JUDAY CREEK
WATERSHED MANAGEMENT PLAN

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ENGINEERS
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PLANNERS

Prepared by:

Cole Associates Inc.
under contract to the
ST. JOSEPH COUNTY DRAINAGE BOARD
Providing Technical Services To The
ST. JOSEPH RIVER BASIN COMMISSION

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1.0 INTRODUCTION AND PURPOSE

The St. Joseph River Basin Commission (SJRBC) is an organization of seven counties in Indiana organized under an act of the 1988 Indiana State Legislature. It is dedicated to maintaining or improving the quality of water in the St. Joseph River Basin, of which the Juday Creek watershed is a part, for increased fisheries and recreation. The purposes of the SJRBC are to:

1. Provide a forum for discussion, study, and evaluation of water resource issues of common concern in the basin;
2. Facilitate and foster cooperative planning and coordinated management of the basin's water and related land resources;
3. Develop positions on major water source issues and serve as an advocate of the basin's interests;
4. Develop plans to improve water quality in the basin;
5. Make recommendation on matters related to its functions and objectives to political subdivisions in the basin, and to other public and private agencies.

Juday Creek, designated as a breeding brown trout (Salmo trutta) stream, is a 12-mile long waterway, which originates in the northeastern portion of St. Joseph County, and discharges into the St. Joseph River in the north central portion of the County. The 37.7-square mile watershed which lies in St. Joseph County, Indiana and Cass County, Michigan, is characterized by a mix of urban, commercial, and agricultural land use.

Researchers at the University of Notre Dame have used Juday Creek as an outdoor laboratory due to its proximity to the campus, and its transversing portions of University property. As early as 1985, researchers began to note an increased sediment load in portions of the Creek. The St. Joseph County Drainage Board increased its maintenance schedule for the sediment trap installed at the west end of the Creek, on property occupied by the Izaak Walton League. This schedule change occurred in 1988-89.

As this noticeable increase in sediment began, an increased concern over the long term impacts on the trout in the creek was realized. There is a direct correlation between increased sedimentation and reduction in benthic invertebrate populations, which serve as a food source for trout. As sedimentation within a creek increases, two changes in stream morphology occur. First, large deposits of sediment reduce the number of pools and riffled areas. These areas are important parts of the habitat for brown trout, utilized for refuge and spawning. Secondly, the transported fines settle between the coarser bed materials. Deposition of such material has a suffocating affect on the habitat utilized by invertebrates. As a result, a reduced invertebrate population has a detrimental affect on the higher orders of habitants within the Creek.

Spurred by reports of observed sedimentation increase, the SJRBC set out to measure the impacts of erosion and sedimentation on Juday Creek. In March 1991, the SJRBC submitted a proposal to the Indiana Department of Environmental Management for a Clean Water Act, Section 319 grant, to quantify the impacts of sedimentation on the invertebrate population within Juday Creek. A grant was awarded to the St. Joseph River Basin Commission in June 1992.

One goal of this project is to prepare this document, the Juday Creek Watershed Management Plan. The purpose of this plan is to:

1. Assemble the studies of the subcontractors discussed in Section 2.

2. List watershed management goals as determined by the SJRBC as part of it's project activities.

3. Present Best Management Practices (BMP's) which are best suited to achieving the watershed management goals set for Juday Creek.

4. Present a strategy of implementation of those BMP's including a discussion of the authorities and responsibilities of the various stakeholders and agencies.

2.0 PRIOR STUDIES

The St. Joseph River Basin Commission (SJRBC) has subcontracted with the University of Notre Dame, Departments of Civil Engineering and GeoScience (CE/GEOS) and Biology (BIOS). Additionally, services were subcontracted with the United States Department of Interior Geological Survey (USGS). The Indiana Department of Natural Resources Division of Soil Conservation has provided and consulted with the SJRBC on specific site issues. The St. Joseph County Drainage Board is providing technical assistance to the SJRBC on this project. The studies of CE/GEOS, BIOS, USGS. and Division of Soil Conservation are documented in reports which are included in the appendix. The information contained therein provides the basis for this watershed management plan. The scope of work of these studies is summarized below:

2.1 UNIVERSITY OF NOTRE DAME, DEPARTMENT OF CIVIL ENGINEERING AND GEOSCIENCE (CE/GEOS)

CE/GEOS was subcontracted to determine the influence which groundwaters have on the flow and quality of Juday Creek. This study involved:

1. Installation of four borings or monitoring wells at each of five locations adjacent to the creek, with depths ranging from ten to thirty-five feet;

2. Analysis of water samples from the monitoring borings or wells for temperature, chloride, bromide, pH, alkalinity, sodium and calcium. All samples analyzed, were done by laboratories with EPA approved Quality Assurance/Quality Control (QA/QC) Plans and QA/QC documentation was submitted with sample analysis results;

3. Determination of stage-discharge relationships at each of the five groundwater stations through the use of pressure transducers installed in the stream and a manually operated pygmy flow meter;

4. Measurement of monitoring well water elevations and temperature profiles on a monthly basis;

5. Production of a final report describing the results of the study.

The final report, item 5 above, is included in **Appendix A.**

2.2 UNIVERSITY OF NOTRE DAME, DEPARTMENT OF BIOLOGY (BIOS)

BIOS was subcontracted to continue studies of the aquatic fauna of Juday Creek expanding their scope to provide scientific support for urban non-point source prevention efforts in the watershed. This involved:

1. Delineation of five previously un-evaluated upstream stream reaches;

2. Identification and quantification of invertebrate specimens collected from downstream reaches in 1985-86;

3. Quarterly monitoring of invertebrate populations in downstream reaches, plus the five new upstream reaches;

4. Initial physical and biological characterization of each stream reach using the procedures outline by Plats, et al., in "Methods of Evaluating Stream, Riparian landowners, and Biotic Conditions";

5. Prediction of probable effects of changes in the Creek's thermal regime, sediment load and nutrient load;

6. Collection and identification of fish to ascertain community structure at each site;

7. Examination of fish gut contents to establish feeding preferences of each species at each monitoring site;

8. Estimation of secondary production rates of dominant invertebrate species at each site and subsequent estimation of fish populations supportable by the instream invertebrate population;

9. Evaluation of each stream reach for habitat quality and suitability for biotic habitation;

10. Comparison of historical and proposed sampling results to determine changes in the biological fauna of the stream over the past decade and, more specifically, to assess the impact of development of drainage maintenance operations along the upper portion of the stream;

11. Preparation of a report describing results and conclusions of the studies.

The report, Item 11 above, is included in **Appendix B.**

2.3 UNITED STATES DEPARTMENT OF INTERIOR GEOLOGICAL SURVEY (USGS)

USGS was subcontracted to install and operate a gage on Juday Creek. The gage was installed near the confluence of Juday Creek with the St. Joseph River. The discharge of Juday Creek at this point was measured through the water year 1993, from October, 1992 through September, 1993. Tabular and graphical representations of their measurements are included in **Appendix E.**

In addition to the above, the USGS was also subcontracted to study the characteristics, transport and yield of sediment in Juday Creek. Their draft report, produced as part of that study, is included in **Appendix C.**

2.4 INDIANA DEPARTMENT OF NATURAL RESOURCES, DIVISION OF SOIL CONSERVATION

The Indiana Department of Natural Resources, Division of Soil Conservation performed a site inspection of one reach of Juday Creek in the Northeast 1/4 of Section 32 of Clay Township in St. Joseph County along which there has been much erosion. The purpose of the investigation was to evaluate the causes of the erosion and assess possible erosion management and remediation practices. A letter reporting their findings is included in **Appendix D.**

2.5 J.F. NEW & ASSOCIATES, INC.

The St. Joseph County Drainage Board has contracted with J.F. New & Associates Inc. to investigate alternatives to existing direct stormwater discharges into Juday Creek. These alternatives would remediate detrimental impacts of those discharges such as sedimentation, nutrient loading, and thermal pollution while minimizing possible detrimental impacts of the alternatives themselves, such as thermal pollution.

The investigation is documented in a report contained in **Appendix H.** In the report twelve sites are evaluated for possible stormwater discharge remediation. Significant remediation was recommended at nine of the sites, minimal remediation was recommended at two of the sites, and no remediation was recommended at one site. At each site where remediation was recommended there exists one or more point sources, primarily storm sewer outfalls. Where more than one point source exists at a site separate remediation plans are offered for each point source, where feasible.

Significant remediation efforts proposed include one or more of the following features:

1. Sediment traps to capture sediment. These traps would require continuing maintenance (removal of accumulated sediment) on an as-needed basis.

2. Bottom discharge detention ponds to alleviate discharge of warm water to Juday Creek and as an incidental benefit provide additional sediment removal and flow velocity reduction.

3. Wetlands to remove sediment, reduce flow velocity and remove nutrients through plant uptake.

Features 2 and 3 above would expose the water to the atmosphere and solar radiation for significant periods of time which may increase warming. Shielding the water surface with vegetative cover is recommended to alleviate this. Minimal remediation efforts proposed include primarily providing vegetative cover to shield the water surface from the sun.

The investigation was conceptual in nature. Before implementing any of the proposed remediation efforts, further site specific feasibility studies and prioritization of the feasible remediation sites is recommended in the report. That prioritization will require an analysis of the benefits to Juday Creek with respect to achieving the goals set out in this plan versus the cost of implementation on a site by site basis.

2.6 LIMNO-TECH, INC.

The St. Joseph County Drainage Board also contracted with Limno-Tech, Inc. to assess potential impacts on Juday Creek resulting from a previously proposed stormwater detention basin upstream of Fir Road. The assessment was to determine if creek water temperature changes caused by the proposed ponds would exceed Indiana State standards for a salmonoid water protected for cold water fish. Their assessment is documented in a report contained in **Appendix I.**

In their study, Limno-Tech, Inc. conducted a survey of creek temperatures and flows as well as researched previous studies. Using a preliminary detention pond design provided by Cole Associates, Inc. for the St. Joseph County Drainage Board in October of 1989, Limno-Tech, Inc.

then modeled the stream under existing baseline (non storm event) conditions, baseline conditions with the proposed detention basin and storm flow conditions with the detention basin.

The findings of the study were that the proposed pond would increase water temperatures above the maximum temperatures and maximum temperature increases allowed by state standards. The proposed ponds therefore have not been constructed.

The report, completed in 1991, is very useful in that it provides additional data on stream temperatures and flows and is illustrative of the severe detrimental impacts detention ponds, if not properly designed and constructed with cool water bottom discharge and shaded linear layout, can have on stream water quality, specifically temperature.

3.0 EXISTING WATERSHED AND CREEK DESCRIPTION

3.1 DELINEATION AND PHYSICAL CHARACTERISTICS

The boundary of the Juday Creek Watershed is shown in **Figures 1 through 7.** It includes 37.7 square miles of land, with 29.7 square miles in St. Joseph County, Indiana and 8.0 square miles in Cass County, Michigan. Juday Creek proper begins in Harris Township in northeastern St. Joseph County, Indiana and runs through Harris, Penn, Portage and Clay Townships as well as the cities of South Bend and Mishawaka and the University of Notre Dame, discharging to the St. Joseph River in Clay Township. It is approximately 12 miles long and has a gradient of approximately 8 feet per mile. Its course is shown on **Figures 1 through 7.**

3.2 HYDROLOGIC AND HYDRAULIC CHARACTERISTICS

As part of this project several studies relating to the hydrology and hydraulics of Juday Creek and its watershed have been made and are included in the appendices. The findings of some of those studies relating to the hydrologic and hydraulic characteristics of Juday Creek are summarized here. The reader is referred to all of those studies for more thorough and specific information.

The findings of the University of Notre Dame, Department of Civil Engineering and GeoScience (CE/GEOS) study are summarized in the following excerption from the executive summary of their final report.

The primary conclusions derived from this study include:

(i) Where the water surface in a stream is above the groundwater table, water will flow out of the stream into the surrounding ground. The stream is said to be a losing stream where this occurs. Where the water surface in a stream is lower than the groundwater table, water will flow into the stream from the surrounding groundwater table aquifer. The stream is said to be a gaining stream where this occurs. Juday Creek is essentially a gaining stream in the upper half of the creek (with a possible exception in the area around Grape Road) and a losing stream below the lake at Lake Shore Estates with the exception of the lower half of the Isaac Walton League property near the confluence of the creek and the St. Joseph River, as shown in **Figure 6**.

(ii) During periods in which the ground is not frozen, the portion of the creek east of Lake Shore Estates is strongly driven by groundwater response to storm events. Within this region, the creek appears to buffer the groundwater response to storm events and does not show a strong signature of surface runoff. During periods in which the ground is frozen, surface runoff appears to have greater impact on the creek in terms of both flow and water quality.

(iii) Below the lake at Lake Shore Estates, the creek does not follow the groundwater response. The groundwater near the creek appeared to show a delayed response to the creek hydrograph with substantially reduced amplitude. There is evidence that chloride contamination within the creek is impacting groundwater quality at the Notre Dame property.

(iv) Groundwater in this region, that part of Juday Creek watershed near Juday Creek, appears to respond on a daily cycle to water consumption by plants. The magnitude of this response is the largest in late July and August and essentially non-existent between late September and mid-May. In the upper reaches of Juday Creek (where the creek is controlled by the groundwater), this response of groundwater is reflected in daily fluctuations in creek level. In the lower reaches of the creek, the creek does not show as strong a response to these fluctuations.

In conjunction with the above study research was performed and a masters thesis was prepared by Mr. Timothy J. Carlsen, a graduate student at the University of Notre Dame. The basis for the thesis were two hypothesis:

(1) There exists in the Juday Creek system close communication between the groundwater and the creek.

(2) Diurnal creek stage fluctuations will be present in the gaining portions of Juday creek from May through September.

The findings of this research are summarized in the following excerption from the chapter "General Conclusions" of Mr. Carlsen's thesis.

The following conclusions have been drawn with regard to the first hypothesis that there exists in the Juday creek stream system close communication between the groundwater and the creek:

- Juday Creek at the St. Joseph Farm maintains a rapid communication between the creek and the groundwater; further, the groundwater level responds to storms ahead of the creek level.

- Juday Creek gains approximately 7-9 cfs of water from the groundwater between the Prairie Lane and St. Joseph Farm stations.
- Juday Creek at the lake inflow station is gaining water from the groundwater; additionally, the groundwater and the creek respond similarly in time and water level amplitude to storm events.
- Juday Creek at the Notre Dame property site is losing water to the groundwater; further, the groundwater response to storms is lower in amplitude than the creek and delayed by approximately 12 hours.

The following conclusions have been drawn with regard to the second hypothesis that diurnal creek stage fluctuations will be present in the gaining portions of Juday Creek from May through September.

- Analysis of hydrographs shows low amplitude creek and groundwater level fluctuations with a frequency of 1 cycle/day at all monitoring stations except the Notre Dame property site where the signal is present in the groundwater, but not in the creek.
- The water level fluctuations are seasonal, emerging in the late-spring and early summer, then diminishing in the late-summer and early fall. It is suspected that the fluctuations are not present during other seasons.
- All hydrographs show the time of maximum daily water depth between 5:00 and 7:30 am, and minimum daily water levels between 4:30 and 8:00 pm.
- The creek water level fluctuations are not due to temperature-induced sediment hydraulic conductivity changes.
- The water level fluctuations originate in the groundwater and are communicated to the creek only in the creek's gaining portions.
- A good correlation exists between the daily drawdown in the groundwater and the potential evapotranspiration process. Also, the seasonality of the fluctuations correlates well to the seasonality of the evapotranspiration process.
- Evapotranspiration is the primary driver for creek and groundwater fluctuations observed along Juday Creek.

The findings of the USGS stream flow measurements of Juday Creek at its confluence with the St. Joseph River contained in **Appendix E** are summarized in the following excerption from the USGS discharge measurement tabulation.

Summary Statistics	For 1993 Water Year *	
Annual Daily Mean	27.7 CFS	
Highest Daily Mean	163 CFS	Jun 9
Lowest Daily Mean	13 CFS	Aug 9
Annual Seven-Day Minimum	14 CFS	Aug 26
Instantaneous Peak Flow	226 CFS	June 9
Instantaneous Peak Stage	3.39 FT	Jun 9
10 Percent Exceeds	39 CFS	
50 Percent Exceeds	25 CFS	
90 Percent Exceeds	16 CFS	

*October 1992 through September, 1993

The results of the USGS Study of the characteristics, transport and yield of sediment in Juday Creek relating to stream hydraulics are not summarized here because the purpose of that study was not specifically to study stream hydraulics. The same is true of stream hydraulics contained in other reports contained in the Appendix.

3.3 WATER QUALITY

As part of the study performed by the University of Notre Dame, Department of Civil Engineering and GeoScience (CE/GEOS) a total of approximately 150 samples were collected from the creek at four locations. The sampling schedules varied among the four sites. The samples were analyzed for chloride, total hardness (reported as calcium carbonate) and temperature.

The total hardness data showed a variation from approximately 160 ppm to approximately 280 ppm, with the higher values occurring later in the year. This was considered to be consistent with the stream flow being composed more of surface runoff during the spring than during the late summer.

The chloride data showed a variation from approximately 30 ppm to approximately 65 ppm, with the higher values occurring earlier in the year.

The temperature data showed a variation from approximately 35°F to approximately 70°F with the higher temperatures occurring later in the summer. Temperatures were measured simultaneously at several sites along the creek on six different dates in 1991 and 1993. With the exception of measurements made very early in the year, on March 4, 1993, these measurements showed a decrease in temperature from the most upstream site to the in-stream pond at Lake Shore Estates and an increase in temperature from the pond to the most downstream site. This was considered to be consistent with the stream gaining water from the cooler groundwater in its upper reaches and losing water to the groundwater in its lower reaches.

3.4 AQUATIC BIOLOGY

Juday Creek sustains one of the few naturally reproducing populations of brown trout (salmo trutta) in Indiana. It also harbors several other species of fish including sun fish, sculpin and creek chub.

The findings of the University of Notre Dame Department of Biological Sciences' study of the aquatic fauna of Juday Creek are summarized in the following excerption from the Conclusions & Recommendations section of its Final Report, contained in **Appendix B**. The reader is referred to that report for more thorough and specific information.

1. The benthic invertebrate densities observed in 1992-93 are at levels about 5-10% of those in 1981-82.
2. The decrease in invertebrate densities was first reported in 1989-90; since then there have been further declines in densities.
3. The 1992-93 secondary production rates of the important benthic invertebrates are at levels 1-4% of 1981-82 and as a result, the fishery supportable by Juday Creek is likely to have been similarly impacted.
4. The brown trout population has been adversely affected by the reduction in the biotic habitability of the stream.
5. The evidence suggests that the brown trout population is no longer self-sustaining.
6. The evidence supports the hypothesis that habitat destruction (by high sediment loading) is the cause of the decrease in the biotic habitability of Juday Creek

rather than some form of chemical pollution.

7. The increase in the stream sediment load appears to have begun in the mid to late 1980s and has not decreased as of 1993.
8. If erosion and sediment transport within the stream were controlled the biotic habitability of the stream could return to early 1980s level.
9. Remediation of the riparian landowners zone in the upper and middle sections of the creek could control the erosion of the stream banks and improve the temperatures of the creek water.
10. Avoid instream operations that change the geomorphology, remove woody debris, or increase erosion and sediment transport.

3.5 EXISTING LAND USE AND DEVELOPMENT HISTORY

Figure 3 shows land uses categorized as either agricultural, residential or commercial as they existed in 1982. **Figure 4** shows those land uses as they existed in September of 1992. Comparison of those figures reveals that most of the riparian landowners areas of the watershed have remained as they were with the exception of the area between Fir and Grape roads which has experienced rapid commercial and residential growth. The SJRBC has found that approximately 3,037 acres of agricultural land within the watershed, which is approximately 12% of the total watershed area, has been converted to residential, commercial, industrial or manufacturing use from 1982 to 1992.

3.6 EXISTING POINT DISCHARGES

Several point discharges, primarily storm sewers, have been located along Juday Creek. Their locations are shown on **Figure 5.** The one NPDES permitted discharge located on a tributary to Juday Creek, is from an interceptor well at a salt storage site. The remainder are storm sewers.

3.7 SUPERFUND SITE

The United States Environmental Protection Agency has identified a site with severe groundwater contamination, which is located south of Interstate 80/90, east of State Road 23 and approximately 3/8 of a mile north of Douglas Road, shown on **Figure 5.** It has been designated a "superfund" site. No remediation has been performed to date. The contamination is not known to be entering Juday Creek.

4.0 WATERSHED MANAGEMENT PLAN GOALS

4.1 GOAL DETERMINATION METHODOLOGY

In order to establish a Watershed Management Plan it is first necessary to determine to what ends the watershed is to be managed. Juday Creek means many things to and serves many purposes for many different people, businesses, and organizations. To determine what the needs and desires of the many stakeholders in the watershed were, the St. Joseph River Basin Commission (SJRBC) devised and implemented a process to ascertain those needs and desires. That process is summarized here.

Through direct mailings to parties which would probably have an interest in Juday creek, such as riparian landowners, publications in local newspapers and public meetings, the SJRBC has solicited input from many stakeholders. Some of those efforts to obtain input are briefly discussed in the following paragraphs.

On Wednesday, July 13, 1994, the SJRBC sponsored a town meeting at the Izaak Walton League, specifically to provide a forum for expression of opinions by stakeholders in Juday Creek. A summary of the comments made by the attendees is included in **Appendix J.**

On Tuesday, January 10, 1995, the SJRBC sponsored a second town meeting, this time at the St. Joseph County Francis Branch Library, to provide all interested parties an update of the progress of this planning effort. Discussions included the preliminary results of the USGS sediment transport study and a stream bank erosion remediation demonstration project planned to be constructed by the St. Joseph County Drainage Board and NUTEC Supply later in the winter or spring (weather permitting). NUTEC Supply is a vendor of erosion control and remediation materials and products. The demonstration project was to be constructed on three properties east of S.R. 23 using natural fiber (coconut) rolls and mats and plantings appropriate to the site.

On Tuesday, May 23, 1995, the SJRBC sponsored a third town meeting, again at the St. Joseph County Francis Branch Library, to provide all interested parties an opportunity to comment on the Draft Juday Creek Watershed Management Plan. The draft plan had been placed in the St. Joseph County Francis Branch Library and at the offices of the St. Joseph County

Surveyor and the Michiana Area Council of Governments (MACOG) prior to the meeting for public review. Public notice of the meeting and of the availability of the draft plan for public review had been made through direct mailing to known interested parties and by publication in local newspapers. A transcript of the town meeting is included in **Appendix K**.

Prior to the above mentioned town meting, written comments were solicited from all interested parties and public agencies. This solicitation had been made through direct mailing to certain public agencies and by publication in local newspapers. Comments received are included in **Appendix L**. This plan includes revisions made in response to those comments.

4.2 GOALS

From the efforts discussed above, the following Juday Creek Watershed Management Plans Goals have been established:

Goal 1. Preserve and improve the creek's population of brown trout and other species to 1986 levels.

Goal 2. Reduce the frequency and severity of flooding of riparian landowners' properties.

Goal 3. Eliminate stream bank erosion.

Goal 4. Prevent groundwater contamination.

Goal 5. Develop a master planning process which will address future development in the watershed.

Goal 6. Restore sediment movement in Juday Creek to natural levels based on USGS and IDNR guidance.

Goal 7. Reduce E. Coli concentrations in Juday Creek by 50% by the year 2000.

Goal 8. Strictly adhere to existing rules and regulations governing activities along the creek.

Goal 9. Establish filter strips along both sides of the creek in agricultural use areas by the year 2000 based on IDNR guidelines.

Goal 10. Preserve and protect the creek's natural wetlands at current locations, meeting or exceeding 1995 levels.

5.0 GOAL ATTAINMENT BEST MANAGEMENT PRACTICES (BMP's)

5.1 BMP DETERMINATION METHODOLOGY

Management practices which achieve specific goals in one watershed may not work or otherwise be suited to achieving those same goals in another watershed. This may be due to differences in the physical characteristics of the two watersheds or differences in the desires of the watershed stakeholders. It is necessary to determine what management practices are best suited to the Juday Creek Watershed to achieve the established goals.

As Juday Creek travels from its source to its confluence with the St. Joseph River, it passes through several areas. Each has its own character and the desires of the stakeholders vary from one area to another. For the purposes of this watershed management plan, Juday Creek is therefore divided into seven creek segments hereinafter referred to as "reaches" which are delineated on **Figure 8.** Each reach will be addressed individually. Those reaches are:

Reach 1.	Source to Fir Road
Reach 2.	Fir Road to Grape Road
Reach 3.	Grape Road to State Road 23
Reach 4.	State Road 23 to Ironwood Road
Reach 5.	Ironwood Road to Juniper Road
Reach 6.	Juniper Road to U.S. 33
Reach 7.	U.S. 33 to St. Joseph River

Reach 1: From its source to Fir Road, Juday Creek passes through primarily agricultural land. It is gaining water from the groundwater table. It receives surface runoff from adjacent farms.

Reach 2: From Fir Road to Grape Road, Juday Creek first passes through residentially developed land and then through the commercial development along Grape Road. Juday Creek continues to gain water from the groundwater table. It receives surface runoff and discharge from storm water detention ponds and runoff from roadways. It is this one reach that has seen a large change in riparian landowners' land use over the past fifteen years.

Reach 3: From Grape Road to S.R. 23, Juday Creek continues through the commercially developed Grape Road Corridor and then passes into an in-stream, man-made lake at Lake Shore Estates near the middle of this reach. This 6-acre lake has been identified as the lower extent of the groundwater gaining section of the stream as shown on **Figure 6.** From the lake downstream, Juday Creek loses water to the groundwater table. It also passes south of a U.S. EPA "Superfund" site on the east side of S.R. 23 south of Interstate 80/90, approximately 3/8 of a mile north of Juday Creek. Juday Creek then passes through an established residential development. Many riparian landowners have constructed off-line ponds adjacent and connected to Juday Creek in this area. Although Juday Creek does not flow through these ponds, they have experienced sedimentation objectionable to the riparian landowners.

Reach 4: From S.R. 23 to Ironwood Road, Juday Creek continues through established residential development. In this reach it passes under Douglas Road. Juday Creek continues to lose water to the groundwater table.

Reach 5: From Ironwood Road to Juniper Road, Juday Creek passes through undeveloped University of Notre Dame property and then through a sparse residential development. Juday Creek continues to lose water to the groundwater table through this reach. It flows under Interstate 80/90 receiving stormwater runoff from the highway.

Reach 6: From Juniper Road to U.S. 33, Juday Creek continues through established residential development and continues to lose water to the groundwater table. It again flows under Interstate 80/90 receiving runoff from the road. Near U.S. 33 it passes through an established commercial corridor.

Reach 7: From U.S. 33 to the St. Joseph River, Juday Creek continues through the established commercial corridor along U.S. 33, flows under Interstate 80/90 for the last time and then continues through established residential development. Along its lowest reach before joining the St. Joseph River, Juday Creek passes through land occupied by the Izaak Walton league which is primarily undeveloped. A short section of the creek immediately upstream of the St. Joseph River gains water from the groundwater table as shown on **Figure 6.**

5.2 BMP's

As discussed in the studies performed by the various subcontractors and documented in their reports in the appendices, the population of brown trout in Juday Creek is in imminent danger of being eliminated. It has been found that the populations of benthic invertebrates upon which the trout rely as a food source have drastically decreased in the past decade. It is believed that this is caused by changes in the aquatic habitat in which these organisms live. The most significant change in aquatic habitat has been the increase in the sedimentation of the creek bottom. To preserve the Juday Creek brown trout population, it is therefore necessary to reverse the trend of increasing sedimentation. The sediment in Juday Creek originates either as soils eroded from the Juday Creek channel or as sediment carried to Juday Creek in surface runoff, storm sewer discharges and tributary ditches and streams. Causes of increased erosion of the Juday Creek channel are basically twofold. One is increased stream flow and thence increased flow velocity and the other is defoliation of and other changes to the stream banks. The eroded materials are carried downstream and deposited on the stream bottom forming sediment.

Aside from increased chloride levels in Juday Creek following the spring snow melt and in the groundwater table at the University of Notre Dame property north of Douglas Road, no chemical contamination of Juday Creek was noted by the various subcontractors. The chloride contamination was not noted to have any detrimental impacts on the brown trout population or otherwise.

REACH 1

In the first reach of Juday Creek from its source to Fir Road, the stakeholders have expressed no concerns about problems related to the stream. It serves to drain their farm fields and control the level of the groundwater table. As a legal drain, it is maintained by the St. Joseph County Drainage Board for that purpose. A lack of stream bank vegetation and problems with bank erosion were noted. The erosion is apparently due to the lack of vegetation to hold the stream bank soils in place and the steepness of the channel banks. Best management practices that are suited to achieving the goals for Juday Creek in this reach are as follows:

1. Establish a buffer strip of vegetation along the creek. This would stabilize the stream bank soils and shade the stream. Taller more permanent vegetation such as trees providing more shading should be established on the south bank. Taller more permanent vegetation should also be established on the outside of turns in

the creek and other erosion prone areas. Suitable trees and vegetation are listed in **Appendices F & G.** Plants that should not be used are listed in **Appendix M.** Further study is required along Juday Creek to determine where buffer strips are feasible and what their widths should be. Possible incentives to riparian landowners may be investigated for buffer strip implementation along agricultural lands east of Fir Road. Such incentives may include assessment reductions for property set asides similar to assessment reductions currently made for stormwater retention basin drainage easements.

2. Establish flatter stream banks. When maintaining the channel construct a section with flatter, more stable banks such as 1 on 3 slope. Immediately stabilize disturbed soil surfaces with appropriate ground covers such as fast germinating seed mixtures and mulch. Provide additional soil erosion and bank stabilization using erosion control blankets and other material as determined appropriate based on site specific conditions.

3. Establish and maintain sediment traps at strategic points along Juday Creek.

4. Discourage further conversion of farmland to residential, commercial or other land use. This is most important for land adjacent to the creek. Zoning can be useful in this.

5. As land in this area is developed, or other land-disturbing activities are performed, the soil erosion and sedimentation control provisions of 327 IAC 15-5, Storm Water Run-Off Associated With Construction Activity should be strictly enforced by the Indiana Department of Environmental Management and the St. Joseph County Soil and Water Conservation District. Riparian landowners should implement those soil erosion and sedimentation control methods at all construction or other land-disturbing activity sites, not only those which fall under 327 IAC 15-5, Storm Water Run-Off Associated With Construction Activity jurisdiction. Local governments should determine if they have the authority to enact ordinances controlling land disturbing activities with regard to erosion and sedimentation. If they do, enactment of such ordinances and strict enforcement should be considered.

6. Insofar as land in this area is developed, limit storm event peak discharges to pre-existing flow rates. Detention and retention ponds are one method of accomplishing this. Retention ponds, which discharge to the groundwater, may be beneficial in that they fully eliminate the surface runoff and its attendant thermal pollution. They may, however, not be allowed because of possible groundwater contamination by surface runoff, particularly in developed areas, of the underlying sole source aquifer. Law and regulations pertinent to this issue should be closely monitored. Detention ponds must be carefully designed and maintained to prevent thermal pollution. Shading with trees and cool water

bottom discharge are recommended.

