

**TRAIL CREEK WATERSHED
SEDIMENT TRANSPORT MODELING
PHASE I – SCOPING STUDY**

October 2003

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of Engineers** ®
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Executive Summary

The scope of sediment transportation concerns across the whole of the Trail Creek watershed and the development of a watershed management tools are addressed. Foundations for many of the conclusions expressed herein are supported by three major watershed hydraulics/hydrology studies and personal communications with federal, state, and local agencies: *Trail Creek/Michigan City Harbor Sediment Management Investigations* (December, 1992); *Trail Creek Watershed Management Plan* (30 September 1993), *Tail Creek Sediment Trap Study* (February 1995), personal communication MCSD, and Purdue Extension.

Project goals are the development and dissemination of a long-term control program that allows stakeholder communities to track the impact of urbanization, specifically the effects of sedimentation. Reports compiled by the USACE, USGS, and USDA provide the framework for the development of a sediment model, while the *Watershed Management Plan* provides the overall watershed guidance. Results from the USACE 1992 report deduced that 15 percent of the yearly sediment deposition in the Federal channel was derived from sources along the channel. *Trail Creek Watershed Management Plan* provides the guidance framework for rectification methods of the aforementioned “in stream” depositions.

This document provides the background material for the development of the BASINS model and HEC-6 model; which are proposed for the Trail Creek Watershed Management Model (TCWMM). Current status of the Trail Creek Watershed Management Plan implementation, ramification of the USEPA NPDES Phase II permitting, IDEM Rule 13, Michigan City Waste Treatment Plant modifications, and CSO modification are reviewed.

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Acronyms

BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
CDF	Confined Disposal Facility
cfs	Cubic Feet per Second
<i>E. Coli</i>	Escherichia coli
HEC	Hydrological Engineering Center
HSPF	Hydrological Simulation Program – FORTRAN
IDEM	Indiana Department of Environmental Management
LWD	Low Water Datum
LTMS	Long Term Management Strategy
MCSO	Michigan City Sanitary District
MS4	Municipal Separate Storm Sewer Systems
NAD27	North American Datum of 1927
NGVD	National Geodetic Vertical Datum
NIRPC	Northwestern Indiana Regional Planning Commission
NPDES	National Pollution Discharge Elimination System
NPS	Nonpoint Source
NRCS	National Resources and Conservation Service (formally SCS)
SWCD	Soil and Water Conservation District (Indiana)
TCWMM	Trail Creek Watershed Management Model
WWTP	Wastewater Treatment Plants
USACE	U.S. Army Corp of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WRDA	Water Resources Development Act

1.0 PURPOSE and OBJECTIVE

1.1 Authority

USACE authority to maintain the Federal navigation channel at Michigan City harbor is authorized by the River and Harbor Act of 1836 and subsequent amendments (1927 and 1960). Recent legislative acts under WRDA 1986 and 1996 maintain this authority. WRDA 1996 section 516(e) authorizes USACE to develop a sediment transport model for the Trail Creek Watershed.

1.2 Purpose

The purpose of this scoping study is to review the needs and scope of sediment delivery to the Federal channel portion of the Trail Creek Watershed. Prior work in this area provides the basis for this scoping study: *Trail Creek/Michigan City Harbor Sediment Management Investigations* (December, 1992); *Trail Creek Watershed Management Plan* (30 September 1993); and *Tail Creek Sediment Trap Study* (February 1995).

A watershed approach to sediment management is the scope of this document. Stakeholders in the Trail Creek watershed have expressed interest in obtaining a modeling tool which will allow them to track the effects of urbanization. Direct effect of this tributary model is the establishment of a long term management strategy (LTMS) for the Trail Creek Watershed.

1.3 Objective

This Scoping Study will provide the reader an overview of the material collected to date, and this report will outline the modeling methodologies proposed in the Trail Creek Watershed Management Models. LTMS, detailed in the 1992 and 1995 USACE reports, outlines a strategy to alleviate long-term dredging costs through the construction of a sediment trap. Since the publishing of this report NPDES Phase II regulation and various aspects of the *Trail Creek Watershed Management Plan* have been implemented. cursory review of these projects as they relate to sedimentation reduction will be reported.

Congress has given USACE authorization, WRDA Section 515(e), to utilize a watershed approach in its LTMS. Materials will be developed using EPA's BASINS model and USACE's HEC-6 model or similar models as recommended. A comprehensive report will be detailed in Phase II of the Trail Creek Watershed Management Model development. Lastly, a User's Manual will be developed and made available to the community in addition to all applicable input files.

