trunk sewers, CSO diversion structures and the interceptor to the WWTP. The collection system hydraulic model was originally calibrated in 2001 for use in the 2002 Terre Haute Long Term Control Plan. Since that time, the City has made changes in the collection system that warranted model recalibration. The model software originally selected for the collection system was Version 8.0 of EPA's Storm Water Management Model (SWMM) from XP-Software. *The CSO Control Program Model Calibration and Verification Report* can be found in Appendix 3-1. That report, which was approved by IDEM in December 2006, explains the recalibration process for the collection system hydraulic model. The current model software used for the collection system is SWMM2000 Version 8.52 of EPA's Storm Water Management Model (SWMM) from XP-Software, which is an updated version of the previous modeling program. This version of the model is commonly referred to as XP-SWMM and this notation will be used throughout the rest of the report when referring to the model. This subsection also presents the estimated CSO and storm water discharge volumes to the Wabash River in response to actual storms and various size typical storms. The estimated CSO and storm water discharge volumes during the actual storms were used to calibrate and verify the Wabash River computer model.

This subsection presents the following information:

- Description of Terre Haute's XP-SWMM combined sewer system computer model.
- Estimated CSO service areas dry weather flow rates.
- Development of a calibrated XP-SWMM Runoff Block Model to estimate the runoff volumes from the combined sewer areas.
- Development of a calibrated XP-SWMM Extran Block Model to estimate wet weather flow rates through the major trunk sewers and the interceptor.
- Estimate of the CSO volumes and durations to the river.

- Estimate of the storm water volumes to the river.

### 3.1.2 Combined Sewer System Model

The XP-SWMM model provides the following capabilities for the City:

- Developed from EPA SWMM software for technical and regulatory credibility of results.
- A user-friendly graphical interface for cost-effective use and updating
- A physical based model with formulations explicitly linked to actual conditions in the field as input by the user.
- Can be used to simulate the hydraulic conditions of the modeled trunk sewers, interceptors, gravity sewers, force mains, pump stations, and treatment plants during dry and wet weather.
- Can be used to evaluate CSO control alternatives and interceptor capacities.
- As the CSO control plan is implemented and as the City develops, the XP-SWMM model can be progressively updated.
- Can estimate flows from separate sewered areas.

XP-SWMM is one of the most comprehensive model packages available for assessing CSS. XP-SWMM computations are based on the well-documented and widely accepted USEPA SWMM model. It may be used to simulate continuous (multi-year) or single storm events. It can estimate runoff flow from several subcatchment basins and route the flow through the sewer system to treatment facilities or to the receiving waters.

XP-SWMM has three main simulation blocks; RUNOFF block, TRANSPORT block and EXTRAN block. The RUNOFF block simulates runoff in response to rainfall. Most model parameters that are adjusted during calibration are in the RUNOFF block. The TRANSPORT and EXTRAN blocks simulate conveyance of combined runoff and sanitary flow through conduits and flow diversion structures. The EXTRAN block is capable of simulating surcharged conditions and outfall tail water effects. The TRANSPORT block is incapable of directly simulating these conditions. The EXTRAN block was used to model Terre Haute's trunk sewers to the CSO diversion structures and the interceptor system.

### 3.1.3 Simulation of Overland Flow

Overland flow or runoff from combined sewer areas is simulated in the XP-SWMM RUNOFF Block. The RUNOFF Block represents a combined sewer area as an aggregate of idealized rectangular subcatchments. It accepts rainfall hyetographs and makes a step-by-step accounting of the rainfall over pervious and impervious areas to synthesize sewer inlet hydrographs for input to the EXTRAN Block. The synthesized runoff hydrographs are based on the surface condition in the combined sewer service areas and is independent of the sewer collection system model.

### 3.1.4 Simulation of Flow through Trunk Sewers to CSO Diversion Structures

Terre Haute trunk sewers were simulated using the EXTRAN Block. The RUNOFF Block is capable of simulating a complete network of interconnected trunk sewers in either single event or continuous (cumulative) mode. The RUNOFF Block routes the flow as follows:

- It assumes the sewer system is a series of cascading reservoirs ignoring tailwater effects and control points.
- In the event of a surcharge, the RUNOFF Block indicates what section of the trunk sewer system is surcharged and the full flow capacity of the conduit is used during flow routing. Flow in excess of the full flow capacity of the conduit is stored in the upstream manhole until the trunk sewer can handle the flow.

Because of the above limitations of the RUNOFF Block, CSO service area trunk sewers for the Terre Haute model are simulated in the EXTRAN Block. The EXTRAN Block offers the following advantages:

- Simulates surcharged pipe conditions allowing higher than full pipe flow capacity to be conveyed.
- Simulates tailwater effects and control points to estimate the hydraulic grade lines in any sewer segment and at any time during the simulation.

CSO trunk sewers were simulated to mimic the response of the sewer collection system during high rainfall events. The CSO tailwater effects and surcharged conditions can propagate to the upper reach of the trunk sewer during such conditions.

### 3.1.5 Simulation of Flow Through Interceptor System

The EXTRAN Block determines the combined amount of storm water runoff and dry weather flow that goes through the throttle pipe to the interceptor and through the overflow pipe to the river. The EXTRAN Block uses the synthesized runoff hydrographs as input and simultaneously solves all hydraulic conditions as flow is routed through the conduits and CSO diversion structures.

The EXTRAN Block has the added capability of simulating dry weather flow, pump stations, detention basins and flow diversion structures. The table below summarizes the different types of flow diversion structures used in the model.

| TYPE | DESCRIPTION |
|---|---|
| Orifice | The Orifice can be either a bottom or side discharge orifice (similar to a throttle pipe). Flow in excess of the orifice capacity is routed to the overflow pipe. |
| Pumps | Used for modeling lift stations. |
| Weir | The weir can either be a transverse (perpendicular to flow) or side (parallel to flow). Flow diversion occurs when the hydraulic grade line exceeds the weir invert elevation. |

### 3.1.6 Runoff Block Input Data

Basic input to the RUNOFF Block are rainfall data and the watershed parameters. The watershed parameters pertains to the combined sewer service areas only and are as follows:

- Rainfall Data
- Subcatchment areas
- Percent imperviousness
- Subcatchment widths
- Overland slope
- Depression storage
- Overland flow Manning's roughness coefficient
- Soil infiltration parameters

The rainfall data and watershed parameters are described in the following subsections.

### 3.1.7 Rainfall Data

Rainfall data represents the average precipitation that falls on an area within a defined time interval. Rainfall data can be entered in the model as total rainfall or rainfall intensity occurring within a time interval. The rainfall time interval can be as small as every minute or as large as every hour. Generally, the model results satisfactorily match flow monitor data when the rainfall time interval does not exceed 15 minutes.

### 3.1.8 Subcatchment Areas

Subcatchment areas represent the surface area that contributes overland wet weather flow to the combined sewers. The subcatchment areas are shown on Figure 3.1-1. The CSO service areas include combined and separate sewered areas. Large CSO service areas were sub-divided into more than one subcatchment to develop a more accurate runoff model. Service Area 008 is a single subcatchment area. Service Areas 010, 009, 007, 005/006, 004/011 and 003 were subdivided into subcatchments, as shown on Figure 3.1-1. *(CSO 002, Main Lift Station is assumed to be impacted by all other basins.)* Table 3.1-1 shows the subcatchment area land use breakdown. Subcatchment boundaries were determined from the sewer system maps, topographical maps and land use. AutoCAD computer software was used to estimate the acreage within a subcatchment boundary. The model represents a subcatchment as a rectangular area with the overland slope perpendicular to the subcatchment width. The point where the runoff enters the sewer is called the point of concentration. Table 3.1-1 shows the area and point of concentration of each subcatchment. The land use for each subcatchment area was determined using aerial photography maps of the City. The different land use areas consisted of single-family residential (houses), multi-family residential (apartment complexes), commercial, industrial and open spaces. The land use of the Indiana State University area contains several buildings, parking lots and some open space and was determined that it closely represented a commercial area. Therefore, during analysis, the university area was added to the commercial area for the subcatchment that the university was located in. The land use acreage is used to estimate the subcatchment's percent imperviousness. Figures 3.1-2A through 3.1-2E show the collection system as laid out for use in the XP-SWMM model.

## Table 3.1-1
## Subcatchment Area Land Use

| CSO Sub-basin | Sub-catchment | Runoff Model Point of Concentration | Total Area (Acres) | Land Use (Acres) | | | | | | Flow Length (ft) | Elevation Difference (ft) | | Rain Gauge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Single-Family | Multi-Family | Commercial | University | Industrial | Open Space | | High | Low | |
| 003 | 003-1 | 003-209TN | 97.44 | 70.36 | 0.00 | 3.95 | | 4.50 | 18.63 | 3800 | 495 | 485 | 5 |
| | 003-2 | 003-204TN | 105.04 | 36.47 | 0.00 | 41.50 | | 14.85 | 12.22 | 3300 | 489 | 478 | 5 |
| | 003-3 | 003-217TN | 86.17 | 30.05 | 2.24 | 36.42 | | 8.02 | 9.44 | 2800 | 492 | 484 | 5 |
| | 003-4 | 003-226N | 131.17 | 23.81 | 14.10 | 0.00 | | 50.15 | 43.11 | 2200 | 493 | 487 | 5 |
| | 003-5 | 003-225TN | 194.01 | 144.02 | 2.91 | 15.85 | | 3.67 | 27.56 | 4400 | 491 | 485 | 5 |
| 004/011 | 004/011-1 | 004-292TN | 124.33 | 43.67 | 0.00 | 21.75 | | 46.77 | 12.14 | 3400 | 513 | 486 | 5 |
| | 004/011-2 | 004-290TN | 121.99 | 110.74 | 0.00 | 11.25 | | 0.00 | 0.00 | 5700 | 503 | 488 | 3 |
| | 004/011-3 | 011-121N | 133.62 | 81.42 | 0.00 | 31.40 | | 16.34 | 4.46 | 3600 | 492 | 487 | 4 |
| | 004/011-4 | 004-295TN | 152.56 | 76.28 | 0.00 | 0.00 | | 43.70 | 32.58 | 4800 | 491 | 488 | 4 |
| | 004/011-5 | 011-083N | 129.92 | 94.01 | 0.00 | 0.00 | | 32.76 | 3.15 | 5200 | 502 | 487 | 3 |
| | 004/011-6 | 004/011-6N | 96.31 | 34.91 | 12.18 | 3.85 | | 24.07 | 21.30 | 2900 | 488 | 486 | 4 |
| | 004/011-7 | 004-298TN | 77.52 | 45.06 | 0.00 | 4.18 | | 0.00 | 28.28 | 2600 | 488 | 487 | 4 |
| | 004/011-8 | 004-140TN | 166.07 | 122.96 | 0.00 | 0.00 | | 0.00 | 43.11 | 4800 | 507 | 487 | 4 |
| | 004/011-9 | 011-150N | 41.92 | 32.76 | 0.00 | 3.99 | | 0.00 | 5.17 | 1600 | 502 | 497 | 4 |
| | 004/011-10 | 004-342N | 67.82 | 48.67 | 0.00 | 0.00 | | 5.17 | 13.98 | 2100 | 501 | 489 | 4 |
| | 004/011-11 | 011-183TN | 69.65 | 69.65 | 0.00 | 0.00 | | 0.00 | 0.00 | 2400 | 493 | 489 | 4 |
| | 004/011-12 | 011-174TN | 73.51 | 73.51 | 0.00 | 0.00 | | 0.00 | 0.00 | 4400 | 500 | 488 | 4 |
| | 004/011-13 | 004-245TN | 71.87 | 27.43 | 0.00 | 14.42 | | 10.15 | 19.87 | 3000 | 491 | 488 | 3 |
| | 004/011-14 | 004-255TN | 49.24 | 33.16 | 0.00 | 10.46 | | 0.00 | 5.62 | 2000 | 492 | 488 | 3 |
| | 004/011-15 | 004-257N | 126.22 | 112.09 | 0.00 | 6.82 | | 0.00 | 7.31 | 4000 | 500 | 489 | 4 |
| 005/006 | 005/006-1 | 005/006-1N | 56.43 | 0.00 | 30.65 | 0.00 | | 10.02 | 15.76 | 3200 | 511 | 467 | 3 |
| | 005/006-2 | 5/6-210N | 28.76 | 7.44 | 4.07 | 17.25 | | 0.00 | 0.00 | 3500 | 513 | 494 | 3 |
| | 005/006-3 | 5/6-200N | 83.16 | 78.70 | 2.34 | 0.00 | | 0.00 | 2.12 | 3400 | 512 | 502 | 3 |