7. Limit or avoid use of agricultural chemicals toxic to aquatic invertebrates or fish.

REACH 2

In the second reach of Juday Creek from Fir Road to Grape Road, the stakeholders have expressed concern about increased flow rates in Juday Creek and resulting increased erosion and sedimentation. They have also expressed concern about thermal pollution. The increased flow rates and warming of the water are suspected to be the result of residential and commercial development in this area. Best management practices that are best suited to achieving the goals for Juday Creek in this reach would therefore be:

1. Establish a buffer strip to shade the creek and stabilize the banks as discussed for Reach 1 above. In residential areas, riparian landowners would forego having well manicured lawns up to the creek bank but would opt for a more "natural" setting along the creek. Recommended plantings are included in **Appendices F & G.** Plants that should not be used are listed in **Appendix M.**

2. Limit or avoid lawn care products which are toxic to aquatic invertebrates or fish.

3. As this area continues to be developed and as remedial action to alleviate impacts of existing development, stormwater detention and retention ponds are encouraged. Retention ponds, which discharge to the groundwater, may be beneficial in that they fully eliminate the surface runoff and its attendant thermal pollution. They may, however, not be allowed because of possible groundwater contamination by surface runoff, particularly in developed areas, of the underlying sole source aquifer. Law and regulations pertinent to this issue should be closely monitored. Detention ponds must be carefully designed and maintained to prevent thermal pollution. Shading with trees and cool water bottom discharge are recommended.

4. As this area continues to be developed, strictly enforce the soil erosion and sedimentation control provisions of 327 IAC 15-5, Storm Water Run-Off Associated With Construction Activity. Implement those soil erosion and sedimentation control methods at all construction or other land disturbing activity sites, not only those which fall under 327 IAC 15-5, Storm Water Run-Off Associated With Construction Activity jurisdiction.

5. Extension of the sanitary sewer system throughout the Winding Brook Park residential subdivision should be encouraged to eliminate problems associated with the septic systems in this area.

REACH 3

In the third reach of Juday Creek from Grape Road to S.R. 23, the stakeholders have expressed concern about increased flow rates in Juday Creek and resulting increased erosion and sedimentation. They have also expressed concern about thermal pollution. As with Reach 2 above, these are suspected to result from residential and commercial development.

Riparian landowners in this reach have also expressed concern about their backyard ponds adjacent and connected to Juday Creek which are collecting sediment from the creek. Riparian landowners have also expressed concern about stream bank erosion. In addition, the U.S. EPA "superfund" site lies approximately 3/8 of a mile north of the creek in this area. Best management practices 1 through 4 discussed for Reach 2 above are also applicable to this reach, as well as the following measures:

1. Excavation of steep erosive stream banks to a gentler less erosion susceptible 1 on 2 or 1 on 3 slope with subsequent soil stabilization and planting of buffer strip vegetation.

2. Cleanup of the EPA "Superfund" site should be completed. It should be funded as soon as possible to prevent the vinyl chlorides found in the groundwater at the site from entering the creek.

3. Remediate existing storm sewer discharges as recommended in the report by J.F. New & Associates contained in **Appendix H.**

4. Stabilize eroded stream banks using site appropriate vegetation and ecological stabilization technology.

REACH 4

In the fourth reach of Juday Creek, from S.R. 23 to Ironwood Road, the concerns expressed by the stakeholders are the same as those for the third reach discussed above. These include increased flow rates and thermal pollution. Best management practices 1 through 4 discussed for Reach 2 above and Nos. 1, 3 & 4 discussed for Reach 3 above are also applicable to this reach.

REACH 5

In the fifth reach of Juday Creek, from Ironwood Road to Juniper Road, the stakeholders expressed no specific concerns about the stream. As this is a primarily residential and undeveloped area, the best management practices 1 through 4 discussed for Reach 2 above and No. 3 discussed for Reach 3 above apply. In addition, where Juday Creek flows under Interstate 80/90, contamination of Juday Creek from road salt and possible spills of substances harmful to brown trout and the benthic invertebrates upon which they feed are of concern. When spills occur, immediate implementation of contamination containment and remediation plans is essential.

REACHES 6 AND 7

In the sixth and seventh reaches from Juniper Road to U.S. 33 and from U.S. 33 to the St. Joseph River, respectively, the stakeholders expressed concern with flooding of basements from increased groundwater tables after rainfall events. As discussed in the University of Notre Dame, Department of Civil Engineering and GeoScience Final Report, included in **Appendix A,** these floods occur in an area where Juday Creek is losing water to the groundwater table. Efforts such as installation of detention and retention ponds to control the response of the creek to rainfall events and hence the response of the groundwater table may be effective, but cannot be reliably analyzed. Again the best management practices 1 through 4 discussed for Reach 2 above and No. 3 discussed for Reach 3 above are best suited here. Since Juday Creek flows under Interstate 80/90 twice and under U.S. 33 once in these two reaches, the need for contamination containment and remediation discussed for Reach 5 above applies here as well.

6.0 GOAL ATTAINMENT STRATEGIES

To attain the goals set forth in Chapter 4 herein, the best management practices discussed in Chapter 5 should be implemented. This will require a coordinated effort on the part of the individuals, organizations and agencies responsible for that implementation. The St. Joseph County Drainage Board should be the lead agency in that effort. It should continue existing informational and educational programs through the St. Joseph River Basin Commission (SJRBC) as well as initiate new ones necessary to inform the various individuals, governmental agencies and organizations of what each needs to do and how it can best be done. The Board will have ultimate responsibility for continual monitoring of plan goals and BMP selection and implementation to achieve those goals, revising those goals, BMP selections and implementation methods as found necessary.

It is recommended that a joint task force be created comprised of technical staff from the several governmental agencies, private organizations and individuals having an interest in Juday Creek and its watershed management. This task force would serve to provide the St. Joseph County Drainage Board with technical advice regarding watershed management issues. It would also serve as a forum for the expression of the concerns and needs of these entities and governmental units.

It is suggested that the task force consist of 8 or 9 individuals; possibly including a developer, a biologist, a St. Joseph County Soil and Water Conservation District representative, a representative of the Izaak Walton League, representatives of riparian landowner organizations and other interested parties. Governmental units and agencies which might be represented include the cities of South Bend and Mishawaka, St. Joseph County Drainage Board, St. Joseph County Health Department and the Michiana Area Council of Governments. This task force would aid the St. Joseph County Drainage Board in its continuing efforts to select and implement BMP's and monitor goals. Details of the functioning of the task force, such as meeting place and schedule, could be established by the St. Joseph County Drainage Board in consultation with the various groups represented.

6.1 IMPLEMENTATION OF BMP'S

The strategy for the implementation of the BMP's determined best suited for achieving the goals set herein for Juday Creek includes:

1. The St. Joseph County Drainage Board will distribute this plan to the various governmental units and other individuals and organizations which may have roles to play in its implementation. It will also make the plan available to the public by placing it in public libraries and other places where the public may have access to it. It will inform the public of its availability through the news media and direct correspondence.
2. The St. Joseph County Drainage Board will initiate the formation of the joint task force by contacting the various governmental units and their agencies and soliciting their participation in the formation. It will coordinate that formation.
3. The St. Joseph County Drainage Board will oversee the activities of the various role players providing initiative, guidance and assistance as needed. The joint task force will make recommendations to the St. Joseph County Drainage Board.
4. The St. Joseph County Drainage Board will aid the various role players in their efforts where possible, one way of which may be the financial support it may be able to lend by distributing funds it has available which can be used to implement BMP's. One source of such funding may be grants issued by the United States Environmental Protection Agency under Section 319 of the Clean Water Act. The Indiana Department of Environmental Management is the administrator of Section 319 grants in Indiana.

The SJRBC, as part of its Section 319 grant application process, has developed an implementation plan and schedule. That plan is summarized on the following excerption from its Section 319 grant application. Tasks listed therein are explained on the following sections of this plan.

Work Plan of Activities for Project

FROM DATE	TO DATE	TASKS TO BE COMPLETED
July 1, 1995	September 30, 1995	•Hold public meeting announcing receipt of grant, and objectives of project; •Identify monitoring sites; Solicit volunteer observers; Hold informational meeting session for observers; •Install "monitoring poles"; •Begin voluntary monitoring program (to continue throughout project);
October 1, 1995	December 31, 1995	•St. Joseph Co. Drainage Board begins prioritizing sites for BMP installation; Begin BMP construction; •MACOG begins work on informational packet •Complete article for inclusion in neighborhood newsletters
January 1, 1996	January 31, 1996	•Continue work on informational packet;

FROM DATE	TO DATE	TASKS TO BE COMPLETED
February 1, 1996	March 31, 1996	•Begin planning of first field day focusing on BMP's installed by Drainage Board; •Voluntary monitoring continues; •Meet with volunteers to discuss problems, share information, etc. •BMP installation continues; •Plan informational workshop related to cost-share project. •Complete article for submission in neighborhood newsletter.
April 1, 1996	April 30, 1996	•BMP installations continue; •Voluntary monitoring continues; •Complete informational packet; Mailing of packets; •Information workshop related to cost-share project; Solicit cost-share project cooperators;
May 1, 1996	July 31, 1996	•BMP installations continue; •Homeowner BMP's begin; •Drainage Board-installed BMP's field day; •Meet with volunteer observers;
August 1, 1996	October 31, 1996	•Volunteer monitoring continues; •Observation of BMP progress; •Submit article for neighborhood newsletters;

FROM DATE	TO DATE	TASKS TO BE COMPLETED
November 1, 1996	December 31, 1996	•Volunteer monitoring continues; •Plan spring BMP field day;
January 1, 1997	January 31, 1997	•Voluntary monitoring continues;
April 1, 1997	May 31, 1997	•Complete production of PSA; •Develop evaluation questionnaire; •Begin conducting door-to-door evaluation; •Conduct residential BMP field day;
June 1, 1997	June 30, 1997	•Voluntary monitoring to continue. •Complete evaluation survey; •Completion of project summary.

6.2 GOVERNMENTAL UNITS AUTHORITIES, ROLES AND RESPONSIBILITIES

This plan or any of the other activities of the SJRBC does not have the effect of law. No individuals, organizations or governmental units are required by law to take actions as recommended herein. The purpose of this plan is to provide a framework for a coordinated effort on the part of all the individuals, agencies, etc. to achieve the goals which they, as a part of this planning effort, have established. As part of the implementation of this plan, the many governmental units and their agencies which do have authority by law to act and to require action by others should consider this plan and act and require action by others as recommended herein.

Following is a list of various governmental units and their authorities, roles and responsibilities.

6.2.1 ST. JOSEPH RIVER BASIN COMMISSION

The SJRBC has no legal authority to require action or to otherwise regulate the actions of individuals, organizations or governmental units. It is not a riparian landowner to Juday Creek and therefore has no riparian landowners rights. Its role is administrative and advisory. Its general responsibilities are discussed above.

Contingent upon funding availability, the SJRBC will implement a cost-share program to encourage riparian landowners to install BMP's. It will conduct a BMP training workshop and fund a part of the riparian landowners' BMP installation costs. The SJRBC, in cooperation with volunteer riparian landowners will monitor the sediment depth on the Juday Creek bottom. It will also conduct photographic surveys of the creek before, during and after BMP installation.

The SJRBC will continue its public outreach program as described in the following excerpt from its Section 319 grant application.

The public awareness program will include a workshop, two (2) field days, the development and production of a 30 second video public service announcement (PSA) focusing on the impacts of riparian landowners non-point source (NPS) activities, and the design and production of an informational packet for riparian landowners property owners. The workshop and demonstrations will be publicized by the local media.

One field day which focuses on display of best management practices during the cost-share program, will be conducted to encourage riparian landowners to install NPS pollution

BMP's.

Another field day will be held to demonstrate the BMP's installed by the St. Joseph County Drainage Board. The target audience for this field day will be state, federal and local agencies including surveyors, engineers, Drainage Boards, SCS, SWCD, Army Corps staff and Plan Commissions, throughout the St. Joseph River Basin.

The informational packet will be designed and produced to educate riparian landowners on issues dealing with NPS pollution and possible solutions. The packet will provide reference information for permit requirements in a floodway, septic maintenance, etc.

The MACOG will continue to contribute informational articles in their dedicated column in the Friends of Juday Creek newsletter "The Creekside". The MACOG has also identified two other neighborhood groups within the riparian landowners portion of the watershed, that produce newsletters. The MACOG will also use these documents as forums for outreach and informational dissemination. Requests to share information about the Creek will also be honored by the MACOG.

A door-to-door survey of the riparian landowners will be conducted to measure the effectiveness of the public outreach program. A questionnaire will be developed to determine individual's awareness of the NPS pollution campaign and the willingness of the landowners to include BMP's in future property improvements.

6.2.2 INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

The Indiana Department of Environmental Management (IDEM) has the responsibility to enforce the soil erosion and sedimentation control provisions of 327 IAC 15-5, Storm Water Run-Off Associated With Construction Activity. It should strictly do so. IDEM also has the responsibility of regulating public wastewater treatment and disposal and is the state agency with the responsibility of issuing National Pollution Discharge Elimination System (NPDES) Permits.

The Indiana Department of Environmental Management, Nonpoint Source Section runs a nonregulatory water management program which administers the Section 319 grants program for implementation of nonpoint source pollution controls.

6.2.3 ST. JOSEPH COUNTY DRAINAGE BOARD

Juday Creek is a legal drain and as such, an annual maintenance fund is collected by St. Joseph County to maintain Juday Creek for drainage purposes as may benefit or be in the best interest of the people of its watershed. The Drainage Board has rights of ingress and egress and may, at its discretion, conduct activities in and adjacent to the creek as may be necessary for its maintenance.

The St. Joseph County Drainage Board will continue to provide technical support. It may also provide financial support in the form of BMP installations such as bank stabilization and sediment traps. Such financial support may be funded by disbursements from the annual maintenance fund. The St. Joseph County Drainage Board will also regulate the activities of others insofar as it has authority to do so under law to assure that the goals of this plan are achieved.

6.2.4 CITY OF SOUTH BEND and

6.2.5 CITY OF MISHAWAKA and

6.2.6 ST. JOSEPH COUNTY

The cities of South Bend and Mishawaka, as well as St. Joseph County, through their zoning ordinances, have the responsibility to regulate land use and development, setting minimal requirements for new developments. The cities and the county in cooperation with the SJRBC and the St. Joseph County Drainage Board should set minimum requirements for prevention of sediment entering Juday Creek and limitation of peak stormwater runoff discharges to Juday Creek.

The cities and the county are also riparian landowners to Juday Creek in that public roads and other lands owned or under the jurisdiction of the cities and county abut Juday Creek. They can therefore take the same actions as other riparian landowners such as installing bank stabilization and other BMP's, complying with 327 IAC 15-5, Storm Water Run-Off Associated With Construction Activity and voluntarily implementing its provisions where, due to size of project, 327 IAC 15-5, Storm Water Run-Off Associated With Construction Activity may not apply.

6.2.7 ST. JOSEPH COUNTY PUBLIC HEALTH DEPARTMENT

The St. Joseph County Public Health Department has the authority and responsibility to regulate on-site wastewater disposal systems (septic systems) to assure that the public health and safety is not endangered. The Public Health Department should monitor the concentrations of e-coli and other water contamination indicators to determine if and where existing septic systems are not functioning properly in that their discharge is entering Juday Creek. Where necessary, remedial action should be required by the Public Health Department. The department should also continue its efforts to prevent future public health risks through its septic system construction permitting program, denying permits for systems which, due to poor soil types, high groundwater table or other reasons are likely to pollute Juday Creek.

6.2.8 UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

The USEPA has the authority and responsibility to identify and remediate (cleanup) sites of very large contamination. The sites are generally known as "superfund" sites. The USEPA should implement a remediation program at the one identified "superfund" site in the Juday Creek watershed.

The USEPA, under the Clean Water Act, has the authority and responsibility to monitor and, through Section 319 Grant Program, fund non point source pollution education programs. The USEPA should continue in its efforts to remediate NPS pollution of Juday Creek by granting additional funds for this purpose to the SJRBC. It should also continue monitoring the progress of the SJRBC to assure that the money is well spent and the goals of this plan are achieved.

6.2.9 INDIANA DEPARTMENT OF NATURAL RESOURCES

The Indiana Department of Natural Resources (IDNR) has the authority to regulate flood control works in surface waters of the state under their jurisdiction. Any such work, such as dams, must be approved by the Natural Resource Commission. Construction within the floodway of a river or stream must be permitted by IDNR. In its regulatory and permitting functions, the IDNR should take into consideration the goals discussed in this plan and, within its authority under the law, require that any activities which fall within its jurisdiction comply with the recommendations of this plan and otherwise serve to attain the goals of this plan.

The IDNR Division of Fish & Wildlife is responsible for the protection, management, control and enhancement of all non-domestic fish and wildlife. The Division of Fish & Wildlife should closely monitor the condition of the brown trout in Juday Creek and take action, within its authority under the law, to preserve and improve the brown trout population of Juday Creek.

The IDNR, Division of Soil Conservation has responsibility to provide technical assistance and educational programs to enable operators and/or contractors to comply with the requirements of 327 IAC 15-5, Storm Water Run-Off Associated with Construction Activity.

6.2.10 UNITED STATES DEPARTMENT OF THE ARMY, CORPS OF ENGINEERS

The United States Department of the Army, Corps of Engineers (COE) has the authority to regulate the dredging and filling of inland waters and wetlands. Any such activity must be reviewed by the COE and a permit obtained. The COE should take into consideration the goals discussed in this plan and, within its authority under the law, require that any activities that fall within its jurisdiction comply with the recommendations of this plan and otherwise serve to attain the goals of this plan.

6.2.11 INDIANA STATE BOARD OF HEALTH

The Indiana State Board of Health has the authority to regulate discharges from on-site wastewater disposal systems, such as home septic systems. It also has the authority to regulate discharges from other sources, such as swimming pools, into Juday Creek. The Indiana State Board of Health should monitor the water quality of Juday Creek, specifically for the presence of E. Coli and other indicators of contamination from failed or malfunctioning on-site wastewater disposal systems. When such indicators are found, it should determine their source and take appropriate action, under it's authority under the law, to protect the public health and safety and to attain the goals of this plan. The Indiana State Board of Health should act similarly with respect to direct discharges from other sources, such as swimming pools, acting to attain the goals of this plan to the greatest extent possible within it's authority under the law.

6.2.12 ST. JOSEPH COUNTY SOIL AND WATER CONSERVATION DISTRICT

The St. Joseph County Soil and Water Conservation District has the responsibility to review and evaluate each erosion control plan submitted in accordance with 327 IAC 15-5, Storm Water Run-Off Associated With Construction Activity and provide technical assistance for implementing the soil erosion control plan. It is also a source of technical assistance for on-site planning and implementation of BMP's. The St. Joseph County Soil and Water Conservation District should continue fulfilling it's responsibilities under 327 IAC 15-5, Storm Water Run-Off Associated With Construction Activity. When providing technical assistance, that assistance should guide persons receiving the assistance toward actions which will help to achieve the goals of this plan.

6.3 RIPARIAN LANDOWNERS' ROLES AND RESPONSIBILITIES

The riparian landowners of Juday Creek are the most important role players in this plan. By virtue of their ownership of land along Juday Creek they have the authority and right to do many things that could benefit Juday Creek or harm it.

Their role in this plan is to practice good stewardship of the land and creek as recommended in this plan. Specific actions that they may take, either in coordination with the SJRBC or on their own are:

1. Leave or install a buffer strip of appropriate vegetation along Juday Creek. Forego having a well manicured lawn up to the creek bank. Opt for a more "natural" setting.

2. Limit or avoid use of lawn care chemicals toxic to aquatic invertebrates or fish.

3. Limit or avoid land disturbing activities which may result in runoff of sediment laden water into Juday Creek. Where these activities are necessary, implement appropriate soil erosion and sedimentation control practices such as installing sediment traps or sediment fencing where runoff from the construction site might enter the creek and stabilize and re-vegetate disturbed surfaces as soon as possible.

4. Work with the SJRBC in its efforts. Volunteering for its planned sediment monitoring and cost-share BMP programs are encouraged. The SJRBC intends to continue its efforts to reach out to riparian landowners and other stakeholders. A coordinated effort to achieve the goals of this plan is essential. Cooperating in the efforts of the SJRBC by being receptive to their outreach program would be

helpful. Participation in grass roots organizations concerned with Juday Creek, such as the Friends of Juday Creek, is also suggested.

6.4 OTHER ORGANIZATION'S ROLES AND RESPONSIBILITIES

6.4.1 UNIVERSITY OF NOTRE DAME

The University of Notre Dame as a riparian landowners to Juday Creek has the same authorities, roles and responsibilities as all other riparian landowners. The university, which has used Juday Creek as a backyard laboratory for many years, has the ability to provide surveillance as part of its use of Juday Creek in its educational and academic programs. The university, as a subcontractor to the SJRBC and as a voluntary good neighbor, has over the years, provided invaluable service in the interest of Juday Creek. It is encouraged to continue in this capacity.

6.4.2 FRIENDS OF JUDAY CREEK

The Friends of Juday Creek is a grass roots organization of individuals with a common interest in the welfare of Juday Creek. Many are riparian landowners of Juday Creek. The organization publishes a newsletter, the "Creekside" which is distributed to members.

The Friends of Juday Creek has no legal authority but nevertheless may play an important role. It can aid the SJRBC in its public outreach program. It may also provide a representative to be a member of a joint task force providing technical advice to the St. Joseph County Drainage Board regarding watershed management issues.

6.4.3 IZAAK WALTON LEAGUE

The Izaak Walton League as an occupant of land through which Juday Creek flows has much the same authorities, roles and responsibilities as riparian landowners. In addition, as a large organization it can aid the SJRBC in it's public outreach program. It may also provide a representative to be a member of a joint task force providing technical advice to the St. Joseph County Drainage Board regarding watershed management issues.

6.5 BMP IMPLEMENTATION PRIORITIZATION

Prioritization of the implementation of the BMP's discussed above must consider the feasibility of each on a site by site basis. As discussed in the storm water discharge study by J.F. New & Associates, Inc. contained in **Appendix H,** further studies are required to determine the feasibility of the recommended treatments at each site. This is also true for each of the other BMP's discussed in this plan, such as flattening stream banks. Once a list of feasible BMP implementations is established they should then be prioritized to assure that the most benefit is realized for the efforts and resources expended. It must be kept in mind that benefit is defined as progress toward achieving the goals set in this plan.

The above discussion does not apply to all the BMP's discussed in this plan. Many, such as not disturbing existing streamside vegetation and limiting or avoiding the use of agricultural or lawn care chemicals toxic to aquatic invertebrates or fish, are simply good stewardship practices which can begin immediately or continue without expenditure of resources.

The BMP implementations which require expenditure of effort and resources are either private sector or public sector projects. The cost effectiveness of the private sector projects must be evaluated by the individual private sector entities, primarily riparian landowners, who must bear the costs and put forth the efforts for those implementations. The SJRBC and the St. Joseph County Drainage Board may be contacted for help in those evaluations. They may be able to give advice or guidance concerning whether or not a specific BMP implementation is worth the time and trouble. The SJRBC may continue its public outreach program, one aim of which is to provide just such advice and guidance. The SJRBC may also begin a cost share program, funded by its section 319 grant, to help and encourage private sector BMP implementations as discussed earlier in this plan. To educate and encourage the private sector, the St. Joseph County Drainage Board will construct "demonstration projects" which will showcase the methods, materials and results of certain BMP's, such as stream bank stabilization using "fiber rolls and blankets".

The public sector projects are usually larger and more expensive constructions, such as the storm sewer discharge treatments recommended in the study by J.F. New and Associates, Inc., contained in **Appendix H** and stream bank flattening, stabilization and vegetation projects. To prioritize the expenditure of public funds, the governmental agencies should develop preliminary designs, cost estimates, and cost/benefit analyses for the projects in consultation with the experts who can determine the benefits with respect to achieving the plan goals. The projects can then be prioritized taking into consideration the cost/benefits of each and any other issues which may bear on the subject.

In their planning and evaluation of BMP implementations, both private and public sector entities can obtain educational and technical assistance from the St. Joseph County Soil and Water Conservation District. The district can provide general education regarding good practices and also site or project specific technical assistance in the planning and implementation of BMP's.

7.0 GLOSSARY OF TERMS

ALKALINITY:	The capacity of water to neutralize acids by its content of bicarbonates, carbonates, hydroxides, and other alkaline substances.
ANTECEDENT SOIL CONDITION:	Soil moisture condition at the start of a storm event that influences the amount of runoff.
AQUATIC:	Plants or animal life living in, growing in, or adapted to water.
AQUIFER:	A sand, gravel, or rock formation capable of storing or conveying water below the surface of the land.
BASELINE FLOW:	The part of the stream flow that is not due to direct runoff from precipitation; it is usually supported by water draining from natural storage in groundwater, lakes or wetlands.
BEDLOAD:	The sediment in a stream channel that moves by sliding, rolling, or skipping on or near the stream bottom.
BERM:	An earthen mound used to direct the flow of runoff around or through a structure.
BENTHIC MACRO-INVERTEBRATES:	Organisms that live in, crawl upon, or attach themselves to the bottom.
BEST MANAGEMENT PRACTICE (B.M.P.):	Structural devices or non-structural practices that are designed to prevent pollutants from entering into storm water flows, to direct the flow of storm water or to treat polluted storm water flows.
BIOCHEMICAL OXYGEN DEMAND (B.O.D.)	Measures the amount of organic material in water.
BIOENGINEERING:	Restoration or reinforcement of slopes and streambanks with living plant material.

BUFFER STRIP: An area of land adjacent to a water body which acts to trap and filter out suspended sediments, nutrients and chemicals before reaching surface waters. Harvesting and other forest management activities are permitted in the strip as long as the functional integrity of the strip is maintained. Shade from the strip may also reduce thermal pollution of an adjacent stream.

COLIFORM BACTERIA: A group of bacteria predominantly inhabiting the intestines of man or animal but also found in soil. While harmless themselves, coliform bacteria are commonly used as indicators of the possible presence of pathogenic organisms.

CONFLUENCE: A flowing together or place of junction of two or more streams.

CONTAMINANT: A substance that is not naturally present in the environment or is present in amounts that can, in sufficient concentrations, adversely affect the environment. A contaminant in such concentrations becomes a pollutant.

COST EFFECTIVENESS: A term used to compare alternatives on the basis of costs (inputs) per unit of benefits (outputs), such as dollars per unit of pollutant load reduction.

DETENTION BASIN: Temporarily stores water before discharging into a surface water body. Primarily used to reduce flood peaks.

DISCHARGE: A release or flow of storm water or other substance from a conveyance or storage container. It is usually expressed as cubit feet per second (CFS).

DRAINAGE: The removal of excess soil water from the soil profile.

DRAINAGE AREA: The area of the watershed, usually expressed in square miles or acres.

EROSION: The wearing away of land surface by wind or water. Erosion occurs naturally from weather or runoff, but can be intensified by land-clearing practices related to arming, residential or industrial development, road building, or timber-cutting.

EVAPO-TRANSPIRATION: The loss of water from an area by evaporation from the soil and plant surfaces and by transpiration of plants.

EXCAVATION:	The process of removing earth, stone, or other materials.
FERTILIZER:	Materials such as nitrogen and phosphorus that provide nutrients for plants. Commercially sold fertilizers may contain other chemicals or may be in the form of processed sewage sludge.
FILTER FABRIC:	Textile of relatively small mesh or pore size that is used to (a) allow water to pass through while keeping sediment out (permeable), or (b) prevent both runoff and sediment from passing through (impermeable).
FILTERSTRIP:	Usually long, relatively narrow area of undisturbed or planted vegetation used to retard or collect sediment for the protection of watercourses, reservoirs, or adjacent properties.
FIRST FLUSH:	Highly concentrated pollutant loading during the early portion of stormwater runoff, due to the rapid runoff of accumulated pollutants.
FLOODPLAIN:	The channel proper, and the areas adjoining any wetland, lake, or watercourse, which have been or hereafter may be covered by the regulatory flood. The "floodplain" includes both the floodway and the floodway fringe districts.
FLOODWAY:	The channel of a river or stream and those portions of the floodplain adjoining the channel which are reasonably required to efficiently carry and discharge the peak flood flow of the regulatory flood of any river or stream.
FLOODWAY FRINGE:	Those portions of the floodplain lying outside the floodway.
GROUNDWATER:	The subsurface water supply in the saturated zone below the water table.
HYDROGRAPH:	A graph, usually of discharge or stage versus time, at a given point along a stream.
HYDROLOGIC CYCLE:	The continuous process of the exchange of water between the earth and the atmosphere.
HYDROLOGY:	The science dealing with the occurrence and movement of water upon and beneath the land areas of the earth.

IMPERVIOUS:	A surface through which little or no water will infiltrate into the ground. Impervious areas include paved lots and roof tops.
INFILTRATION:	The penetration of water through the ground surface into sub-surface soil or the penetration of water from the soil into sewer or other pipes through defective joints, connections, or manhole walls.
IN-LINE DETENTION:	The detention is provided within the flow carrying network (stream).
IRRIGATION:	Human application of water to agricultural or recreational land for watering purposes.
100-YEAR FLOOD:	A flow of water within a watercourse, with a magnitude which has a 1 percent chance of occurring or being exceeded in any given year.
MEAN STORM:	Over a long period of years, the average rainfall event, usually expressed in inches.
MEAN-STORM VOLUME:	The runoff volume produced by the "mean storm".
MONITOR:	To systematically and repeatedly measure something in order to track changes.
MULCH:	A natural or artificial layer of plant residue or other materials covering the land surface which conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.
NON-POINT SOURCE POLLUTION:	Pollution that is not identifiable to one particular source, and is occurring at locations scattered through the drainage basin. Typical sources include erosion, agricultural activities, and urban runoff.
NUTRIENTS:	Mineral elements in the forest ecosystem, such as nitrogen, phosphorus or potassium, that are naturally present or may be added to the forest environment by forest practices such as fertilizer or fire retardant applications. Substances necessary for the growth and reproduction of organisms. In water, those substances that promote growth of algae and bacteria; chiefly nitrates and phosphates.

OUTFALL:	The point, location, or structure where wastewater or drainage discharges from a sewer pipe, ditch, or other conveyance to a receiving body of water.
OVERTOPPING:	Drainage over the top of dikes, diversions, or other embankments because of high water conditions.
PEAK DISCHARGE:	The maximum instantaneous rate of flow during a storm.
PERCOLATION RATE:	The rate, usually expressed as a velocity, at which water moves through saturated granular material.
PERMIT:	An authorization, license, or equivalent control document issued by EPA or an approved State agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.
PERMIT ISSUING AUTHORITY:	The State agency or EPA Regional Office which issues NPDES or other environmental permits to regulated facilities.
PERVIOUS:	A surface that will allow water to infiltrate into the ground.
POLLUTANT:	Generally, any substance introduced into the environment that adversely affects the usefulness of a resource.
PRECIPITATION:	The supply of water received from the atmosphere, such as rain, snow, sleet and hail.
POINT SOURCE:	Any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, discrete fissure, container, rolling stock, concentrated animal feed operation, or vessel, or other floating craft, from which pollutants are or may be discharged.
REACH LENGTH:	A longitudinal length of stream channel selected for use in hydraulic or other computations.
RETENTION POND:	A stormwater management practice that captures stormwater runoff, and does not discharge directly to a surface water body. The water infiltrates into the ground, or evaporates.

RETROFIT:	To modify an existing structure to improve the pollutant removal or flood peak reduction capability. A retrofit can consist of the construction of a new BMP in the developed area, the enhancement of an older storm water management structure, or a combination of improvement and new construction.
RIPARIAN HABITAT:	Areas adjacent to rivers and streams that have a high density, diversity, and productivity of plant and animal species relative to nearby uplands.
RILL EROSION:	The formation of numerous, closely spread small channels caused by the removal of surface soils by storm water or other water.
RUNOFF:	That part of precipitation, snow melt, or irrigation water that does not infiltrate or evaporate and runs off the land into streams or other surface water. It can carry pollutants from the air and land, into the receiving water.
SANITARY SEWER:	A system of underground pipes that carries sanitary waste or process wastewater to a treatment works plant.
SANITARY WASTE:	Domestic or industrial sewage.
SOURCE CONTROL:	A practice or structural measure (such as covering) to prevent pollutants from entering storm water runoff or other waste materials.
STORM DRAIN (Storm Sewer):	A slotted opening leading to an underground pipe or an open ditch for exclusively carrying surface runoff.
STORM WATER:	Runoff from a storm event, snow melt runoff, and surface runoff and drainage.
SUSPENDED SOLIDS:	That portion of material which is retained by a filter.
SCOUR:	The cleaning and digging action of flowing water, especially the downward erosion caused by stream water in sweeping away mud and silt from the stream bed and outside bank of a curved channel.