2.0 BACKGROUND and HISTORY

2.1 Watershed Characteristics

2.1.1 Size and Description

Trail creek originates in La Porte County, Indiana, a few miles east and south of the Michigan City corporate limits. The creek is a small tributary to Lake Michigan, and drains approximately 59.1 square miles. The Federal navigation channel at Trail Creek extends from the mouth of Trail Creek at Lake Michigan to a point just below the “E” street bridge as shown in figure 1. The flow in Trail Creek is from south to north until it terminates at Lake Michigan.

2.1.2 Flow Regime

The USGS placed a stream flow gauge upstream of the Federal channel, near Springland Avenue. USGS Gauge No. 04095300 (Latitude 41°43'00", Longitude 86°51'35" NAD27) is located 584.02 feet above the NGVD (1929). Data has been recorded from June 1969, to the present. The long-term average flow for the stream is 72.6 cfs. The maximum discharge recorded was 4,240 cfs at a river elevation of 12.97 ft. The minimum discharge recorded at this point on the river was 20 cfs 01 August 1977 (USGS, 1994).

1994 USGS relocated the stream gauge (USGS Gauge No. 04095380, Latitude 41°43'22", Longitude 86°54'15" NAD27). The new location is near the Franklin Street bridge, upstream of harbor. Annual mean stream flow for period of record 2000 and 2001 are 121 cfs and 112 cfs, respectively. Maximum discharge recorded at this location on the river was 3,610 cfs at a river stage height of 3.54 feet, 01 June 2000 (USGS, 2003).

2.1.3 Land Use

Land use in the Trail Creek basin is very diverse. Approximately, 70 percent of the basin is agricultural, beginning from the source until the creek reaches the city limits. The remaining 30 percent is heavily developed, and land use is mainly urban residential and industrial.

In 1993 IDEM contracted with Triad Engineering to perform an *E. Coli* TMDL for the Trail Creek Watershed. Land use was identified by sub-watershed. The values used here are combined totals for the entire watershed. Triad only delimited land use into agricultural, forest, transitional, and developed acreages. For the sake of comparison this report shows the combined agricultural value on the Pastureland row in Table 1. Some discrepancy in values reported can be linked to institution definitions of land use terms.

Table 1 – Trail Creek Landuse

Landuse ID	USDA (1993)	Triad (2003)
Cropland	9,700 ac (28%)	See Note Below ¹
Pastureland	2,600 ac (8%)	19,631 ac (52%)
Woodland	14,300 ac (41%)	10,966 ac (29%)
Urban Land	7,400 ac (21%)	6,221 ac (17%)
Other	600 ac (2%)	845 ac (2%)
1. <i>Cropland</i> was not designated, group with <i>Pastureland</i>		

2.1.4 Soil Types

Unlike most parts of northern Indiana, which are dominated by clay-rich soils of glacial origin, soils within the Trail Creek basin are composed mostly of sand (due to its location in the Calumet Lacustrine Plain, the Valparaiso Morainal Plain, and the Kankakee Outwash Lacustrine Plain). Soils range from loose sandy soils of beach deposit and eolian (wind deposited) origin to black sandy and loamy soils of lacustrine origin. All soils within the basin are highly transmissive because of their high sand content. As a result, drainage within the basin is good despite low topographic relief.

2.2 Navigation Project

2.2.1 History of Construction

The mouth of Trail Creek was confined beginning in 1836 by construction of east and west entrance piers. These piers were subsequently extended periodically through 1869. The project was further modified during the period 1873-1885 to provide for an outer harbor immediately east of the original entrance piers. A detached breakwater was constructed in 1889. This breakwater was removed and replaced by the existing detached breakwater during the period of 1903-1904. The existing Federal project was essentially completed in 1910. The harbor channels are maintained at varying depths. Lakeward of turning basin No. 2 at Blocksom & Co., depths range from 10 to 14 feet. From turning basin No. 2 to the end of the Federal channel at the “E” Street Bridge, the depth is maintained at 6 feet, as shown in figure2. The selection of these safe navigation depths was based on the fact that the users of the channel are small recreational craft and commercial fishing boats.

2.2.2 History of Use

Deep draft waterborne commerce at the Michigan City Harbor virtually ceased in 1971. Only commercial fishing continues. Recreational boating is now the dominant use of the harbor.