| CSO Sub-basin | Sub-catchment | Runoff Model Point of Concentration | Total Area (Acres) | Land Use (Acres) | | | | | | Flow Length (ft) | Elevation Difference (ft) | | Rain Gauge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Single-Family | Multi-Family | Commercial | University | Industrial | Open Space | | High | Low | |
| | 005/006-4 | 5/6-100N | 102.73 | 47.15 | 0.00 | 29.02 | | 21.52 | 5.04 | 2600 | 512 | 480 | 3 |
| 007 | 007-1 | 007-160N | 117.21 | 0.00 | 0.00 | 112.59 | | 0.00 | 4.62 | 5100 | 507 | 492 | 3 |
| | 007-2 | 007-120N | 137.91 | 91.62 | 0.00 | 42.71 | | 0.00 | 3.58 | 3300 | 495 | 490 | 3 |
| | 007-3 | 004-102TN | 160.30 | 118.28 | 0.00 | 34.06 | | 0.00 | 7.96 | 4400 | 493 | 488 | 3 |
| | 007-4 | 004-061N | 200.32 | 113.82 | 0.00 | 49.38 | | 16.87 | 20.25 | 3100 | 502 | 486 | 2 |
| | 007-5 | 007-5N | 211.66 | 151.07 | 0.00 | 35.60 | | 0.00 | 24.99 | 4100 | 511 | 487 | 4 |
| | 007-6 | 004-338TN | 185.00 | 113.89 | 0.00 | 12.55 | | 0.00 | 58.56 | 3600 | 503 | 496 | 4 |
| | 007-7 | 007-152N | 67.06 | 0.00 | 0.00 | 0.00 | | 44.08 | 22.98 | 2400 | 497 | 485 | 3 |
| 008 | 008-1 | 008-100N | 86.97 | 0.00 | 0.00 | 40.20 | 15.10 | 22.87 | 8.80 | 2300 | 507 | 489 | 3 |
| 009 | 009-1 | 009-325TN | 104.83 | 0.00 | 0.00 | 0.00 | 57.20 | 32.82 | 14.81 | 2800 | 502 | 488 | 3 |
| | 009-2 | 009-312TN | 108.40 | 16.57 | 0.00 | 0.00 | 72.20 | 0.00 | 19.63 | 3000 | 504 | 489 | 3 |
| | 009-3 | 009-092N | 108.70 | 28.76 | 8.18 | 43.69 | | 9.37 | 18.70 | 2400 | 494 | 486 | 3 |
| 010 | 010-1 | 010-1N | 80.15 | 17.36 | 0.00 | 3.84 | 11.79 | 22.20 | 24.96 | 3200 | 502 | 495 | 3 |
| | 010-2 | 010-302TN | 149.91 | 74.21 | 0.00 | 18.67 | | 6.48 | 50.55 | 4000 | 503 | 485 | 3 |
| | 010-3 | 010-236TN | 108.38 | 76.84 | 0.00 | 22.02 | | 0.00 | 9.52 | 4000 | 492 | 486 | 3 |
| | 010-4 | 010-319TN | 68.60 | 40.09 | 0.00 | 17.11 | | 0.00 | 11.40 | 4400 | 502 | 491 | 3 |
| | 010-5 | 010-129N | 55.83 | 39.92 | 0.00 | 13.09 | | 0.00 | 2.82 | 4100 | 499 | 487 | 2 |
| | 010-6 | 010-318TN | 110.74 | 75.03 | 0.00 | 33.08 | | 0.00 | 2.63 | 3600 | 495 | 486 | 2 |
| | 010-7 | 010-171TN | 129.04 | 81.12 | 2.64 | 11.93 | | 14.87 | 18.48 | 4200 | 493 | 189 | 2 |
| | 010-8 | 010-270TN | 87.32 | 56.02 | 0.00 | 0.00 | | 19.07 | 12.23 | 3100 | 493 | 488 | 2 |
| | 010-9 | 010-266N | 52.40 | 39.09 | 0.00 | 2.97 | | 0.00 | 10.34 | 2800 | 494 | 488 | 2 |
| | 010-10 | 010-018N | 109.63 | 57.48 | 0.00 | 0.00 | | 29.72 | 22.43 | 3600 | 503 | 489 | 2 |
| | 010-11 | 010-021N | 55.55 | 53.64 | 0.00 | 1.91 | | 0.00 | 0.00 | 2500 | 503 | 496 | 2 |
| | 010-12 | 010-151TN | 60.36 | 60.36 | 0.00 | 0.00 | | 0.00 | 0.00 | 2800 | 495 | 489 | 2 |
| | 010-13 | 010-042TN | 95.55 | 71.01 | 0.00 | 6.35 | | 0.00 | 18.19 | 4200 | 497 | 488 | 2 |

| CSO Sub-basin | Sub-catchment | Runoff Model Point of Concentration | Total Area (Acres) | Land Use (Acres) | | | | | | Flow Length (ft) | Elevation Difference (ft) | | Rain Gauge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Single-Family | Multi-Family | Commercial | University | Industrial | Open Space | | High | Low | |
| | 010-14 | 010-045N | 99.09 | 90.22 | 0.00 | 0.00 | | 0.00 | 8.87 | 2800 | 498 | 488 | 2 |

### 3.1.9 Percent Impervious

Percent imperviousness is the ratio of hydraulically connected impervious areas (parking lots, streets, etc.) to the total subcatchment area. Hydraulically connected means that the travel path of overland flow is continuous over impervious areas until the point of concentration is reached. Rooftops are considered impervious areas if the rain leaders are directly connected to the combined sewer system.

Values used for percent imperviousness for different land uses are as shown in Table 3.1-2.

**Table 3.1-2**
**Assumed Values of Percent Imperviousness**

| Land Use | Percent Imperviousness |
|---|---|
| Single Family Residential | 20-33 |
| Multi-Family Residential | 57 |
| Commercial | 68 |
| Industrial | 25-96 |

A study was conducted by the City to investigate the percentage of rain leaders connected to the combined sewer system. These percentages are shown in Table 3.1-3. The percent imperviousness for each single-family residential land use in each CSO sub-basin varied due to the difference in the percentage of rain leaders connected to the combined sewer system. Therefore the percent imperviousness values for the single-family residential areas range from 20% to 33%. The percent imperviousness for each industrial land use area was calculated individually because each area was significantly different. Therefore, the percent imperviousness values for the industrial areas range from 25% to 96%. The percent imperviousness for each subcatchment is shown in Table 3.1-4.

**Table 3.1-3**
**Rain Leader Estimate**

| Basin | Percent Not Connected to Sewer | Percent Connected to Sewer |
|---|---|---|
| 003 | 85 | 15 |
| 004/011 | 65 | 35 |
| 005/006 | 50 | 50 |
| 007 | 65 | 35 |
| 008 | 10 | 90 |
| 009 | 40 | 60 |
| 010 | 80 | 20 |

**002 (Main Lift Station is within Basin 003 and impacted by all basins)*

## Table 3.1-4
## Percent Imperviousness

| CSO Sub-basin | Sub-catchment Number | Total Sub-catchment Area (Acres) | Single Family Land Use | | | Multi-Family Land Use | | | Commercial Land Use | | | Industrial Land Use | | | | | | Open Area (Acres) | Total Impervious Area (Acres) | % Impervious | Total Pervious Area (Acres) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total (Acres) | % Impervious | Pervious (Acres) | Total (Acres) | % Impervious | Pervious (Acres) | Total (Acres) | % Impervious | Pervious (Acres) | Total (Acres) | Roofs (Acres) | Streets (Acres) | Impervious (Acres) | % Impervious | Pervious (Acres) | | | | |
| 003 | 003-1 | 97.44 | 70.36 | 20% | 56.57 | 0.00 | 57% | 0.00 | 3.95 | 68% | 1.26 | 4.50 | 0.44 | 2.03 | 2.47 | 55% | 2.03 | 18.63 | 18.95 | 19% | 78.49 |
| | 003-2 | 105.04 | 36.47 | 20% | 29.32 | 0.00 | 57% | 0.00 | 41.50 | 68% | 13.28 | 14.85 | 3.36 | 8.07 | 11.43 | 77% | 3.42 | 12.22 | 46.80 | 45% | 58.24 |
| | 003-3 | 86.17 | 30.05 | 20% | 24.16 | 2.24 | 57% | 0.96 | 36.42 | 68% | 11.65 | 8.02 | 2.27 | 3.13 | 5.4 | 67% | 2.62 | 9.44 | 37.33 | 43% | 48.84 |
| | 003-4 | 131.17 | 23.81 | 20% | 19.14 | 14.10 | 57% | 6.06 | 0.00 | 68% | 0.00 | 50.15 | 9.85 | 21.67 | 31.52 | 63% | 18.63 | 43.11 | 44.22 | 34% | 86.95 |
| | 003-5 | 194.01 | 144.02 | 20% | 115.79 | 2.91 | 57% | 1.25 | 15.85 | 68% | 5.07 | 3.67 | 0.61 | 2.6 | 3.21 | 87% | 0.46 | 27.56 | 43.87 | 23% | 150.14 |
| 004/011 | 004/011-1 | 124.33 | 43.67 | 23% | 33.49 | 0.00 | 57% | 0.00 | 21.75 | 68% | 6.96 | 46.77 | 5.65 | 15.12 | 20.77 | 44% | 26.00 | 12.14 | 45.74 | 37% | 78.59 |
| | 004/011-2 | 121.99 | 110.74 | 23% | 84.94 | 0.00 | 57% | 0.00 | 11.25 | 68% | 3.60 | 0.00 | | | 0.00 | | 0.00 | 0.00 | 33.45 | 27% | 88.54 |
| | 004/011-3 | 133.62 | 81.42 | 23% | 62.45 | 0.00 | 57% | 0.00 | 31.40 | 68% | 10.05 | 16.34 | 7.22 | 1.26 | 8.48 | 52% | 7.86 | 4.46 | 48.80 | 37% | 84.82 |
| | 004/011-4 | 152.56 | 76.28 | 23% | 58.51 | 0.00 | 57% | 0.00 | 0.00 | 68% | 0.00 | 43.70 | 6.42 | 4.48 | 10.9 | 25% | 32.80 | 32.58 | 28.67 | 19% | 123.89 |
| | 004/011-5 | 129.92 | 94.01 | 23% | 72.11 | 0.00 | 57% | 0.00 | 0.00 | 68% | 0.00 | 32.76 | 5.35 | 7.03 | 12.38 | 38% | 20.38 | 3.15 | 34.28 | 26% | 95.64 |
| | 004/011-6 | 96.31 | 34.91 | 23% | 26.78 | 12.18 | 57% | 5.24 | 3.85 | 68% | 1.23 | 24.07 | 6.52 | 2.92 | 9.44 | 39% | 14.63 | 21.30 | 27.13 | 28% | 69.18 |
| | 004/011-7 | 77.52 | 45.06 | 23% | 34.56 | 0.00 | 57% | 0.00 | 4.18 | 68% | 1.34 | 0.00 | | | 0.00 | | 0.00 | 28.28 | 13.34 | 17% | 64.18 |
| | 004/011-8 | 166.07 | 122.96 | 23% | 94.31 | 0.00 | 57% | 0.00 | 0.00 | 68% | 0.00 | 0.00 | | | 0.00 | | 0.00 | 43.11 | 28.65 | 17% | 137.42 |
| | 004/011-9 | 41.92 | 32.76 | 23% | 25.13 | 0.00 | 57% | 0.00 | 3.99 | 68% | 1.28 | 0.00 | | | 0.00 | | 0.00 | 5.17 | 10.35 | 25% | 31.57 |
| | 004/011-10 | 67.82 | 48.67 | 23% | 37.33 | 0.00 | 57% | 0.00 | 0.00 | 68% | 0.00 | 5.17 | 0.59 | 1.14 | 1.73 | 33% | 3.44 | 13.98 | 13.07 | 19% | 54.75 |
| | 004/011-11 | 69.65 | 69.65 | 23% | 53.42 | 0.00 | 57% | 0.00 | 0.00 | 68% | 0.00 | 0.00 | | | 0.00 | | 0.00 | 0.00 | 16.23 | 23% | 53.42 |
| | 004/011-12 | 73.51 | 73.51 | 23% | 56.38 | 0.00 | 57% | 0.00 | 0.00 | 68% | 0.00 | 0.00 | | | 0.00 | | 0.00 | 0.00 | 17.13 | 23% | 56.38 |
| | 004/011-13 | 71.87 | 27.43 | 23% | 21.04 | 0.00 | 57% | 0.00 | 14.42 | 68% | 4.61 | 10.15 | 2.44 | 3.02 | 5.46 | 54% | 4.69 | 19.87 | 21.66 | 30% | 50.21 |
| | 004/011-14 | 49.24 | 33.16 | 23% | 25.43 | 0.00 | 57% | 0.00 | 10.46 | 68% | 3.35 | 0.00 | | | 0.00 | | 0.00 | 5.62 | 14.84 | 30% | 34.40 |
| | 004/011-15 | 126.22 | 112.09 | 23% | 85.97 | 0.00 | 57% | 0.00 | 6.82 | 68% | 2.18 | 0.00 | | | 0.00 | | 0.00 | 7.31 | 30.75 | 24% | 95.47 |
| 005/006 | 005/006-1 | 56.43 | 0.00 | 26% | 0.00 | 30.65 | 57% | 13.18 | 0.00 | 68% | 0.00 | 10.02 | 2.53 | 7.1 | 9.63 | 96% | 0.39 | 15.76 | 27.10 | 48% | 29.33 |
| | 005/006-2 | 28.76 | 7.44 | 26% | 5.51 | 4.07 | 57% | 1.75 | 17.25 | 68% | 5.52 | 0.00 | | | 0.00 | | 0.00 | 0.00 | 15.98 | 56% | 12.78 |