SEDIMENT:	Soil, sand and minerals transported from its site of origin by water. May be in form of bedload (along the bed), by bouncing along the bed, suspended, or dissolved.
SEDIMENT TRAP:	A device for removing sediment from water flows; usually installed at outfall points.
SEDIMENTATION:	The process of depositing soil particles, clays, sands, or other sediments that were picked up by runoff.
SOIL EROSION:	The wearing away of land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices related to farming, residential or industrial development, road building, or timber-cutting.
SURFACE WATER:	All water naturally open to the atmosphere (rivers, lakes, reservoirs, streams, wetlands impoundments, seas, etc.); also refers to springs, wells, or other collectors which are directly influenced by surface water.
TOXIC POLLUTANTS:	Materials contaminating the environment that causes death, disease, and/or birth defects in organisms that ingest or absorb them. The quantities and length of exposure necessary to cause these effects can vary widely.
TRANSPIRATION:	The process of passing water, in vapor form, through the pores of a plant (usually in the leaves) to the atmosphere.
TRIBUTARY:	A river or stream that flows into a larger river or stream.
TURBIDITY:	Results from suspended solids in water; the opposite of clarity.
WATER TABLE:	The depth or level below which the ground is saturated with water.
WETLANDS:	A area that is regularly saturated by surface or ground water and subsequently is characterized by a prevalence of vegetation that is adopted for life in saturated soil conditions.
WATERWAY:	A channel for the passage or flow of water.
WOODY PLANTS:	Woody, tree-like plants, including trees and shrubs.

WATER QUALITY:	The biological, chemical, and physical conditions of a waterbody; measure of a waterbody's ability to support life.
WATERSHED:	The geographic region within which water drains into a particular river, stream, or body of water. A watershed includes hills, lowlands, and the body of water into which the land drains. Watershed boundaries are defined by the ridges separating watersheds. Every activity on the surface of the land within a watershed can send pollutants into the water.

St. Joseph River Basin Commission

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JUDAY CREEK WATERSHED

FIGURE 1

● BIOS OBSERVATION POINTS

▲ CE/GEOS OBSERVATION WELLS

■ USGS GAGING STATION

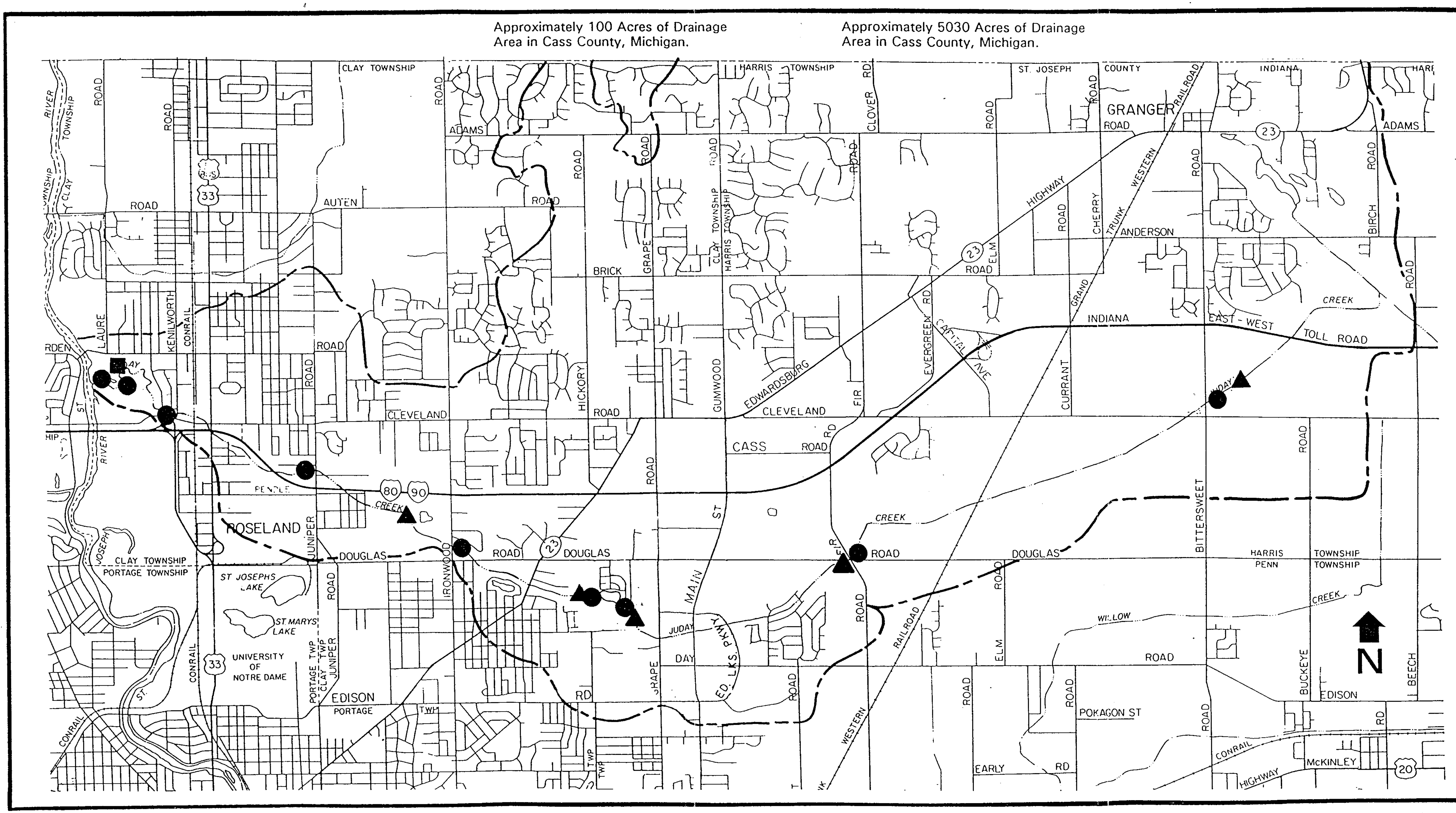

FIGURE 2

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JUDAY CREEK WATERSHED

LIMITED SOILS FOR ON-SITE WASTE WATER DISPOSAL

SEWERED AREA

Limited-soils boundary is approximate only. Please refer to St. Joseph County Soil Survey for detailed information.

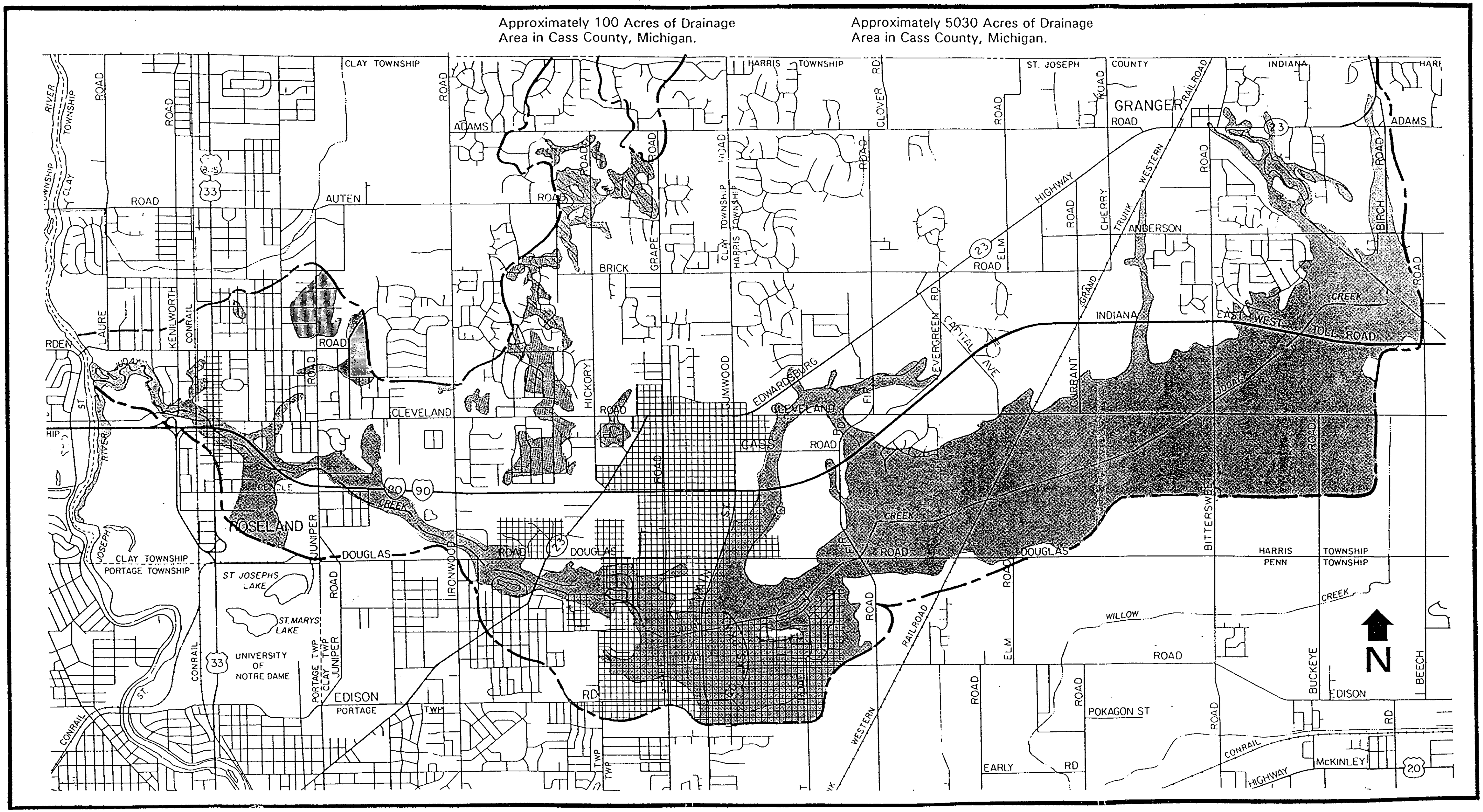

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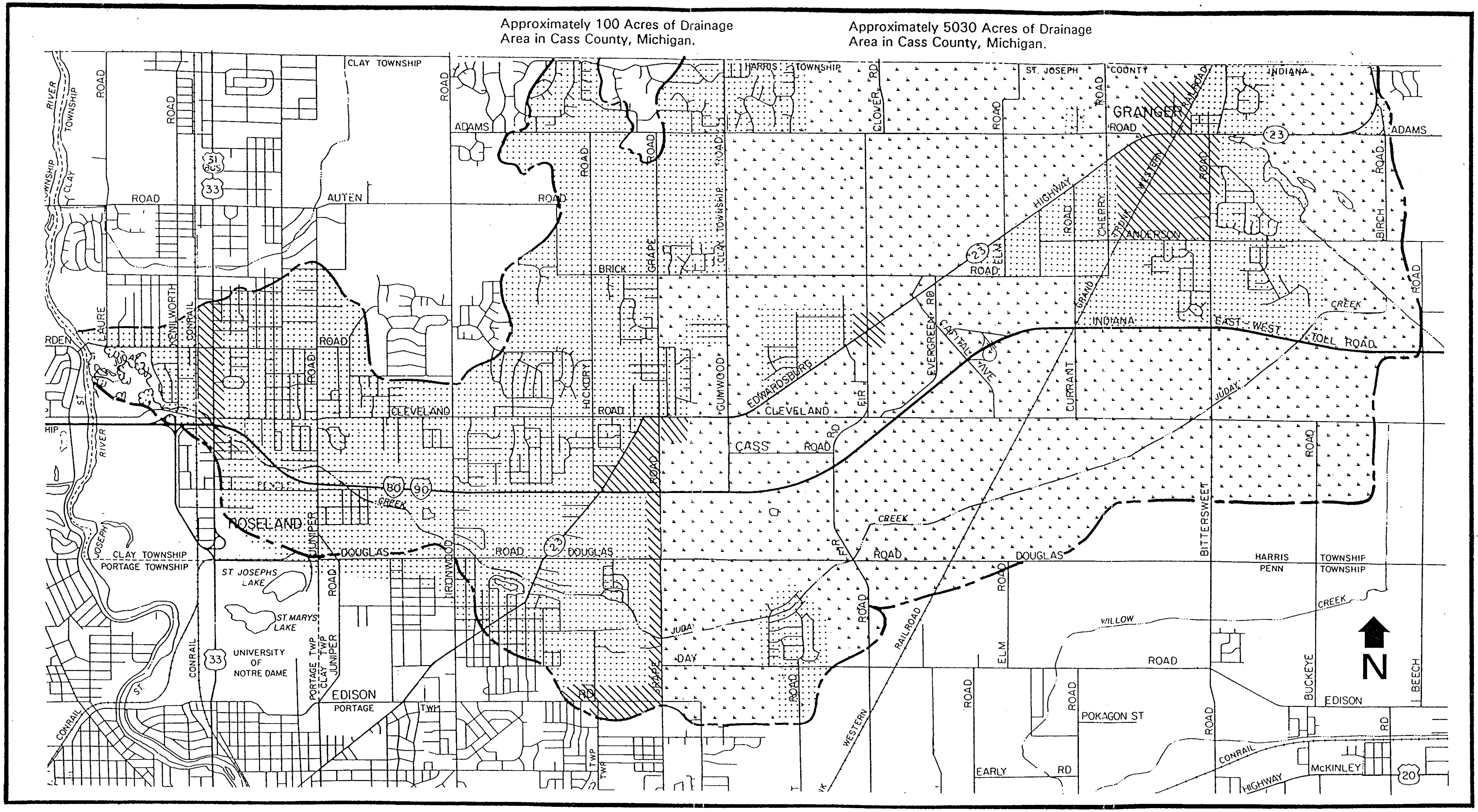
FIGURE 3

JUDAY CREEK WATERSHED

LAND USE MAP - 1982

Land use data was obtained from the St. Joseph County Surveyor and St. Joseph County Area Plan Commission.

AGRICULTURE
COMMERCIAL
RESIDENTIAL



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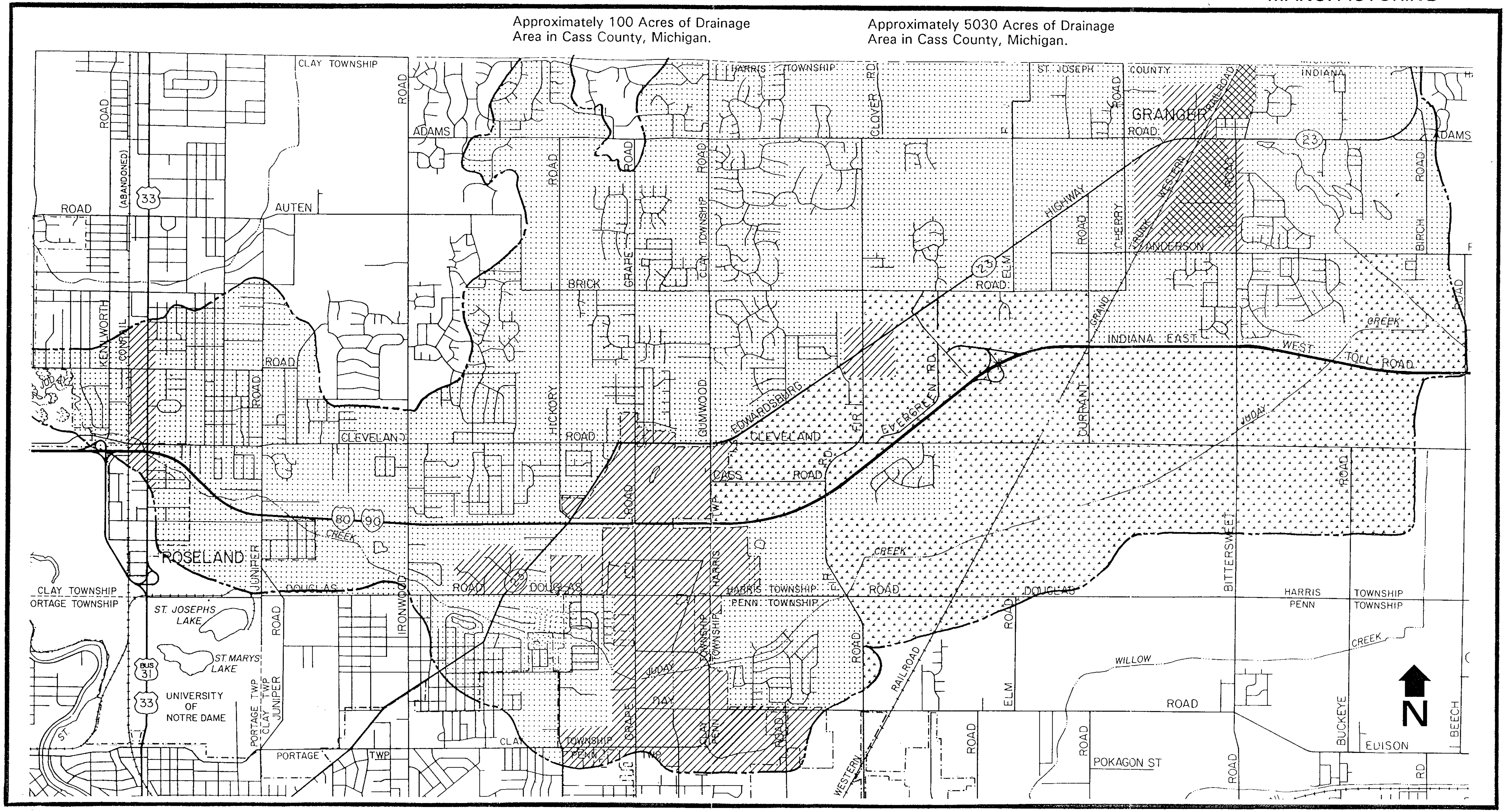
JUDAY CREEK WATERSHED

LAND USE MAP - SEPTEMBER 1992

Land use data was obtained from the St. Joseph County Surveyor and St. Joseph County Area Plan Commission.

- AGRICULTURE
- COMMERCIAL
- RESIDENTIAL
- INDUSTRIAL/ MANUFACTURING



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JUDAY CREEK WATERSHED

- ● STORMWATER DISCHARGE
- ■ NPDES PERMITED DISCHARGE
- ⬢ US EPA SUPERFUND SITE

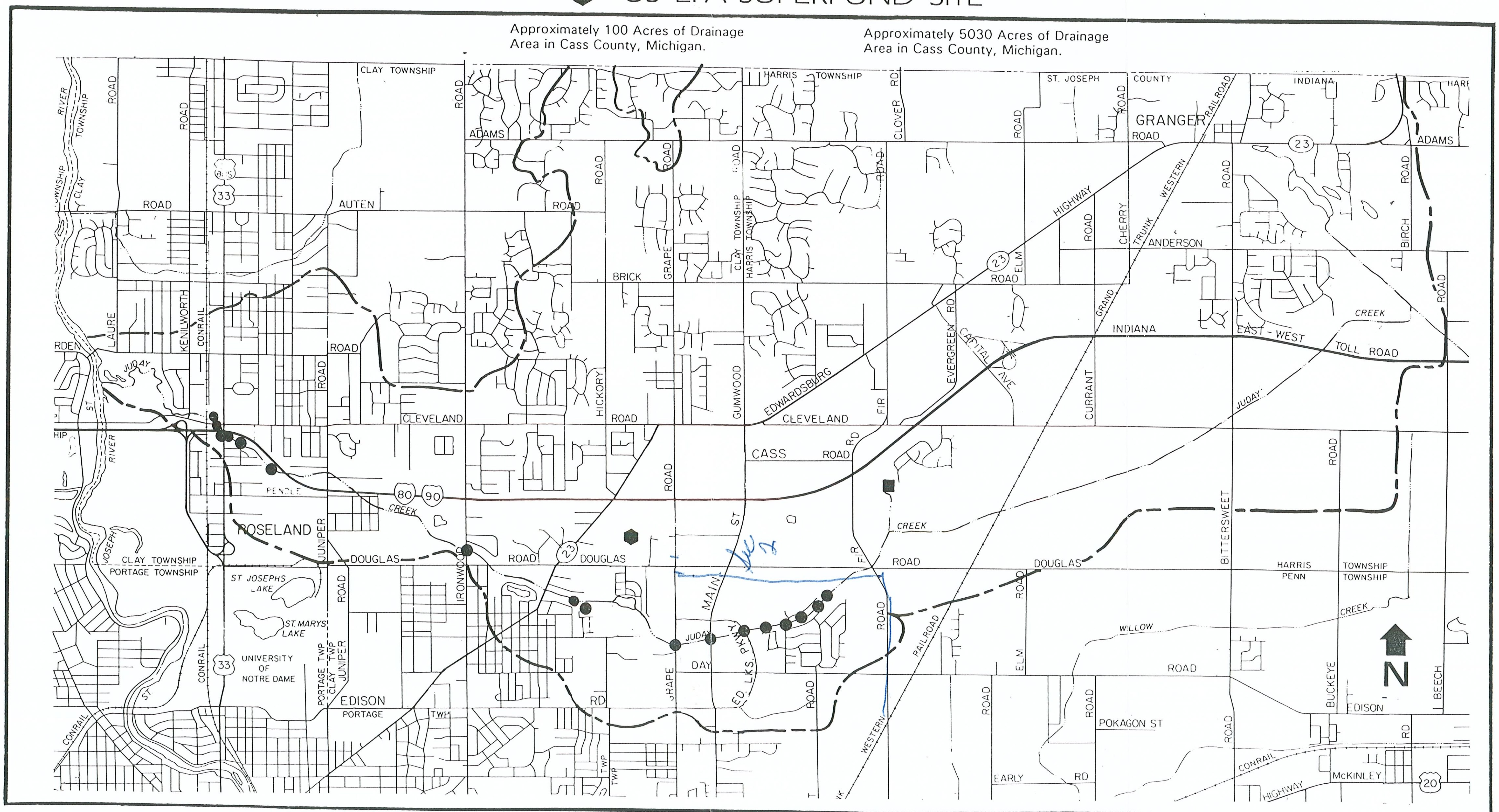

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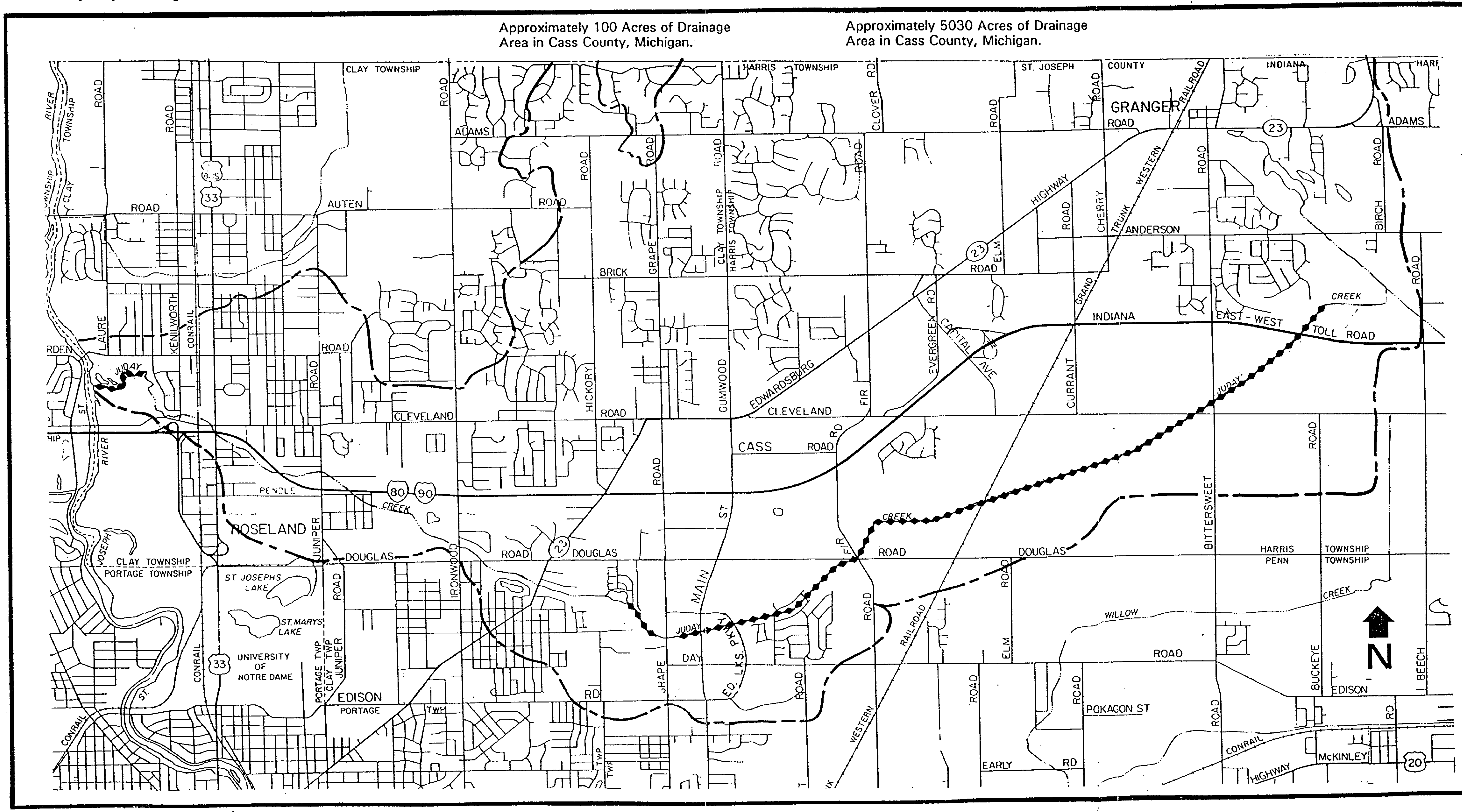
FIGURE 6

JUDAY CREEK WATERSHED

GROUNDWATER/SURFACE WATER HYDROLOGY

GROUNDWATER DISCHARGE TO CREEK

CREEKWATER DISCHARGE TO GROUNDWATER



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JUDAY CREEK WATERSHED

JURISDICTIONAL BOUNDARIES

FIGURE 7

•••••••••••• MISHAWAKA

– – – – – – – SOUTH BEND

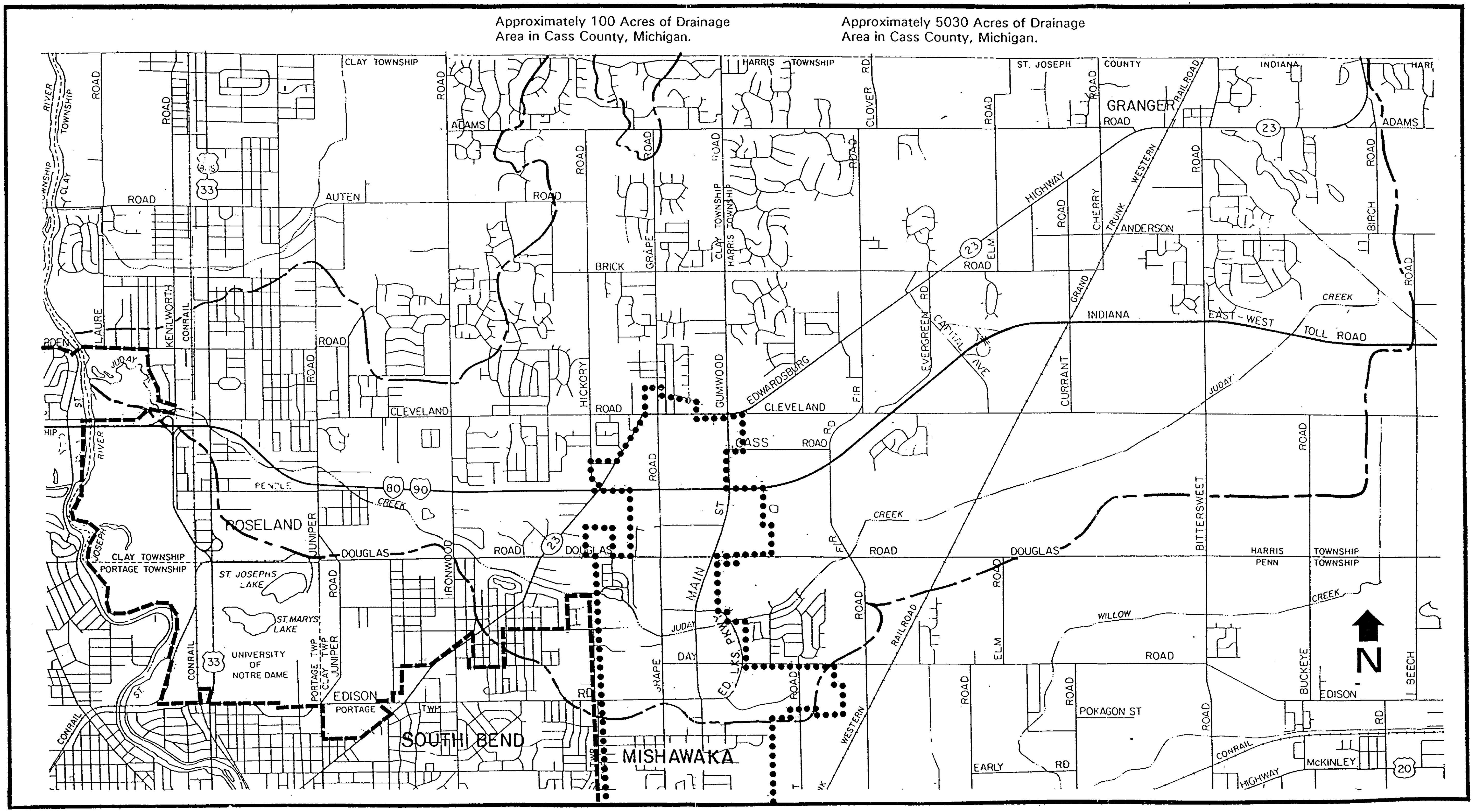

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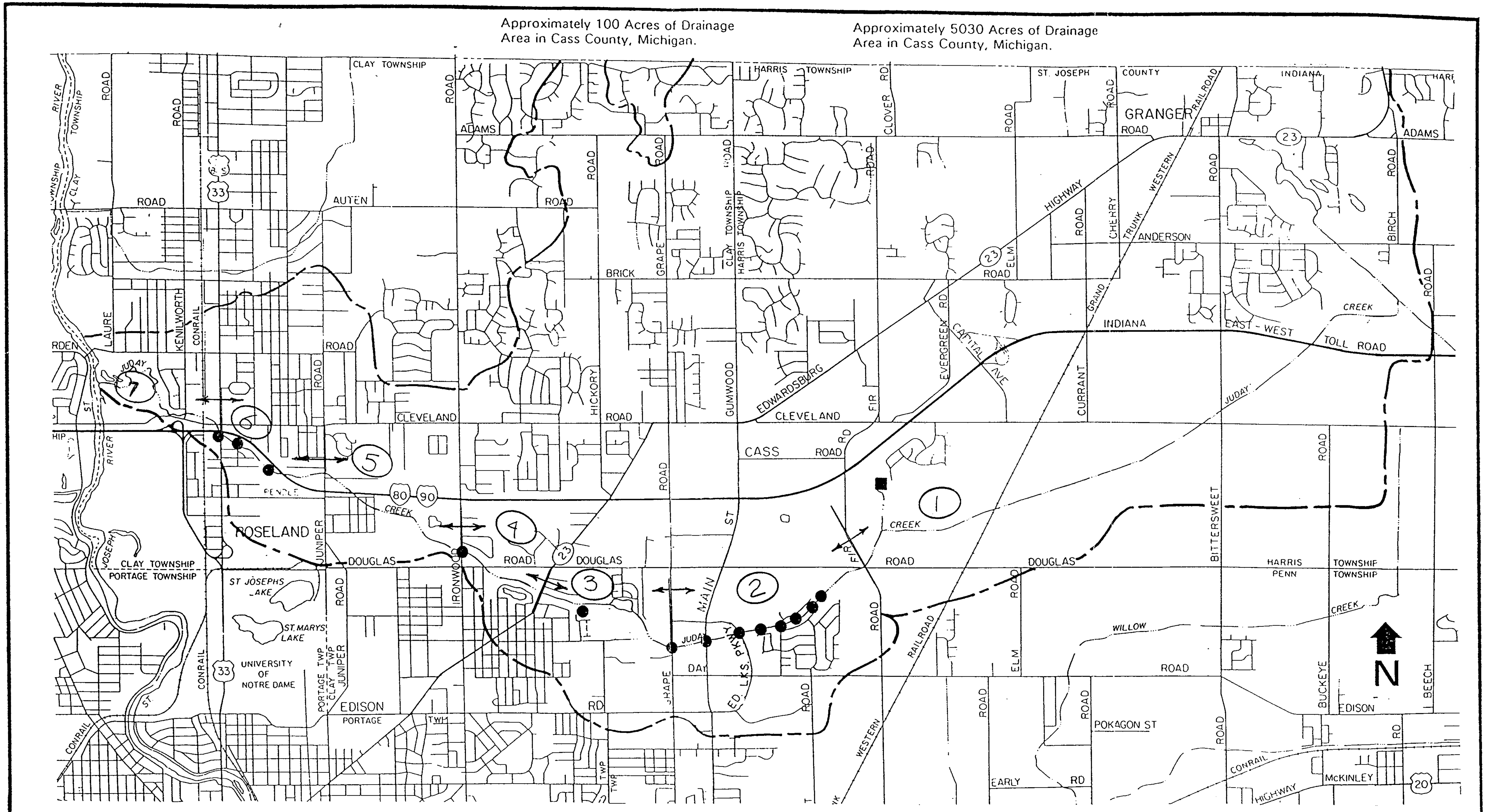
FIGURE 8

JUDAY CREEK WATERSHED

(#) PLAN REACH DELINEATION



CLEAN WATER ACT, SECTION 319 GRANT

JUDAY CREEK - ST. JOSEPH COUNTY, INDIANA

DEPARTMENT OF CIVIL ENGINEERING AND
GEOLOGICAL SCIENCES

UNIVERSITY OF NOTRE DAME

*** FINAL REPORT ***

EFFORTS COMPLETED THROUGH SEPTEMBER, 1993

PI: DR. STEPHEN E. SILLIMAN

REPORT SUBMITTED: OCTOBER 31, 1993

FINAL REVISIONS SUBMITTED: May 31, 1994

EXECUTIVE SUMMARY

During the past 15 months, the Department of Civil Engineering and Geological Sciences (CE/GEOS) has studied the hydrologic characteristics of Juday Creek in northern Indiana. The primary goals of this effort were to examine the interaction of the creek with groundwater, the relative reaction of the creek versus the groundwater during storm events, and the primary controls on creek elevation and flux. Tools utilized to address these issues included the drilling of several wells along the creek, the monitoring of water level elevations in the wells and in the creek, collection of water and sediment temperature data along the creek, collection of water quality samples along the creek, measurement of hydraulic gradients in the sediments underlying the creek, and application of a statistical analysis of the frequency of fluctuations along the creek. The project within CE/GEOS was also utilized to provide hands-on contact with these environmental issues for a variety of students including one Masters candidate in our program, a number of undergraduates (both through directed research and through course work), and a number of high school students from northern Indiana and southern Michigan. The primary conclusions derived from this study include:

(i) Juday Creek is essentially a gaining stream in the upper half of the creek (with a possible exception in the area around Grape Road) and a losing stream below the lake at Lake Shore Estates with the exception of the lower half of the Isaac Walton League property near the confluence of the creek and the St. Joseph River,

(ii) During periods in which the ground is not frozen, the portion of the creek east of Lake Shore Estates is strongly driven by groundwater response to storm events. Within this region, the creek appears to buffer the groundwater response to storm events and does not show a strong signature of surface runoff. During periods in which the ground is frozen, surface runoff appears to have greater impact on the creek in terms of both flow and water quality.

