4 Section Four – Receiving Stream Model Development

4.1 Introduction

This section presents an overview of the development, calibration and application of a river model of the Wabash River to simulate water quality in the river from upstream of the City of Terre Haute to approximately 11.5 miles downstream of the City's waste water treatment plant (Figure 4.1-1). The development, calibration and application were described previously (LimnoTech 2008b) and this memorandum has been included in this LTCP as Appendix 4-1. The water quality model provides a causal linkage between the discharge of CSO pollutants and impacts on river water quality. It provides a more complete assessment of water quality conditions than data alone by filling gaps between sampling locations and collection times and for simulating conditions under a "typical" or average year. The calibrated model also provides the capability to forecast relative improvements in water quality conditions resulting from various CSO controls (described in Section 7).

The model domain for the Wabash River extends from Vigo County at RM 217.5 downstream to RM 200.0, downstream of the City's WWTP and all of the City's CSOs. A schematic of the model is shown in Figure 4.1-1. The extent of the model domain of the Wabash River was chosen for several reasons:

- The upstream boundary of the model is upstream of the City's CSOs and will provide insight to the loads not originating from Terre Haute;
- The model domain includes Sugar Creek, a tributary to the Wabash River, which may identify another potential source of *E. coli*; and
- The model extends over fourteen miles beyond the last CSO outfall and 11.5 miles beyond the City's WWTP (at RM 211.50), which allows an assessment of the impact of the City's sources on water quality downstream of the City.