| CSO Sub-basin | Sub-catchment Number | Total Sub-catchment Area (Acres) | Single Family Land Use | | | Multi-Family Land Use | | | Commercial Land Use | | | Industrial Land Use | | | | | | Open Area (Acres) | Total Impervious Area (Acres) | % Impervious | Total Pervious Area (Acres) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total (Acres) | % Impervious | Pervious (Acres) | Total (Acres) | % Impervious | Pervious (Acres) | Total (Acres) | % Impervious | Pervious (Acres) | Total (Acres) | Roofs (Acres) | Streets (Acres) | Impervious (Acres) | % Impervious | Pervious (Acres) | | | | |
| | 005/006-3 | 83.16 | 78.70 | 26% | 58.24 | 2.34 | 57% | 1.01 | 0.00 | 68% | 0.00 | 0.00 | | | 0.00 | | 0.00 | 2.12 | 21.80 | 26% | 61.36 |
| | 005/006-4 | 102.73 | 47.15 | 26% | 34.89 | 0.00 | 57% | 0.00 | 29.02 | 68% | 9.29 | 21.52 | 5.34 | 13.64 | 18.98 | 88% | 2.54 | 5.04 | 50.97 | 50% | 51.76 |
| 007 | 007-1 | 117.21 | 0.00 | 23% | 0.00 | 0.00 | 57% | 0.00 | 112.5 9 | 68% | 36.03 | 0.00 | | | 0.00 | | 0.00 | 4.62 | 76.56 | 65% | 40.65 |
| | 007-2 | 137.91 | 91.62 | 23% | 70.27 | 0.00 | 57% | 0.00 | 42.71 | 68% | 13.67 | 0.00 | | | 0.00 | | 0.00 | 3.58 | 50.39 | 37% | 87.52 |
| | 007-3 | 160.30 | 118.28 | 23% | 90.72 | 0.00 | 57% | 0.00 | 34.06 | 68% | 10.90 | 0.00 | | | 0.00 | | 0.00 | 7.96 | 50.72 | 32% | 109.58 |
| | 007-4 | 200.32 | 113.82 | 23% | 87.30 | 0.00 | 57% | 0.00 | 49.38 | 68% | 15.80 | 16.87 | 4.04 | 7.11 | 11.15 | 66% | 5.72 | 20.25 | 71.25 | 36% | 129.07 |
| | 007-5 | 211.66 | 151.07 | 23% | 115.87 | 0.00 | 57% | 0.00 | 35.60 | 68% | 11.39 | 0.00 | | | 0.00 | | 0.00 | 24.99 | 59.41 | 28% | 152.25 |
| | 007-6 | 185.00 | 113.89 | 23% | 87.35 | 0.00 | 57% | 0.00 | 12.55 | 68% | 4.02 | 0.00 | | | 0.00 | | 0.00 | 58.56 | 35.07 | 19% | 149.93 |
| | 007-7 | 67.06 | 0.00 | 23% | 0.00 | 0.00 | 57% | 0.00 | 0.00 | 68% | 0.00 | 44.08 | 8.15 | 12.15 | 20.3 | 46% | 23.78 | 22.98 | 20.30 | 30% | 46.76 |
| 008 | 008-1 | 86.97 | 0.00 | 33% | 0.00 | 0.00 | 57% | 0.00 | 55.30 | 73% | 14.93 | 22.87 | 2.18 | 13.86 | 16.04 | 70% | 6.83 | 8.80 | 56.41 | 65% | 30.56 |
| 009 | 009-1 | 104.83 | 0.00 | 28% | 0.00 | 0.00 | 57% | 0.00 | 57.20 | 86% | 8.01 | 32.82 | 20.26 | 6.96 | 27.22 | 83% | 5.60 | 14.81 | 76.41 | 73% | 28.42 |
| | 009-2 | 108.40 | 16.57 | 28% | 11.96 | 0.00 | 57% | 0.00 | 72.20 | 87% | 9.39 | 0.00 | | | 0.00 | | 0.00 | 19.63 | 67.42 | 62% | 40.98 |
| | 009-3 | 108.70 | 28.76 | 28% | 20.76 | 8.18 | 57% | 3.52 | 43.69 | 68% | 13.98 | 9.37 | 1.58 | 1.67 | 3.25 | 35% | 6.12 | 18.70 | 45.62 | 42% | 63.08 |
| 010 | 010-1 | 80.15 | 17.36 | 24% | 13.16 | 0.00 | 57% | 0.00 | 15.63 | 92% | 1.25 | 22.20 | 4.6 | 4.15 | 4.15 | 19% | 18.05 | 24.96 | 27.33 | 34% | 52.82 |
| | 010-2 | 149.91 | 74.21 | 24% | 56.25 | 0.00 | 57% | 0.00 | 18.67 | 68% | 5.97 | 6.48 | 1.11 | 2.07 | 2.07 | 32% | 4.41 | 50.55 | 33.83 | 23% | 116.08 |
| | 010-3 | 108.38 | 76.84 | 24% | 58.24 | 0.00 | 57% | 0.00 | 22.02 | 68% | 7.05 | 0.00 | | | 0.00 | | 0.00 | 9.52 | 33.57 | 31% | 74.81 |
| | 010-4 | 68.60 | 40.09 | 24% | 30.39 | 0.00 | 57% | 0.00 | 17.11 | 68% | 5.48 | 0.00 | | | 0.00 | | 0.00 | 11.40 | 21.34 | 31% | 47.26 |
| | 010-5 | 55.83 | 39.92 | 24% | 30.26 | 0.00 | 57% | 0.00 | 13.09 | 68% | 4.19 | 0.00 | | | 0.00 | | 0.00 | 2.82 | 18.56 | 33% | 37.27 |
| | 010-6 | 110.74 | 75.03 | 24% | 56.87 | 0.00 | 57% | 0.00 | 33.08 | 68% | 10.59 | 0.00 | | | 0.00 | | 0.00 | 2.63 | 40.65 | 37% | 70.09 |
| | 010-7 | 129.04 | 81.12 | 24% | 61.49 | 2.64 | 57% | 1.14 | 11.93 | 68% | 3.82 | 14.87 | 3.88 | 6.31 | 10.19 | 69% | 4.68 | 18.48 | 39.44 | 31% | 89.60 |
| | 010-8 | 87.32 | 56.02 | 24% | 42.46 | 0.00 | 57% | 0.00 | 0.00 | 68% | 0.00 | 19.07 | 2.8 | 9.63 | 12.43 | 65% | 6.64 | 12.23 | 25.99 | 30% | 61.33 |
| | 010-9 | 52.40 | 39.09 | 24% | 29.63 | 0.00 | 57% | 0.00 | 2.97 | 68% | 0.95 | 0.00 | | | 0.00 | | 0.00 | 10.34 | 11.48 | 22% | 40.92 |
| | 010-10 | 109.63 | 57.48 | 24% | 43.57 | 0.00 | 57% | 0.00 | 0.00 | 68% | 0.00 | 29.72 | 3.82 | 14.11 | 17.93 | 60% | 11.79 | 22.43 | 31.84 | 29% | 77.79 |
| | 010-11 | 55.55 | 53.64 | 24% | 40.66 | 0.00 | 57% | 0.00 | 1.91 | 68% | 0.61 | 0.00 | | | 0.00 | | 0.00 | 0.00 | 14.28 | 26% | 41.27 |
| | 010-12 | 60.36 | 60.36 | 24% | 45.75 | 0.00 | 57% | 0.00 | 0.00 | 68% | 0.00 | 0.00 | | | 0.00 | | 0.00 | 0.00 | 14.61 | 24% | 45.75 |

| CSO Sub-basin | Sub-catchment Number | Total Sub-catchment Area (Acres) | Single Family Land Use | | | Multi-Family Land Use | | | Commercial Land Use | | | Industrial Land Use | | | | | | Open Area (Acres) | Total Impervious Area (Acres) | % Impervious | Total Pervious Area (Acres) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total (Acres) | % Impervious | Pervious (Acres) | Total (Acres) | % Impervious | Pervious (Acres) | Total (Acres) | % Impervious | Pervious (Acres) | Total (Acres) | Roofs (Acres) | Streets (Acres) | Impervious (Acres) | % Impervious | Pervious (Acres) | | | | |
| | 010-13 | 95.55 | 71.01 | 24% | 53.83 | 0.00 | 57% | 0.00 | 6.35 | 68% | 2.03 | 0.00 | | | 0.00 | | 0.00 | 18.19 | 21.50 | 23% | 74.05 |
| | 010-14 | 99.09 | 90.22 | 24% | 68.39 | 0.00 | 57% | 0.00 | 0.00 | 68% | 0.00 | 0.00 | | | 0.00 | | 0.00 | 8.87 | 21.83 | 22% | 77.26 |

#### 3.1.9.1 Subcatchment Widths

Subcatchment width determines the shape of the runoff hydrograph. Higher peak flow rates and more immediate response to a storm event can be achieved when the subcatchment width is increased for the same area. For model calibration this parameter is adjusted to match the model's peak runoff rate to the flow monitor's peak runoff rate without significant change in the model's runoff volume. The widths for each subcatchment are shown in Table 3.1-4.

#### 3.1.9.2 Overland Slope

Overland slope affects the travel time of overland flow, peak runoff rate and runoff volume. Steeper slope decreases the travel time, increases the peak runoff rate and increases the runoff volume. Average overland slope was estimated by overlaying the subcatchment area boundary over current USGS contour maps. The overland slope for each subcatchment is shown in Table 3.1-4.

#### 3.1.9.3 Depression Storage

Depression storage relates to both pervious and impervious areas and is defined as the amount of incidental surface depressions that must be filled before runoff begins. For pervious areas, the following values were used prior to calibration (Greeley and Hansen Engineers, 1994):

| Land Use | Pervious Depression Storage |
|---|---|
| Residential/Commercial | 0.20 |
| Industrial/Open Grass Area | 0.15 |

Impervious depression storage is a function of the average subcatchment slope and was estimated from the following equation (Kidd, 1978 referenced in Huber and Dickinson, 1988):

$$\text{Depression storage (in)} = 0.0303 \times (\text{average slope } (\%))^{-0.49}$$

The values for the pervious and impervious depression storage for each subcatchment are shown in Table 3.1-5.