(iii) Below the lake at Lake Shore Estates, the creek does not follow the groundwater response. The groundwater near the creek appeared to show a delayed response to the creek hydrograph with substantially reduced amplitude. There is

evidence that chloride contamination within the creek is influencing groundwater quality at the Notre Dame property.

(iv) Groundwater in this region appears to respond on a daily cycle to water consumption by plants. The magnitude of this response is the largest in late July and August and essentially non-existent between late September and mid-May. In the upper reaches of Juday Creek (where the creek is controlled by the groundwater), this response of groundwater is reflected in daily fluctuations in creek level. In the lower reaches of the creek, the creek does not show as strong a response to these fluctuations.

Based on these conclusions, the following observations are made:

(i) Attempts to reduce flooding of basements during periods in which the ground is not frozen will meet with limited success if the design is based on the assumptions that the flooding is caused primarily by Juday Creek and/or that the rise in water levels on Juday Creek are related primarily to overland flow.

(ii) Current flooding of basements is most commonly a result of increased groundwater levels due to direct infiltration of precipitation into the ground and not to flow in the creek.

(iii) Excavations of reservoirs in or near the creek should be completed with great caution as the hydrologic impact of such excavations is unclear based on our present knowledge of this hydrologic system. This caution is particularly appropriate above the lake at Lake Shore Estates as this is the portion of the creek along which the creek is gaining water from the ground.

(iv) Changes in land use in undeveloped portions of the creek should be authorized only after consideration of the impact of the new land uses in terms of surface water runoff, reduced infiltration, or lowering of the water table in the development of a water supply. Each of these impacts has the potential to dramatically alter the characteristics of Juday Creek.

(v) Creek elevations, groundwater elevations, water quality, and creek/ groundwater interactions should be monitored at regular intervals.

1.0 INTRODUCTION

This report covers research efforts related to the Section 301 Grant targeted for analysis of Juday Creek. In particular, this report covers the efforts completed by the Department of Civil Engineering and Geological Sciences (CE/GEOS) at the University of Notre Dame. This portion of the project dealt primarily with the interaction of the creek with the local groundwater aquifer(s).

This report follows the format of progress reports in that the sections below are divided according to previously specified tasks. In addition, this report contains an analysis section in which the various aspects of the CE/GEOS efforts are coordinated and general conclusions regarding the hydrologic behavior of Juday Creek are formulated. Because this portion of the project terminates earlier than other portions of the project (in particular, the biological studies), the conclusions presented here have not been coordinated with the final conclusions to be derived from the work of other investigators on this project.

2.0 WORK ELEMENT 1: DISSEMINATION OF INFORMATION

The first work element was defined as the dissemination of information obtained during the project, and to encourage citizen involvement in watershed protection.

Dissemination of results of this project are being pursued in a number of ways. During the initial stages of the project, a paper was submitted to the Journal of Hydrology with Dr. Silliman and Mr. David Booth as coauthors. Mr. Booth was partially supported as a summer intern on this project. The paper reported on the temperature signature efforts performed on the creek (leading to the conclusion that the upper portion of the creek was gaining and the lower portion was losing). Acknowledgments in the paper include reference to continuing study on the creek through support of the St. Joseph River Basin Commission. Response to this paper has been extremely favorable. An additional paper on the temperature work was recently submitted to the Journal of Hydrology. Although the work in this paper is outside the scope of the present project, the paper does acknowledge that the source of the data were, in part, from the continuing study by the River Basin Commission. Reprints of the paper by Silliman and Booth and a preliminary copy (the version submitted) of the second paper have been delivered to the St. Joseph River Basin Commission.

Mr. Tim Carlsen completed a Masters thesis on the daily fluctuations in creek level. Although Mr. Carlsen's stipend was not provided by the project, the majority of his work is based on the project equipment and objectives. Mr. Carlsen acknowledged the project in his Masters. In addition, two professional papers are in preparation. Copies will be provided to the Basin Commission at the time that they are submitted for publication.

Results from this project have also been discussed at several presentations. In addition to the presentation in front of the River Basin Commission, presentations on this work have been given at three national meetings of the American Geophysical Union. The American Geophysical Union is one of the leading professional organizations for practitioners in the area of water resources and hydrology. These talks were very well received and several requests for copies of our published work have been received.

CE/GEOS has actively encouraged participation in this project by a number of individuals not directly connected with the project. In addition to the efforts of Mr. Carlsen, a number of undergraduates have been actively involved in this project. A total of three undergraduates have been active in this project from a research standpoint. These include Mr. David Booth who was supported by the project and two summer students who were supported through an NSF grant. In addition, a significant number of undergraduates have learned from this project through the groundwater hydrology course taught at Notre Dame. Over the past two years, the undergraduates involved in the groundwater course have measured flow rates within the creek, water quality in the creek, water levels in all wells on the Notre Dame property, and water quality at all wells on the Notre Dame property. It is fully expected that the groundwater laboratory will continue to be focused on the creek.

During the past two summers, a total of six high school students have assisted with the Juday Creek project. Taken from high schools in northern Indiana and southern Michigan, these students spent between 20 and 30 hours per week working on the Juday Creek project and accomplished a number of experimental successes including a local tracer test on the eastern portion of the creek, collection of initial turbidity measurements on the creek, collection of water quality / temperature data, and analysis of water samples from the creek. In addition to this summer involvement, one student has continued to be associated with the project during the academic year. This student is monitoring water quality in the creek and in the wells on the Notre Dame property on a regular basis.

In reviewing the significant number of ways in which this project has involved transfer of information from the researcher to either the public or the professional community, we have found that this project has been provided by far the highest return per research dollar of any project for which the Dr. Silliman has been involved in nearly eight years at Notre Dame. This record of dissemination is something for which both CE/GEOS and the River Basin Commission can be proud.

3.0 WORK ELEMENT 2: INSTALLATION OF MONITORING WELLS

This work element involved strategic placement of monitoring wells along the creek. Through cooperation with the River Basin Commission, locations at the St. Joseph Farm, at the intersection of Fir and Douglas Roads, at the inflow to the Lake Shore Estates lake, at the outflow from the Lake Shore Estates lake, and on Notre Dame property were selected. Due to limitations in site access and competing uses of the land, the number of wells installed at these sites varied from two to four.

Three wells were installed at the St. Joseph Farm. Two wells are on the northwestern side of the creek with the third well on the southeastern edge of the creek. One well was placed in the creek gully and has a one-foot screen (the same for all wells) at a depth of approximately 4 feet. The distance from the well to the creek varied based on creek elevation from as far away as two feet from the creek to the well being under water during floods on the creek. The second well on the northwestern side was placed at the top of the creek bank, approximately 10 feet from the creek during normal flows, with a total depth of approximately 10 feet. The well on the southeastern side of the creek was placed at the top edge of the creek bank and is approximately 10 feet from the creek during normal flows. It has a total depth of approximately 15 feet.

We would like to acknowledge the personnel from the St. Joseph Farm for their cooperation in allowing us to access these wells on a regular basis. It should be noted that Mr. Hank Sands, the farm manager, has requested that all three well be removed as early as possible next spring. As agreed between the Commission and Dr. Silliman, the Basin Commission bears responsibility for the maintenance / removal of these wells.

Two wells were installed along the southeastern corner of Fir and Douglas Roads. Both wells are along the northern bank of the creek as the southern bank is on private property and it was not anticipated that a well along the southern bank would significantly increase the value of the data collected at this site. These wells are approximately 5 feet and 10 feet deep, respectively. The ten foot well is approximately 15 feet from the creek and has been essentially dry during the latter part of the summer of 1993.

Four wells were installed upstream of the inflow to the Lake Shore Estates lake.

Two were installed on the north side of the creek and two were installed on the south side of the creek. Distance from the creek varied from approximately 5 feet to approximately 15 feet from the creek. Depths ranged from approximately 10 to approximately 15 feet. These wells are relatively exposed and the locks on these wells have been subject to some vandalism (substantial vandalism was experienced at this site with respect to the stage monitoring station).

Two wells were installed on the southern shore downstream from the outflow of this lake. Two wells were originally planned for the northern shore. However, our metal detectors identified a number of linear metal features in the field on the northern shore which could not be identified by the utility or cable companies. Hence, it was decided that safety overrode any desire to drill wells along this shore. In retrospect, this decision had no negative impact upon the project. The two wells on the southern shore are approximately 10 and 20 feet from the creek. Depths of these wells were approximately 10 feet.

Three wells were drilled near the creek on the Notre Dame property. Two of these wells are on the southern side of the creek. The first well on the southern side is approximately 5 feet from the creek and has a total depth of approximately 14 feet. The second well is approximately 15 feet from the creek and has a total depth of approximately 18 feet (although total depth of drilling was approximately 25 feet, ending in a thick clay layer). The well on the northern side of the creek is within one-foot of the creek and has a total depth of approximately 5 feet.

In addition to the wells installed specifically for this project, CE/GEOS has made use of ten wells previously existing on the Notre Dame property, a new well drilled for the groundwater course on the Notre Dame property, and well number 9 in the U.S. Geological Survey well array. Well number 9 is located south of the St. Joseph Farm site and was utilized as a control well separated from Juday Creek.

Additional sites mentioned for possible installation of monitoring wells were northeast of the St. Joseph Farm (north of the Tollway). This location would have provided insights into the headwaters of the creek. However, the County Surveyors office advised against this location due to the uncertain direction of development in this area. The second location discussed was on the property of the Isaac Walton League. While this location has potential to contribute to understanding the hydrology in this immediate region, it was argued by CE/GEOS that this location would provide minimal new insight into the behavior of the creek as the groundwater / surface water interaction on this property is evidenced by the presence of springs. Further, the groundwater in this section of the creek would have little influence over the behavior of the creek upstream except through temperature and water-chemistry control at the confluence with the St. Joseph River. As a result, this site was of relatively low priority in terms of understanding the hydraulics along the majority of the creek. It was therefore decided, in discussions with the River Basin Commission, that neither of these two possible well locations warranted the additional effort of installation of new wells.

In retrospect, it may have been useful to have a well north of the Tollway to allow conditions above the farm to be monitored. However, through use of well number 9 installed by the U.S.Geological Survey during their county groundwater survey, we have been able to fill in for information lost by the absence of the northern well. To date, our analysis has not shown any limitations related to the lack of a well near the confluence of the creek and the river.

4.0 WORK ELEMENT 3: COLLECTION OF CHEMICAL SAMPLES

This work element was to characterize the variation in basic chemistry of the creek during the year. The original species to be tested included temperature, chloride, bromide, pH, alkalinity, sodium and calcium.

During this project, a number of samples (approximately 150) have been collected from the creek at four locations: (i) the St. Joseph Farm site, (ii) the Lake Inflow site, (iii) the Lake Outflow site, and (iv) the Notre Dame property site. All analytical work was performed with standard ion-selective electrodes on a mV meter. These samples cover two sampling periods. The first, concentrated at the St. Joseph Farm and lake sites, involved multiple samples during the large March, 1993, thaw event. The second, collected over all sites, involved weekly samples between mid-July and the beginning of October, 1993. In addition, random samples from the creek were collected during the spring academic semester as related to the groundwater course. These samples were tested solely for Chloride.

Early efforts with Bromide indicated that the concentration of Bromide was consistently below reliable detection with these probes. As a result, Bromide was not considered to be a reliable indicator of creek quality and was therefore not measured in later samples. Work with pH, and a literature survey of techniques for pH, indicated that this parameter could not be reliably measured within the scope of this project using the equipment available. While pH readings could be reported, we felt that the values may lead to gross misrepresentation of the field values. Therefore, pH is not reported here and, within the limit of our equipment, is not considered to be a good indicator of the chemical variations in the creek. The measurement of Sodium was contingent upon our being able to purchase a Sodium specific electrode within the budget available for the project. As Chloride and total hardness were considered more important to the overall analysis, our priorities led to the elimination of Sodium as a measured parameter. Calcium and Alkalinity measurements were combined in this project through direct measurement of total hardness (reported as ppm calcium carbonate). Chloride was also recorded in ppm. During selected sampling trips, trip blanks (water samples taken from the laboratory into the field to determine the potential for contamination during handling) were carried and tested. Testing of the trip blanks showed little or no contamination of these samples (<2 ppm chloride and <5 ppm hardness).

Figure 1 shows selected hardness values as recorded at the four sites. The majority of these data are shown for the lake inflow site. Due to a failure in our hardness probe which required replacement of equipment in combination with the timing of the end of our phase of the project (September, 1993), hardness samples for the St. Joseph Farm could not be run. As noted in the next paragraph, however, the failure to obtain these samples did not significantly affect our ability to interpret the overall (long term) mechanism governing the geochemistry at this site. Based on response to a presentation of these results at the American Geophysical Union meeting in Baltimore (May, 1994), there may be benefit in completing detailed analysis of geochemistry during major storm events.

The most obvious result of the data shown in Figure 1 is the overall change in total hardness from the March snowmelt event to the summer samples. The low hardness values during the runoff event are consistent with a weather event in which precipitation (e.g. snowmelt) enters the creek without passing through the underlying aquifer (where it can increase in hardness through dissolution of calcium carbonate). The higher hardness values later in the year are consistent with our hypothesized flow of water through the groundwater system prior to entering the creek. It is noted that the two samples run for the St. Joseph Farm during the summer months are low in hardness. If this trend continues, this result would be consistent either with overland runoff or with flow through an aquifer with substantially lower amounts of available calcium carbonate and/or lower contact time with the aquifer (e.g. short flow paths). Given the high hardness values at the lake inflow and the other indications we have that the creek is gaining water from the aquifer in the vicinity of the farm, we believe that the low hardness values are indicative of the change in soil properties in the vicinity of the farm. Once again, continued research into water chemistry specifically during storm events may be worthwhile.

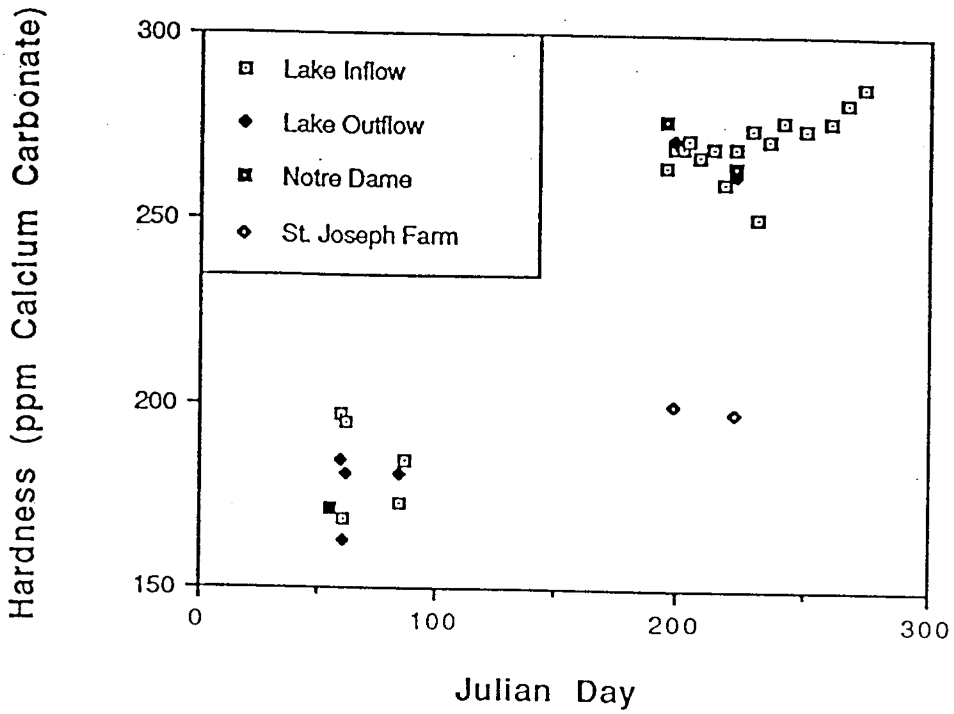


Figure 1: Hardness (as ppm Calcium Carbonate) in Juday Creek samples.

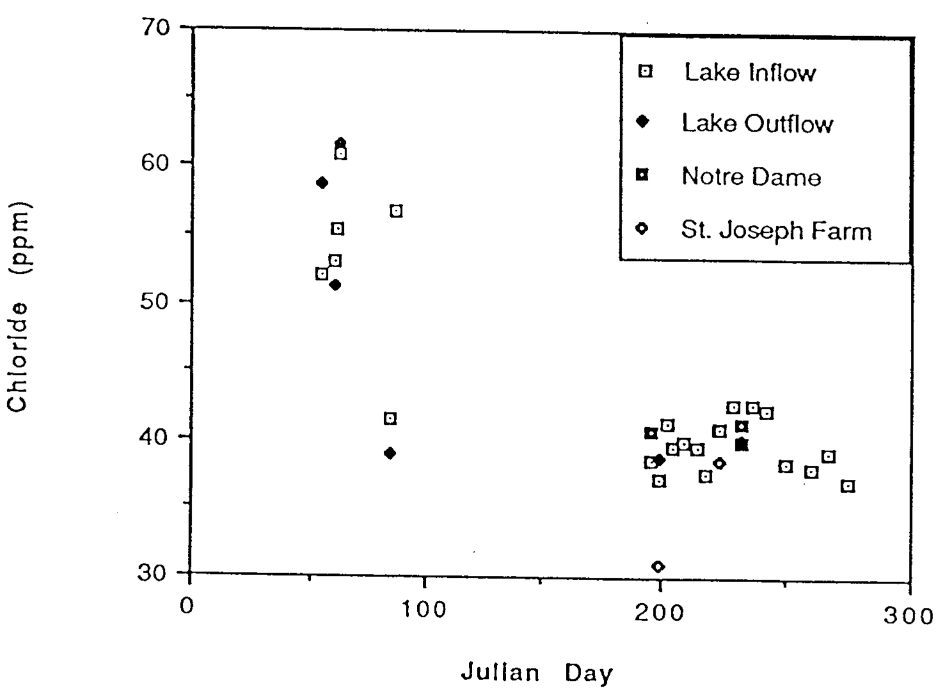


Figure 2: Chloride (ppm) in Juday Creek samples.

Figure 2 shows the results of the chloride measurements. Not unexpectedly, these results are consistent with an increase in chloride during the spring snowmelt with a steady, but relatively low, level of chloride during the summer and fall months. In addition to these samples, samples collected by students on the Notre Dame property in late March showed chloride concentrations in the creek above 100 ppm.

Chloride concentrations in wells at the field site used for the Notre Dame groundwater course and those installed on the Notre Property for this project are shown in Figure 3. Values for the field site cover a three year period and all were collected in March of the respective year (top value in the box next to each well represents the concentration in 1993, middle value is from 1992, and bottom value is from 1991). Two conclusions are apparent from this figure. First, the wells immediately next to the creek have relatively high concentrations of chloride (>100 ppm). Second, these values are higher than many of the other values observed within the field site. Hence, we might conclude that the creek is leading to contamination of the aquifer in this region. This would be consistent with the observation that this portion of the creek is a losing creek (based on previous work and the discussion below). However, it is cautioned that this conclusion may be somewhat premature as we do not have a history of chloride concentrations on the creek and many of the other wells at this field site show elevated chloride concentrations relative to the chloride concentrations measured in the creek at the lake inflow (Figure 2).

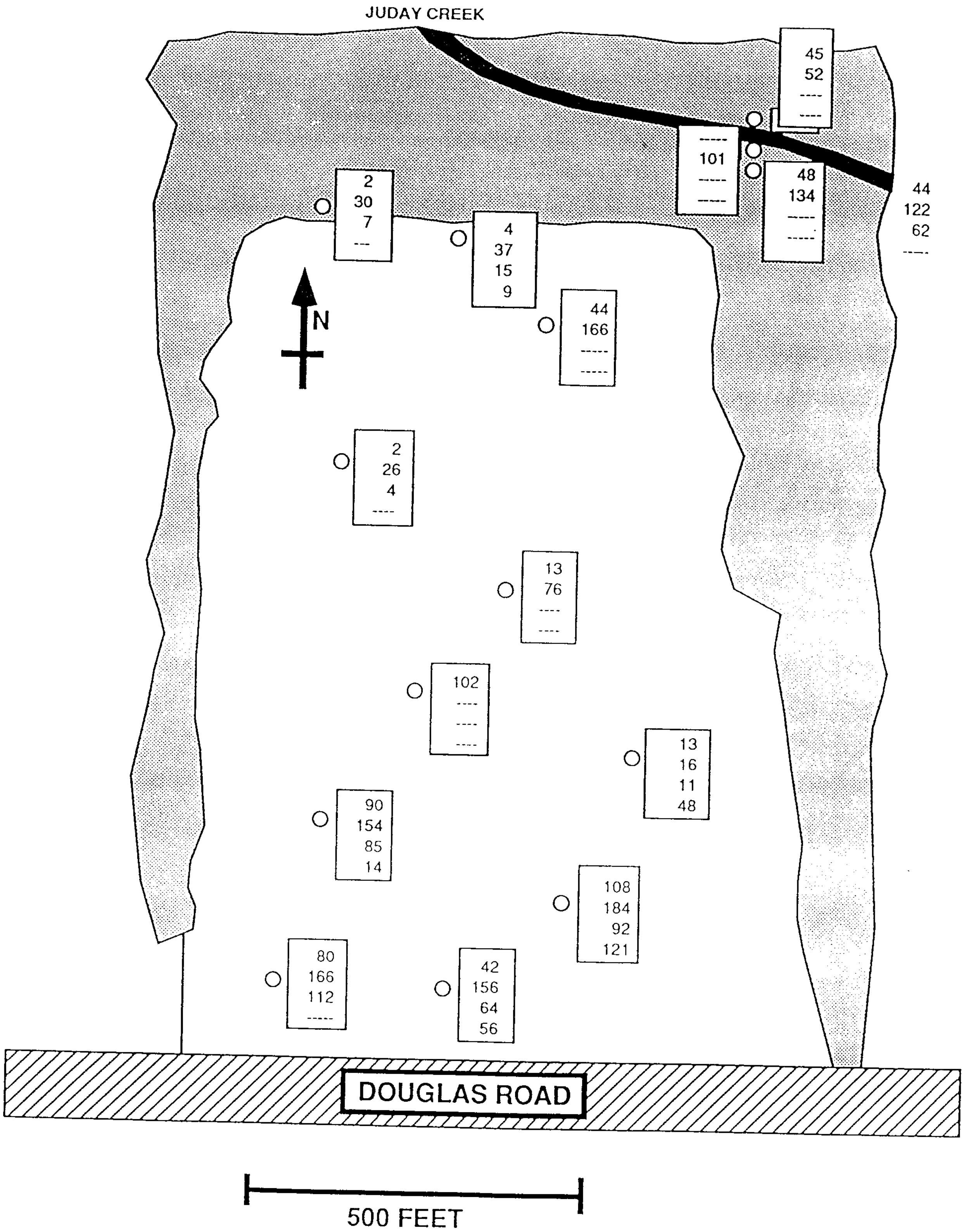


Figure 3: Distribution of Chloride at Notre Dame field site. [These values represent concentrations in late winter 1991-1994: 1991 values are shown at the bottom while 1994 values are at the top of each box next to the well sampled].

5.0 WORK ELEMENTS 4 AND 5: STAGE MEASUREMENT AND MONITORING OF WELL WATER ELEVATION / TEMPERATURES

These two work elements covered the focal point of this project, namely the measurement of the interaction of the creek with the groundwater. Further, these two elements are very closely related to each other. As such, they are discussed simultaneously in this report.

Five approaches to monitoring the interaction of the surface water with the groundwater were utilized during this study: (i) Hourly measurement of stage in the creek at various stations, (ii) Hourly measurement of water level in wells bordering the creek, (iii) Weekly measurement of sediment and water temperatures at a number of stations along the creek, (iv) Weekly measurement of well water levels at a number of stations along the creek, and (v) Direct measurement of hydraulic gradients along the creek. In addition, these approaches were supported by independent measurement of evaporation from the creek, statistical analysis of the stage measurements, and measurement of creek flow rates.

5.1 Hourly Measurement of Stage in the Creek

In an effort to reduce the bulk of the present report, the details of all instruments and installations utilized in this work are to be included in the Masters thesis of Mr. Tim Carlsen and are therefore omitted here. Mr. Carlsen's thesis has been provided to the River Basin Commission. The present report presents only a brief summary of the instruments and techniques utilized.

Creek stage was measured through use of a Druck PDCR 830 pressure transducer with a 5 psig total range. These pressure transducers have been used by our research group on a number of previous occasions and are known for their quality and reliability. Testing of one of our transducers under controlled laboratory conditions led to the determination that the standard deviation of a reading on the transducer was less than 0.005 inches of water. As a result, we were quite confident in using these transducers to measure changes in water level greater than 0.01 inches.

These transducers were used to measure stage in the creek by attaching the transducer under water in the center of the creek. A number of techniques were utilized to anchor the transducer depending on the site location. An electrical line connected the pressure transducer to a field computer which was buried on the bank of the creek. This computer allowed measurement of the pressure at the transducer on an hourly basis. The data on the field computer were transferred to a portable computer every other week. The data on the portable computer were then transferred to the primary computers at Notre Dame for analysis. No human transcription of the data was required during any part of this process, thus eliminating transcription errors in the data set.

Figure 4 shows the hydrograph recorded on Juday Creek during the spring and summer of 1993 for the St. Joseph Farm site, the lake inflow site and the Notre Dame site [Note: Julian day is simply the sequential day in the year - January 1 is day 1 and December 31 (in a non-leap year) is day 365]. A single transducer was used at the farm site. The Lake Inflow site and the Notre Dame site were monitored with the same field computer (hence the separation of record). Gaps in the record are related to electronics problems. This hydrograph shows some of the largest stages recorded on this creek in a number of years. In particular, during the June flood event, the creek rose a number of feet at the farm and over a foot at the lake inflow. Among the casualties to this flood were the field computers installed at both of these sites during this event. Both field computers were later dried in the laboratory and are still functioning.

It is apparent from figure 4 that Juday creek is extremely responsive. Time lags from the onset of the rising limb of the hydrograph to the peak of the hydrograph are often on the order of a few hours with the majority of the recession curve occurring in similar time intervals. The amplitude of rise in water level decreases below the farm. This is expected as the width of the creek increases substantially between the farm and the lake inflow. Close examination of these data indicate that there is a slight delay in the time of peak in the hydrograph between the farm and the lake inflow. The same observation applies to a comparison of peak times between the farm and the Notre Dame property. However, the delay is quite short, rarely being more than 2-3 hours.