2.2.3 Maintenance Dredging History

Records of dredging activities completed by the Chicago District at the Michigan City Federal Harbor and Trail Creek are show below in Table 2.

Table 2 – Trail Creek Dredging History

<u>Year</u>	<u>Volume Dredged (cu-yd)</u>	<u>Approx. Location</u>	<u>Disposal Site</u>
2002	39,750	Trail Creek	
2000	2,971	Trail Creek	Deercroft
2000	85,251	Harbor	Mt. Baldy
1996	57,658	Harbor	Mt. Baldy
1994	36,316	Trail Creek	Berm
1992	64,642	outer harbor ¹	Mt. Baldy
1990	3,000	outer harbor ¹	Mt. Baldy
1987	25,054	Trail Creek	CDF ²
1986	68,039	outer harbor ¹	Mt. Baldy
1979	29,355	turn. basin No. 2	CDF ²
1978-79	34,819	outer harbor	Lake Mich.
1978-79	22,670	Trail Creek	CDF ²
1972	5,825	outer harbor ¹	Bev. Shores
1971	24,900	outer harbor ¹	Bev. Shores
1970	45,075	outer harbor ¹	Lake Mich.

1. outer harbor is lake-side of west pier

2. CDF = confined disposal facility

2.3 Potential Sources of Sediment Contamination

2.3.1 Agricultural

Agriculture accounts for a majority of the land use along Trail Creek from its source until the creek reaches the city limits. In Michigan City land use is predominately urban residential and industrial. Runoff from agricultural land may have elevated nutrient levels, primarily nitrogen and phosphorus.

2.3.2 Industrial

The largest industry in the immediate project vicinity is the Northern Indiana Public Service Company. There are Michigan Central railroad switchyards, Tom & Blank and Blocksom & Company boat docks, and recreational boat facilities. The Michigan City Sanitary District Treatment Plant is located upstream of the Federal channel, on the south bank of the creek. Further upstream, on the north side, is the Waste, Inc. landfill,

which has been placed on the National Priority List for cleanup under the Superfund program.

Until 1989, the Anderson Company (ANCO) discharged treated effluent to a tributary that joins with Trail Creek about 1000 feet upstream of the USGS gauging station on Springland Avenue as shown in figure 3. After 1989, ANCO began sending pretreated effluent (0.3 MGD) to the Michigan City WWTP. In May 1987, IDEM conducted a compliance inspection at the ANCO industrial wastewater treatment plant. As part of this inspection, sediment samples were taken in the unnamed ditch where ANCO discharged treated effluent. A sediment sample taken at the effluent outfall showed very high concentrations of chromium (1,400 mg/kg). Chromium levels decreased to 15 mg/kg in a sediment sample taken just upstream of the confluence with Trail Creek. Effluent samples also contained high concentrations of chromium.

2.3.3 Michigan City Sanitary District

Upstream of the Federal channel, the Michigan City Sanitary District maintains their main effluent outfall and emergency bypass conduit. There is also a discharge point for the Lake Avenue storm sewer line. IDEM took sediment and water samples in October 1988, to assess impacts from the Michigan City WWTP on the creek. The locations for these samples were in the creek at the site, and upstream and downstream of the site. The contaminate levels attributed to this site during the 1988 program were found to be lower than levels previously detected in a sample composite in September 1986 by IDEM. This composite sample consisted of sediments taken from just upstream of the "E" Street bridge through about a mile upstream of this point.

2.3.4 Combined Sewer Overflow (CSO)

Sediments delivered to Trail Creek as a result of deposition from combined sewer overflows are a concern. Michigan City is in the process of separating the sanitary and storm sewer systems. There are two major CSO outfalls (48" and 96" diameter) to Trail Creek

2.3.5 Storm water runoff

IDEM considers Michigan City and Trail Creek as MS4 entities. Rule 13 (327 IAC 15-13), as it has been called, is Indiana's version of the USEPA NPDES Phase II ruling effective March 2003. The impacts that both the NPDES Phase II and Rule 13 will have on the sediment loading are speculative at this current time. Reductions in total sediment from anthropogenic sources and activities are stipulated in the permitting of MS4 facilities and smaller construction sites.