## Table 3.1-5
## Model Input Data

| CSO Service Area | Subcatchment Number | Runoff Model Point of Concentration | Combined Area (Acres) | Percent Impervious | Subcatchment Width (ft) | Overland Slope (%) | Depression Storage (in) | | Overland Mannings "n" | | Green Ampt Parameters | | | Rain Gauge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Impervious | Pervious | Impervious | Pervious | Permeability (in/hr) | Initial Moisture Deficit (in/in) | Capillary Suction (in) | |
| 003 | 003-1 | 003-209TN | 97.44 | 19% | 1117 | 0.009 | 0.305 | 0.188 | 0.014 | 0.20 | 0.630 | 0.140 | 4.330 | 5 |
| | 003-2 | 003-204TN | 105.04 | 45% | 1387 | 0.008 | 0.324 | 0.187 | 0.014 | 0.20 | 1.247 | 0.140 | 4.330 | 5 |
| | 003-3 | 003-217TN | 86.17 | 43% | 1341 | 0.006 | 0.373 | 0.190 | 0.014 | 0.20 | 1.726 | 0.140 | 4.330 | 5 |
| | 003-4 | 003-226N | 131.17 | 34% | 2597 | 0.002 | 0.593 | 0.164 | 0.014 | 0.19 | 0.630 | 0.140 | 4.330 | 5 |
| | 003-5 | 003-225TN | 194.01 | 23% | 1921 | 0.003 | 0.512 | 0.192 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 5 |
| 004/011 | 004/011-1 | 004-292TN | 124.33 | 37% | 1593 | 0.017 | 0.223 | 0.176 | 0.014 | 0.18 | 2.000 | 0.140 | 4.330 | 5 |
| | 004/011-2 | 004-290TN | 121.99 | 27% | 932 | 0.016 | 0.229 | 0.200 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 3 |
| | 004/011-3 | 011-121N | 133.62 | 37% | 1617 | 0.003 | 0.514 | 0.192 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 4 |
| | 004/011-4 | 004-295TN | 152.56 | 19% | 1384 | 0.002 | 0.612 | 0.175 | 0.014 | 0.19 | 2.000 | 0.140 | 4.330 | 4 |
| | 004/011-5 | 011-083N | 129.92 | 26% | 1088 | 0.014 | 0.247 | 0.186 | 0.014 | 0.19 | 1.863 | 0.149 | 4.554 | 3 |
| | 004/011-6 | 004/011-6N | 96.31 | 28% | 1447 | 0.001 | 0.763 | 0.176 | 0.014 | 0.19 | 2.430 | 0.137 | 4.138 | 4 |
| | 004/011-7 | 004-298TN | 77.52 | 17% | 1299 | 0.001 | 1.016 | 0.182 | 0.014 | 0.20 | 2.147 | 0.143 | 4.346 | 4 |
| | 004/011-8 | 004-140TN | 166.07 | 17% | 1507 | 0.013 | 0.252 | 0.187 | 0.014 | 0.20 | 3.075 | 0.133 | 3.850 | 4 |
| | 004/011-9 | 011-150N | 41.92 | 25% | 1141 | 0.004 | 0.434 | 0.194 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 4 |
| | 004/011-10 | 004-342N | 67.82 | 19% | 1407 | 0.009 | 0.313 | 0.186 | 0.014 | 0.20 | 4.013 | 0.134 | 3.594 | 4 |
| | 004/011-11 | 011-183TN | 69.65 | 23% | 1264 | 0.003 | 0.509 | 0.200 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 4 |
| | 004/011-12 | 011-174TN | 73.51 | 23% | 728 | 0.016 | 0.226 | 0.200 | 0.014 | 0.20 | 2.860 | 0.134 | 3.946 | 4 |
| | 004/011-13 | 004-245TN | 71.87 | 30% | 1044 | 0.003 | 0.533 | 0.179 | 0.014 | 0.20 | 0.630 | 0.230 | 6.570 | 3 |
| | 004/011-14 | 004-255TN | 49.24 | 30% | 1072 | 0.004 | 0.469 | 0.194 | 0.014 | 0.20 | 3.010 | 0.160 | 4.416 | 3 |
| | 004/011-15 | 004-257N | 126.22 | 24% | 1375 | 0.008 | 0.323 | 0.197 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 4 |
| 005/006 | 005/006-1 | 005/006-1N | 56.43 | 48% | 768 | 0.057 | 0.123 | 0.177 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 3 |

| CSO Service Area | Subcatchment Number | Runoff Model Point of Concentration | Combined Area (Acres) | Percent Impervious | Subcatchment Width (ft) | Overland Slope (%) | Depression Storage (in) | | Overland Mannings "n" | | Green Ampt Parameters | | | Rain Gauge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Impervious | Pervious | Impervious | Pervious | Permeability (in/hr) | Initial Moisture Deficit (in/in) | Capillary Suction (in) | |
| | 005/006-2 | 5/6-210N | 28.76 | 56% | 358 | 0.053 | 0.128 | 0.200 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 3 |
| | 005/006-3 | 5/6-200N | 83.16 | 26% | 1065 | 0.009 | 0.298 | 0.199 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 3 |
| | 005/006-4 | 5/6-100N | 102.73 | 50% | 1721 | 0.019 | 0.214 | 0.187 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 3 |
| 007 | 007-1 | 007-160N | 117.21 | 65% | 1001 | 0.015 | 0.237 | 0.198 | 0.014 | 0.20 | 1.795 | 0.154 | 4.666 | 3 |
| | 007-2 | 007-120N | 137.91 | 37% | 1820 | 0.003 | 0.545 | 0.199 | 0.014 | 0.20 | 1.197 | 0.217 | 5.847 | 3 |
| | 007-3 | 004-102TN | 160.30 | 32% | 1587 | 0.003 | 0.510 | 0.198 | 0.014 | 0.20 | 0.904 | 0.206 | 4.894 | 3 |
| | 007-4 | 004-061N | 200.32 | 36% | 2815 | 0.006 | 0.382 | 0.191 | 0.014 | 0.20 | 0.904 | 0.206 | 4.894 | 2 |
| | 007-5 | 007-5N | 211.66 | 28% | 2249 | 0.011 | 0.280 | 0.194 | 0.014 | 0.20 | 1.863 | 0.148 | 4.247 | 4 |
| | 007-6 | 004-338TN | 185.00 | 19% | 2239 | 0.003 | 0.511 | 0.184 | 0.014 | 0.20 | 1.521 | 0.171 | 4.961 | 4 |
| | 007-7 | 007-152N | 67.06 | 30% | 1217 | 0.01 | 0.291 | 0.150 | 0.014 | 0.17 | 0.767 | 0.221 | 6.346 | 3 |
| 008 | 008-1 | 008-100N | 86.97 | 65% | 1647 | 0.011 | 0.277 | 0.147 | 0.014 | 0.19 | 2.000 | 0.140 | 4.330 | 3 |
| 009 | 009-1 | 009-325TN | 104.83 | 73% | 1631 | 0.009 | 0.312 | 0.068 | 0.014 | 0.19 | 2.000 | 0.140 | 4.330 | 3 |
| | 009-2 | 009-312TN | 108.40 | 62% | 1574 | 0.01 | 0.296 | 0.058 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 3 |
| | 009-3 | 009-092N | 108.70 | 42% | 1973 | 0.004 | 0.450 | 0.187 | 0.014 | 0.20 | 1.863 | 0.149 | 4.554 | 3 |
| 010 | 010-1 | 010-1N | 80.15 | 34% | 1091 | 0.006 | 0.360 | 0.141 | 0.014 | 0.19 | 2.000 | 0.140 | 4.330 | 3 |
| | 010-2 | 010-302TN | 149.91 | 23% | 1633 | 0.011 | 0.276 | 0.181 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 3 |
| | 010-3 | 010-236TN | 108.38 | 31% | 1180 | 0.005 | 0.403 | 0.196 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 3 |
| | 010-4 | 010-319TN | 68.60 | 31% | 679 | 0.016 | 0.228 | 0.192 | 0.014 | 0.20 | 3.505 | 0.130 | 3.658 | 3 |
| | 010-5 | 010-129N | 55.83 | 33% | 593 | 0.02 | 0.205 | 0.197 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 2 |
| | 010-6 | 010-318TN | 110.74 | 37% | 1340 | 0.007 | 0.352 | 0.199 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 2 |
| | 010-7 | 010-171TN | 129.04 | 31% | 1338 | 0.003 | 0.523 | 0.187 | 0.014 | 0.20 | 1.726 | 0.158 | 4.686 | 2 |
| | 010-8 | 010-270TN | 87.32 | 30% | 1227 | 0.004 | 0.449 | 0.182 | 0.014 | 0.19 | 2.000 | 0.140 | 4.330 | 2 |
| | 010-9 | 010-266N | 52.40 | 22% | 815 | 0.007 | 0.336 | 0.190 | 0.014 | 0.20 | 2.000 | 0.140 | 4.330 | 2 |
| | 010-10 | 010-018N | 109.63 | 29% | 1327 | 0.011 | 0.282 | 0.176 | 0.014 | 0.19 | 1.932 | 0.145 | 4.442 | 2 |

| CSO Service Area | Subcatchment Number | Runoff Model Point of Concentration | Combined Area (Acres) | Percent Impervious | Subcatchment Width (ft) | Overland Slope (%) | Depression Storage (in) | | Overland Mannings "n" | | Green Ampt Parameters | | | Rain Gauge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Impervious | Pervious | Impervious | Pervious | Permeability (in/hr) | Initial Moisture Deficit (in/in) | Capillary Suction (in) | |
| | 010-11 | 010-021N | 55.55 | 26% | 968 | 0.007 | 0.339 | 0.200 | 0.014 | 0.20 | 0.973 | 0.205 | 5.396 | 2 |
| | 010-12 | 010-151TN | 60.36 | 24% | 939 | 0.006 | 0.360 | 0.200 | 0.014 | 0.20 | 1.247 | 0.188 | 5.255 | 2 |
| | 010-13 | 010-042TN | 95.55 | 23% | 991 | 0.009 | 0.303 | 0.190 | 0.014 | 0.20 | 0.767 | 0.218 | 5.732 | 2 |
| | 010-14 | 010-045N | 99.09 | 22% | 1542 | 0.006 | 0.358 | 0.196 | 0.014 | 0.20 | 0.630 | 0.225 | 5.496 | 2 |

### 3.1.9.4 Mannings' Roughness Coefficient

The following Manning's roughness coefficients were used for pervious overland flow (Crawford and Linsley, 1966 and Engman, 1936, referenced in Huber and Dickinson, 1988):

| Land Use | Manning Coefficient |
|---|---|
| Residential/Commercial | 0.20 |
| Industrial | 0.15 |

The Manning's roughness coefficient used for impervious overland flow was 0.015.

### 3.1.9.5 Soil Infiltration

Infiltration parameters influence the runoff hydrograph from the combined sewer system subcatchments by absorbing rainfall into the soil. The infiltration capacity of the soil is exceeded when the soil becomes saturated during continuous simulation and heavy precipitation. When soil saturation is reached, most of the subsequent rainfall becomes runoff making the pervious areas behave as impervious areas.

The Green-Ampt infiltration equation was used to represent the soil infiltration parameters. The percentage of the different soil types for each subcatchment was determined from the *Soil Survey of Vigo County, Indiana* obtained from the United States Department of Agriculture (USDA, 1974). For each type of soil, the values of the saturated hydraulic conductivity (permeability, in./hr.) and the available water capacity (initial moisture deficit, in./in.) were found in the *Soil Survey of Vigo County, Indiana*. The values of the average capillary suction (inch) were found using the *Handbook of Hydrology* (D.R. Maidment, 1993). Once all the soil infiltration parameters were determined for each soil, a value for each parameter was calculated for each subcatchment and then entered into the model. The values for each parameter are shown in Table 3.1-6.

# Table 3.1-6
# Green-Ampt Parameters

| | Soil Type | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil Characteristics | AdB | Cr | EiA | EiB | Ma[3] | Pt | Rg | Rn | Tp | WrA | WrB2 | Ws |
| Permeability (in/hr) [1] | 6.3 - 20.0 | .63 - 2.0 | 2.0 - 6.3 | 2.0 - 6.3 | .63 - 2.0 | .63 - 2.0 | .63 - 2.0 | .63 - 2.0 | .63 - 2.0 | .63 - 2.0 | .63 - 2.0 | .63 - 2.0 |
| Selected Permeability (in/hr) | 6.3 | 0.63 | 2 | 2 | 2 | 0.63 | 0.63 | 0.63 | 0.6 | 0.6 | 0.63 | 0.63 |
| Available Water Capacity (in/in) | .10 - .12 | .22 - .24 | .13 - .15 | .13 - .15 | .13 - .16 | .22 - .24 | .20 - .23 | .20 - .23 | .13 - .15 | .13 - .15 | .13 - .15 | .22 - .24 |
| Average AWC | 0.11 | 0.23 | 0.14 | 0.14 | 0.14 | 0.23 | 0.215 | 0.215 | 0.14 | 0.14 | 0.14 | 0.23 |
| Soil Classification [1] | Loamy Sand | Silt Loam | Sandy Loam | Sandy Loam | Sandy Loam | Silt Loam | Loam | Loam | Silt Loam | Sandy Loam | Sandy Loam | Silt Loam |
| Suct (in) [2] | 2.41 | 6.57 | 4.33 | 4.33 | 4.33 | 6.57 | 3.50 | 3.50 | 6.57 | 4.33 | 4.33 | 6.57 |