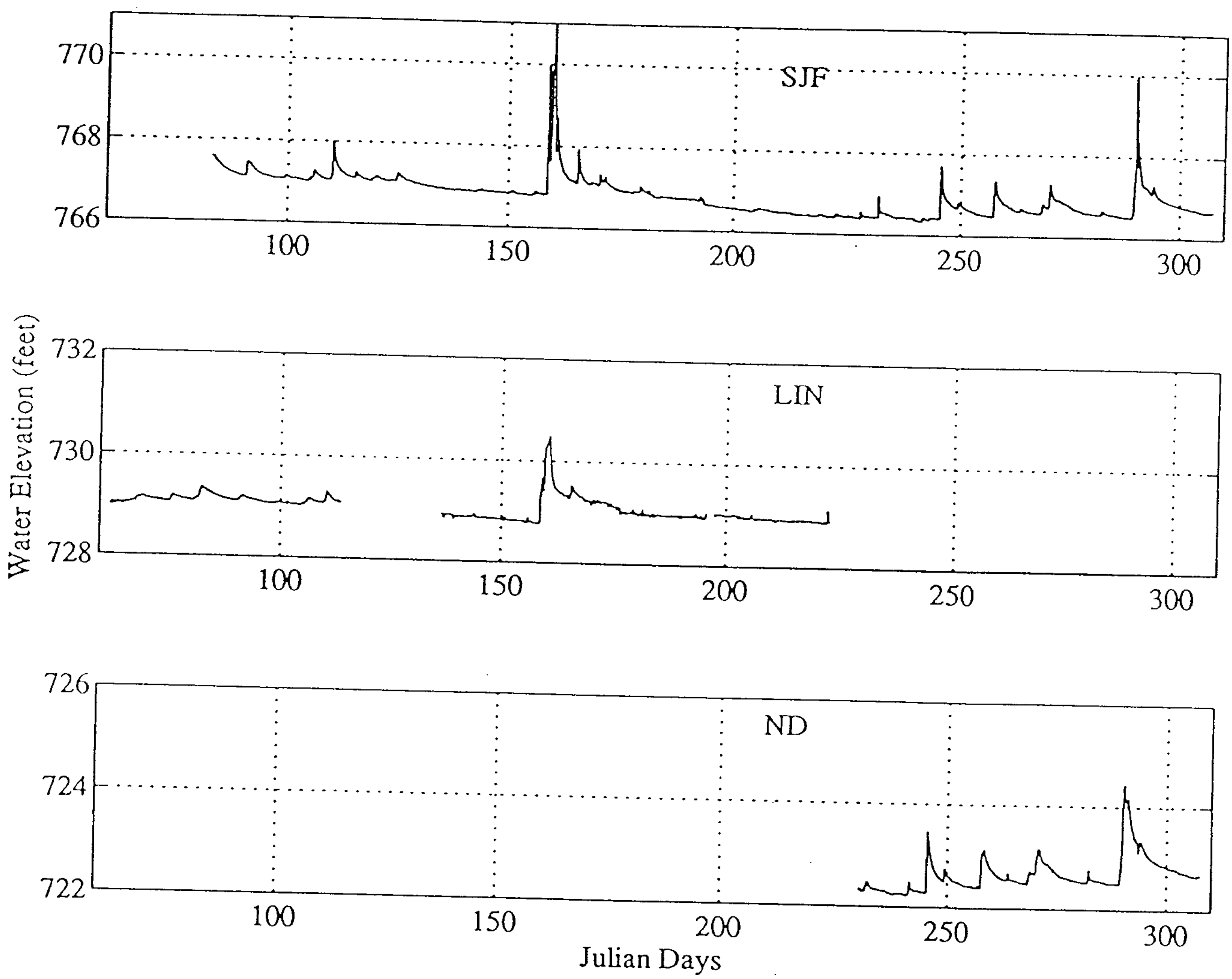


Figure 4: Hydrograph records at the St. Joseph Farm Site (SJF), the Lake Inflow Site (LIN), and the Notre Dame site (ND) for the spring and summer of 1993.

5.2 Hourly Water Level Measurement in Wells

Simultaneous with the hourly measurement of stage in the creek, we recorded water level in a well bordering the creek at the same location. Figure 5 shows the results of measurements performed at the farm site and demonstrates nearly simultaneous response in the creek and in the well bordering the creek. Further, the amplitude of response in the well was regularly greater than the amplitude of response in the creek. Further, as shown in Figure 6 (a comparison of the water level response in the well near Juday Creek and well #9 installed by the U.S. Geological Survey approximately 0.5 miles south of this location), the amplitude of groundwater response appears to increase with distance from the creek.

These observations combine to provide clear evidence that, during periods in which the ground is not frozen, the groundwater aquifer is controlling the creek stage and that the creek is acting as a buffer to the groundwater response to storm events. This conclusion is further supported by the observation that during storm events, we did not observed the creek level becoming greater than the groundwater level. As a result, we observe that, for the period shown in Figure 5, flow was always from the aquifer into the creek. Such a result is relatively unusual in groundwater/surface-water systems as it requires the soil and underlying aquifer to allow rapid infiltration of precipitation with little or no overland flow during large storms. It also requires a very shallow water table, thus allowing the rapid groundwater response to storm events observed in these data.

Figure 7 is an enlargement of the response during the late summer periods at the farm. It is noted that there is a decline in water level in both the well and the creek in the late afternoon and early evening. Statistical analysis of this daily fluctuation shows that this daily cycle first appeared in late May and died out in mid-September with the strongest signature present in late July and early August. A similar pattern of fluctuation was observed in 1991 during the latter part of the summer. Based on the statistical analysis and our interpretation of this system, we believe that these fluctuations are a direct result of the water use by the local plants. This conclusion is consistent with observations made by other scientists working in shallow water table environments, but may be one of the first cases in which this behavior has such a direct impact on a surface

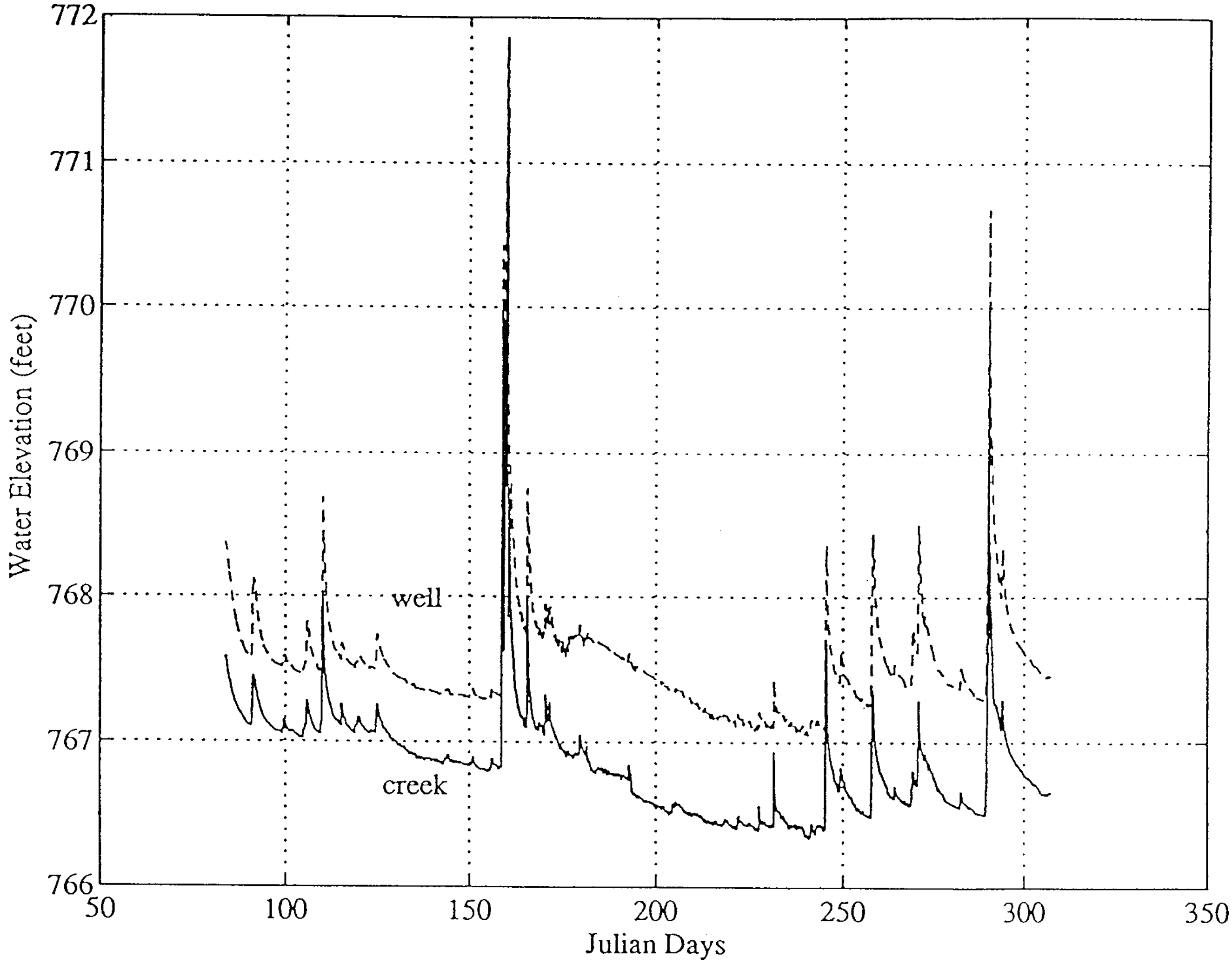


Figure 5: Comparison of hydrographs from the creek and the well bordering the creek at the St. Joseph Farm site.

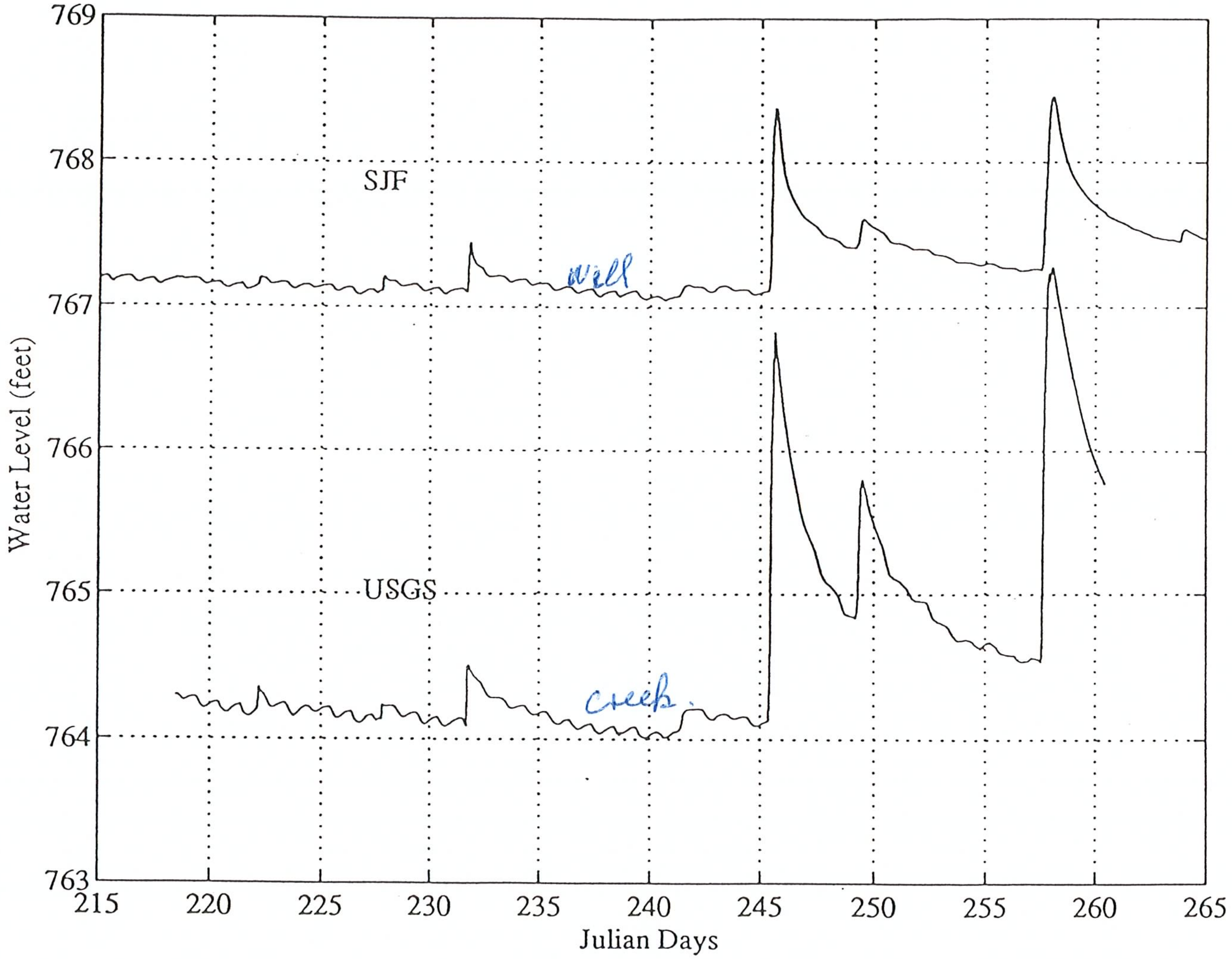


Figure 6: Comparison of water level variations in the well at the St. Joseph Farm site and well #9 installed by the U.S. Geological Survey.

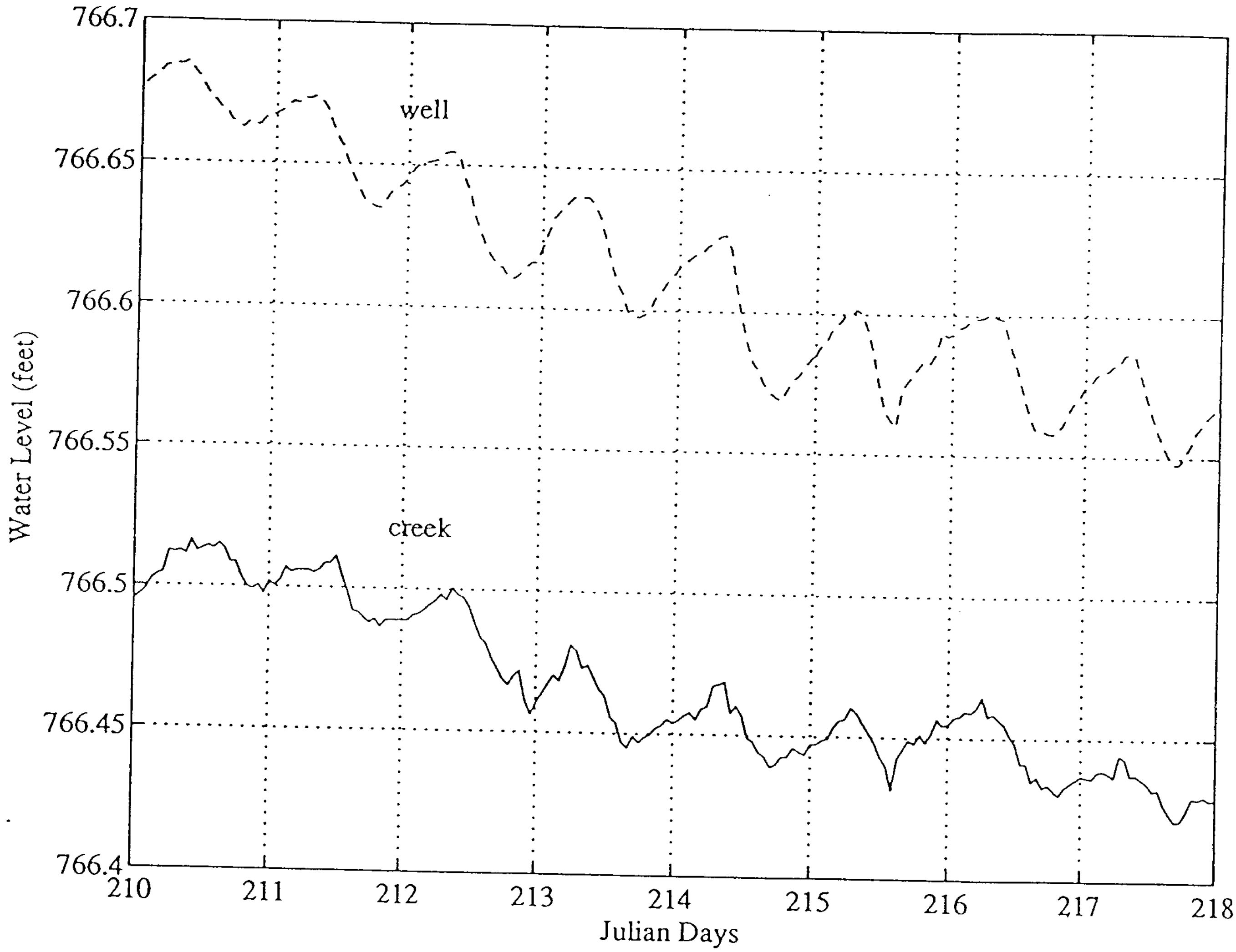


Figure 7: Detail of hydrograph from St. Joseph Farm site showing daily fluctuations during the late summer months.

creek (due to the groundwater control of the creek). As discussed later in this report, this observation may have important ramifications regarding land use in this area.

Figure 8 shows the response at the lake inflow. The response of the creek and the groundwater is similar to that observed at the farm site, although at a reduced amplitude. Combination of the information in Figures 5-8 have significant implications as to the cause and effect of flooding during periods in which the ground is not frozen. These will be considered in the section on discussion of results presented later in this report. It is noted here, and will be repeated in the discussion of results, that the conclusion that the groundwater controls creek stage is limited to periods in which the ground is not frozen.

Figure 9 shows the relative response of the surface and groundwater on the Notre Dame property. This set of hydrographs is substantially different in content than those shown in the previous figures. Specifically, the surface water hydrograph is substantially different than the groundwater hydrograph. The surface water hydrograph shows relatively rapid response to a precipitation event. The groundwater response to this event is delayed substantially in time and is of significantly lower amplitude. Further, the groundwater response shows the daily response to water consumption by the plants whereas the surface water hydrograph does not reflect this daily cycle. These results are consistent with the hypothesis stated in our previous work that the creek is losing water in this reach. As a result of the losing creek, groundwater in this region does not control creek stage. Rather, the creek directly influences local groundwater elevations and, as indicated earlier in the chloride samples collected from the wells on the Notre Dame property, may pose a contamination risk to the groundwater supply.

In addition to the water level measurements in the wells, selected locations were tested for hourly temperature in the sediment and the water column. The results of those measurements were consistent with the temperature profiles detailed in the paper by Silliman and Booth and are not discussed further here except to say that they support the conclusion that the creek is gaining near the farm site.

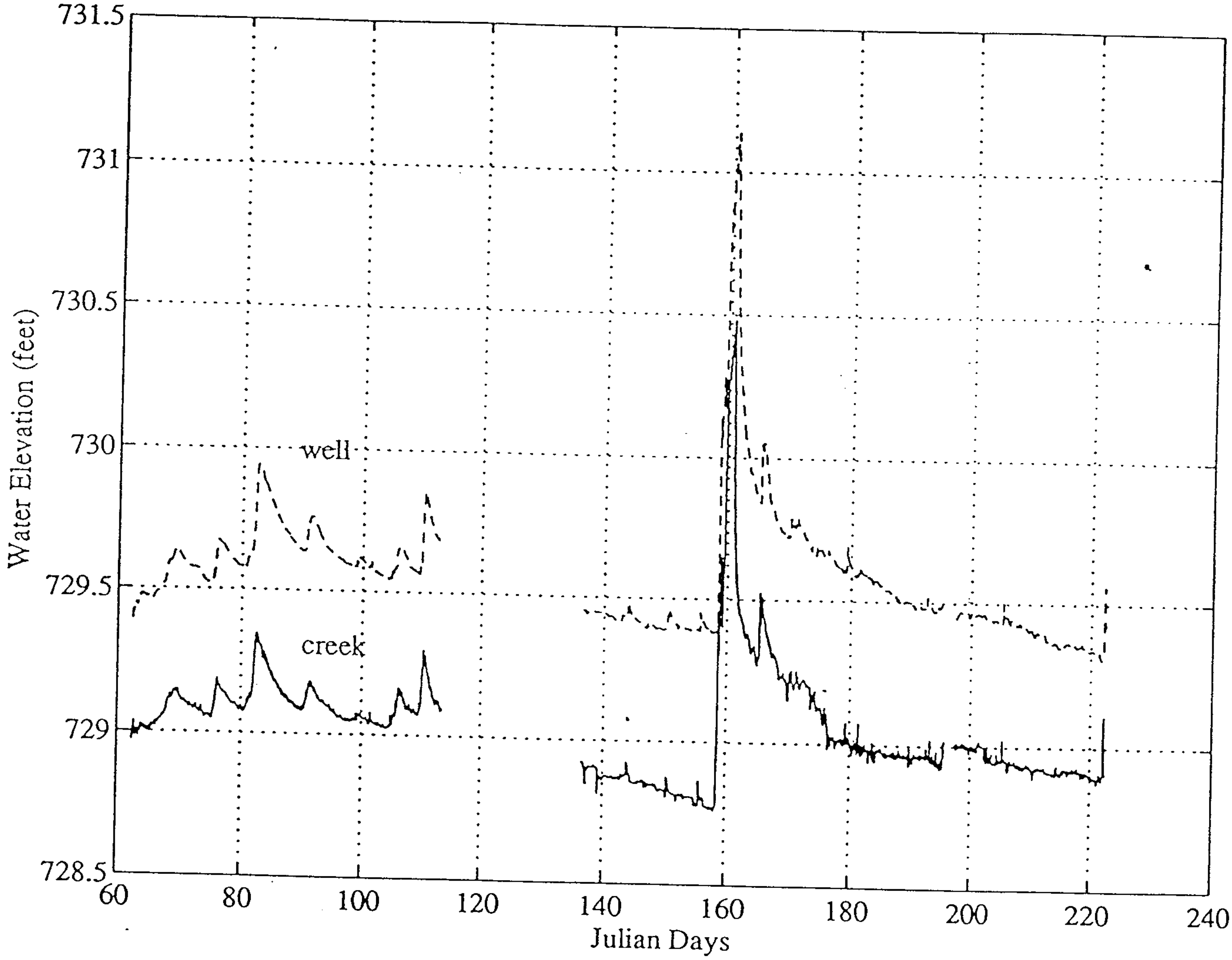


Figure 8: Hydrographs from the creek and well #2 at the Lake Inflow site during the spring and summer of 1993.

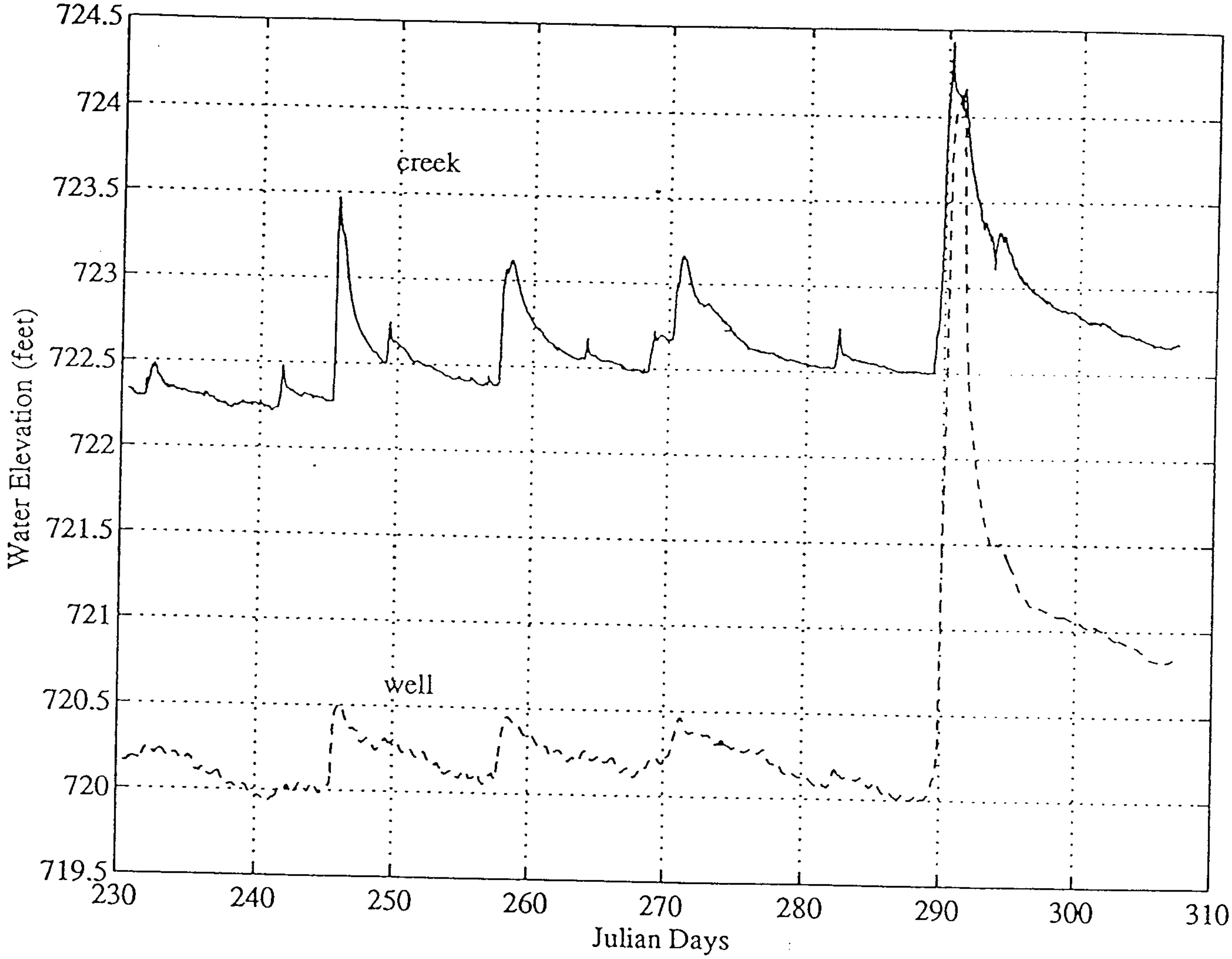


Figure 9: Hydrographs from the creek and well #2 at the Notre Dame site during the late summer and fall of 1993.

5.3 Weekly Measurement of Water and Sediment Temperatures

During the spring and summer of 1993, sediment and water temperatures were collected at a number of locations along the creek on a weekly basis. These measurements were performed utilizing a calibrated thermistor (electronic thermometer) and hand held meter. The same thermistor was used for all readings. Water temperature was recorded by placing the thermistor in the water column and waiting for a steady temperature reading on the meter. Sediment temperatures were recorded by forcing the thermistor approximately three inches into the sediments and then waiting for a steady temperature reading on the meter.

Figures 10 and 11 show the variation in water and sediment temperature versus time at four different locations along the creek. In all cases, both the water and sediment temperatures increased with time through August, but showed an initial, rapid decline in temperature in September. It is interesting to note in comparing the results obtained at various sites that, despite the dominance of groundwater inflow in the upper portion of the creek, the heat of the summer has a dramatic influence on the entire creek.

Figures 12 and 13 show the distribution of temperature in the water and sediments, respectively, along the creek on selected days throughout this past spring and summer. It will be noted on these figures that, despite the warming of the entire creek system via the summer heat, the influence of the groundwater inflow in the upper portion of the creek is clearly evidenced. Above the Lake Shore Estates lake, both the water temperature and the temperature of the sediments are cooler than observed downstream. This cooling, we believe, is a direct result of the groundwater inflow to the creek in this region. On Figure 12, we have shown measurements of creek water temperature collected in the hot drought of 1991. Despite the fact that the creek was generally warmer that year (due to the high temperatures in 1991), the pattern of water temperature within the creek is the same. Thus, the pattern shown in Figure 12 is reproducible in both one of the driest (and hottest) years (1991) and one of the wettest years (1993) on record for this region. We have confidence, therefore, in predicting that this pattern of temperature will be maintained under most summer weather conditions. Further, based on the 1991 data, it is anticipated that under current land use conditions,

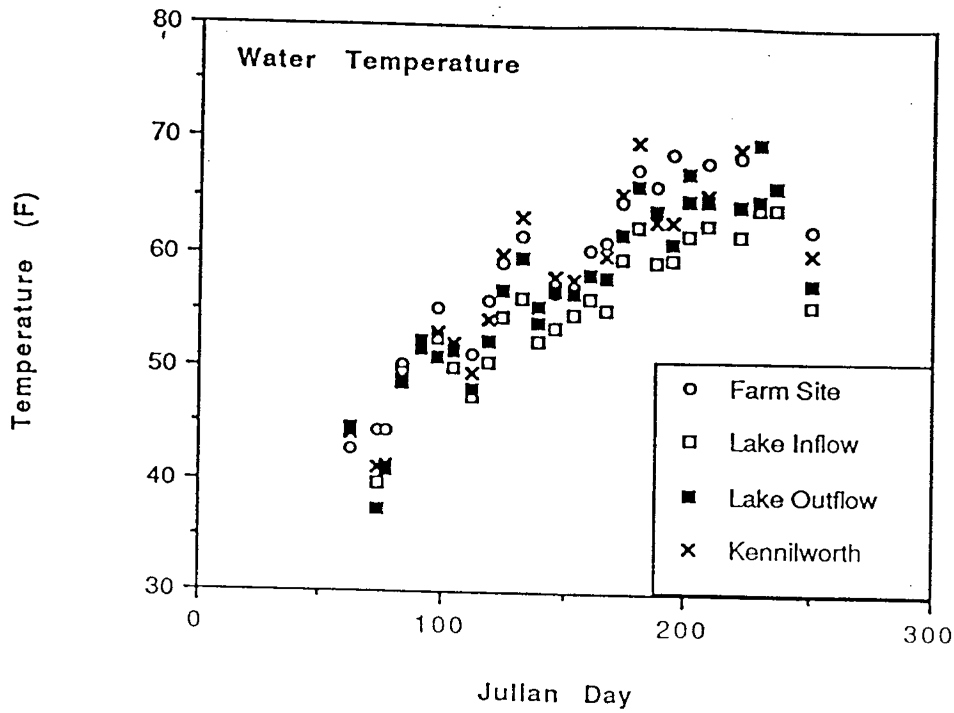


Figure 10: Measurement of water temperature in Juday Creek, 1993.

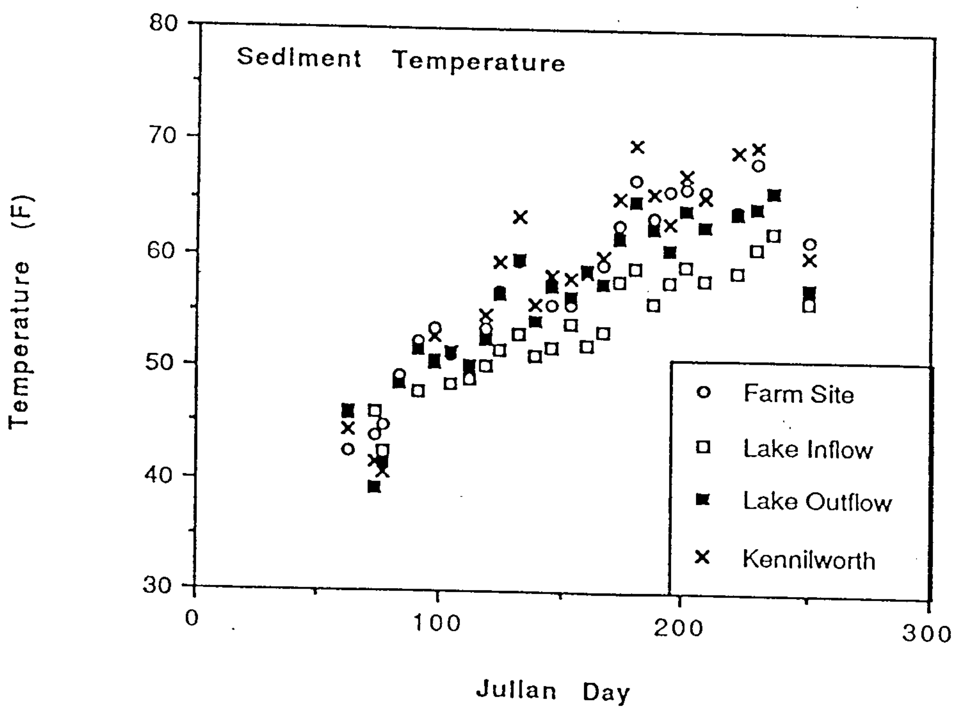


Figure 11: Measurement of sediment temperature in Juday Creek, 1993.

