

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 sewer 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 pertain 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	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	Ip	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	Capillary
Number	AdB	Cr	EiA	EiB	Ma ³	Pt	Rg	Rn	Ip	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**

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)
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 than 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 gauges 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

¹Rain Gauge assignments based on Thiessen 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

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



City of Terre Haute, Indiana

Combined Sewer Overflow Long-Term Control Plan

HANNUM, WAGLE & CLINE ENGINEERING

3.4 CS Model Verification

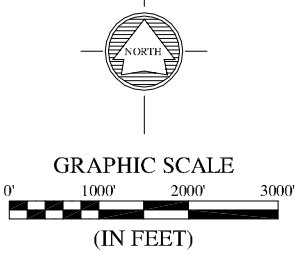
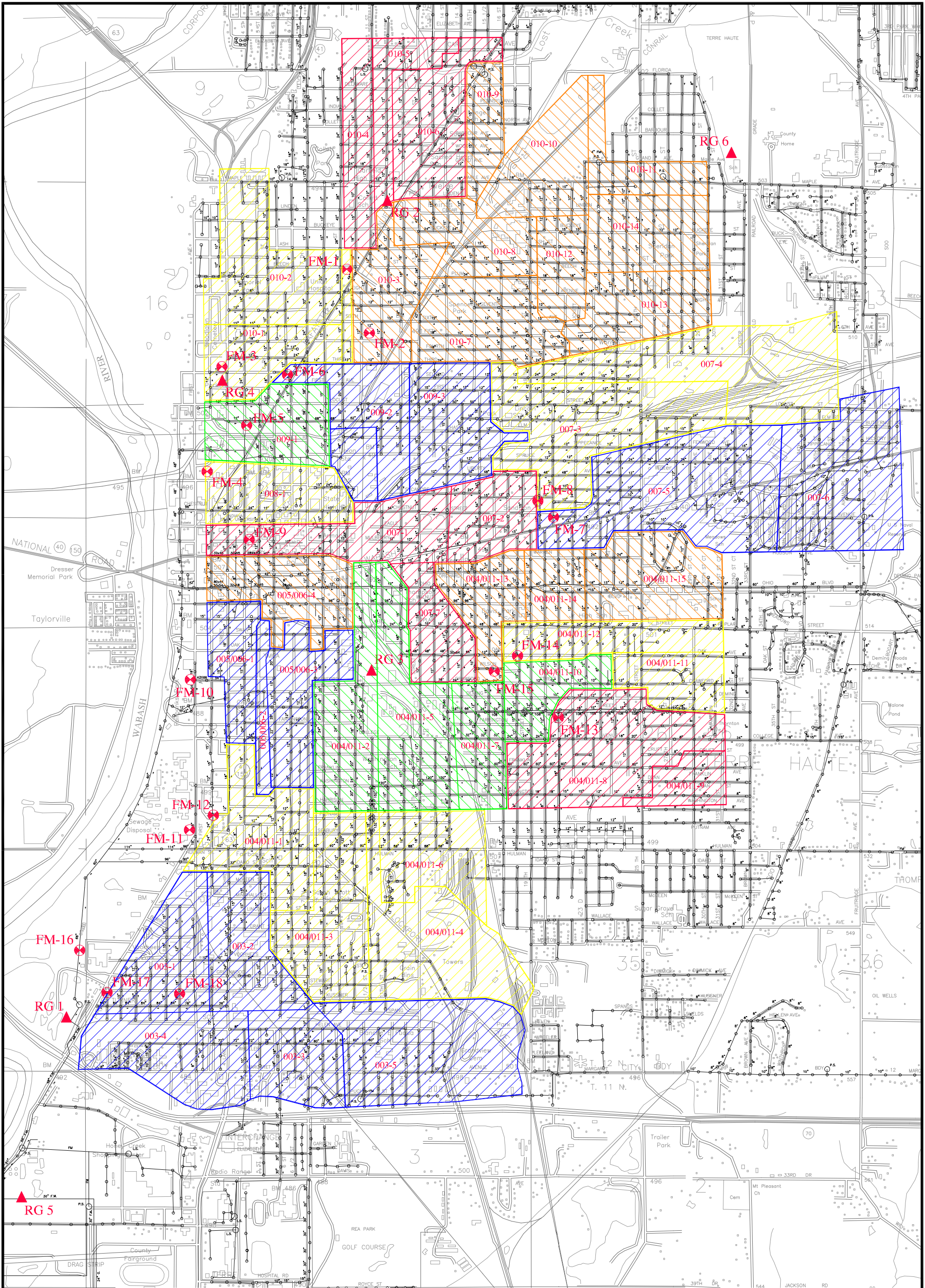
According to EPA Guidance on Modeling and Modeling (1999), “validation is the process of testing the calibrated model using one or more independent data set(s) of rainfall data.”