| | | | | | | | | | | | | | Computed Parameters | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subcatchment | Percent Soil Type | | | | | | | | | | | | Permeability | Initial Moisture | Capilary |
| Number | AdB | Cr | EiA | EiB | Ma[3] | Pt | Rg | Rn | Tp | WrA | WrB2 | Ws | (in/hr) | Deficit (in/in) | Suction (in) |
| 003-1 | | | | | | | | | | 65% | 35% | | 0.630 | 0.140 | 4.330 |
| 003-2 | | | 45% | | | | | | | 55% | | | 1.247 | 0.140 | 4.330 |
| 003-3 | | | 80% | | | | | | | 20% | | | 1.726 | 0.140 | 4.330 |
| 003-4 | | | | | 8% | | | | | 88% | 4% | | 0.630 | 0.140 | 4.330 |
| 003-5 | | | 100% | | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 004/011-1 | | | 90% | 10% | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 004/011-2 | | | 45% | 55% | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 004/011-3 | | | 96% | 4% | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 004/011-4 | | | 97% | 3% | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 004/011-5 | | | 85% | 5% | | 10% | | | | | | | 1.863 | 0.149 | 4.554 |
| 004/011-6 | 10% | | 90% | | | | | | | | | | 2.430 | 0.137 | 4.138 |
| 004/011-7 | 5% | | 90% | | | 5% | | | | | | | 2.147 | 0.143 | 4.346 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 004/011-8 | 25% | | 60% | 15% | | | | | | | | | 3.075 | 0.133 | 3.850 |
| 004/011-9 | | | 45% | 55% | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 004/011-10 | 50% | | 40% | | | 10% | | | | | | | 4.013 | 0.134 | 3.594 |
| 004/011-11 | | | 100% | | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 004/011-12 | 20% | | 80% | | | | | | | | | | 2.860 | 0.134 | 3.946 |
| 004/011-13 | | | | | | 100% | | | | | | | 0.630 | 0.230 | 6.570 |
| 004/011-14 | 34% | | 33% | | | 33% | | | | | | | 3.010 | 0.160 | 4.416 |
| 004/011-15 | | | 92% | 8% | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 005/006-1 | | | 35% | 65% | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 005/006-2 | | | 50% | 50% | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 005/006-3 | | | 75% | 25% | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 005/006-4 | | | 85% | 15% | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 007-1 | | | 80% | 5% | | 15% | | | | | | | 1.795 | 0.154 | 4.666 |
| 007-2 | 10% | | | | | 80% | 10% | | | | | | 1.197 | 0.217 | 5.847 |
| 007-3 | | | 10% | 10% | | 40% | 40% | | | | | | 0.904 | 0.206 | 4.894 |
| 007-4 | | | 10% | 10% | | 40% | 40% | | | | | | 0.904 | 0.206 | 4.894 |
| 007-5 | | | 70% | 20% | | | 10% | | | | | | 1.863 | 0.148 | 4.247 |
| 007-6 | | 20% | 55% | 10% | | | | 5% | 10% | | | | 1.521 | 0.171 | 4.961 |
| 007-7 | | | 10% | | | 90% | | | | | | | 0.767 | 0.221 | 6.346 |
| 008-1 | | | 100% | | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 009-1 | | | 100% | | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 009-2 | | | 100% | | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 009-3 | | | 90% | | | 10% | | | | | | | 1.863 | 0.149 | 4.554 |
| 010-1 | | | 100% | | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 010-2 | | | 100% | | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 010-3 | | | 100% | | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 010-4 | 35% | | 65% | | | | | | | | | | 3.505 | 0.130 | 3.658 |
| 010-5 | | | 100% | | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 010-6 | | | 100% | | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 010-7 | | | 80% | | | 17% | 3% | | | | | | 1.726 | 0.158 | 4.680 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 010-8 | | | 100% | | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 010-9 | | | 100% | | | | | | | | | | 2.000 | 0.140 | 4.330 |
| 010-10 | | | 95% | | | 5% | | | | | | | 1.932 | 0.145 | 4.442 |
| 010-11 | | | | 25% | | 40% | | 20% | | | | 15% | 0.973 | 0.205 | 5.396 |
| 010-12 | | | 45% | | | 45% | 10% | | | | | | 1.247 | 0.188 | 5.255 |
| 010-13 | | | 10% | | | 70% | 20% | | | | | | 0.757 | 0.218 | 5.732 |
| 010-14 | | | | | | 65% | | 35% | | | | | 0.630 | 0.225 | 5.496 |

### 3.1.10 Dry Weather Flow

Dry weather flow to the CSO diversion structure is the sum of sanitary flow and infiltration. Dry weather flow is estimated based on land use and flow monitoring information. Dry weather flow to a CSO diversion structure was estimated as follows:

- Identify the major dry weather flow contributors based on water consumption data.
- Identify the land use and area of each major dry weather flow contributor.
- Estimate the area of residential, multi-family, commercial, industrial and open area land uses for each CSO service area.
- Estimate the dry weather flow for each land use and major contributor.
- Compare estimated dry weather flows to flow monitoring data and adjust dry weather flows as necessary.

Table 3.1-7 shows the estimated dry weather flow for each CSO service area subcatchment. Dry weather flow is broken down by land use and infiltration. The dry weather flow was used as input for each service area subcatchment's point of concentration in the EXTRAN model.

# Table 3.1-7
# Dry Weather Flow Estimation

| | | | | Land Use (Acres) | | | | | | Dry Weather (gpd) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CSO Sub-basin | Sub-catchment | Runoff Model Point of Conc. | Total Area (Acres) | Single-Family | Multi-Family | Commercial | University | Industrial | Open Space | Infiltration | Residential | Commercial | Point (mgd) | Point (cfs) |
| 003 | 003-1 | 003-209TN | 97.44 | 70.36 | 0.00 | 3.95 | 0.00 | 4.50 | 18.63 | 10,213 | 26,049 | 1,971 | 0.038 | 0.059 |
| | 003-2 | 003-204TN | 105.04 | 36.47 | 0.00 | 41.50 | 0.00 | 14.85 | 12.22 | 12,029 | 13,502 | 20,710 | 0.046 | 0.072 |
| | 003-3 | 003-217TN | 86.17 | 30.05 | 2.24 | 36.42 | 0.00 | 8.02 | 9.44 | 9,944 | 11,955 | 18,175 | 0.040 | 0.062 |
| | 003-4 | 003-226N | 131.17 | 23.81 | 14.10 | 0.00 | 0.00 | 50.15 | 43.11 | 11,412 | 14,035 | 0 | 0.025 | 0.039 |
| | 003-5 | 003-225TN | 194.01 | 144.02 | 2.91 | 15.85 | 0.00 | 3.67 | 27.56 | 21,571 | 54,398 | 7,910 | 0.084 | 0.130 |
| 003 | 003-6 | 003-400N* | 2086.82 | 250.00 | 125.00 | 250.00 | 0.00 | | 1461.00 | 81,101 | 138,837 | 124,762 | 0.345 | 0.533 |
| 004/011 | 004/011-1 | 004-292TN | 124.33 | 43.67 | 0.00 | 21.75 | 0.00 | 46.77 | 12.14 | 14,539 | 16,168 | 10,854 | 0.042 | 0.064 |
| | 004/011-2 | 004-290TN | 121.99 | 110.74 | 0.00 | 11.25 | 0.00 | 0.00 | 0.00 | 15,809 | 40,999 | 5,614 | 0.062 | 0.097 |
| | 004/011-3 | 011-121N | 133.62 | 81.42 | 0.00 | 31.40 | 0.00 | 16.34 | 4.46 | 16,738 | 30,144 | 15,670 | 0.063 | 0.097 |
| | 004/011-4 | 004-295TN | 164.52 | 76.28 | 0.00 | 0.00 | 0.00 | 43.70 | 32.58 | 17,098 | 28,241 | 0 | 0.045 | 0.070 |
| | 004/011-5 | 011-083N | 129.92 | 94.01 | 0.00 | 0.00 | 0.00 | 32.76 | 3.15 | 16,428 | 34,805 | 0 | 0.051 | 0.079 |
| | 004/011-6 | 004/011-6N | 96.31 | 34.91 | 12.18 | 3.85 | 0.00 | 24.07 | 21.30 | 9,721 | 17,434 | 1,921 | 0.029 | 0.045 |
| | 004/011-7 | 004-298TN | 77.52 | 45.06 | 0.00 | 4.18 | 0.00 | 0.00 | 28.28 | 6,381 | 16,683 | 2,086 | 0.025 | 0.039 |
| | 004/011-8 | 004-140TN | 166.07 | 122.96 | 0.00 | 0.00 | 0.00 | 0.00 | 43.11 | 15,935 | 45,524 | 0 | 0.061 | 0.095 |
| | 004/011-9 | 011-150N | 41.92 | 32.76 | 0.00 | 3.99 | 0.00 | 0.00 | 5.17 | 4,762 | 12,129 | 1,991 | 0.019 | 0.029 |
| | 004/011-10 | 004-342N | 67.82 | 48.67 | 0.00 | 0.00 | 0.00 | 5.17 | 13.98 | 6,977 | 18,019 | 0 | 0.025 | 0.039 |
| | 004/011-11 | 011-183TN | 69.65 | 69.65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9,026 | 25,787 | 0 | 0.035 | 0.054 |
| | 004/011-12 | 011-174TN | 73.51 | 73.51 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9,526 | 27,216 | 0 | 0.037 | 0.057 |
| | 004/011-13 | 004-245TN | 71.87 | 27.43 | 0.00 | 14.42 | 0.00 | 10.15 | 19.87 | 6,739 | 10,155 | 7,196 | 0.024 | 0.037 |
| | 004/011-14 | 004-255TN | 49.24 | 33.16 | 0.00 | 10.46 | 0.00 | 0.00 | 5.62 | 5,653 | 12,277 | 5,220 | 0.023 | 0.036 |
| | 004/011-15 | 004-257N | 126.22 | 112.09 | 0.00 | 6.82 | 0.00 | 0.00 | 7.31 | 15,410 | 41,499 | 3,404 | 0.060 | 0.093 |
| Sep-4/11 | 004/011-16 | 011-190TN | 1079.00 | 100.00 | 600.00 | 79.00 | 0.00 | 0.00 | 300.00 | 100,952 | 259,162 | 39,425 | 0.400 | 0.618 |
| Sep-4/11 | 004/011-17 | 011-190TN | 400.00 | 30.00 | 198.00 | 30.00 | 0.00 | 0.00 | 142.00 | 33,435 | 84,413 | 14,971 | 0.133 | 0.206 |
| 005/006 | 005/006-1 | 005/006-1N | 56.43 | 0.00 | 30.65 | 0.00 | 0.00 | 10.02 | 15.76 | 5,270 | 11,348 | 0 | 0.017 | 0.026 |

| CSO Sub-basin | Sub-catchment | Runoff Model Point of Conc. | Total Area (Acres) | Land Use (Acres) | | | | | | Dry Weather (gpd) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Single-Family | Multi-Family | Commercial | University | Industrial | Open Space | Infiltration | Residential | Commercial | Point (mgd) | Point (cfs) |
| | 005/006-2 | 5/6-210N | 28.76 | 7.44 | 4.07 | 17.25 | 0.00 | 0.00 | 0.00 | 3,727 | 4,261 | 8,609 | 0.017 | 0.026 |
| | 005/006-3 | 5/6-200N | 83.16 | 78.70 | 2.34 | 0.00 | 0.00 | 0.00 | 2.12 | 10,502 | 30,004 | 0 | 0.041 | 0.063 |
| | 005/006-4 | 5/6-100N | 102.73 | 47.15 | 0.00 | 29.02 | 0.00 | 21.52 | 5.04 | 12,660 | 17,456 | 14,482 | 0.045 | 0.069 |
| Sep-5/6 | 005/006-5 | 3071N | 36.22 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 26.00 | 1,324 | 0 | 0 | 0.001 | 0.002 |
| 007 | 007-1 | 007-160N | 117.21 | 0.00 | 0.00 | 112.59 | 0.00 | 0.00 | 4.62 | 14,591 | 0 | 56,188 | 0.071 | 0.110 |
| | 007-2 | 007-120N | 137.91 | 91.62 | 0.00 | 42.71 | 0.00 | 0.00 | 3.58 | 17,408 | 33,921 | 21,314 | 0.073 | 0.112 |
| | 007-3 | 004-102TN | 160.30 | 118.28 | 0.00 | 34.06 | 0.00 | 0.00 | 7.96 | 19,742 | 43,791 | 16,998 | 0.081 | 0.125 |
| | 007-4 | 004-061N | 200.32 | 113.82 | 0.00 | 49.38 | 0.00 | 16.87 | 20.25 | 23,336 | 42,140 | 24,643 | 0.090 | 0.139 |
| | 007-5 | 007-5N | 211.66 | 151.07 | 0.00 | 35.60 | 0.00 | 0.00 | 24.99 | 24,191 | 55,931 | 17,766 | 0.098 | 0.151 |
| | 007-6 | 004-338TN | 185.00 | 113.89 | 750.00 | 12.55 | 0.00 | 0.00 | 58.56 | 16,386 | 42,166 | 6,263 | 0.065 | 0.100 |
| | 007-7 | 007-152N | 67.06 | 0.00 | 0.00 | 0.00 | 0.00 | 44.08 | 22.98 | 5,712 | 0 | 0 | 0.006 | 0.009 |
| Sep-7 | 007-8 | 004-332TN* | 2890.00 | 275.00 | 0.00 | 50.00 | 0.00 | 0.00 | 1815.00 | 139,311 | 379,487 | 24,952 | 0.544 | 0.841 |
| 008 | 008-1 | 008-100N | 86.97 | 0.00 | 0.00 | 40.20 | 15.10 | 22.87 | 8.80 | 10,130 | 0 | 27,597 | 0.038 | 0.058 |
| Sep-8 | 008-2 | 301TN | 7.61 | 0.00 | 0.00 | 0.00 | 0.00 | 4.11 | 3.50 | 533 | 0 | 0 | 0.001 | 0.001 |
| 009 | 009-1 | 009-325TN | 104.83 | 0.00 | 8.18 | 0.00 | 57.20 | 32.82 | 14.81 | 11,666 | 0 | 28,546 | 0.040 | 0.062 |
| | 009-2 | 009-312TN | 108.40 | 16.57 | 0.00 | 0.00 | 72.20 | 0.00 | 19.63 | 11,504 | 6,135 | 36,031 | 0.054 | 0.083 |
| | 009-3 | 009-092N | 108.70 | 28.76 | 0.00 | 43.69 | 0.00 | 9.37 | 18.70 | 11,663 | 13,676 | 21,803 | 0.047 | 0.073 |
| Sep-9 | 009-4 | 1201N | 7.27 | 0.00 | 0.00 | 0.00 | 0.00 | 5.27 | 2.00 | 683 | 0 | 0 | 0.001 | 0.001 |
| 010 | 010-1 | 010-1N | 80.15 | 17.36 | 0.00 | 3.84 | 11.79 | 22.20 | 24.96 | 7,152 | 6,427 | 7,800 | 0.021 | 0.033 |
| | 010-2 | 010-302TN | 149.91 | 74.21 | 0.00 | 18.67 | 0.00 | 6.48 | 50.55 | 12,876 | 27,475 | 9,317 | 0.050 | 0.077 |
| | 010-3 | 010-236TN | 108.38 | 76.84 | 0.00 | 22.02 | 0.00 | 0.00 | 9.52 | 12,811 | 28,449 | 10,989 | 0.052 | 0.081 |
| | 010-4 | 010-319TN | 68.60 | 40.09 | 2.64 | 17.11 | 0.00 | 0.00 | 11.40 | 7,413 | 14,843 | 8,539 | 0.031 | 0.048 |
| | 010-5 | 010-129N | 55.83 | 39.92 | 0.00 | 13.09 | 0.00 | 0.00 | 2.82 | 6,870 | 14,780 | 6,533 | 0.028 | 0.044 |
| | 010-6 | 010-318TN | 110.74 | 75.03 | 0.00 | 33.08 | 0.00 | 0.00 | 2.63 | 14,010 | 27,778 | 16,509 | 0.058 | 0.090 |
| | 010-7 | 010-171TN | 126.40 | 81.12 | 0.00 | 11.93 | 0.00 | 14.87 | 18.48 | 13,986 | 31,011 | 5,954 | 0.051 | 0.079 |
| | 010-8 | 010-270TN | 87.32 | 56.02 | 0.00 | 0.00 | 0.00 | 19.07 | 12.23 | 9,731 | 20,740 | 0 | 0.030 | 0.047 |
| | 010-9 | 010-266N | 52.40 | 39.09 | 0.00 | 2.97 | 0.00 | 0.00 | 10.34 | 5,451 | 14,472 | 1,482 | 0.021 | 0.033 |