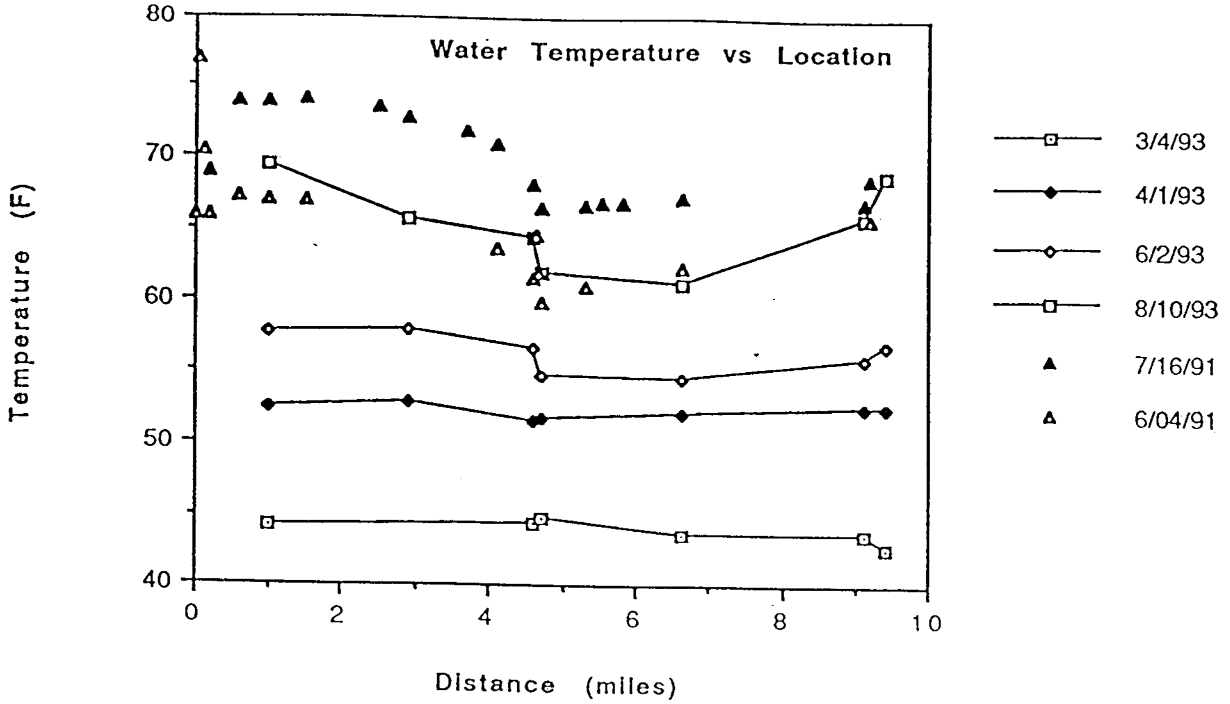


Figure 12: Distribution of water temperature in Juday Creek on various dates in 1993.

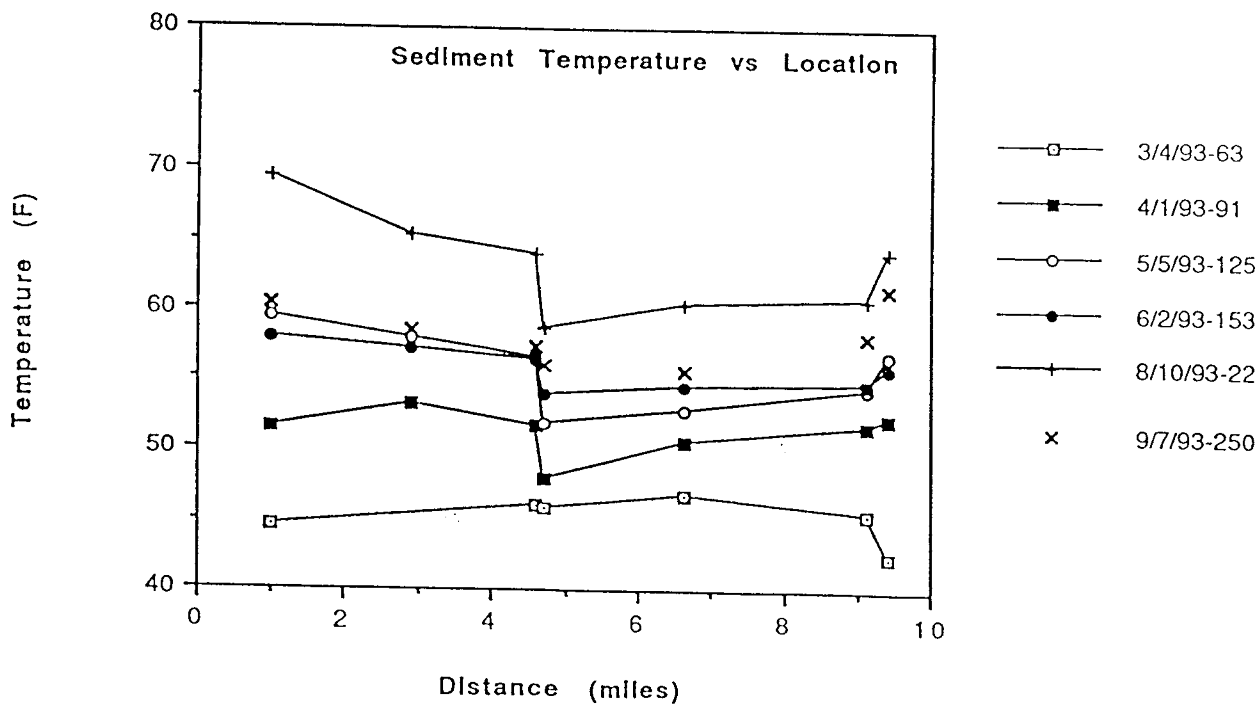


Figure 13: Distribution of sediment temperature in Juday Creek on various dates.

the majority of the creek will remain below 75 degrees Fahrenheit as a maximum temperature. As discussed below, changes in land use may alter this conclusion.

5.4 Weekly Measurement of Water Level Elevations in the Wells

During the spring and summer of 1993, water levels were collected utilizing a standard steel tape on essentially a weekly basis from all wells not directly involved in the hourly water level measurements. Within the graphs below, all results are presented as depth to water measurements. Hence, a smaller number (lower depth to water) should be interpreted as a higher water level in the well.

Figure 14 shows the response at wells 1 and 3 at the St. Joseph Farm site (well 2 was used to monitor hourly water levels). When corrected for elevation of the well casings, these two records are essentially identical. These curves show several features of interest. First, the response to the June storm is apparent in the rapid decrease in the depth to water around day 155. Following this event, the water levels show a rapid recovery of approximately 0.8 feet and a significantly delayed recovery of the additional foot to move the water levels to their prestorm levels (note that the minimum depth to water during the storm is not captured in this plot as this plot represents only one record per week -- as a result, the peak response may have been far greater than shown here -- see, for example, the hourly hydrograph for well #2 given in Figure 5).

These data indicate that the peak response during the storm was countered by a rapid discharge of groundwater. Two possible areas for discharge may be identified. The first is Juday Creek and the second is deeper portions of the aquifer (or a confined aquifer underlying the shallow aquifer). Certainly some of the water was discharged to the creek and the rapid drop in groundwater level may be related to the increased bank area available for discharge during this storm. It is anticipated that the slower response after day 165 is related to long term discharge of the aquifer to the creek (often termed baseflow).

Despite the extremely wet conditions this summer, the average level of the groundwater appears to be declining during this period of record. It is noted that the depth to water between approximately day 140 and approximately day 200 increased by

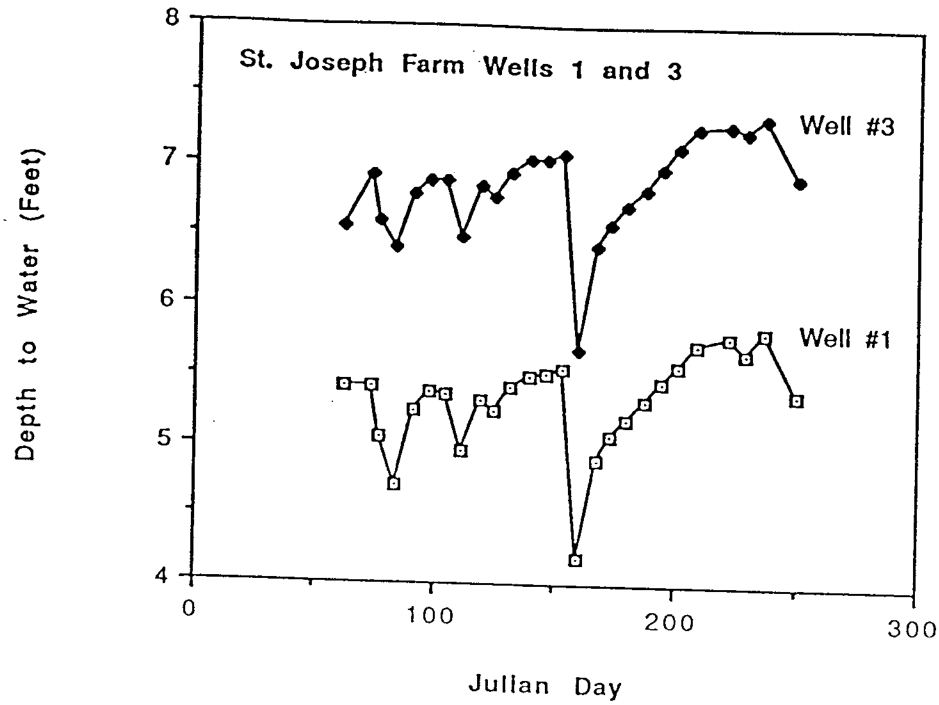


Figure 14: Water levels collected on weekly basis at St. Joseph Farm wells.

approximately 0.1 - 0.2 feet despite the large influx of water during the June storm. It can be concluded from this that during the summer months in this portion of the aquifer, water is being withdrawn from the aquifer faster than it is being replenished (withdrawn by plants, evaporation and human activity). One must therefore conclude that the aquifer is recharged sometime during the winter months. The most probable time being late winter and early spring.

Figure 15 shows the depth to water data for three of the wells at the lake inflow site (the fourth well was monitored on an hourly basis). The data have been artificially shifted to show details of each hydrograph. When corrected for well elevation, each of these plots are essentially identical.

Once again, the water level response in each of the wells is the same. The response to the June storm is once again quite rapid, but lower in amplitude than the response at the farm. The relatively long recession from the storm is also apparent in these data. Finally, the general decline in water level during the summer is evident.

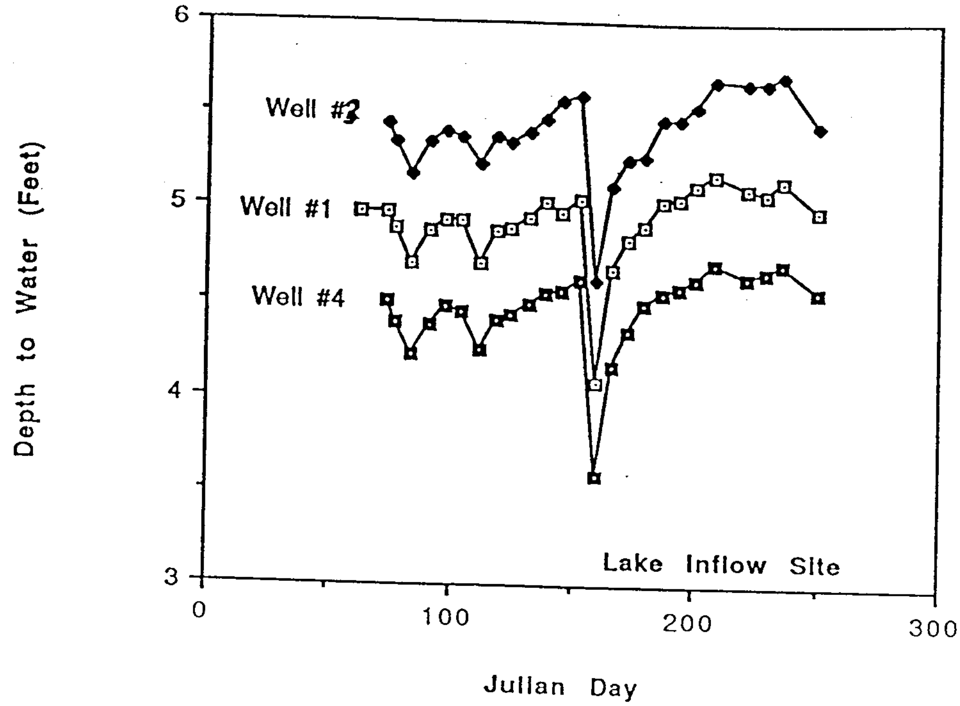


Figure 15: Weekly water level measurements at Lake Inflow wells 1, 3, and 4.

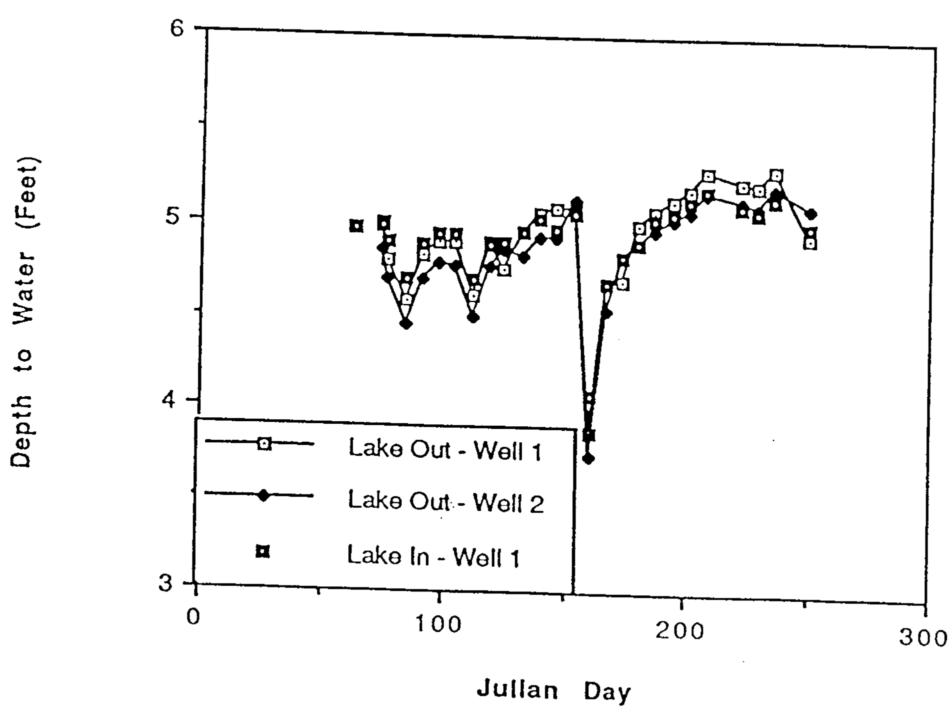


Figure 16: Weekly water level measurements at Lake Outflow wells 1 and 2 and Lake Inflow well #1.

However, the drop in water level over the period of day 140 to day 200 apparent in Figure 14 is not apparent in these data, implying a slower decline in water level during the latter part of the summer near this site. Initial analysis of this observation would seem to be consistent as there is less agriculture in the area around this portion of the creek. The data, however, are insufficient to fully analyze the reason for this slight difference in water level decline at the lake inflow as compared to the farm.

Figure 16 shows the depth to water data for the two wells at the lake outflow and well #1 at the lake inflow. In this case, we have not artificially separated the graphs. It is apparent from this figure that the response at the lake outflow is essentially identical to the response at the lake inflow. Thus the groundwater response on both sides of the lake are well coordinated either through regional groundwater flow or through control by the lake.

Figure 17 shows the water level response on the Notre Dame property. These hydrographs provide a different view of the subsurface system in this area as compared to the other field sites. As noted earlier, the response to storms in this area is observed first in the creek and then, delayed in time and reduced in amplitude, in the wells. During the June storm, however, well #1 showed significantly different response. This well is completed near the top of a clay layer observed between 15 and 25 feet at this site. Both wells #2 and #3 are completed in the sand and gravel overlying this clay. The response during the June storm in well #1 was recorded to be approximately 4 feet. This is substantially greater than the response at either of the other two wells and reflects water levels rising slightly above land surface. This rapid, high magnitude response is followed by approximately two weeks of slow decay of the water level increase and then by a rapid decline in water level over the following week. After this period, well #1 mimics the behavior in wells #2 and #3 quite closely.

The unusual response in well #1 opens several possibilities as to the hydrologic behavior of this system and/or the hydrologic behavior of this well installation. If this signature is real, it would imply either that this well is sampling a different hydrologic unit (e.g. a lower aquifer) which responded to the June storm with a large magnitude (> 4 foot) rise in water level or that the build up of water above a natural dam which formed immediately above this location was significantly influencing water levels in this area. If the signature is not real (i.e. is an artifact of our measurement system), then the source of error in our system must be identified. Sampling error has been ruled out as duplication of depth to water measurements were conducted. Other possible mechanisms whereby this signature could be generated have been discussed with fellow hydrologists. To date, a reasonable explanation has not been established. Although not of tremendous significance relative to the study of the creek, this observation opens an interesting area of research with respect to groundwater hydraulics.

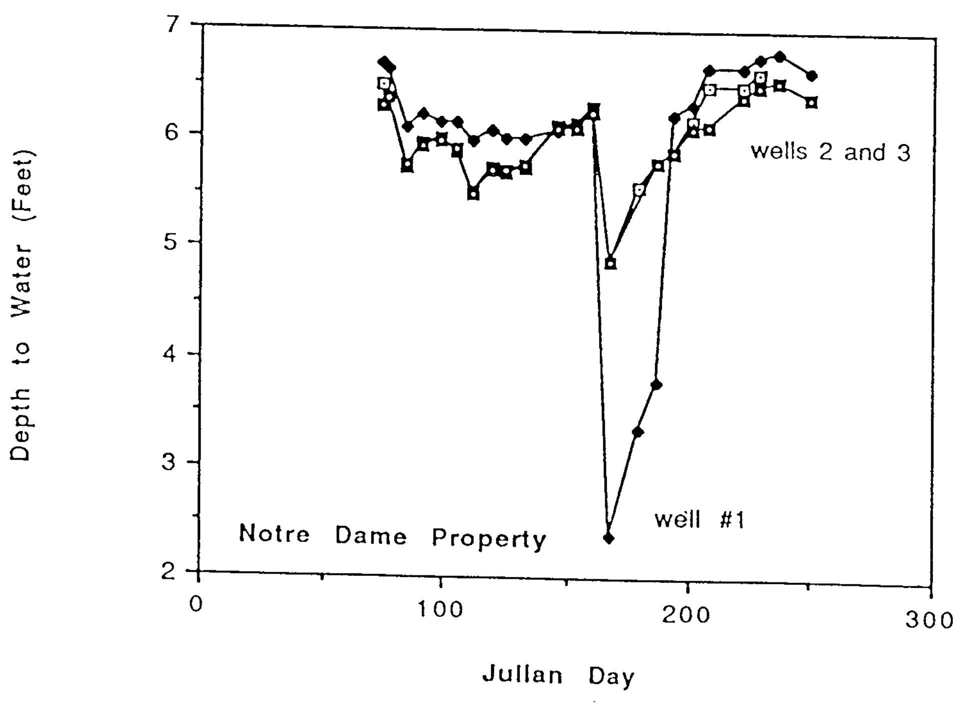


Figure 17: Water level measurements at Notre Dame site wells.

5.5 Measurement of Hydraulic Gradients in the Creek Bed

In addition to the methods originally suggested for application in the field, CE/GEOS has applied a tool designed to directly measure the hydraulic gradient in the creek sediments. Described in detail in the thesis by Mr. Tim Carlsen, this probe allows measurement of relative hydraulic head at different depths within the sediments. Application of this probe at the farm field site has shown that the hydraulic head increases with depth. This gradient in hydraulic head would lead to the conclusion that there is upflow in this region, a conclusion which is consistent with our hypothesis that the creek is gaining in this region. Measurements at the inflow to the lake also showed increased head with depth and, therefore, that the creek is gaining in this region.

Measurements of hydraulic head at the Notre Dame property showed a decreasing head with depth. This result implies downflow in this region, consistent with our hypothesis that the creek is losing water in this region. The measurements at the Notre Dame property also indicated that while the sediments immediately underlying the creek were saturated, sediments at depths of approximately 1 foot were unsaturated. This is, once again, a strong indication of a losing creek and may be related to the unusual water level measurements recorded in well #1 at this site.

5.6 Miscellaneous Measurements in Support of the Project

During the project period, a number of flow measurements have been collected. Due to the tremendous sediment load carried during the June event, however, we do not feel confident in estimating a stage-discharge relationship at this time. While further measurements will be collected in order to establish a stage/discharge relationships for the period following the June event for each of our monitoring stations, such relationships are not considered to be of significant value for the present studies for a number of reasons. First, the primary focus of this work is to determine the relationship between creek flow and groundwater flow. This relationship has been firmly established without the need for flow measurements. Second, the accuracy with which we could measure flow at our sites will be limited by the awkward geometries present at these sites, the heavy vegetation along the edges of the creek at these sites, the variation in flow with time during the day at these sites and the limitations of the flow meter we currently utilize. As a result, the tremendous precision with which we have measured relative response in terms of water levels would be lost in translating these numbers to flow values. Third, because these sites are uncontrolled and non-engineered, each large storm will change the slope and geometry of the gauging location. As a result, the stage discharge relationship is continually evolving and a relationship based on the previous six months worth of data is not accurate for application to stage measurements collected after the next big storm. It is recommended that the gauging stations utilized be interpreted entirely in terms of creek stage and that all discussion of flow through the creek be tied to the flow estimates derived from the U.S. Geological Survey gauging station installed on the Isaac Walton League property (where an excellent stage/ discharge relationship has been developed).

We also attempted to measure evaporation from the surface of Juday Creek for a 45 day period between mid-July and early September. Results from these measurements indicated that evaporation from the surface of the creek was insufficient to produce the observed fluctuations in creek levels. Estimates of evapotranspiration were also obtained for the corn grown at this site. The magnitude of the evapotranspiration is consistent with the magnitude of the response in the creek. These data provide further support of our hypothesis that the afternoon declines in water level are related to water consumption by the plants.

6.0 DISCUSSION OF RESULTS FROM HYDROLOGIC STUDY

Within this section of the report, an attempt is made to synthesize the data generated in this project into a number of observations regarding the behavior of the creek and potential human interaction with the creek. These observations pertain to: (i) the general nature of the hydrology along the creek, (ii) the interaction of groundwater and surface water (and thereby the development of flooding events) along the creek, (iii) the role of seasons on creek behavior, (iv) potential impacts of changes in land use in the vicinity of the creek, and (v) suggested monitoring in the future to follow changes in the creek and regional groundwater aquifer.

6.1 General Nature of Hydrology Along the Creek

The data and analysis presented indicate that Juday Creek is an extremely responsive creek in which water level can vary from background levels to peak flows in a matter of a few hours and then return to relatively low flow rates in a matter of 10-20 hours. The data generated in this project support the previous hypothesis that the creek is generally a gaining stream northeast of the lake at Lake Shore Estates and is a losing creek below the lake. Although we did not monitor groundwater levels below the Notre Dame site, the presence of springs on the property of the Isaac Walton League indicate that the stream is once again gaining in the reach immediately above the confluence with the St. Joseph River. The one piece of evidence which is inconsistent with this conclusion is a flow measurement collected by biologists in another portion of this study showing that flow rates in the creek declined in the area of Grape Road. We have not had the opportunity to review those data and suspect that if the observation is correct, the decline is related to local pumping or direct withdrawal of water from the creek in this region, and not a change in hydrologic conditions in this region. The reason for this conclusion is based on the temperature profiles collected in 1991 in which sediment and water temperatures were collected both upstream of this area and downstream of this area without any indication of a change in hydrologic conditions in this region.

6.2 Groundwater Interaction with the Creek and Flooding

The results obtained in this study indicate that the creek water level above the lake at Lake Shore Estates is strongly controlled by groundwater. Even during the major storm in June of 1993, the creek in this region responded primarily to changes in groundwater elevation and not to surface runoff. As a result, reported flooding of basements along the creek during periods of high precipitation are most likely a result of groundwater level increases due to direct infiltration rather than a rise in groundwater related to increased flow in the creek. If anything, it would appear that in the area of the St. Joseph Farm, the creek acts as a buffer to the groundwater response, decreasing the magnitude of rise in the groundwater table during a storm event.

This observation leads to an observation regarding the utility of reservoirs excavated along the creek for the purpose of flood control. Based on our conclusion of strong groundwater control on the creek, it is unclear what influence a large surface reservoir (such as that previously proposed to be constructed above Fir Road) would have on flow in the creek. Designs based on an assumption that the primary portion of the flood wave is related to overland flow may result in misleading predictions of behavior. It is difficult, however, to predict a priori what the behavior of such a reservoir would be. One could, for example, hypothesize either of the following two extremes.

In the first, the reservoir may have little or no effect on flooding downstream. This hypothesized outcome is based on our observation of the control which groundwater has on the creek. If flooding downstream is a direct result of a rise in downstream groundwater levels due to direct infiltration, widening the surface area of the creek upstream should have minimal effect on downstream flooding. Rather, the reservoir would tend to respond extremely rapidly to storm events (through inflow of groundwater), with its primary impact being a dampening effect on the rise in groundwater levels in the immediate vicinity of the reservoir.

In the second, the reservoir may permanently alter the flow of water downstream from the reservoir. This hypothesis might be based on our earlier observation that the artificial lake at Lake Shore Estates is located at the dividing line between reaches along which the creek is gaining and reaches along which the creek is losing. At the present time, we do not fully understand whether the placement of this lake was coincidental with this strategic location on the creek or whether the installation of this artificial lake had direct influence on the line between gaining and losing. If, with further study, it can be shown that excavation of a large lake may lead to significant alteration of the interaction of groundwater and surface water, the potential exists for a man-made lake to seriously alter the nature and volume of flow in the creek.

It needs to be stressed that both of these hypotheses are purely speculative and that they may not represent the range of behavior possible in the reaction of this creek to excavation of a reservoir. Further, in our opinion, the reaction of the creek to installation of a reservoir probably lies somewhere between these extremes. However, until the interaction of the creek with such an excavation is studied in more detail, we suggest that it would be unwise for local government to pursue construction of any significant reservoir projects in the portion of the creek above the lake at Lake Shore Estates.

Below the lake at Lake Shore Estates, the creek and groundwater interaction appears to follow a more classical pattern of a losing creek. During a storm, the water level first rises in the creek and then, with delayed amplitude, in the groundwater immediately surrounding the creek. Given our observation of the rapid response of the groundwater to precipitation events and the high hydraulic conductivities present in these soils, however, we anticipated that the primary influence of the creek on groundwater levels will remain extremely local (e.g. within 100 feet or so of the creek). Further, the magnitude of water level change is unlikely to be more than a few feet given the wide channel and flood plain available to the creek through most of this region. For this section of the creek, we conclude from these observations that flooding of basements within homes more than a couple of hundred feet from the creek is far more likely to be a result of direct infiltration of precipitation into the groundwater than to result from a rise in groundwater levels caused by a rise in the stage of the creek. Further, basement flooding of homes very close to the creek is, in our opinion, related both to the water derived from the creek and water derived from direct infiltration. It is unclear, based on these results, that there would be significant benefit to be derived from an engineering project focused on reducing the volume of flow in the creek during a storm event. It is cautioned, however, that this conclusion is based on periods in which the ground is not frozen. As shown in the next section, dramatically different behavior may be observed during periods in which the ground surrounding the creek is frozen.

6.3 Seasonality of the Interactions on the Creek

As the reader may have noted earlier in this report, the data available during the winter months is limited. The small amount of data between September, 1992, and March, 1993 is related primarily to the difficulty in monitoring during the winter months. In particular, the use of automated data logging during either extremely cold periods or during periods in which the ground is regularly covered with water (e.g. during repeated freeze / thaw periods) is difficult. During extremely cold periods, two practical difficulties limit field efforts at remote locations: (i) battery life and battery power within the data logger during periods when the temperature drops below freezing are extremely limited and (ii) equipment buried for protection from vandalism and tampering by animals cannot be recovered due to the fact that the ground is frozen. During repeated freeze / thaw cycles, there is significant potential for equipment to become wet, thus destroying the field equipment (a single data logger is valued at approximately $3000). Further, during freeze / thaw periods, the ground tends to be firmly solidified with ice, once again reducing the ability to access field equipment.

As a result of these limitations, we do not currently have a consistent record of groundwater versus surface water interaction during winter. Hence, we must analyze field behavior based on limited data sets and indirect measures. Figure 18 shows the hydrograph recorded at the St. Joseph Farm during a heavy rainstorm during the first days of January in 1993. Comparing this hydrograph with the later hydrographs recorded at the Farm during the summer, it will be noted that the recession portion of this hydrograph is significantly steeper than the recession hydrographs from the summer. Further, the hydrograph recesses to below the original creek water level within three days of the onset of the storm. This rapid behavior is an indication that the creek is responding to surface runoff during this period.

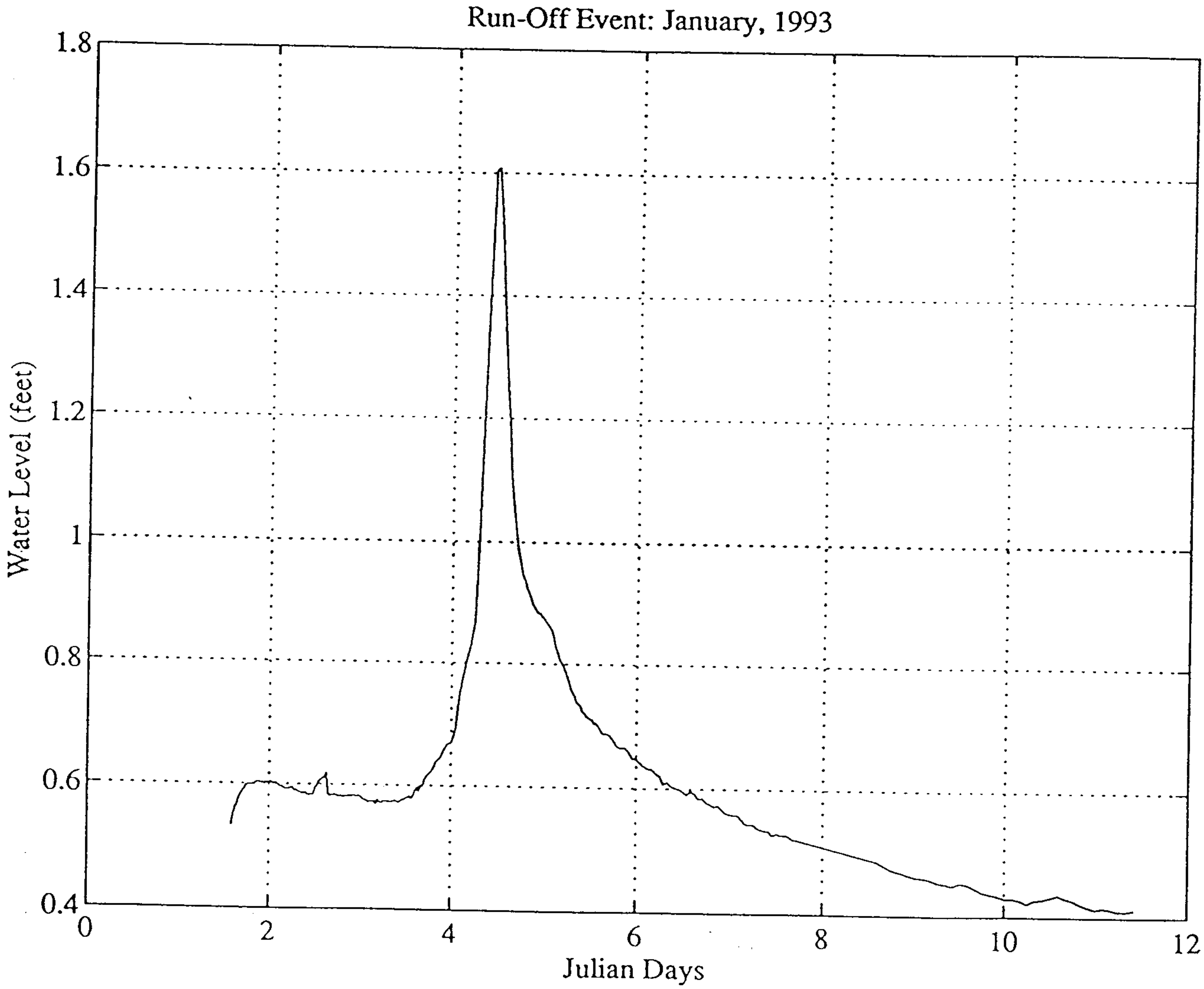


Figure 18: Hydrograph of changes in water levels in creek at St. Joseph Farm. Depths are in feet above the transducer and are not surveyed to absolute elevation.