2.3.6 Landfills, CDF, and CERCLIS

Contamination of water sources by permitted disposal facilities have been addressed by previous reports (NIRPC/IDEM, 1993; USACE 1992). Confined Disposal Facility used

by the USACE to deposit contaminated dredge materials was closed and released to Michigan City in 1987. Updated material on CERCLIS sites in Trail Creek Watershed can be obtained from USEPA website:

http://www.epa.gov/enviro/html/cerclis/cerclis_query.html

2.4 Sedimentation Management Studies

2.4.1 1992 Sedimentation Study (USACE)

Discussions for a Long Term Management Strategy (LTMS), apart of the 1978 USACE Dredged Material Research Program, are outline in this 1992 document. A major focus of this document is the contamination of dredged material and its suitability for open lake disposal is questioned. Purported clean sediments upstream of the Federal channel become contaminated as they are transported through the Federal channel. Collection of sediments, in the form of a trap upstream of the contaminated area, is discussed in detail.

This reconnaissance level assessment was meant to spur further investigation. Sediment chemistry data showed elevated levels of various chemical species relative to Trail Creek. However, a majority of the sediment chemistry of the Federal channel is below State background levels. Statistically, the proposed hypothesis was correct. A note should be made that sediment chemistry data below the depth of dredge were not available at the time of publishing.

Initial sediment trap design and model computations were performed. Major sources of sediment loading were assessed; only 15% of the total sediment load was derived from the Federal channel. Speculation of sources for the sediments in the Federal channel is the MCSD WWTP and CSO outfalls. Current federal regulations on CSO and WWTP could have shifted the percent loadings within the Federal channel.

2.4.2 1993 Trail Creek Natural Resource Plan (USDA)

Developed at the request of the La Porte County Soil and Water Conservation District, the USDA SCS, in cooperation with La Porte County Soil and Water Conservation District, developed a Resource Plan for the agricultural land in the Trail Creek Watershed. Two alternative plans were formulated to meet the needs of the La Porte County Soil and Water Conservation District and fulfill their agreement with NIRPC.

Alternative 1

- Ephemeral erosion reduced by 60%
- Gully erosion reduced by 70%
- Methods
 - Conservative tillage system and land conversion
 - Grassed waterways and grade stabilization structures

Alternative 2

- Ephemeral erosion reduced by 80%
- Gully erosion reduced by 90%
- Methods
 - Application of Alternative 1 methods and,
 - Control basins

Sediment reduction, by these methods, to the harbor channel was estimated at 23 to 29%. Success of the plan is dependant on compliance of landowners. No recommendation plan was selected, and the authors indicated that success is dependant on complicity of landusers to recommendation. Further decision by sponsors and landusers was indicated.

Records of formal implementation of the above recommendation are not forthcoming. Inquiries to the SWCD and Purdue Extension Services indicate that the report was disseminated, however, beyond this no records appear to exist (Personal Communication G. Matzat).

2.4.3 1995 Trail Creek Sedimentation Trap Study (USACE)

Limited in scope, this report presents sedimentation modeling and slope stability results, related sediment sampling events, suggested concepts for construction and maintenance of a sediment trap, and optional uses of uncontaminated dredge material. The report does not detail final designs nor provide an economic feasibility of constructing such a trap. Further soil boring is requested to confirm extent of soil contamination.

2.4.4 1993 Trail Creek Watershed Management Plan

Trail Creek Watershed Management Plan (1993) is the overriding document that attempts to implement the 1992 USACE LTMS for the Trail Creek sedimentation and Michigan City Harbor dredging issues. Section 10 of the above document sets out four goals.

1. Reduce potential health hazards due to poor water quality in the stream of Trail Creek.
2. Improve aquatic life support.
3. Increase quality/quantity of recreational opportunities to stimulate economic growth.
4. Develop a public awareness of the unique and diverse opportunities that the stream of Trail Creek provides.

Each goal is subdivided into attainable objectives. Section 11 of the above document details proposed activities to achieve each of the listed goals and related objectives. Identified sources and issues such as discharge pipes, stormwater management, wetland development, sediment and nutrient control in upland watershed, streambank

protection, and stream corridor survey relate to sediment delivery to the Federal channel.

Important to Trail Creek Watershed development is coordination of activities of some twenty local, state and federal agencies. Section 14 of the *Trail Creek Watershed Management Plan* (1993) sets Michigan City, within its corporate limits, as the lead agent authority for implementation of the plan. The lead agency facilitates at the local level communication and implementation. Local authority, however, does not supercede the federal authority of USACE in maintenance of the Federal channel downstream of Trail Creek.