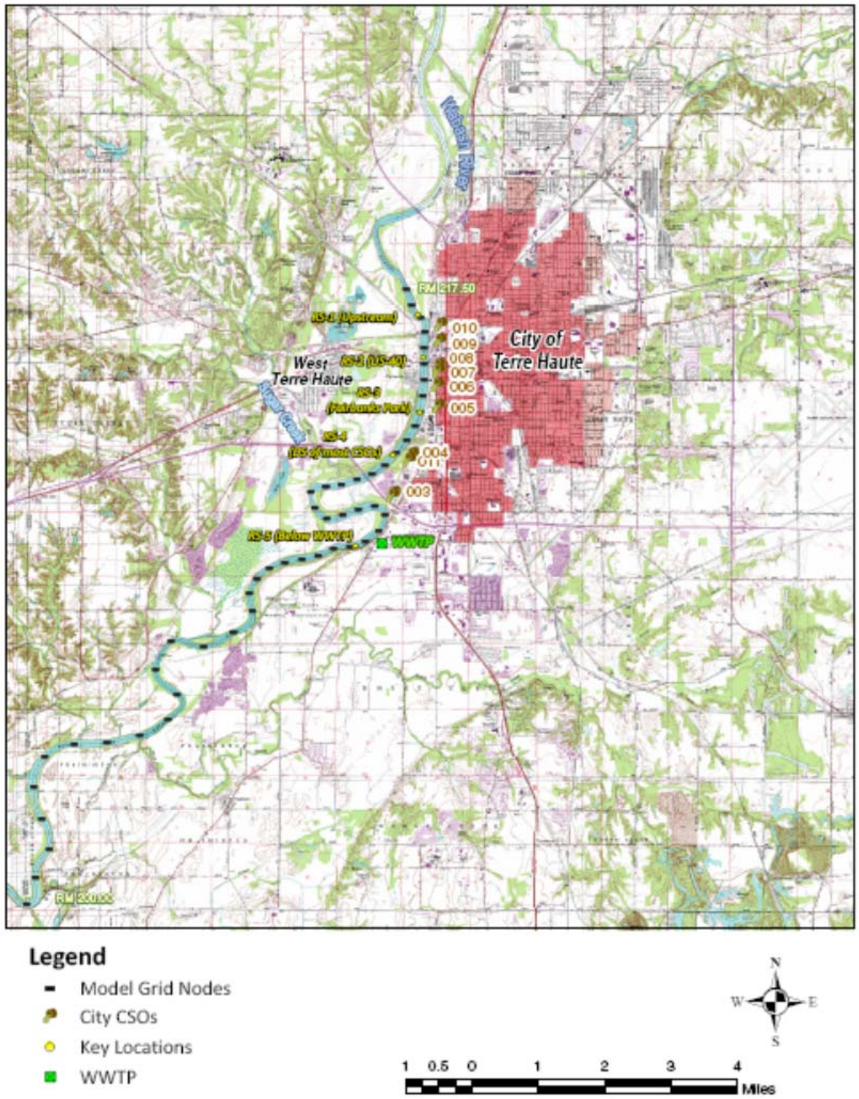


Figure 4.1-1. River Model Extent and CSO Load Inputs.

The United States Geological Survey's (USGS) Branched Lagrangian Transport Model was selected as the model to simulate water quality in the Wabash River near Terre Haute. The river model uses a moving frame of reference (Lagrangian) approach to dynamically calculate *E. coli* concentrations in the river in response to a host of time variable discharges including Terre Haute CSO, stormwater and wastewater treatment plant discharges. The model calculates the influences on each "parcel" of water as it moves through the river system, including bacteria added from the various discharges and bacterial die-off and settling. The Langrangian results are then automatically translated into time variable concentration results for each fixed location in the river. This approach provides a complex dynamic simulation of *E. coli* concentrations in the river based on a multitude of simpler calculations applied to each water parcel in the river. Other sources, including upstream (nonpoint, CSO and urban stormwater), dry weather (failing septic, straight pipe) and tributaries were also included and tracked in the model as separate state variables.

4.2 River Model Calibration and Validation

The model was calibrated to data from three wet weather events sampled by the City in 2007. The monitoring program and data are described in Section 2.4.1.2 and in the previously provided memorandum included as Appendix 2-1 (LimnoTech 2008a). The model calibration and validation was based on comparisons of model predicted concentrations to corresponding in-stream observations at each sampling location using temporal profiles, statistical analyses and sensitivities to critical model inputs (such as the *E. coli* loss rate). The calibration and validation was presented previously (LimnoTech 2008b) and this memorandum is provided in Appendix 4-1.

The calibration and validation of the river model indicates that it is capable of reproducing the timing and magnitude of most of the observed data. The model performs well for a variety of conditions, from dry weather to storms ranging from 0.2 inches up to 2.2 inches. It is suitable for evaluating in-stream impacts from Terre Haute's CSOs and watershed sources under a range of environmental conditions and control scenarios, and therefore should be sufficient for evaluating different CSO control alternatives.

4.3 Application to Characterize Baseline Conditions

The CSO Policy and subsequent EPA guidance recognizes that the annual performance of CSO controls will vary based on rainfall conditions. Long-term hourly rainfall and daily stream flow data were examined on an annual and summer (recreation season, April-October) basis, and compared to historical averages to identify 1978 as a "typical" period of rainfall and stream flow, as described in Section 2.6.3 and described in LimnoTech 2007 (Appendix 2-2). This section provides the results of the application of the river model for the selected "typical" or average year environmental conditions. This work was presented previously (LimnoTech 2008c) and is provided in Appendix 4-2. The City used the results of this scenario as a baseline to compare the effectiveness of CSO control alternatives on improving water quality in the Wabash River, as described in Section 6.

The calibrated BLTM river model was applied for the baseline simulation. External forcing (e.g. flows, bacteria loads, climate) inputs were adjusted to reflect 1978 conditions for this simulation. The calibrated collection system model was applied in a continuous simulation configuration to generate hourly estimates of CSO overflow activations, volumes and durations for input in the river model. Table 4.3-1 summarizes the overflow characteristics for each of the City's CSOs for a "typical" year. Upstream and CSO sources are the predominant sources of *E. coli* in the Wabash River (Figure 4.3-1).