| CSO Sub-basin | Sub-catchment | Runoff Model Point of Conc. | Total Area (Acres) | Land Use (Acres) | | | | | | Dry Weather (gpd) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Single-Family | Multi-Family | Commercial | University | Industrial | Open Space | Infiltration | Residential | Commercial | Point (mgd) | Point (cfs) |
| | 010-10 | 010-018N | 109.63 | 57.48 | 0.00 | 0.00 | 0.00 | 29.72 | 22.43 | 11,300 | 21,281 | 0 | 0.033 | 0.050 |
| | 010-11 | 010-021N | 55.55 | 53.64 | 0.00 | 1.91 | 0.00 | 0.00 | 0.00 | 7,199 | 19,859 | 953 | 0.028 | 0.043 |
| | 010-12 | 010-151TN | 60.36 | 60.36 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 7,822 | 22,347 | 0 | 0.030 | 0.047 |
| | 010-13 | 010-042TN | 95.55 | 71.01 | 0 | 6.35 | 0.00 | 0.00 | 18.19 | 10,025 | 26,290 | 3,169 | 0.039 | 0.061 |
| | 010-14 | 010-045N | 99.09 | 90.22 | 0 | 0.00 | 0.00 | 0.00 | 8.87 | 11,692 | 33,402 | 0 | 0.045 | 0.070 |
| Sep-10 | 010-15 | 010-033TN* | 2902 | 855.00 | 500 | 150 | 0.00 | 0.00 | 1397 | 195,035 | 501,663 | 74,857 | 0.772 | 1.194 |
| Sep-10 | 010-16 | 010-033TN* | 2975 | 1800.00 | 0 | 650 | 0.00 | 0.00 | 525 | 317,499 | 666,416 | 324,381 | 1.308 | 2.024 |
| WWTP | | | 6932 | 1500.00 | 750 | 586 | 0.00 | 0.00 | 4097 | 367,392 | 833,020 | 292,442 | 0.149 | 2.310 |
| Total | | | 24464 | 7721 | 3002 | 2549 | 156 | 459 | 10496.65 | 1,810,000 | 3,970,000 | 1,350,000 | 7.130 | 11.033 |

### 3.1.11 Trunk Sewer and Main Interceptor Data for Model

The nine major trunk sewers were simulated in the EXTRAN model. Pipe lengths, sizes and slopes were determined from sewer system maps provided by the City. If the City record maps did not show the slope of the trunk sewer, the minimum of ground slope or the minimum pipe slope to obtain 2 feet per second full pipe flow velocity was used as input to the EXTRAN model.

### 3.1.12 Other Model Data

The City provided manhole numbers for each modeled manhole. For modeling purposes, the letter N was added to the end of each manhole number to designate a node in the model. The conduit downstream of the manhole has the same name as the manhole, but with the letter L added to the end of it to designate it as a link (pipe) in the model. The example below illustrates the model node and link names with the first three numbers corresponding to the CSO service area:

| | | |
|---|---|---|
| Manhole | - | 004-097TN |
| Downstream Conduit | - | 004-097TL |

CSO structures were labeled as CSO0XX where XX is the CSO service area number. CSO overflow links and nodes were labeled as CSO0XXOF___ where the last character identifies the element as a pipe or manhole, L or N respectively.

#### 3.1.12.1 Computational Time Step

The RUNOFF Block utilizes the following time steps:

| | | |
|---|---|---|
| Wet time step | - | 60 seconds, |
| Wet/Dry time step | - | 60 seconds, and |
| Dry time step | - | 86,400 seconds. |

The EXTRAN Block utilizes a time step of 60 seconds.

## 3.2 CS Model Calibration and Verification

### 3.2.1 Objectives

This section describes the XP-SWMM model calibration and verification. The objective of the calibration and verification process is to obtain a calibrated and verified model that is acceptable to the regulatory agencies for CSO Control Alternatives Evaluation. The previously submitted "CSO Program Model Calibration and Verification" report was reviewed by IDEM and approved for use in further alternative analysis December 2006.

### 3.2.2 Model Development

#### 3.2.2.1 Model Input Data

The model data needed for calibration is comprised of two types of data: Rainfall data and flow monitoring data. This section describes the data used in the calibration and verification of the model.

#### 3.2.2.2 Flow Monitoring Program

Seventeen area-velocity flow meters were placed within the collection system to measure flow for a six month period. Meters gathered data in the collection system from May 18, 2005 to November 22, 2005. The data were collected in 5-minute increments.

Flow meters were installed in three types of locations to assist in calibration: upstream in the system, downstream in the system and on interceptors. Table 3.2-1 shows the location of the flow meters installed in the system.

**Table 3.2.1**
**Flow Monitoring Locations**

| Meter | Location | Installation Date |
|---|---|---|
| FM01 | Intersection of 3rd Ave. and 7th St. | 18-May-05 |
| FM02 | Intersection of 8th and Elm St. | 18-May-05 |
| FM03 | Intersection of Spruce and Water St. | 23-May-05 |
| FM04 | Intersection of Mulberry St. and Water St. | 23-May-05 |
| FM05 | Just southwest of Lafayette and 4th St. | 18-May-05 |
| FM06 | Intersection of 5th and Spruce St. At ISU | 18-May-05 |
| FM07 | Intersection of Ohio and 15th. Line flowing from east to west | 4-May-05 |
| FM08 | Intersection of Ohio and 15th. Line flowing from north to south | 4-May-05 |

| Meter | Location | Installation Date |
|---|---|---|
| FM09 | On Walnut St. between 1st and 2nd St. | 18-May-05 |
| FM10 | In the parking lot of Fairbanks Park | 23-May-05 |
| FM11 | The Idaho line.  Located in the Junkyard | 23-May-05 |
| FM12 | At the intersection of Praireton and Hulman St. | 23-May-05 |
| FM13 | Intersection of 18th and Franklin St. | 18-May-05 |
| FM14 | Intersection of 15th and Park | 18-May-05 |
| FM15 | Intersection of 14th and Park | 18-May-05 |
| FM16 | On side of drive of the Main Lift Station | 23-May-05 |
| FM18 | Intersection of Turner and Dillman St. | 23-May-05 |

Upstream Meters

Flow meters that were installed significantly upstream of the interceptor and upstream of major inputs and diversion structures are referred to as "upstream meters". The upstream meters provide redundancy and a quality control check to the downstream meters. The upstream meters typically yield higher quality flow data because they are in more ideal flow metering conditions that the downstream meters (i.e. not adjacent to weirs that cause turbulent hydraulic conditions).

Downstream Meters

Flow meters that were installed downstream of all major inputs and close to the CSO diversion structures that split flow to the interceptor and to an outfall are referred to as "downstream meters". The downstream meters measure the total runoff from an entire CSO area.

The hydraulic conditions close to weirs is variable and can cause uncertainty in downstream flow monitoring data. Upstream meters were used as a tool in downstream meter calibration.

Interceptors

Flow meters were installed on the interceptor to measure the flow split between the outfall and the throttle pipe to the interceptor.

#### 3.2.2.3 Rainfall Data

The City of Terre Haute has four main rain gauges in the collection system that it uses to record rainfall. The gauges are tipping bucket type gauges that tip after collecting 0.01 inches of rain.

During the flow monitoring period, an additional three rain gauges were installed. Table 3.2-2 lists the rainfall events during the 2005 flow monitoring period.

**Table 3.2-2**
**2005 Monitored Rainfall Events**

| Date | Average Rainfall (inches) | Rainfall Range for Rain Gauges[3] (inches) | Duration (hours) | Maximum Intensity (in/hr) | No. of Dry Days Prior to Storm |
|---|---|---|---|---|---|
| 5/19/2005 | 0.56 | 0.35 - 0.86 | 1.2 | 0.85 | 3 |
| 6/12/2005[1] | 1.70 | 1.51 - 1.80 | 10.2 | 0.61 | 1 |
| 7/11/2005 | 0.55 | 0.44 - 0.74 | 8.8 | 0.35 | 24 |
| 7/21/2005[2] | 1.79 | 1.74 - 1.87 | 4.3 | 1.04 | 2 |
| 7/26/2005 | 0.50 | 0.45 - 0.56 | 3.6 | 0.38 | 4 |
| 8/12/2005 | 1.09 | 0.81 - 1.48 | 7.8 | 0.84 | 15 |
| 8/13/2005 | 0.56 | 0.46 - 0.73 | 3.3 | 0.59 | 0 |
| 8/19/2005 | 0.98 | 0.39 - 1.43 | 4.0 | 0.77 | 4 |
| 8/30/2005 | 0.42 | 0.31 - 0.51 | 11.7 | 0.13 | 2 |
| 9/19/2005 | 0.87 | 0.68 - 1.18 | 9.5 | 0.30 | 2 |
| 9/25/2005 | 1.77 | 1.55 - 2.05 | 18.1 | 0.52 | 4 |
| 9/25/2005[1] | 0.57 | 0.52 - 0.59 | 3.5 | 0.40 | 2 |

[1] Model Calibration storms

[2] Model Verification storm

[3] Rain guages from 4 City rain gauges and 3 ADS rain gauges

Each subcatchment was assigned a rain gauge for model calibration based on the Thiessen Polygon method.

### 3.2.2.4 Model Update

The XP-SWMM model was originally calibrated in 2002. The XP-SWMM model was updated in 2005. The following updates were made:

- City staff raised weirs. The weir heights were updated in the model based on measurements conducted by the City.
- 1st Street cross connections and Oak and Crawford cross connections were updated based on field investigations conducted by the City.

- CSO 002 was closed by the City and the change was reflected in the model.
- Subcatchment 003-5 was removed from the model. Initial model runs indicated that less combined sewer area contributed to combined sewer in which the flow meter was located. The area was further evaluated and it was determined that subcatchment 003-5 is likely served by separate sewers. Therefore, the subcatchment was removed and the flow meter calibrated well.