Michigan City Sanitary District has proposed a steering committee representing 8 different entities that would revise the 1993 management plan under a USEPA Section 319 Grant. *E. coli* and sediment are the focus of the proposed revision (Correspondence G. Matzat). IDEM records show that no 319 grants have been awarded to projects within the Trail Creek Watershed (Personal Communication, A. Henninger).

3.0 MODEL DEVELOPMENT

3.1 In-channel Sediment Transport Models

3.1.1 HEC-6

HEC-6 is a one-dimensional movable boundary open channel flow numerical model designed to simulate and predict changes in river profiles resulting from scour and/or deposition over moderate time periods (typically years, although applications to single flood events are possible). A continuous flow record is partitioned into a series of steady flows of variable discharges and durations. For each flow a water surface profile is calculated thereby providing energy slope, velocity, depth, etc. at each cross section. Potential sediment transport rates are then computed at each section. These rates, combined with the duration of the flow, permit a volumetric accounting of sediment within each reach. The amount of scour or deposition at each section is then computed and the cross section adjusted accordingly. The computations then proceed to the next flow in the sequence and the cycle is repeated beginning with the updated geometry. The sediment calculations are performed by grain size fraction thereby allowing the simulation of hydraulic sorting and armoring. Features of HEC-6 include: capability to analyze networks of streams, channel dredging, various levee and encroachment alternatives, and to use several methods for computation of sediment transport rates.

Separation of sediment deposition from the hydraulics of flow is valid in some circumstances; for example, deposition in deep reservoirs can usually be characterized as a progressive reduction in storage capacity if the material is rarely entrained once it is deposited. Prediction of sediment behavior in shallow reservoirs and most rivers, however, requires that the interactions between the flow hydraulics, sediment transport, channel roughness and related changes in boundary geometry be considered. HEC-6 is designed to incorporate these interactions into the simulation.

HEC-6 simulates the capability of a stream to transport sediment, given the yield from upstream sources. This computation of transport includes both bed and suspended load as described by Einstein's Bed-Load Function (1950)¹. A reach of river with a bed composed of the same type of sediment material as that moving in the stream is termed an "alluvial" reach (Einstein 1950). Einstein recognized that an alluvial reach provides a record of the sediment that the stream has, and does, transport. That record is reflected in the materials that form the stream boundaries. Using the hydraulic properties of the flow and the characteristics of the sediment material (which can be determined by analyzing samples of the riverbed sediment particles), one can compute the rate of sediment transport. HEC-6 implements similar concepts to compute the movement of

¹ Although Einstein's Bed-Load Function is not included in this version of HEC-6, his concepts of particle movement and interchange have guided development of the algorithms used in HEC-6 to describe the dynamic interactions between bed material composition and bed material transport.

sediment materials for a temporal sequence of flows and, through volume conservation of bed material, changes in channel dimensions. The transport, deposition, and erosion of silts and clays may also be calculated. Effects of the creation and removal of an armor layer are also simulated.

HEC-6 processes a discharge hydrograph as a sequence of steady flows of variable durations. Using continuity of sediment, changes are calculated with respect to time and distance along the study reach for the following: total sediment load, volume and gradation of sediment that is scoured or deposited, armoring of the bed surface, and the cross section elevations. In addition, sediment outflow at the downstream end of the study reach is calculated. The location and amount of material to be dredged can be obtained if desired.

(Source HEC- 6 Users Manual)

3.2 Watershed Sediment Loading Models

3.2.1 BASINS

BASINS is a multipurpose environmental analysis system for use by regional, state, and local agencies in performing watershed and water quality based studies. This new software makes it possible to quickly assess large amounts of point source and nonpoint source data in a format that is easy to use and understand. Installed on a personal computer, BASINS allows the user to assess water quality at selected stream sites or throughout an entire watershed. It is an invaluable tool that integrates environmental data, analytical tools, and modeling programs to support development of cost-effective approaches to environmental protection.

The U.S. Environmental Protection Agency's water programs and their counterparts in states and pollution control agencies are increasingly emphasizing watershed and water quality-based assessment and integrated analysis of point and nonpoint sources. **Better Assessment Science Integrating point and Nonpoint Sources (BASINS)** is a system developed to meet the needs of such agencies. It integrates a geographic information system (GIS), national watershed and meteorological data, and state-of-the-art environmental assessment and modeling tools into one convenient package.