Table 4.3-1
Overflow Characteristics by CSO for a Typical Year

		Total Overflow Volume (MG):	Total Hours of Overflow:	Total Number of Events:
CSO 010	Spruce	76.1	93	21
CSO 009	Chestnut	76.3	339	30
CSO 008	Ohio	12.6	131	32
CSO 007	Walnut	116.7	145	27
CSO 006	Oak	7.8	74	21
CSO 005	Crawford	15.4	145	29
CSO 004	Hulman	229.3	222	33
CSO 011	Idaho	137.1	165	29
CSO 003	Turner	18.6	90	21
Totals		690.0	362	33

CSO 002 (Main Lift Station) is an emergency overflow only with no overflows predicted in the typical year.

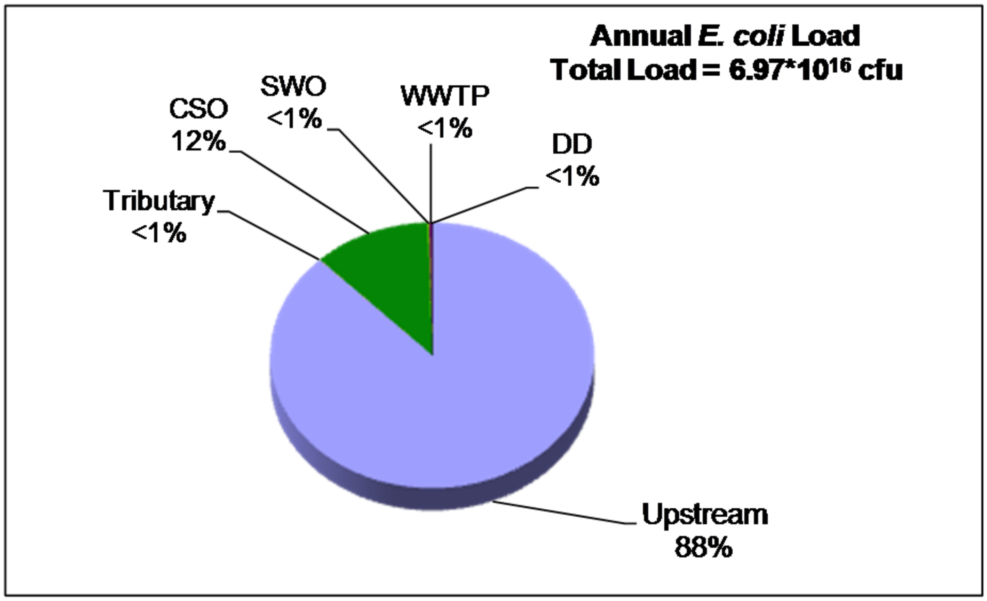
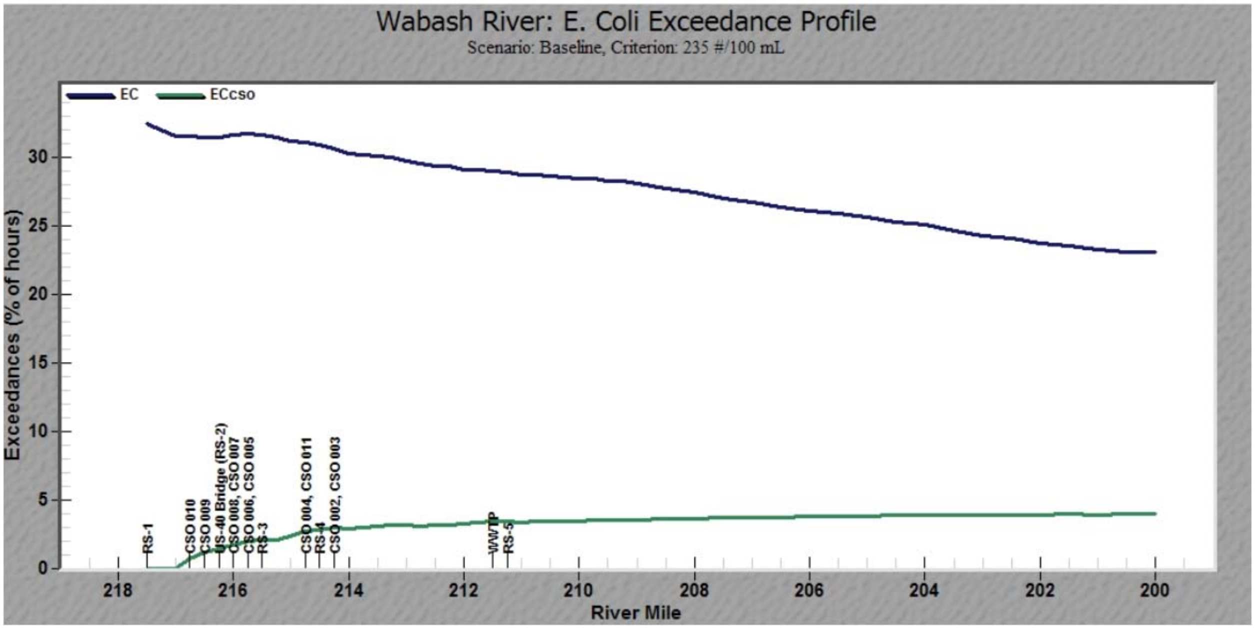