### 3.2.3 Calibration and Verification Objectives

The main objective of the model calibration was to obtain a good visual comparison of model and metered hydrographs, in terms of peak flow, total volume, peak flow rate of occurrence and shape of the hydrograph for a range of storm sizes. The goal of model calibration is for model results to meet or exceed the measured flow data to be conservative. The calibration process incorporates EPA's suggestions for model calibration along with the City's knowledge of the performance of its collection system in wet weather.

#### 3.2.3.1 Dry Weather Calibration

Dry weather flow to the CSO diversion structure is the sum of sanitary flow and infiltration. Dry weather flow was estimated based on land use and flow monitoring information. The dry weather calibration consisted of comparing the dry weather model results to the actual flow monitoring data collected. A diurnal curve was created to simulate varied flow patterns over the course of a day by evaluating a period of one month.

The dry weather inputs were adjusted until the model results approximated the metered flows. The dry weather inputs are as shown in Table 3.2-3.

**Table 3.2-3**
**Dry Weather Flow Inputs**

| Subcatchment Number | Flow Rate | Flow | Units |
|---|---|---|---|
| 003-204TN | 0.072 | 0.072 | CFS |
| 003-209TN | 0.059 | 0.059 | CFS |
| 003-210TN | 0.0243 | 0.0376 | MGD |
| 003-217TN | 0.062 | 0.062 | CFS |

| Subcatchment Number | Flow Rate | Flow | Units |
|---|---|---|---|
| 003-225TN | 0.13 | 0.13 | CFS |
| 003-226N | 0.039 | 0.039 | CFS |
| 004-061N | 0.2 | 0.2 | CFS |
| 004-102TN | 0.2 | 0.2 | CFS |
| 004-110N | 0.0035 | 0.0054 | MGD |
| 004-140TN | 0.095 | 0.095 | CFS |
| 004-245TN | 0.037 | 0.037 | CFS |
| 004-225TN | 0.036 | 0.036 | CFS |
| 004-257N | 0.093 | 0.093 | CFS |
| 004-288TN | 0.105 | 0.1625 | MGD |
| 004-290TN | 0.097 | 0.097 | CFS |
| 004-292TN | 0.064 | 0.064 | CFS |
| 004-295TN | 0.07 | 0.07 | CFS |
| 004-298TN | 0.039 | 0.039 | CFS |
| 004-332TN | 1.1 | 1.702 | MGD |
| 004-342N | 0.039 | 0.039 | CFS |
| 301IN | 0.001 | 0.001 | CFS |
| 009-092N | 0.3 | 0.3 | CFS |
| 009-312TN | 0.15 | 0.15 | CFS |
| 010-014TN | 0.1 | 0.1547 | MGD |
| 010-018N | 0.05 | 0.05 | CFS |
| 010-020N | 0.035 | 0.0542 | MGD |
| 010-021N | 0.043 | 0.043 | CFS |
| 010-033TN | 1.5 | 2.3208 | MGD |
| 010-042TN | 0.061 | 0.061 | CFS |
| 010-045N | 0.07 | 0.07 | CFS |
| 010-129N | 0.044 | 0.044 | CFS |
| 010-151TN | 0.047 | 0.047 | CFS |
| 010-236TN | 0.081 | 0.081 | CFS |
| 010-266N | 0.033 | 0.033 | CFS |
| 010-270TN | 0.047 | 0.047 | CFS |
| 010-302TN | 1 | 1 | CFS |
| 010-303TN | 0.09 | 0.1393 | MGD |
| 010-318TN | 0.09 | 0.09 | CFS |
| 010-319TN | 0.048 | 0.048 | CFS |
| 011-083N | 0.079 | 0.079 | CFS |
| 011-121N | 0.097 | 0.097 | CFS |
| 011-174TN | 0.057 | 0.057 | CFS |

| Subcatchment Number | Flow Rate | Flow | Units |
|---|---|---|---|
| 011-183TN | 0.054 | 0.054 | CFS |
| 011-190TN | 0.824 | 0.824 | CFS |
| 011-198TN | 0.0635 | 0.0982 | MGD |
| 010-171TN | 0.079 | 0.079 | CFS |
| 004/011-6N | 0.045 | 0.045 | CFS |
| 011-150N | 0.029 | 0.029 | CFS |
| 010-1N | 0.033 | 0.033 | CFS |
| 009-325TN | 0.062 | 0.062 | CFS |
| 008-100N | 0.058 | 0.058 | CFS |
| 007-160N | 0.11 | 0.11 | CFS |
| 007-120N | 0.112 | 0.112 | CFS |
| 007-5N | 0.151 | 0.151 | CFS |
| 004-338TN | 0.1 | 0.1 | CFS |
| 5/6-200N | 0.063 | 0.063 | CFS |
| 5/6-210N | 0.026 | 0.026 | CFS |
| 005/006-1N | 0.026 | 0.026 | CFS |
| 5/6-100N | 0.069 | 0.069 | CFS |
| 120IN | 0.001 | 0.001 | CFS |
| 307IN | 0.002 | 0.002 | CFS |
| 360IN | 0.001 | 0.0015 | MGD |
| 010-330TN | 0.034 | 0.0526 | MGD |
| 003-400N | 0.745 | 1.1527 | MGD |
| 007-150N | 0.017 | 0.0263 | MGD |
| 007-200N | 0.012 | 0.0186 | MGD |
| 007-152N | 0.009 | 0.009 | CFS |

### 3.2.3.2 Wet Weather Calibration and Verification Summary

The wet weather calibration consisted of running the model with rainfall data collected from selected storms and then comparing the calculated results to the actual flow monitoring data collected. The model parameters were adjusted and the process repeated until the calculated results approximated the actual flow monitor measurements. Goals for the model calibration included:

- To match model runoff volumes (volume under curve) to actual runoff volumes (calculated with flow meter data) within approximately +/- 20%

- To match model runoff peak flow rates to actual flow monitor runoff peak flow rates within approximately +/- 20%
- To match model peak flow rate time of occurrence to actual flow monitored peak flow rate time of occurrence within approximately +/- one hour

The model calibration effort consisted of calibrating runoff from CSO Service Areas 010. 009, 007, 004, 011 and 003. The areas comprise approximately 93% of the total combined sewer area.

The model calibration began with the most upstream flow meter. Once an upstream meter was calibrated, those parameters were not adjusted to calibrate downstream meters. Each CSO service area was calibrated independently. Figure 3.1-1 also shows a schematic of flow meter and rain gauge locations used in data collection for the model calibration.

The runoff from the six CSO service areas was calibrated with two storms and then the model was verified independently with one storm.

## 3.3 CS Model Calibration

The June 12, 2005 and September 28, 2005 storms were used to calibrate the model. Storm event data is shown in Table 3.2-2. The June 12th storm had an average total rainfall of 1.70 inches. The September 28th storm had an average total rainfall of 0.57 inches. The goal was to calibrate the model with two storm events with even rainfall distribution and with various total rainfalls, intensities and durations. The chosen storm events met this goal. Even rainfall distribution increases the likelihood that the rain gauge data represents the actual rainfall that occurred in the entire flow metered basin.

The rainfall from the June 12th and September 28th storm events were entered in to the XP-SWMM model. Modifications were made to percent imperviousness, subcatchment width and depression storage to obtain the desired calibration curves. The model results were compared to the actual flow monitoring data collected. The model parameters were adjusted and the process repeated until the calibrated results approximated the actual flow monitor measurements.

Table 3.3-1 shows the initial RUNOFF parameters prior to calibration and Table 3.3-2 shows the final RUNOFF parameters after calibration. An effort was made to balance the modeled response between storm events while striving to predict the meter response on the average.

## Table 3.3-1
## Initial Model Data

| CSO Service Area | Subcatchment Number | Runoff Model Point of Concentration | Combined Area (Acres) | Percent Impervious | Subcatchment Width (ft) | Overland Slope (%) | Depression Storage (in) | | Overland Mannings "n" | | Rain Gauge[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Impervious | Pervious | Impervious | Pervious | |
| 003 | 003-1 | 003-209TN | 97 | 19% | 1,117 | 0.003 | 0.058 | 0.188 | 0.014 | 0.2 | ADS1 |
| | 003-2 | 003-204TN | 105 | 45% | 1,387 | 0.003 | 0.052 | 0.187 | 0.014 | 0.2 | ADS1 |
| | 003-3 | 003-217TN | 86 | 43% | 1,341 | 0.003 | 0.056 | 0.19 | 0.014 | 0.2 | ADS1 |
| | 003-4 | 003-226N | 131 | 34% | 2,597 | 0.003 | 0.057 | 0.164 | 0.014 | 0.19 | ADS1 |
| | 003-5 | 003-225TN | 194 | 23% | 1,921 | 0.001 | 0.08 | 192 | 0.014 | 0.2 | ADS1 |
| 004/011 | 004/011-1 | 004-292TN | 124 | 37% | 1,593 | 0.008 | 0.034 | 176 | 0.014 | 0.18 | ADS3 |
| | 004/011-2 | 004-290TN | 122 | 27% | 932 | 0.003 | 0.058 | 0.2 | 0.014 | 0.2 | ADS3 |
| | 004/011-3 | 011-121N | 134 | 37% | 1,617 | 0.001 | 0.08 | 0.192 | 0.014 | 0.2 | ADS3 |
| | 004/011-4 | 004-295TN | 153 | 19% | 1,384 | 0.001 | 0.118 | 0.175 | 0.014 | 0.19 | ADS3 |
| | 004/011-5 | 011-083N | 130 | 26% | 1,088 | 0.003 | 0.056 | 0.186 | 0.014 | 0.19 | ADS3 |
| | 004/011-6 | 004/011-6N | 96 | 28% | 1,447 | 0.001 | 0.112 | 0.176 | 0.014 | 0.19 | ADS3 |
| | 004/011-7 | 004-298TN | 78 | 17% | 1,299 | 0.0004 | 0.15 | 0.182 | 0.014 | 0.2 | ADS3 |
| | 004/011-8 | 004-140TN | 166 | 17% | 1,507 | 0.004 | 0.047 | 0.187 | 0.014 | 0.2 | ADS3 |
| | 004/011-9 | 011-150N | 42 | 25% | 1,141 | 0.003 | 0.054 | 0.194 | 0.014 | 0.2 | ADS3 |
| | 004/011-10 | 004-342N | 68 | 19% | 1,407 | 0.006 | 0.04 | 0.186 | 0.014 | 0.2 | ADS3 |
| | 004/011-11 | 011-183TN | 70 | 23% | 1,264 | 0.002 | 0.073 | 0.2 | 0.014 | 0.2 | ADS3 |
| | 004/011-12 | 011-174TN | 74 | 23% | 728 | 0.003 | 0.057 | 0.2 | 0.014 | 0.2 | ADS3 |
| | 004/011-13 | 004-245TN | 72 | 30% | 1,044 | 0.001 | 0.094 | 0.179 | 0.014 | 0.2 | ADS3 |
| | 004/011-14 | 004-255TN | 49 | 30% | 1,072 | 0.002 | 0.067 | 0.194 | 0.014 | 0.2 | ADS3 |
| | 004/011-15 | 004-257N | 126 | 24% | 1,375 | 0.003 | 0.057 | 0.197 | 0.014 | 0.2 | ADS3 |
| 005/006 | 005/006-1 | 005/006-1N | 56 | 48% | 768 | 0.014 | 0.026 | 0.177 | 0.014 | 0.2 | ADS3 |
| | 005/006-2 | 5/6-210N | 29 | 56% | 358 | 0.005 | 0.041 | 0.2 | 0.014 | 0.2 | ADS3 |
| | 005/006-3 | 5/6-200N | 83 | 26% | 1,065 | 0.003 | 0.055 | 0.199 | 0.014 | 0.2 | ADS3 |
| | 005/006-4 | 5/6-100N | 103 | 50% | 1,721 | 0.012 | 0.027 | 0.187 | 0.014 | 0.2 | ADS3 |
| 007 | 007-1 | 007-160N | 117 | 65% | 1,001 | 0.003 | 0.055 | 0.198 | 0.014 | 0.2 | ADS3 |