During the snow melt event which occurred early in March of 1993, we were able to collect hydrographs from both the creek and one of the wells at the Farm (Figure 19). During this period, it will be observed that the well lags behind the creek in response (although it is not reduced in amplitude), suggesting that the creek first responded to overland flow. The relatively slow decline in this hydrograph is indicative both of the extended period of snow melt and, potentially, emerging dominance of the groundwater over the creek as the ground began to thaw.

These two hydrographs indicate that during the winter, the ground may be frozen, providing a substantially different hydrologic regime to the creek. While base flow in the creek during these periods is still supported by groundwater inflow, it would appear that reaction to storms (January data) or snow melt (March data) is driven by overland flow with recharge to the groundwater following surface runoff.

This hypothesis is further supported by the hardness data shown previously in this report. The relatively high hardness values observed during the summer months at the Lake Shore Estates lake and below are indicative of water which has been in contact with the groundwater system. The relatively low hardness values observed in early March (during the snow melt event) are indicative of surface runoff providing the majority of the water to the creek. As a result, these data support the hypothesis that storm or snowmelt runoff during periods in which the ground is frozen dominates the creek flow while creek response to storm events during periods in which the ground is not frozen is driven by groundwater response to the precipitation event.

6.4 Land Use

The data generated within this project clearly show a daily reaction in both the groundwater and the creek during periods in which plants are actively utilizing water. While a direct line of proof that these fluctuations are a result of consumption by plants cannot be established due to lack of data quantifying plant consumption during this period, our statistical and hydrologic analyses indicate that the plants are almost certainly the primary influence on this daily cycle.

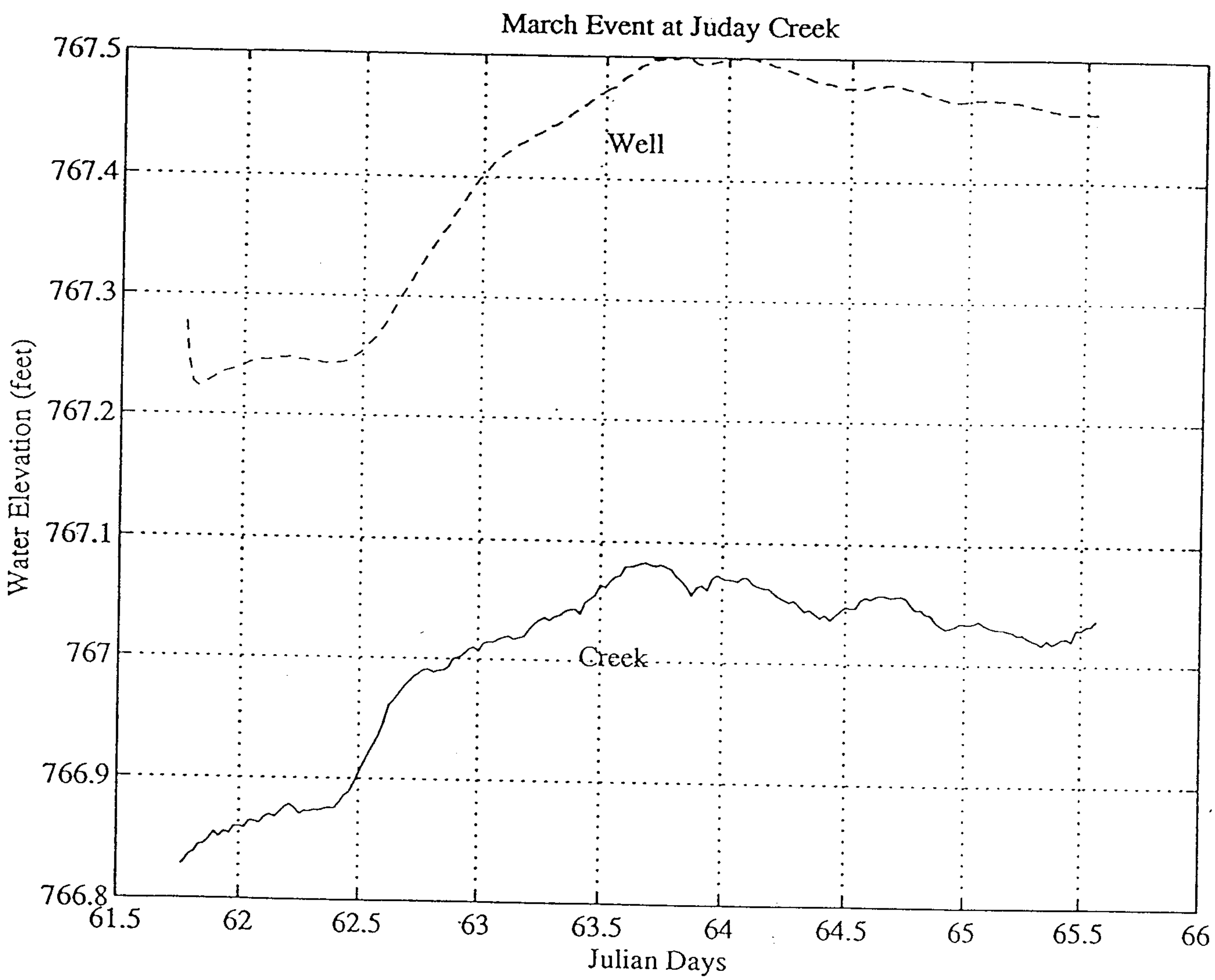


Figure 19: Recorded water levels in creek and well #2 at St. Joseph Farm during the March snow-melt event. As in Figure 18, elevations are not surveyed to absolute elevation.

Combining this observation with the observation of the rapid response of the groundwater (and thereby the creek) to precipitation events, a conclusion can be drawn that the water level in the creek is closely related to land use practices in the vicinity of the creek. For example, development of a significant groundwater supply in the vicinity of the creek which leads to a cone of depression intersecting the creek will lead to a reduction of flow in the creek. The magnitude of this reduction being directly proportional to the magnitude of the drawdown.

Further, changes in land use which substantially influence either the water consumption by the plants in the area or significantly change the rate and location of recharge to the aquifer may lead to changes in the flow patterns within the creek. For example, development of a housing or industrial complex which substantially reduces local infiltration to the aquifer may change the character of the response of the creek to storm events. This would be particularly true if the loss of infiltration surface were accompanied by an increase in direct runoff to the creek (e.g. storm drains discharging directly to the creek). Also, development of a housing or industrial complex which effectively removes plant life from the area surrounding the creek may, for better or worse, reduce the daily cycles observed in the flow of the creek in the late summer months.

As a result, it is concluded that changes in land use in the immediate vicinity of the creek will significantly alter the character of flow in the creek. Whether such changes in the character of flow will lead to either positive or adverse changes in such things as creek temperature, sediment transport, biological populations, or water quality would need to be considered on a case by case basis.

6.5 Proposed Continuation of Studies

Juday Creek has been noted by a number of hydrologists to be relatively unique due to the extreme nature of the groundwater dominance over creek flows during the summer months. This uniqueness provides incentive for continuing study from a variety of viewpoints (note that the biological aspects are omitted here in anticipation of similar recommendations in the final report submitted for the efforts in the area of biology).

6.5.1 Development of management strategy: Managing the competing uses of the land and water along Juday Creek will require active management of the combined water resource. It is anticipated that little development can occur along the creek which will not result in changes (whether positive or negative) to the hydrogeology of the creek. Further, the jurisdictional boundaries across which the creek passes makes management an unusual challenge. The St. Joseph River Basin Commission is uniquely qualified to approach questions of how best to manage complex jurisdictional questions such as those addressed here.

As a suggestion, the Commission might review the general strategy approach currently being applied to wellhead protection programs. Within this approach, administrative responsibilities of the various agencies involved in decision making are clearly defined along with a carefully defined hierarchy of contacts which must be made in pursuing a zoning change. Further, a protection zone strategy would allow the Commission to define critical use areas along the creek and would provide a means of monitoring those critical use areas. Finally, a protection approach would be based, in part, on active public participation in the protection of the creek through formal programs and formal interaction with public entities.

6.5.2 Quarterly monitoring of well water levels: Water levels in the wells along the creek (and to the extent possible monitoring of U.S. Geological Survey wells) should be maintained to provide an adequate data base for analysis of changes to the aquifer system. Two specific comments on this proposed continuation of monitoring. First, Notre Dame (as long as Dr. Silliman is an active faculty member) will make every effort to monitor these wells on a quarterly basis without further funding from the Commission.

Second, the primary difficulty with continuation of monitoring is the maintenance of the wells. At the present time, the Commission owns all of the wells installed for this project. By state law, these wells must be monitored on a regular basis or plugged. Hence, continued monitoring will put a small financial burden on the Commission at a later date to remove and/or plug these wells. In particular, the management at the St.

Joseph Farm have indicated that they would like the wells on their property removed this coming spring.

While Notre Dame has no control over these wells, we suggest that wherever possible, the wells be maintained to provide a continuing record of the behavior of the creek and aquifer. This suggestion extends, if practical, to all developed sites including at least the two western wells at the farm site. A continuing data base could be of significant value in the continuing management of the creek.

It is noted here that Notre Dame did not spend the entire budgeted amount on this project. As a result, Notre Dame requested a no cost extension on spending the money from the Commission in order to support continued monitoring through the winter (1993) and spring (1994) from these funds. The Commission did not respond to this request.

6.5.3 Annual monitoring of groundwater / creek interaction: One of the most interesting aspects of this study has been the development of a basic understanding of the interaction of groundwater and the creek. It is recommended that a 4 week period be selected each summer during which creek levels and well levels can be monitored on an hourly basis. These data will provide a clear picture as to whether the interaction of the creek and the groundwater has changed with time. It is recommended that this monitoring occur either at the Lake Inflow site (to monitor the cumulative effects above this point) or at a site near the St. Joseph Farm (e.g. the culvert on Cleveland Road where two U.S.G.S. wells currently exist). The site near the farm would provide insight into the influence of land use changes in the upper portion of the creek.

Once again, Notre Dame is willing to pursue this sampling assuming that our data loggers are available (i.e. not dedicated to another project and still functioning), the pressure transducers are still functional, and Dr. Silliman is still active at Notre Dame.

6.5.4 Monthly temperature monitoring: Recording of water and sediment temperature has been an extremely valuable tool in the analysis of the hydrology on this creek. Further, temperature is apparently critical to the survival of the trout population. Hence, we recommend that water and sediment temperatures continue to be recorded on a monthly basis. Once again, Notre Dame is willing to pursue this monitoring within the constraints of other commitments.

6.5.5 Continued recording at U.S.G.S. gauging station: Critical to quantifying changes in the hydraulic response in the creek is the presence of a documented gauging station. Although we would like to see an established gauging station further upstream (e.g. near Grape Rd. or Main Street), it is strongly encouraged that the U.S.G.S. gauging station at the Isaac Walton League property be maintained.

6.5.6 Development of management water balance model: The Juday Creek system is complicated enough that it is difficult to use "gut instinct" or basic field measurements to predict the reaction of the creek to changes in land use planning. It is therefore recommended that the Commission pay to have a regional model developed with which they can predict how changes in land use will effect the hydrologic budget (i.e. the inflows and outflow from the creek). While Notre Dame is interested in this type of modelling challenge and may be working on such a model as an unsupported project, it is recommended that this model be supported financially and be developed by an agent independent of those currently working on the creek. Examples of possible entities to complete this task would be Dr. Henk Haitjema at Indiana University, Dr. Victor Bierman at LimnoTech, Inc. of South Bend, or another consulting firm with demonstrated strength in computer modelling of complex hydrologic systems (e.g. a firm which has a solid history of developing computer models in both groundwater and surface water hydrology). The Commission is urged to specifically avoid entities who would apply computer programs which were written by other firms (e.g. firms who would propose using HEC or MODFLOW), particularly if the entities do not have intimate knowledge of the complexity of this creek system and a demonstrated ability to modify the computer program for this application. Further, the Commission is urged to keep its local experts actively communicating with the consultant during the development of this model.

7.0 DATA ARCHIVES

An extremely large data base has been developed during this hydrologic study (approximately ten pieces of information per hour since late March, 1993). This data base may be of significant value in the future when comparing response of the creek to storm events. Hence, all data collected electronically are archived at Notre Dame both on an active hard disc on the Sun computer system and on floppy discs. The format on these discs is Unix. However, the data can easily be translated to a DOS format if required.

All data collected manually (temperatures, concentrations, calibrations, etc.) are being archived in the form of field notebooks in Dr. Silliman's office and/or in the thesis of Mr. Tim Carlsen. Inspection of these data can be arranged through contacting Dr. Silliman.

United States Department of the Interior

U.S. GEOLOGICAL SURVEY

Water Resources Division
5957 Lakeside Boulevard
Indianapolis, Indiana 46278

FOR IMMEDIATE RELEASE

Mailed: September 11, 1995

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JUDAY CREEK STUDY SHOWS LOW LEVELS OF SUSPENDED SEDIMENT

Sediment conditions along Juday Creek and the effects on trout populations have been the focus of concern for area residents, government officials, and environmentalists. Juday Creek near South Bend, Ind., has been identified as one of the few streams in Indiana with a naturally reproducing brown trout population. A report that describes the sediment characteristics along Juday Creek was released by the U.S. Geological Survey (USGS), U.S. Department of the Interior. The report, prepared by the USGS in cooperation with the Indiana Department of Natural Resources (IDNR) and the St. Joseph County Drainage Board, presents results of sampling during three storms and measurements of scour and fill at six sites along the stream.

The report authors, Kathleen K. Fowler and John T. Wilson, USGS hydrologists, said that bedload (particles bouncing along the channel bottom) is the predominant type of sediment affecting Juday Creek. Bedload can clog gravel beds and bury insect larvae (the food source for much of the fish population). The suspended-sediment levels found are below levels that can adversely affect the trout population.

The channel at the six measuring sites was surveyed five times during the study to evaluate the changes in channel shape and amounts of deposition and scour. At most of the sites, some scour was evident after a June 1993 storm, but the channel soon refilled to near pre-storm conditions. Only one site showed evidence of significant sediment deposition during the study period.

The report, "Characteristics, Transport, and Yield of Sediment in Juday Creek, St. Joseph County, Indiana, 1993-94," is published as U.S. Geological Survey Water-Resources Investigations Report 95-4135. Copies of the report are available for inspection at U.S. Geological Survey, 5957 Lakeside Boulevard, Indianapolis, IN 46278 and may be purchased at cost from the Open-File Reports Section, Denver Federal Center, Box 25286, Mail Stop 517, Denver, CO 80225 (phone: 303-202-4651). Orders must include check or money order payable to Department of the Interior–U.S. Geological Survey, and specify the report identification number (WRIR 95-4135).

# # #

Characteristics, Transport, and Yield of Sediment in Juday Creek, St. Joseph County, Indiana, 1993–94

By KATHLEEN K. FOWLER and JOHN T. WILSON

Prepared in cooperation with the
INDIANA DEPARTMENT OF NATURAL RESOURCES, DIVISION OF WATER,
and the ST. JOSEPH COUNTY DRAINAGE BOARD

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95–4135

Indianapolis, Indiana

1995

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To Obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
pound (lb)	454	grams
pound per cubic foot (lb/ft^3)	16.02	kilogram per cubic meter
pound per day (lb/d)	0.4536	kilogram per day
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.590	square kilometer
ton, short	0.9072	megagram
ton per acre per year (ton/acre/yr)	2.242	megagram per hectare per year
ton per day (ton/d)	0.9072	megagram per day
ton per square mile (ton/mi^2)	0.3503	megagram per square kilometer
ton per square mile per day ($ton/mi^2/d$)	0.3503	megagram per square kilometer per day

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

The following abbreviations are used in this report:

Abbreviation	Description
g	gram
mg/L	milligram per liter
mm	millimeter
EWI	equal width increment

Characteristics, Transport, and Yield of Sediment in Juday Creek, St. Joseph County, Indiana, 1993–94

By Kathleen K. Fowler *and* John T. Wilson

Abstract

Juday Creek is a tributary of the St. Joseph River in St. Joseph County, north-central Indiana. The creek has been identified as one of the few streams in the State that can support a naturally reproducing brown trout population. A recent study of benthic invertebrates shows a decline in the production rate of insect species and suggests that this decline may be caused by increased sedimentation. This report presents the results of a study of the sediment conditions in Juday Creek from April 1993 through June 1994. Measurements of streamflow, suspended sediment, and bedload were made at six sampling sites during three storms and a period of low flow. A total of 11 samples were collected during storms, and 1 sample was collected during low flow at each site. Bed-material samples were collected at the six sites. Sediment cores were collected from the delta of an instream pond and at a sediment trap near the mouth of the stream. Scour and fill at the six sites were monitored by means of scour chains and surveyed cross sections. The instream pond was surveyed twice, and the volume weight of the sediment was determined to estimate the yield of sediment for the upper reach of Juday Creek.

Particle-size distributions indicate that the bed material is predominantly sand and gravel and that very little of the bed material is silt or finer (less than 0.062 millimeter). Analysis of sediment cores showed that most of the sediment deposited in the sediment trap and instream pond was sand.

Sediment sampling during a period of low flow detected only minimal concentrations of suspended sediment; the maximum concentration was 6 milligrams per liter, equivalent to a daily load of 0.32 ton. Bedload ranged from 5.2 to 76.7 grams per cross-channel sampling, equivalent to 0.11 to 1.70 tons per day.

Sediment sampling during the storms indicates that bedload discharge is the primary mode of sediment transport. Suspended-sediment concentration ranged from 4 to 67 milligrams per liter; the median was 17 milligrams per liter. Bedload ranged from 3.4 to 862 grams per cross-channel sampling; the median was 109 grams. Only 15 percent of the samples were less than 50 grams.

Scour chains and surveyed cross sections documented some scour and fill at most of the sites. Scour and fill tended to balance out; after a 1-year period, the net change in the streambed altitude was minimal. Some infilling was the net result at most of the sites.

Surveys of the instream pond determined that the volume of sediment delivered to the pond from April 1993 to April 1994 was approximately 26,500 cubic feet. The average volume weight of the sediment was determined to be 102 pounds per cubic foot. The sediment yield for the upper reach of Juday Creek from April 1993 to April 1994 was estimated to be 48 tons per square mile.

INTRODUCTION

Many small streams in the upper Midwest are known for cool temperatures, gravel beds, and clear water—conditions favorable for trout. In contrast, streams in the lower Midwest have higher temperatures, greater amounts of sediment, and tend to have fish populations with greater tolerance to these conditions. Juday Creek in northern Indiana is one of the few streams in the State that can support a naturally reproducing brown trout (*Salmo trutta*) population (U.S. Army Corps of Engineers, 1986). Trout depend on the stream substrate not only for food (macroscopic organisms), but also for spawning areas (streambed gravels).

Currently, the extent of the brown trout population in Juday Creek is unknown. According to a recent study of benthic invertebrates, however, the production rates of insect species in the stream have significantly declined since 1981–82 (Kohlhepp, 1991). An increase in sedimentation is a possible cause of this decline, but data on sediment conditions in Juday Creek have not been collected prior to 1992 (Runde, 1994). Suspended-sediment characteristics in other streams in Indiana were compiled by Crawford and Mansue in 1988 and at Trail Creek in northern Indiana (Crawford and Jacques, 1992). Bedload was not measured in either study.

This report documents the sediment conditions in Juday Creek and is the result of a study by the U.S. Geological Survey (USGS) in cooperation with the Indiana Department of Natural Resources (IDNR), Division of Water, and the St. Joseph County Drainage Board.

Purpose and Scope

The purpose of this report is to describe the sediment conditions in Juday Creek during April 1993 through June 1994. Sediment characteristics, transport, and yield were determined by evaluating sediment movement during three runoff events and during low-flow conditions, analyzing streambed material, surveying channel and pond cross-sections, and collecting sediment cores during 1993–94. Information on sediment conditions is beneficial in management decisions by State and local officials concerned with flood control, water-quality management, and fish and wildlife preservation.

Six measurement and sampling sites were selected along Juday Creek (fig. 1). Sediment characteristics were determined from bed-material analyses and sediment cores. Sediment transport was determined from measurements of streamflow, suspended-sediment concentration, and bedload during three periods of runoff and during low-flow conditions. Scour chains and cross-section surveys were used to indicate areas of scour and fill. Channel cross sections at each site were surveyed five times during the course of the study. These cross sections were compared, and changes in channel geometry were evaluated.

Sediment yield was estimated for a reach of Juday Creek just upstream from an area that had been identified as an area of substantial sediment deposition. This area was the delta of an instream pond near site 3 (fig. 1). Cross sections within this area of deposition were surveyed at the beginning and end of the study. Changes in altitude of the pond bottom were used to calculate the volume of sediment deposited. The bulk density, or volume weight, of the accumulated sediment was estimated from sediment samples collected at the pond delta. The change in volume of sediment and average volume weight were used to calculate the load of sediment deposited during a 1-year period.

Physical Setting

Juday Creek is in St. Joseph County in the north-central part of the State. It is tributary to the St. Joseph River and drains approximately 37.7 mi^2 (Hoggatt, 1975). Land use in the area is diverse. Approximately 25 percent of the basin is agricultural, 60 percent residential, and 15 percent commercial (St. Joseph River Basin Commission, 1994). Normal precipitation in the area is about 39 in/yr (National Oceanic and Atmospheric Administration, 1993b).

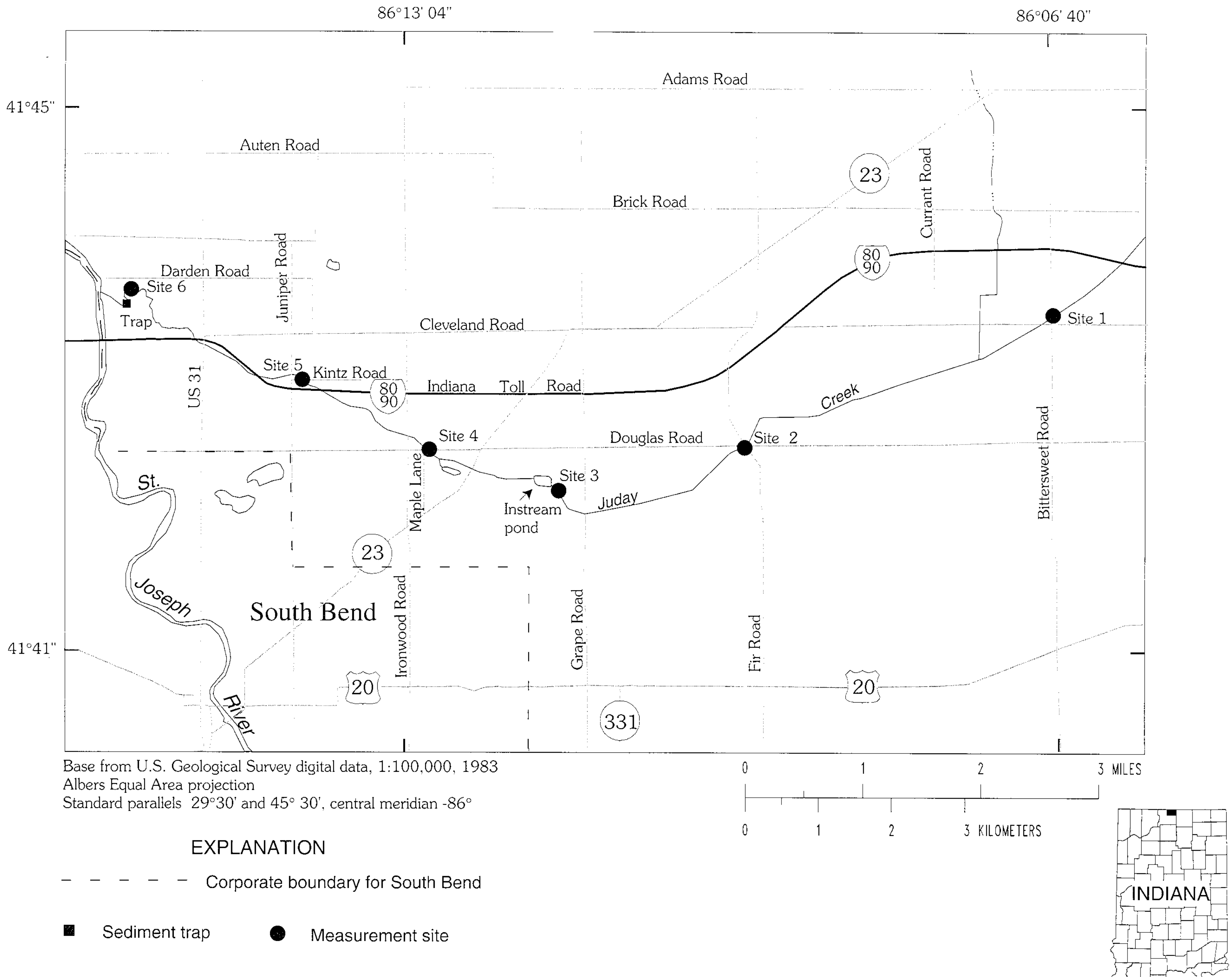

Figure 1. Location of measurement sites on Juday Creek, near South Bend, Indiana.

The Juday Creek Basin is part of the Kankakee Outwash and Lacustrine Plain, which is included in the Northern Moraine and Lake Physiographic Region (Malott, 1922, p. 112). Land-surface altitudes range from 700 ft near the St. Joseph River to 865 ft close to the Michigan border. The Juday Creek Basin is in an area of thick, highly permeable glacial deposits. Much of the area is covered by fine-grained alluvium and underlain by thick outwash sand and gravel. The sand and gravel was deposited by glacial meltwaters at several different times during the late Wisconsin glaciation (Schneider, 1966, p. 42, 52). Sand, transported by the wind and formed into dunes, overlies outwash in some areas. Unconsolidated deposits are typically about 150–200 ft thick (Fowler, 1994, p. 28).

Two general soil types predominate in the basin. Toward the west, the soils are deep, nearly level to sloping, well-drained, coarse- to moderately coarse-textured soils on outwash plains and terraces. In the east, the soils are deep, nearly level, poorly drained, and medium to coarse textured on outwash plains (Benton and others, 1977). Average annual soil loss for these types of soil associations is typically low, ranging from 0 to 4.9 (ton/acre)/yr (Brentlinger and others, 1979, p. 9).

Streamflow in Juday Creek steadily increases from the most upstream site to the instream pond and then declines downstream. This pattern shows that Juday Creek has a gaining reach upstream and a losing reach downstream as noted by Silliman (1994). The upstream reach is affected by the inflow of ground water, whereas the downstream reach loses flow to ground water (Arihood, 1994).

Continuous streamflow records for Juday Creek are available for 1993–94 (Stewart and others, 1994, p. 217; 1995, p. 209). Daily mean flows during this period range from 11.0 to 163 ft^3/s. The instantaneous peak flow for the period of record is 226 ft^3/s on June 9, 1993. The mean annual flow is 23.8 ft^3/s; 80 percent of the time, flow is between 13 and 36 ft^3/s. Figure 2 shows the streamflow at the gaged site (site 6 on figure 1) during the study period and the daily precipitation recorded by the National Weather Service (National Oceanic and Atmospheric Administration, 1993a, 1994).

Methods of Investigations

Site Selection

Selection of the six measurement sites along Juday Creek was based on land-use changes, site accessibility, and basin coverage. Table 1 describes the location, drainage area, altitude, and land use of the sites. The approximate altitudes of the sites are estimates of channel altitudes based on USGS topographic maps with 5-ft contour intervals.

Site 1, the most upstream location, is northwest of the intersection of Bittersweet and Cleveland Roads (fig. 1) and is in an active agricultural area. The stream flows in a ditch approximately 10 ft deep. Channel banks at the measurement site are covered with thick grasses and some overhanging willow trees. Downstream from site 1, Juday Creek passes through more agricultural areas and eventually through a golf course and some residential areas.

Site 2 is near the intersection of Douglas and Fir Roads; the banks are grassy and somewhat undercut. As the stream flows between sites 2 and 3, it passes through residential and agricultural areas and into the Grape Road commercial development area (near the intersection of Grape Road and Douglas Road). Previously an agricultural zone, this area recently has been converted to a commercial and business area.

Site 3 is just upstream from the point where Juday Creek flows through a pond of approximately 6 acres (fig. 1). This pond is referred to hereafter as the "instream pond." The stream widens in this area from approximately 15 ft at site 2 to 25 ft at site 3, and the banks are somewhat more undercut and

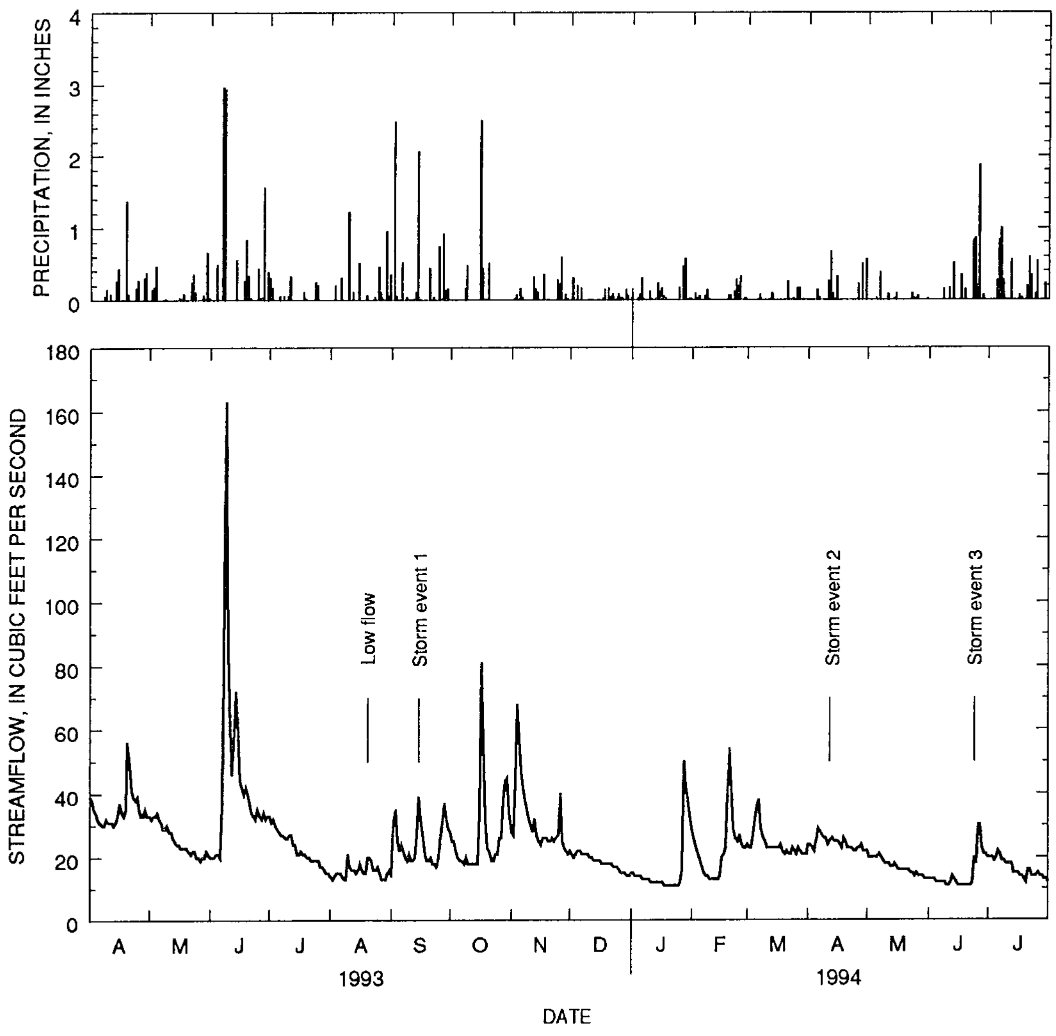

Figure 2. Hydrograph for Juday Creek near South Bend, Indiana (04101370), during the study period with approximate sampling times and the precipitation record for South Bend (National Oceanic and Atmospheric Administration, 1993a-94).