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.





- LEGEND
- FM-10 FLOW METER
 - RG 3 RAIN GAUGE
 - 005/006-3 SUBCATCHMENTS

FIGURE 3.1-1
CONTRIBUTING AREAS
FOR FLOW METERS
TERRE HAUTE, INDIANA

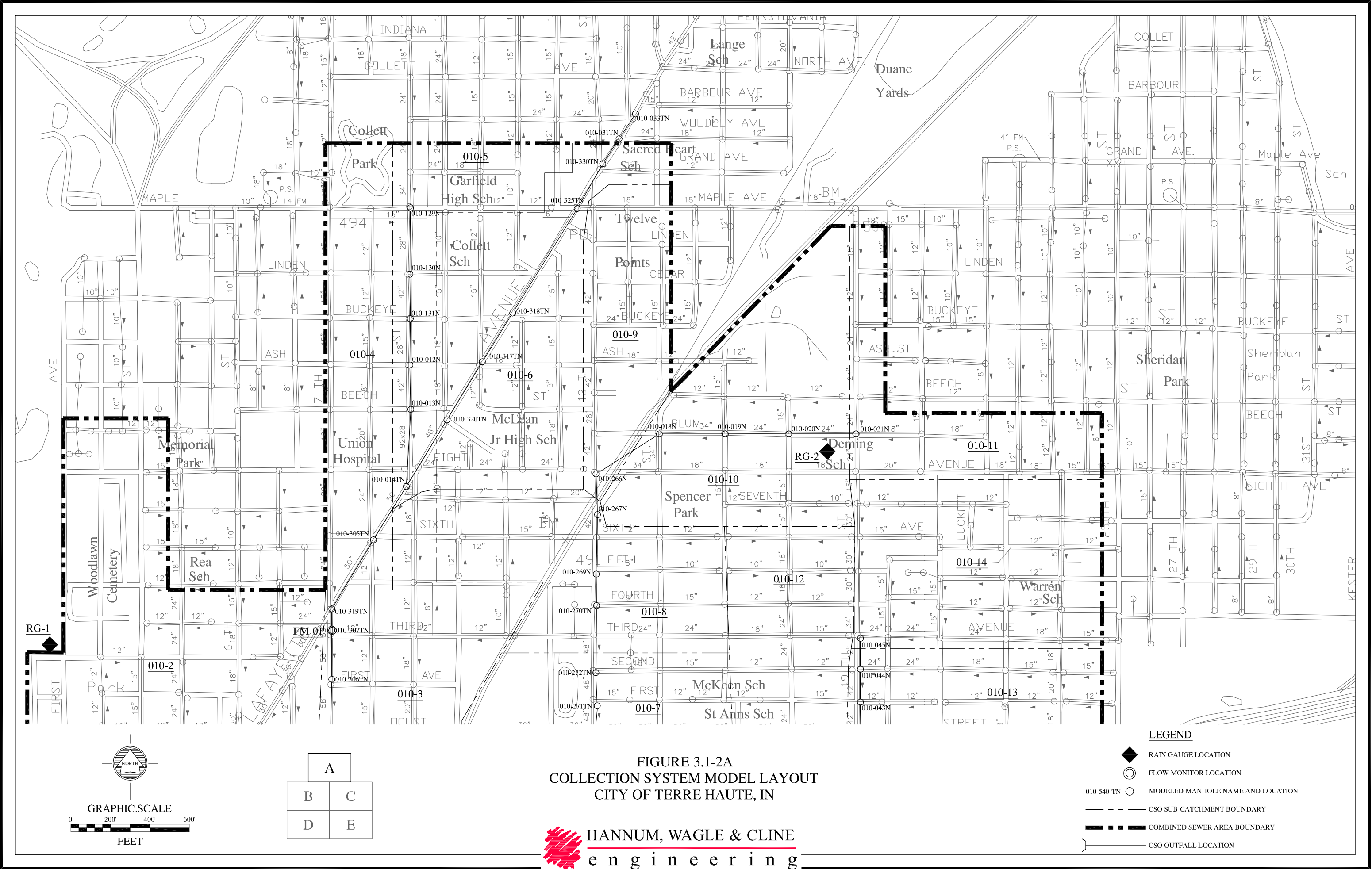


FIGURE 3.1-2A
COLLECTION SYSTEM MODEL LAYOUT
CITY OF TERRE HAUTE, IN

 **HANNUM, WAGLE & CLINE**
engineering

LEGEND

-  RAIN GAUGE LOCATION
-  FLOW MONITOR LOCATION
-  MODELED MANHOLE NAME AND LOCATION
-  CSO SUB-CATCHMENT BOUNDARY
-  COMBINED SEWER AREA BOUNDARY
-  CSO OUTFALL LOCATION