| CSO Service Area | Subcatchment Number | Runoff Model Point of Concentration | Combined Area (Acres) | Percent Impervious | Subcatchment Width (ft) | Overland Slope (%) | Depression Storage (in) | | Overland Mannings "n" | | Rain Gauge[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Impervious | Pervious | Impervious | Pervious | |
| | 007-2 | 007-120N | 138 | 37% | 1,820 | 0.002 | 0.076 | 0.199 | 0.014 | 0.2 | ADS3 |
| | 007-3 | 004-102TN | 160 | 32% | 1,587 | 0.001 | 0.088 | 0.198 | 0.014 | 0.2 | ADS3 |
| | 007-4 | 004-061N | 200 | 36% | 2,815 | 0.005 | 0.042 | 0.191 | 0.014 | 0.2 | City6 |
| | 007-5 | 007-5N | 212 | 28% | 2,249 | 0.006 | 0.039 | 0.194 | 0.014 | 0.2 | City7 |
| | 007-6 | 004-338TN | 185 | 19% | 2,239 | 0.002 | 0.068 | 0.184 | 0.014 | 0.2 | City7 |
| | 007-7 | 007-152N | 67 | 30% | 1,217 | 0.005 | 0.043 | 0.15 | 0.014 | 0.17 | ADS3 |
| 008 | 008-1 | 008-100N | 87 | 65% | 1,647 | 0.008 | 0.034 | 0.147 | 0.014 | 0.19 | City4 |
| 009 | 009-1 | 009-325TN | 105 | 73% | 1,631 | 0.005 | 0.043 | 0.068 | 0.014 | 0.19 | City4 |
| | 009-2 | 009-312TN | 108 | 62% | 1,574 | 0.005 | 0.043 | 0.058 | 0.014 | 0.2 | City4 |
| | 009-3 | 009-092N | 109 | 42% | 1,973 | 0.003 | 0.052 | 0.187 | 0.014 | 0.2 | ADS2 |
| 010 | 010-1 | 010-1N | 80 | 34% | 1,091 | 0.002 | 0.064 | 0.141 | 0.014 | 0.19 | City4 |
| | 010-2 | 010-302TN | 150 | 23% | 1,633 | 0.005 | 0.045 | 0.181 | 0.014 | 0.2 | City4 |
| | 010-3 | 010-236TN | 108 | 31% | 1,180 | 0.002 | 0.077 | 0.196 | 0.014 | 0.2 | ADS2 |
| | 010-4 | 010-319TN | 69 | 31% | 679 | 0.003 | 0.06 | 0.192 | 0.014 | 0.2 | ADS2 |
| | 010-5 | 010-129N | 56 | 33% | 593 | 0.003 | 0.055 | 0.197 | 0.014 | 0.2 | ADS2 |
| | 010-6 | 010-318TN | 111 | 37% | 1,340 | 0.003 | 0.06 | 0.199 | 0.014 | 0.2 | ADS2 |
| | 010-7 | 010-171TN | 129 | 31% | 1,338 | 0.001 | 0.096 | 0.187 | 0.014 | 0.2 | ADS2 |
| | 010-8 | 010-270TN | 87 | 30% | 1,227 | 0.002 | 0.074 | 0.182 | 0.014 | 0.19 | ADS2 |
| | 010-9 | 010-266N | 52 | 22% | 815 | 0.002 | 0.064 | 0.19 | 0.014 | 0.2 | ADS2 |
| | 010-10 | 010-018N | 110 | 29% | 1,327 | 0.004 | 0.048 | 0.176 | 0.014 | 0.19 | ADS2 |
| | 010-11 | 010-021N | 56 | 26% | 968 | 0.003 | 0.057 | 0.2 | 0.014 | 0.2 | City6 |
| | 010-12 | 010-151TN | 60 | 24% | 939 | 0.002 | 0.064 | 0.2 | 0.014 | 0.2 | ADS2 |
| | 010-13 | 010-042TN | 96 | 23% | 991 | 0.002 | 0.064 | 0.19 | 0.014 | 0.2 | City6 |
| | 010-14 | 010-045N | 99 | 22% | 1,542 | 0.004 | 0.05 | 0.196 | 0.014 | 0.2 | City6 |

[1]Rain Guage assignments based on Thisessen Polygon Method. ADS refers to ADS rain gauge. City refers to city rain gauge.

## Table 3.3-2
## Final Model Data

| CSO Service Area | Subcatchment Number | Runoff Model Point of Concentration | Combined Area (Acres) | Percent Impervious | Subcatchment Width (ft) | Overland Slope (%) | Depression Storage (in) | | Overland Mannings "n" | | Rain Gauge[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Impervious | Pervious | Impervious | Pervious | |
| 003 | 003-1 | 003-209TN | 97 | 10% | 559 | 0.003 | 0.116 | 0.188 | 0.014 | 0.2 | ADS1 |
| | 003-2 | 003-204TN | 105 | 23% | 694 | 0.003 | 0.104 | 0.187 | 0.014 | 0.2 | ADS1 |
| | 003-3 | 003-217TN | 86 | 22% | 671 | 0.003 | 0.112 | 0.19 | 0.014 | 0.2 | ADS1 |
| | 003-4 | 003-226N | 131 | 17% | 1,299 | 0.003 | 0.114 | 0.164 | 0.014 | 0.19 | ADS1 |
| 004/011 | 004/011-1 | 004-292TN | 124 | 51% | 2,390 | 0.008 | 0.034 | 176 | 0.014 | 0.18 | ADS3 |
| | 004/011-2 | 004-290TN | 122 | 26% | 5,592 | 0.003 | 0.116 | 0.2 | 0.014 | 0.2 | ADS3 |
| | 004/011-3 | 011-121N | 134 | 51% | 2,426 | 0.001 | 0.08 | 0.192 | 0.014 | 0.2 | ADS3 |
| | 004/011-4 | 004-295TN | 153 | 26% | 2,076 | 0.001 | 0.118 | 0.175 | 0.014 | 0.19 | ADS3 |
| | 004/011-5 | 011-083N | 130 | 25% | 6,528 | 0.003 | 0.112 | 0.186 | 0.014 | 0.19 | ADS3 |
| | 004/011-6 | 004/011-6N | 96 | 39% | 2,171 | 0.001 | 0.112 | 0.176 | 0.014 | 0.19 | ADS3 |
| | 004/011-7 | 004-298TN | 78 | 17% | 7,794 | 0.0004 | 0.3 | 0.182 | 0.014 | 0.2 | ADS3 |
| | 004/011-8 | 004-140TN | 166 | 17% | 9,042 | 0.004 | 0.094 | 0.187 | 0.014 | 0.2 | ADS3 |
| | 004/011-9 | 011-150N | 42 | 50% | 2,567 | 0.003 | 0.068 | 0.194 | 0.014 | 0.2 | ADS3 |
| | 004/011-10 | 004-342N | 68 | 19% | 8,442 | 0.006 | 0.08 | 0.186 | 0.014 | 0.2 | ADS3 |
| | 004/011-11 | 011-183TN | 70 | 26% | 948 | 0.002 | 0.091 | 0.2 | 0.014 | 0.2 | ADS3 |
| | 004/011-12 | 011-174TN | 74 | 26% | 546 | 0.003 | 0.071 | 0.2 | 0.014 | 0.2 | ADS3 |
| | 004/011-13 | 004-245TN | 72 | 29% | 6,264 | 0.001 | 0.188 | 0.179 | 0.014 | 0.2 | ADS3 |
| | 004/011-14 | 004-255TN | 49 | 29% | 6,432 | 0.002 | 0.134 | 0.194 | 0.014 | 0.2 | ADS3 |
| | 004/011-15 | 004-257N | 126 | 23% | 8,250 | 0.003 | 0.114 | 0.197 | 0.014 | 0.2 | ADS3 |
| 005/006 | 005/006-1 | 005/006-1N | 56 | 48% | 768 | 0.014 | 0.026 | 0.177 | 0.014 | 0.2 | ADS3 |
| | 005/006-2 | 5/6-210N | 29 | 56% | 358 | 0.005 | 0.041 | 0.2 | 0.014 | 0.2 | ADS3 |
| | 005/006-3 | 5/6-200N | 83 | 26% | 1,065 | 0.003 | 0.055 | 0.199 | 0.014 | 0.2 | ADS3 |
| | 005/006-4 | 5/6-100N | 103 | 32% | 5,163 | 0.012 | 0.027 | 0.187 | 0.014 | 0.2 | ADS3 |
| 007 | 007-1 | 007-160N | 117 | 42% | 4,004 | 0.003 | 0.11 | 0.198 | 0.014 | 0.2 | ADS3 |

| CSO Service Area | Subcatchment Number | Runoff Model Point of Concentration | Combined Area (Acres) | Percent Impervious | Subcatchment Width (ft) | Overland Slope (%) | Depression Storage (in) | | Overland Mannings "n" | | Rain Gauge[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Impervious | Pervious | Impervious | Pervious | |
| | 007-2 | 007-120N | 138 | 24% | 7,280 | 0.002 | 0.152 | 0.199 | 0.014 | 0.2 | ADS3 |
| | 007-3 | 004-102TN | 160 | 28% | 3,333 | 0.001 | 0.11 | 0.198 | 0.014 | 0.2 | ADS3 |
| | 007-4 | 004-061N | 200 | 32% | 5,912 | 0.005 | 0.053 | 0.191 | 0.014 | 0.2 | City6 |
| | 007-5 | 007-5N | 212 | 40% | 1,687 | 0.006 | 0.098 | 0.194 | 0.014 | 0.2 | City7 |
| | 007-6 | 004-338TN | 185 | 27% | 1,679 | 0.002 | 0.068 | 0.184 | 0.014 | 0.2 | City7 |
| | 007-7 | 007-152N | 67 | 19% | 4,868 | 0.005 | 0.086 | 0.15 | 0.014 | 0.17 | ADS3 |
| 008 | 008-1 | 008-100N | 87 | 65% | 1,647 | 0.008 | 0.034 | 0.147 | 0.014 | 0.19 | City4 |
| 009 | 009-1 | 009-325TN | 105 | 61% | 6,524 | 0.005 | 0.043 | 0.068 | 0.014 | 0.19 | City4 |
| | 009-2 | 009-312TN | 108 | 51% | 7,870 | 0.005 | 0.086 | 0.058 | 0.014 | 0.2 | City4 |
| | 009-3 | 009-092N | 109 | 35% | 9,865 | 0.003 | 0.104 | 0.187 | 0.014 | 0.2 | ADS2 |
| 010 | 010-1 | 010-1N | 80 | 30% | 2,455 | 0.002 | 0.064 | 0.141 | 0.014 | 0.19 | City4 |
| | 010-2 | 010-302TN | 150 | 20% | 3,674 | 0.005 | 0.045 | 0.181 | 0.014 | 0.2 | City4 |
| | 010-3 | 010-236TN | 108 | 26% | 1,770 | 0.002 | 0.13 | 0.196 | 0.014 | 0.2 | ADS2 |
| | 010-4 | 010-319TN | 69 | 28% | 2,037 | 0.003 | 0.225 | 0.192 | 0.014 | 0.2 | ADS2 |
| | 010-5 | 010-129N | 56 | 30% | 1,779 | 0.003 | 0.206 | 0.197 | 0.014 | 0.2 | ADS2 |
| | 010-6 | 010-318TN | 111 | 34% | 4,020 | 0.003 | 0.225 | 0.199 | 0.014 | 0.2 | ADS2 |
| | 010-7 | 010-171TN | 129 | 26% | 1,967 | 0.001 | 0.162 | 0.187 | 0.014 | 0.2 | ADS2 |
| | 010-8 | 010-270TN | 87 | 25% | 1,841 | 0.002 | 0.125 | 0.182 | 0.014 | 0.19 | ADS2 |
| | 010-9 | 010-266N | 52 | 19% | 1,223 | 0.002 | 0.108 | 0.19 | 0.014 | 0.2 | ADS2 |
| | 010-10 | 010-018N | 110 | 25% | 1,991 | 0.004 | 0.081 | 0.176 | 0.014 | 0.19 | ADS2 |
| | 010-11 | 010-021N | 56 | 22% | 1,452 | 0.003 | 0.096 | 0.2 | 0.014 | 0.2 | City6 |
| | 010-12 | 010-151TN | 60 | 20% | 1,409 | 0.002 | 0.108 | 0.2 | 0.014 | 0.2 | ADS2 |
| | 010-13 | 010-042TN | 96 | 19% | 1,487 | 0.002 | 0.108 | 0.19 | 0.014 | 0.2 | City6 |
| | 010-14 | 010-045N | 99 | 19% | 2,313 | 0.004 | 0.084 | 0.196 | 0.014 | 0.2 | City6 |

[1]Rain Guage assignments based on Thisessen Polygon Method. ADS refers to ADS rain gauge. City refers to city rain gauge.

## 3.4 CS Model Verification

According to EPA Guidance on Modeling and Modeling (1999), "validation is the process of testing the calibrated model using one or more independent data set(s) of rainfall data."

After calibration, the next step consisted of using the July 21, 2005 storm as shown in Table 3.2-2, to verify the model. The July 21st storm had an average total rainfall of 1.77 inches and was chosen because of even distribution of rainfall.

The model results were compared to actual flow monitoring data collected. The validation effort resulted in a satisfactory verification. The validation proved the model calibration to be suitable for alternative evaluation.

Detailed information regarding the calibration and verification of the collection system model is provided in the "CSO Program Model Calibration and Verification Report, December 2006" that was previously submitted to IDEM and approved for alternative analysis. The complete report can be found in Appendix 3-1 of this document.