Originally released in September 1996, BASINS addresses three objectives: (1) to facilitate examination of environmental information, (2) to provide an integrated watershed and modeling framework, and (3) to support analysis of point and nonpoint source management alternatives.

BASINS supports the development of total maximum daily loads (TMDLs), which require a watershed-based approach that integrates both point and nonpoint sources. It can support the analysis of a variety of pollutants at multiple scales, using tools that range from simple to sophisticated.

Overcoming the lack of integration, limited coordination, and time-intensive execution typical of more traditional assessment tools, BASINS makes watershed and water quality studies easier by bringing key data and analytical components together "under one roof."

Beside BASINS' primary role in creating TMDL analysis, it has been useful in identifying impaired surface waters from point and nonpoint pollution, wet weather combined sewer overflows (CSO), storm water management issues, and drinking water source protection. BASINS also has been used in urban/rural landuse evaluations, animal feeding operations, and habitat management practices. Another unexpected use of BASINS is providing schools and educational institutions with a quick, free resource of GIS and surface water data for the United States.

The heart of BASINS is its suite of interrelated components essential for performing watershed and water quality analysis. These components are grouped into several categories:

1. nationally derived environmental and GIS databases (the 48 continuous states and the District of Columbia);
2. assessment tools (TARGET, ASSESS, and DATA MINING) for evaluating water quality and point source loadings at a large or small scales;
3. utilities including local data import and management of local water quality observation data;
4. two watershed delineation tools;
5. utilities for classifying elevation (DEM), landuse, soils, and water quality data;
6. an in-stream water quality model (QUAL2E);
7. a simplified GIS based nonpoint source annual loading model (PLOAD);
8. two watershed loading and transport models (HSPF and SWAT);
9. a postprocessor (GenScn) of model data and scenario generator to visualize, analyze, and compare results from HSPF and SWAT; and
10. many mapping, graphing, and reporting formats for documentation.

BASINS' databases and assessment tools are directly integrated within an ArcView GIS environment. By using GIS, a user can fully visualize, explore, and query to bring a watershed to life. The simulation models run in a Windows environment, using data input files generated in ArcView.

3.2

(Source BASIN 3.0 Fact Sheet 2003)

3.2.2 QUAL2E

QUAL-I was initially developed by the Texas Water Development Board in the 1960s. Several improved versions of the model were developed by EPA as part of this effort, and after extensive review and testing the QUAL-II series became widely used. Present

support for the model is provided by the Environmental Protection Agency's Center for Exposure Assessment Modeling (CEAM).

QUAL2E simulates up to 15 water quality constituents in branching stream systems. The model uses a finite difference solution of the advective-dispersive mass transport and reaction equations. A stream reach is divided into a number of computational elements, and for each computational element, a hydrologic balance in terms of stream flow (e.g., m³/s), a heat balance in terms of temperature (e.g., °C), and a material balance in terms of concentration (e.g., mg/l) are written. Both advective and dispersive transport processes are considered in the material balance. Mass is gained or lost from the computational element by transport processes, wastewater discharges, and withdrawals. Mass can also be gained or lost by internal processes such as release of mass from benthic sources or biological transformations.

The program simulates changes in low conditions along the stream by computing a series of steady-state water surface profiles. The calculated stream-flow rate, velocity, cross-sectional area, and water depth serve as a basis for determining the heat and mass fluxes into and out of each computational element due to flow. Mass balance determines the concentrations of conservative minerals, coliform bacteria, and nonconservative constituents at each computational element. In addition to material fluxes, major processes included in mass balance are transformation of nutrients, algal production, benthic and carbonaceous demand, atmospheric reaeration, and the effect of these processes on the dissolved oxygen balance. QUAL2E uses chlorophyll *a* as the indicator of planktonic algae biomass. The nitrogen cycle is divided into four compartments: organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. In a similar manner, the phosphorus cycle is modeled by using two compartments. The primary internal sink of dissolved oxygen in the model is biochemical oxygen demand (BOD). The major sources of dissolved oxygen are algal photosynthesis and atmospheric reaeration.

The model is applicable to dendritic streams that are well mixed. It assumes that the major transport mechanisms, advection and dispersion, are significant only along the main direction of flow (the longitudinal axis of the stream or canal). It allows for multiple waste discharges, withdrawals, tributary flows, and incremental inflow and outflow. It also has the capability to compute required dilution flows for flow augmentation to meet any pre-specified dissolved oxygen level.