Figure 4.3-1. Annual *E. coli* Loads to the Wabash River by Source Type for a Typical Year

The model was applied with a 15-minute computation time step and hourly output frequency. The model output at each model grid node was evaluated and compared to State water quality standards for *E. coli*. Indiana water quality standards include numeric criteria for single sample and 30-day geometric mean concentrations from April through October, inclusive, to protect recreational uses. Both criteria are important when evaluating total *E. coli* results. The river exceeds the State's single sample maximum criterion approximately 30% of the time during the recreation season, as illustrated by the dark blue line in Figure 4.3-2. Terre Haute's CSOs alone cause exceedances of the single sample maximum criterion less than 5% of the time during the recreation season as illustrated by the green line in Figure 4.3-2. Compliance with the 30-day geometric mean criterion was evaluated for total *E. coli* (e.g. the sum of all source contributions). The evaluation was done using a rolling 30-day period. The river complies with this criterion approximately half of the time.



4.3-2. Downstream Profile of Exceedances of Indiana's Single Sample Maximum *E. coli* Criterion (235 cfu/100 mL).

Fairbanks Park was identified as a key location for CSO controls by the Citizens Advisory Committee. Results are shown in Table 4.3-2 at this key location as well as the locations used as sampling stations during the City's Wet Weather Sampling Program, and include a summary of all hourly outputs during the specified period that exceeded the specified criteria. Approximately one-third of the hours during the recreation season exceed the criterion, due largely to upstream source loads.

Table 4.3-2
Hours Exceeding Indiana's *E. coli* Single Sample Water Quality Standard Criterion During the Recreation Season (5,136 hours)[1]

Location	e	All Sources		Terre Haute CSOs Alone	
		hours	% hours	hours	% hours
Upstream of City CSOs	50	1621	31.6%	0	0.0%
US-40 Bridge	6.30	615	31.4%	72	4%
Fairbanks Park	5.50	1627	31.7%	04	2.0%
Downstream of CSOs 004 and 011	4.70	1588	30.9%	43	2.8%
Downstream of WWTP	21.20	1484	28.9%	174	3.4%

Notes:

[1] Defined for Recreation Season only (April-October); Single Sample Maximum Criterion = 235 cfu/100 mL

When considering the in-stream impact from the City's CSOs, the single sample maximum criterion is more restrictive than the 30-day criterion. This is because the City's CSOs are intermittent discharges and do not affect very many days within any given 30-day period. The concentration of *E. coli* in the CSO overflow is several orders of magnitude higher than the Standard's single sample maximum criterion of 235 cfu/100 ml so the resulting in-stream concentration that includes a bacteria loads from the City's CSOs is likely to exceed 235 cfu/100 ml. Therefore, the City evaluated the in-stream water quality benefits of the CSO control alternatives using the State's single sample maximum criterion.

4.3.1 River Sensitivity to Sources of E. coli

The magnitude and relative contribution of upstream and City CSO sources of E. coli, as shown in Figure 4.3-1, to compliance with the State's water quality standards were evaluated by conducting sensitivity simulations with the river model. Figure 4.3-3 shows the change in compliance with the State's single sample maximum E. coli criterion (235 cfu/100 ml) if the City's CSOs were completely eliminated. As this figure illustrates, the river will still exceed the State's criterion at least 20% of the hours in the recreation season (1,027 hours). This suggests that upstream and other sources deliver sufficient load of bacteria to the portion of the river by Terre Haute so that compliance with the State's standards would not be achieved even if the City's CSOs were completely eliminated.

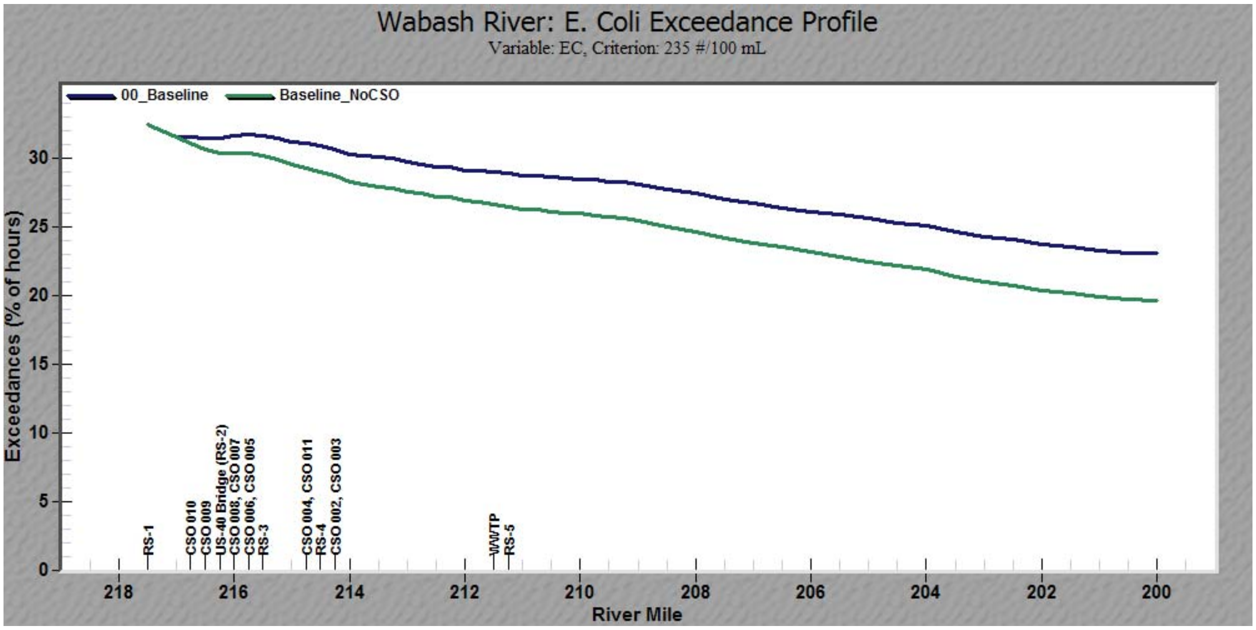


Figure 4.3-3. Downstream Profile of Exceedances of Indiana's Single Sample Maximum *E. coli* Criterion (235 cfu/100 mL) with and without the City's CSOs.