Hydraulically, QUAL2E is limited to the simulation of time periods during which both the stream flow in river basins and input waste loads are essentially constant. QUAL2E can operate as either a steady state or a quasi-dynamic model, making it a very helpful water quality-planning tool. When operated as a steady-state model, it can be used to study the impact of waste loads (magnitude, quality, and location) on in stream water quality. By operating the model dynamically, the user can study the effects of diurnal variations in meteorological data on water quality (primarily dissolved oxygen and temperature) and also can study diurnal dissolved oxygen variations due to algal growth

and respiration. However, the effects of dynamic forcing functions, such as headwater flows or point loads, cannot be modeled in QUAL2E.

(Source QUAL2E Windows Interface User's Guide, EPA/823/B/95/003)

3.2.3 HSPF

Hydrological Simulation Program - FORTRAN (HSPF) is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. This model can simulate the hydrologic, and associated water quality, processes on pervious and impervious land surfaces and in streams and well-mixed impoundments. HSPF incorporates the watershed-scale ARM and NPS models into a basin-scale analysis framework that includes fate and transport in one-dimensional stream channels. It is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions.

The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at any point in a watershed. HSPF simulates three sediment types (sand, silt, and clay) in addition to a single organic chemical and transformation products of that chemical. The transfer and reaction processes included are hydrolysis, oxidation, photolysis, biodegradation, volatilization, and sorption. Sorption is modeled as a first-order kinetic process in which the user must specify a desorption rate and an equilibrium partition coefficient for each of the three solids types.

Resuspension and settling of silts and clays (cohesive solids) are defined in terms of shear stress at the sediment water interface. The capacity of the system to transport sand at a particular flow is calculated and resuspension or settling is defined by the difference between the sand in suspension and the transport capacity. Calibration of the model requires data for each of the three solids types. Benthic exchange is modeled as sorption/desorption and deposition/scour with surficial benthic sediments. Underlying sediment and pore water are not modeled.

(Source HSPF Model System Abstract, Center for Exposure Assessment Modeling (CEAM))

3.2.4 SWAT

SWAT allows a number of different physical processes to be simulated in a watershed. These processes will be briefly summarized in this section. For modeling purposes, a watershed may be partitioned into a number of sub-watersheds or sub-basins. The use of sub-basins in a simulation is particularly beneficial when different areas of the watershed are dominated by land uses or soils different enough in properties to impact

hydrology. By partitioning the watershed into sub-basins, the user is able to relate different areas of the watershed to one another spatially.

Input information for each sub-basin is grouped or organized into the following categories: weather or climate; unique areas of land cover, soil, and management within the sub-basin (hydrologic response units or HRUs); ponds/reservoirs; groundwater; and the main channel, or reach, draining the sub-basin.

No matter what type of problem studied with SWAT, water balance is the driving force behind everything that happens in the watershed. To accurately predict the movement of pesticides, sediments or nutrients, the hydrologic cycle as simulated by the model must conform to what is happening in the watershed. Simulation of the hydrology of a watershed can be separated into two major divisions. The first division is the land phase of the hydrologic cycle. The land phase of the hydrologic cycle controls the amount of water, sediment, nutrient and pesticide loadings to the main channel in each sub-basin. The second division is the water or routing phase of the hydrologic cycle, which can be defined as the movement of water, sediments, etc. through the channel network of the watershed to the outlet.

(Source Soil and Water Assessment Tool Theoretical Documentation Version 2000)

4.0 CONCLUSIONS AND RECOMMENDATIONS

Long Term Management Strategy goals for Trail Creek have been developed and revised since the USACE 1992 report. Deliverables expected from Phase II of this work allows stakeholders an encompassing methodology to manage sediment loads and sediment delivery to the Federal channel and Lake Michigan.

It is recommended that a BASINS dataset be developed and provided to the stakeholders. Due to the complexity and volume of material, it is advisable that a workshop be given. BASINS, as a modeling environment, is user friendly, however, due to the scope of the data presented a walk through of the model environment will enfranchise our stakeholders.

HEC-6 is legacy software of the Hydrologic Engineering Center (HEC) of USACE. Stakeholder familiarity with this modeling environment might warrant either review or a separate workshop. Originally, the data provided was to analyze the design of a sediment trap within the Federal portion of Trail Creek. BASINS has the capacity to determine sediment load delivery within Trail Creek, but HEC-6 moveable boundary algorithms allow for modeling of channel modifications.

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