Table 1. Drainage area, altitude, and land use for the six measuring sites on Juday Creek, near South Bend, Indiana
[mi^2, square miles]

Site number	Latitude	Longitude	Drainage area (mi^2)	Approximate altitude in feet above sea level	Land use
Site 1	41°43′31″	86°06′38″	7.00	761[1]	Agricultural
Site 2	41°42′34″	86°09′38″	23.4	742[2]	Agricultural, residential
Site 3	41°42′18″	86°11′36″	27.9	732[2]	Residential, commercial
Site 4	41°42′33″	86°12′48″	29.2	728[2]	Residential, park
Site 5	41°43′04″	86°14′04″	31.1	715[2]	Residential
Site 6	41°43′43″	86°15′47″	37.6	678[3]	Park, residential, commercial

[1]Osceola Quadrangle, 5-ft contour interval, scale 1:24000.
[2]South Bend East Quadrangle, 5-ft contour interval, scale 1:24000.
[3]South Bend West Quadrangle, 5-ft contour interval, scale 1:24000.

slumped. The instream pond through which Juday Creek flows originated as a borrow pit to supply construction material for the Indiana Toll Road during the late 1940's or early 1950's (Rebecca Moffett-Carey, Michiana Area Council of Governments, oral commun., 1994). As the stream enters the pond, velocities generally are reduced and much of the sediment in transport is dropped. Through time, a delta has formed at the inlet.

Between sites 3 and 4, Juday Creek flows through mainly residential areas and wetlands. Site 4 is near the intersection of Douglas Road and Maple Lane. Upstream from the Douglas Road bridge is a wetland area with grassy banks and overhanging willow trees. Downstream from site 4, the stream flows through residential areas to Ironwood Road. From Ironwood Road to site 5, the stream passes near a gravel quarry and open areas (some planned for development) before passing more residential areas.

Site 5 is near Kintz Road and its intersection with Juniper Road. Downstream from the measuring site are low stone dams constructed by homeowners. These dams pool the water locally for aesthetic purposes and small withdrawals. The channel gradient begins to increase as Juday Creek nears site 6 and the St. Joseph River. The approximate channel gradient upstream from site 5 is 6.3 ft/mi; between site 5 and site 6, the gradient increases to 18.2 ft/mi. Between the two most downstream sites, the stream flows through residential, commercial, and forest land.

Site 6 is within the Izaak Walton League property, which is between Darden Road and the Indiana Toll Road and bordered to the west by the St. Joseph River (fig. 1). The USGS operates a continuous-record stream gage and an observer-maintained rain gage at this site. Downstream from the gaging station is a sediment trap constructed to protect the lower reach of the stream from excessive sediment deposition. During 1981–87, 486 ft^3 of sediment were removed from the trap every 1.5–2 years (Kohlhepp, 1991). In 1988, annual dredging was required. In 1990, the trap filled in 4 months. During this study (1993–94), the trap remained full.

Measurements

Streamflow measurements were made at each measurement site during three storms and once during a period of low flow. Either a Price velocity meter, type AA, or a Price pygmy meter was used depending on water depth (the pygmy meter is used for depths up to 1.5 ft and the AA meter for greater depths) (Rantz and others, 1982, p. 84, 145).

Suspended-sediment samples were collected with a depth-integrating, hand-held sampler (US DH–48) which collects sediment and water in 1-pint glass bottles (Guy and Norman, 1970). This depth-integrating sampler collects a velocity-weighted sample as it is lowered to the streambed and raised to the surface (Edwards and Glysson, 1988, p. 7, 10). By use of equal width increments (EWI) and equal transit rates, samples were collected at 10 to 20 cross-channel sampling stations. Samples were composited at the USGS sediment laboratory in Louisville, Ky., to a single discharge-weighted sample for each measurement. Samples were analyzed for total sediment in grams, concentration of suspended sediment in milligrams per liter, and a determination of the sand-fine break. The sand-fine break represents the percentage of sediment greater than 0.062 mm (sand size and larger) and the percentage less than 0.062 mm (silt and clay-size particles).

Bedload was collected with a Helley-Smith hand-held sampler having a 3-in. opening (Emmett, 1980). Bedload is that sediment carried down a stream by rolling and bouncing on or near the streambed. Samples were collected at approximately 7 to 12 equally spaced cross-channel sampling sites, no closer than 1.5 ft apart. The sampling duration was 30 seconds at each collection point. Samples were dried and weighed in the laboratory to determine the mass of bedload (in grams) corresponding to the water discharge at the time of sampling. Bedload discharge was computed from the measured mass of the sample collected during each cross-channel traverse.

Bed material was collected with the US BMH–53 piston-type sampler (Guy and Norman, 1970), designed to sample bed material in wadeable streams. The piston-type sampler is a stainless-steel cylinder 2 in. in diameter and 8 in. in length. Samples were collected at each measurement site, the sediment trap at the Izaak Walton League property, the delta of the instream pond, and the outlet of the pond. The top 3 in. of each sample were analyzed for particle-size distribution because the top 3 in. is the part of the channel bed that would likely be set into motion with increased stream discharge.

Channel cross sections at the six sampling sites, the instream pond and its delta, and the sediment trap were surveyed. Surveying was completed by use of a total station (theodolite with an electronic measuring device) and a data logger. Cross-section locations were selected near the measurement sites in areas having potential for scour or fill. All altitudes were tied to temporary reference marks (steel spike in utility pole or chiseled mark on a bridge) set at each site. These reference marks were assigned arbitrary datums. Where water depths were too great for wading at the instream pond, a boat-mounted fathometer was used to determine depth from the water surface to the pond bottom.

Sediment cores were collected from the delta of the instream pond and the sediment trap by use of a vibracoring technique. Vibracoring is a technology for penetrating and recovering unconsolidated, usually saturated, sediments by use of the principle of liquefaction or the fluidization of fine-grained sediments. The core barrel (aluminum pipe) is attached to a vibrator head and vibrated into the sediment. The resulting core must be measured and adjusted for compaction. Descriptions of the cores indicated the type of sediment deposited. The cores were obtained to determine original bottom depths and possible seasonal or annual variations in deposition.

Table 2. Analysis of replicates collected for quality control of sediment sampling on Juday Creek, near South Bend, Indiana

[g, grams; mg/L, milligrams per liter; mm, millimeters]

Characteristic	Number of replicates	Median	Minimum	Maximum	Percentage difference with matched sample		
					Median	Minimum	Maximum
Bedload (g)	9	332	18	861	48.3	0.1	78.7
Suspended-sediment concentration (mg/L)	8	16.5	8	30	10.2	0	35.3
Percent <0.062 mm	8	42.2	30	93	13.9	3.8	46.6

Quality control (QC) samples (replicates) were collected during each storm sampling to quantify variability in stream sediment and sampling techniques. Simultaneous or sequential replicates were collected for suspended sediment, and sequential replicates were collected for bedload samples. Quality-control replicates were collected for 12.1 percent of the suspended-sediment samples and 13.6 percent of the bedload samples. In all, 66 storm samples were collected for suspended sediment and bedload. Table 2 shows the analysis of the replicates and the percentage differences between matched samples.

Bedload replicates were collected sequentially. The first cross-channel sample was used for calculating tons per day. The second cross-channel sample was the replicate used for QC analysis. The range in bedload replicates is 18 to 861 g. The maximum percentage difference with a matched sample is 78.7 percent. A conservative decision rule was applied to use the maximum percentage difference as the criterion for determining a significant difference when comparing samples. In the interpretation of bedload, only those samples differing by greater than 78.7 percent can be considered significantly different. The cross-channel measurements of bedload tend to account for spatial variability in the samples. The 78.7 percent difference indicates the high temporal variability of bedload at a given time.

Suspended-sediment replicates were collected simultaneously. Two samples were collected at each vertical. The suspended-sediment concentrations of the replicates range from 8 to 30 mg/L. The maximum percentage difference with a matched sample is 35.3 percent. Only those samples differing by greater than 35.3 percent are considered significantly different. The percentage of suspended-sediment finer than 0.062 mm ranges from 30 to 93 percent. The maximum percentage difference with a matched sample is 46.6 percent. As with the other two sediment characteristics, only samples with differences greater than 46.6 percent are considered significantly different.

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CHARACTERISTICS OF SEDIMENT

Streambed Material

Bed material is defined by the Office of Water Data Coordination as "the sediment mixture of which the bed is composed" (U.S. Geological Survey, 1977, Chap. 3, p. 3–5). Bed material was collected at each sampling site by use of a hand-held, piston-type sampler (US BMH–53). The sampler collects bed material to a depth of approximately 8 in., and it will accept bed material containing particles as large as 30 or 40 mm in diameter. Samples from the top 3 in. were retained and analyzed. These were the particles that could be frequently transported as part of the suspended load or bedload but, when at rest, are considered bed material (Edwards and Glysson, 1988). Three cross-channel bed-material samples (left, center, and right) were obtained from each measurement site in August 1993. Samples also were collected from the delta of the instream pond, the outlet of the instream pond, and the sediment trap at the Izaak Walton League property. Table 3 lists the particle-size distributions at each of the sampling locations.

At site 1, the median grain size of each sample is medium sand (0.50–0.25 mm) (see table 4 for grain-size scale.) At this site, the bed material is fairly uniform from one side of the channel to the other. Similarly, the bed material at site 2 consists of medium-grained sand. Medium sand is easily transportable, and streambeds of medium sand often are unstable (W.W. Emmett, U.S. Geological Survey, written commun., 1994). Streams with shifting sand channels do not provide suitable substrate for most fish reproduction. These two most upstream sites are unlikely areas for brown trout spawning. According to Hansen and others (1983, p. 356), "Sand may decrease the food supplies of trout by scouring or burying desirable substrate, destroy cover by aggrading channels and filling pools, and reduce spawning success by covering up or plugging gravel." In addition, a moving sand bed is a poor substrate for habitat and production of invertebrate food organisms.

Site 3 has a gravel channel; median grain sizes range from 3.1 to 8.8 mm. The channel bed at this site, just upstream from the instream pond, is stable in most areas; the slumping banks provide some of the fine-grained sediments. Coarse to very coarse pebbles also were present at this site. Average velocities generally increase in the downstream direction from site 1 to site 3 (table 6) then decrease after the stream passes through the instream pond. The bed material at the lake outlet also is composed of gravels, but the median grain size is smaller (2.0–3.8 mm) than the gravels at the inlet. Bed material collected for the delta is finer grained than the bed material at the inlet and outlet. The median grain size ranges from 0.34 to 0.48 mm and is probably representative of the easily transportable medium sand from the upstream reaches.

The bed material at site 4 varies across the channel; the largest median grain size (1.5 mm) is in the center. Some gravel-size particles are present, but most are medium to coarse sand. In this area, gravels that would be available for invertebrate populations or salmonid spawning would be at risk of being buried by moving sand. Site 5 also has mostly sand-size bed material mixed with some gravel. Data in table 3 indicate that the range of the median particle sizes is from 3.1 mm on the left to 0.37 mm in the center. The bed-material samples from Site 5 were collected in August 1993. Since that time, there has been significant sand deposition (0.7–1.0 ft) at the measurement site, and much of the gravel has been buried.

Site 6 has bed material composed of sand and gravel. Some of the gravel exceeded the sampling capacity of the BMH–53; therefore, the streambed includes particles coarser than table 3 indicates. The average grain size in the center of the channel was 10.8 mm (medium pebbles). The gravel bed material in this area appears to be fairly stable.

Table 3. Particle-size distributions of streambed material in Juday Creek, near South Bend, Indiana
[l, left side of channel; c, center of channel; r, right side of channel; mm, millimeters]

Site number	Median (mm)	Mean (mm)	Percentage of sample weight finer than sieve size (mm)										
			64	32	16	8	4	2	1	0.50	0.25	0.125	0.062
1-l	0.27	0.32			100.0	97.9	96.3	93.5	91.5	85.0	41.5	4.8	3.6
1-c	.33	.49			100.0	96.9	94.2	89.0	84.9	74.8	25.1	1.5	.8
1-r	.32	1.18			100.0	94.1	87.4	81.3	76.8	71.0	34.0	3.1	1.3
2-l	.38	1.04			100.0	97.7	91.4	81.7	76.8	65.1	14.8	.6	.4
2-c	.45	.84			100.0	98.4	92.3	85.0	76.8	58.3	10.5	1.1	1.0
2-r	.27	.29				100.0	99.5	98.7	98.0	93.5	40.8	1.9	.6
3-l	8.80	11.8		100.0	63.9	49.1	37.4	27.9	17.3	10.0	5.0	2.0	1.3
3-c	6.40	12.9	100.0	83.0	67.8	55.0	43.4	35.3	30.5	24.4	8.1	1.3	.7
3-r	3.10	8.80		100.0	80.9	71.9	58.3	36.2	17.8	11.4	7.0	2.3	1.3
Delta-l	.45	.51				100.0	99.9	99.0	91.3	63.0	18.9	1.6	.4
Delta-c	.48	.53					100.0	99.4	93.9	53.4	8.8	.7	.1
Delta-r	.34	.34					100.0	99.9	99.0	86.2	24.9	.9	.2
Outlet-c	3.80	6.25		100.0	87.8	68.8	52.2	39.0	28.6	15.3	3.7	.5	.3
Outlet-r	1.95	3.60		100.0	96.2	83.8	61.7	50.3	43.0	27.9	5.5	.5	.2
4-l	.30	.40			100.0	97.8	94.6	92.4	89.3	79.6	36.0	2.6	.8
4-c	1.50	3.55		100.0	97.0	81.5	68.3	55.4	44.8	30.4	9.5	2.1	1.4
4-r	.27	.45			100.0	99.5	95.2	90.0	85.1	78.5	47.2	8.6	3.3
5-l	3.10	6.50		100.0	84.8	66.1	54.1	45.1	38.6	27.9	13.4	3.7	2.2
5-c	.37	.49				100.0	98.8	95.6	88.9	69.4	12.9	.4	.2
5-r	.40	3.20		100.0	94.0	82.5	72.5	68.2	64.8	56.3	31.5	4.0	1.6
6-l	.37	1.07		100.0	96.5	91.8	87.5	83.1	78.3	67.2	22.8	2.0	.8
6-c	7.20	10.8		100.0	68.0	52.5	41.3	34.4	28.2	15.0	2.4	.3	.1
6-r	.27	.26		100.0	99.1	95.7	95.7	95.7	95.6	93.6	40.0	1.6	.3
Trap-l	.52	1.00			100.0	94.2	89.6	83.5	73.2	48.7	7.5	1.0	.5
Trap-c	.40	.47			100.0	99.8	97.4	94.1	89.7	73.1	16.1	.6	.4
Trap-r	.22	.24				100.0	99.9	99.7	99.0	96.6	68.7	3.6	.8

Table 4. Sediment grain-size scale
[Modified Wentworth scale; from Ingram (1982, Data Sheet 17.1)]

Grade limits (millimeters)	Grade name	
128 - 64	Small cobbles	
64 - 32	Very coarse pebbles	GRAVEL
32 - 16	Coarse pebbles	
16 - 8	Medium pebbles	
8 - 4	Fine pebbles	
4 - 2	Very fine pebbles	
2 - 1	Very coarse sand	
1 - 0.50	Coarse sand	SAND
0.50 - 0.25	Medium sand	
0.25 - 0.125	Fine sand	
0.125- 0.062	Very fine sand	
0.062 - 0.031	Coarse silt	MUD

The sands being transported tend to continue downstream because of a higher stream gradient and higher velocities than those upstream. Table 6 shows that the highest average velocities were found at the most downstream reach, represented by site 6.

The bed material of the sediment trap, downstream from site 6, is fine to coarse sand. The larger particles were to the left and center of the trap. The sediment trap was nearly full, if not completely full, at the time of sampling. Sediment that reached the full trap would have passed over the spillway.

The particle-size distributions of the channel material at each of the sites also was used in the interpretation of the bedload material and scour and fill. These characteristics are affected directly by that part of the channel material likely to be put in motion.

Sediment Cores

Sediment cores were obtained from the delta of the instream pond and the sediment trap at the Izaak Walton League property. The cores from the instream pond delta showed depositional variation across the delta (for core locations, see fig. 25.) Cores collected from the nose of the delta were mostly medium to coarse sand in the upper 1 to 4 ft., underlain by interbedded organic leafy muck and more medium to coarse sands. Below the sand and organic debris layers was a clay or silty clay layer at a depth of 5.3 ft on the left side (core 1), 5.0 ft toward the center (core 2), and 3.6 ft on the right (core 3). An estimate of the original depth was made from core 3. This core, obtained near the right edge of the delta, contained almost a foot of gravel at the bottom. This was the coarsest material found and was similar in size to the gravel at the pond inlet. The total depth cored was 12.3 ft. Adjusting for compaction, the top of the gravel was at approximately 8.3 ft below the top of the delta. This gravel layer was used to estimate that approximately 8.3 ft of sediment deposition had occurred at this point on the delta since the excavated site began to fill (around 1950).

Core 4, collected upstream from the delta edge and closer to the inlet, was coarse grained (sand and gravel) in the upper 2 ft, sand from 2 to 6 ft, then sandy muck and clay below 6 ft. Attempts to core closer to the inlet channel proved unsuccessful because of the abundance of medium to coarse pebbles.

Two core tubes near the downstream end of the sediment trap (Izaak Walton League property) were driven until they reached a very firm, dense layer assumed to be the trap bottom. Adjusted for compaction, the total depth of the core retrieved from the left side was 7.5 ft and the total depth of the one in the center was 7.1 ft. The two cores were similar in composition. Fine to medium sand with some interbedded organic debris was present from the top to 2 to 3.5 ft. Below the sand were gritty, black, organic layers containing leaf and wood debris. Both cores ended in sand that contained lenses of decomposing debris. Total depths of cores collected progressively upstream were 4.7 ft and 2.9 ft, indicative of a thinning of loose material toward the upstream end of the trap. The upstream core tubes were driven to what was apparently the original channel bottom, represented by sand and gravel.

Analysis of the cores did not reveal seasonal variations or annual layering of the sediments. There was no pattern to the sediments to represent more than 40 years of deposition (assuming no previous dredging) at the instream pond. Estimates of the original bottom depths were made at both sites. Information is insufficient, however, to estimate the total volume of sediment deposited at the sediment trap—surveys comparing volume of the trap before and after dredging would be necessary. Analysis of the cores did show that, like the bed material, the deposits at the pond and trap are predominantly sand and some pebbles. This analysis indicates that most of the sediment was transported to the pond and trap as bedload.

TRANSPORT OF SEDIMENT

Sediment transport was analyzed by measurement of streamflow, suspended sediment, and bedload and by monitoring of scour and fill at the six sampling sites. Suspended sediment and bedload were measured during three storms and once during a time of no overland flow. Sediment discharge was calculated for all of the suspended-sediment and bedload measurements. During the study period, only four sets of sediment samples were collected on Juday Creek. The sediment discharges, therefore, are instantaneous; they only apply to the particular time when the measurements were made. The data are too limited to extrapolate an annual load or sediment yield.

Suspended-sediment discharge was calculated by use of the following equation from Guy (1970):

$$Q_s = Q_w C_s k, \quad (1)$$

where Q_s is instantaneous suspended-sediment discharge, in tons per day;

Q_w is instantaneous streamflow, in cubic feet per second;

C_s is instantaneous suspended-sediment concentration, in milligrams per liter; and

k is a units conversion factor of 0.0027.

Bedload discharge was calculated by use of the following equation from Edwards and Glysson (1988):

$$Q_b = k\,(W_t/T)\,M_t, \quad (2)$$

where Q_b is bedload discharge, in tons per day;

k is a units conversion factor of 0.381 for a 3-in. nozzle;

W_t is total width of stream from which samples were collected, in feet (equal to the increment width times the total number of vertical samples);

T is total time the sampler was on the streambed, in seconds (computed by multiplying the individual sample time by the total number of vertical samples); and

M_t is total mass of sample collected from all verticals sampled in the cross section, in grams.

The total mass, in grams, of the bedload samples is used in the calculation of bedload discharge and is included in tables 5 and 6 and the text to show how the bedload amounts vary from site to site.

Low-Flow Conditions

Suspended sediment and bedload were measured during a period of low flow to determine how much sediment, if any, is transported during low streamflow, in the absence of overland flow. Suspended-sediment concentration was low at all sites (relative to storm samples), ranging from 1 to 6 mg/L (table 5). The mean suspended-sediment concentration of the storm samples was 20 mg/L. Bedload was more variable than suspended-

Table 5. Sediment transport characteristics for Juday Creek, near South Bend, Indiana, during a period of low flow, August 20, 1993

[ft^3/s, cubic feet per second; ft/s, feet per second; mg/L, milligrams per liter; ton/d, tons per day; g, grams]

			Suspended sediment					
					Percentage by size			
Site number	Streamflow (ft^3/s)	Average velocity (ft/s)	Concentration (mg/L)	Discharge (ton/d)	<0.062 mm (silt and clay)	>0.062 mm (sand)	Bedload (g)	Bedload discharge (ton/d)
1	3.99	0.90	4	0.04	47.8	52.2	12.9	0.24
2	17.7	.98	2	.10	20.0	80.0	76.7	1.70
3	18.2	1.30	2	.10	24.7	75.3	21.3	.39
4	20.3	.99	1	.05	40.5	59.5	5.2	.11
5	19.6	.76	3	.16	42.5	57.5	5.5	.11
6	20.0	1.85	6	.32	30.8	69.2	41.1	.84

sediment concentrations, ranging from 5.2 to 76.7 g, or 0.11 to 1.70 ton/d. The mean bedload for the storm samples was 242 g, or 5.37 ton/d. The percentage of suspended sediment less than or greater than the sand-fine break (0.062 mm) is included in table 5; but at such low concentrations, this distinction is not as meaningful as with larger concentrations. The low-flow measurements indicate that some sediment is transported at low flows and that the predominant mode of transport is bedload.

Storm Events

The stream was sampled during three storms for suspended-sediment concentration and bedload. Streamflow also was measured at each sampling. Criteria used to determine response to a storm or rainfall event was the prediction of more than 1 in. accumulating within a 48-hour period. Table 6 is a compilation of the data collected during the three storms, including daily precipitation amounts. Because field crews had to be on site at the onset of the storm, it was essential that the event be forecast by the National Weather Service. Several significant periods of rainfall were not sampled because of the difficulty of predicting rainfall in a small basin. At other times, crews were on site, but the storms missed the Juday Creek Basin.

The first sampled rainfall event was September 14–16, 1993. Five measurements were made at each of the six sites during the rise and fall of the storm hydrograph. Figures 3–8 are graphical representations of the comparisons of the data collected during this event. The first measurements at the sites were made on the steep rising limb of the hydrograph on September 14 (fig. 9). The last measurements were made on the slow decline of the hydrograph on the morning of September 16.

Suspended-sediment concentrations varied from site to site. The lowest concentration, 7 mg/L, was measured at site 1 during the recession (sampling 5, fig. 9). A high of 67 mg/L at site 6 was measured on the rise (sampling 1, fig. 9). The suspended-sediment concentrations obtained from the first sampling event (as well as the two subsequent events) fall below the range where brown trout or other salmonids are affected significantly. According to Lloyd (1987), concentrations below 80 to 100 mg/L constitute a moderate level of protection from suspended sediment. Concentrations greater than 80 mg/L were not measured during the course of this study; however, only a small range of streamflow was sampled. Concentrations as high as 400 mg/L may occasionally occur (Runde, 1994) but are likely to be of short duration.

Table 6. Streamflow, suspended-sediment concentration, bedload, and rainfall data collected during three storms on Juday Creek, near South Bend, Indiana

[Rainfall was measured by the National Weather Service; ft^3/s, cubic feet per second; ft/s, feet per second; mg/L, milligrams per liter; ton/d, tons per day; g, grams; in., inches]

Site number	Sampling date	Streamflow (ft^3/s)	Average velocity (ft/s)	Suspended sediment: Concentration (mg/L)	Suspended sediment: Discharge (ton/d)	Suspended sediment: Percentage by size: <0.062 mm (silt and clay)	Suspended sediment: Percentage by size: >0.062 mm (sand)	Bedload (g)	Bedload discharge (ton/d)	Rainfall (in.)
					Storm event 1					
1	Sept. 14, 1993	8.56	1.03	33	0.76	76.5	23.5	31.6	0.70	
2		20.2	1.01	17	.93	53.4	46.6	109	2.21	
3		28.0	1.51	12	.91	33.6	66.4	191	5.82	
4		24.2	1.10	16	1.04	28.4	71.6	25.9	0.53	
5		25.6	1.04	20	1.38	17.8	82.2	107	2.22	
6		32.4	1.71	67	5.86	32.0	68.0	73.8	1.64	
										2.06
1	Sept. 14, 1993	14.9	1.22	39	1.57	58.8	41.2	68.6	1.52	
2		29.5	1.23	23	1.83	44.9	55.1	109	2.21	
3		35.7	1.74	16	1.54	12.1	87.9	364	10.1	
4		40.8	1.51	12	1.32	19.0	81.0	79.2	1.61	
5		40.3	1.41	34	3.70	30.8	69.2	676	13.9	
6		35.5	1.86	65	6.23	30.0	70.0	414	8.93	
1	Sept. 15, 1993	13.1	1.22	9	.32	48.2	51.8	64.7	1.51	
2		41.1	1.45	13	1.44	59.7	40.3	846	17.2	
3		44.7	1.97	21	2.53	38.6	61.4	406	11.3	
4		46.5	1.61	20	2.51	28.4	71.6	272	5.86	
5		46.4	1.57	30	3.76	19.6	80.4	833	17.4	
6		41.9	1.95	33	3.73	22.6	77.4	475	10.3	
										.01
1	Sept. 15, 1993	11.6	1.23	11	.34	52.1	47.9	78.5	1.74	
2		36.4	1.39	10	.98	45.6	54.4	642	13.0	
3		42.8	1.76	16	1.84	33.8	66.2	612	16.9	
4		42.8	1.35	11	1.27	30.0	70.0	99.4	2.08	
5		45.8	1.50	27	3.34	30.2	69.8	859	18.0	
6		42.2	1.94	24	2.73	28.1	71.9	585	12.6	

Table 6. Streamflow, suspended-sediment concentration, bedload, and rainfall data collected during three storms on Juday Creek, near South Bend, Indiana—Continued

				Suspended sediment						
						Percentage by size				
Site number	Sampling date	Streamflow (ft^3/s)	Average velocity (ft/s)	Concentration (mg/L)	Discharge (ton/d)	<0.062 mm (silt and clay)	>0.062 mm (sand)	Bedload (g)	Bedload discharge (ton/d)	Rainfall (in.)
1	Sept. 16, 1993	9.28	1.17	7	0.18	50.0	50.0	233	5.18	
2		32.6	1.30	24	2.11	21.0	79.0	206	4.20	
3		35.4	1.67	21	2.01	23.1	76.9	636	17.6	
4		36.0	1.34	13	1.26	29.0	71.0	64.4	1.31	
5		37.8	1.35	12	1.22	32.2	67.8	342	7.12	
6		34.0	1.80	21	1.93	38.3	61.7	862	18.1	
										0.00
Storm event 2										
1	April 12, 1994	6.24	.86	19	.32	45.9	54.1	103	2.34	
2		18.6	.82	14	.70	25.1	74.9	9.9	0.21	
3		27.4	1.52	8	.59	42.2	57.8	62.5	1.34	
4		33.7	1.35	45	4.09	15.1	84.9	107	2.41	
5		30.0	1.13	10	.81	45.6	54.4	407	9.26	
6		27.0	1.74	11	.80	26.6	73.4	154	3.20	
										.93[1]
1	April 12, 1994	7.73	.96	12	.25	39.1	60.9	83.6	1.90	
2		25.0	1.07	20	1.35	36.3	63.7	184	3.75	
3		31.3	1.70	8	.68	41.3	58.7	103	2.12	
4		31.3	1.28	11	.93	26.2	73.8	66.3	1.50	
5		29.4	1.12	8	.64	33.7	66.3	320	6.64	
6		26.6	1.89	10	.72	38.0	62.0	242	4.96	

Table 6. Streamflow, suspended-sediment concentration, bedload, and rainfall data collected during three storms on Juday Creek, near South Bend, Indiana—Continued

Site number	Sampling date	Streamflow (ft^3/s)	Average velocity (ft/s)	Suspended sediment: Concentration (mg/L)	Suspended sediment: Discharge (ton/d)	Suspended sediment: Percentage by size: <0.062 mm (silt and clay)	Suspended sediment: Percentage by size: >0.062 mm (sand)	Bedload (g)	Bedload discharge (ton/d)	Rainfall (in.)
				Storm event 3						
1	June 23, 1994	3.24	0.71	27	0.24	11.6	88.4	3.4	0.07	
2		12.6	.63	17	.58	28.8	71.2	31.0	0.67	
3		14.7	1.04	11	.44	70.8	29.2	149	3.03	
4		17.9	.90	17	.82	51.6	48.4	94.5	2.00	
5		14.2	.80	25	.96	47.3	52.7	20.1	0.41	
6		11.9	2.03	44	1.41	43.5	56.5	75.8	1.65	
										0.83
1	June 24, 1994	4.45	.78	9	.11	81.2	18.8	16.1	0.41	
2		21.1	.86	19	1.08	59.2	40.8	88.0	1.99	
3		23.5	1.35	25	1.59	61.6	38.4	387	8.20	
4		26.9	1.27	13	.94	63.8	36.2	483	9.81	
5		20.1	.96	20	1.08	67.3	32.7	163	3.63	
6		20.4	1.96	33	1.82	45.5	54.5	409	10.1	
										.85
1	June 24, 1994	4.05	.80	9	.10	42.1	57.9	8.2	0.18	
2		23.1	.89	10	.62	34.8	65.2	88.9	1.86	
3		24.7	1.40	11	.73	85.6	14.4	263	5.56	
4		26.0	1.16	10	.70	67.6	32.4	402	9.06	
5		22.0	1.09	26	1.54	42.4	57.6	98.4	2.17	
6		19.0	1.92	24	1.23	37.5	62.5	412	9.04	
1	June 25, 1994	4.26	.76	4	.05	94.4	5.6	11.0	0.26	
2		19.2	.80	12	.62	43.2	56.8	76.1	1.72	
3		22.1	1.35	17	1.01	46.0	54.0	87.0	1.77	
4		22.3	1.07	12	.72	55.7	44.3	70.4	1.56	
5		19.5	.97	18	.95	35.9	64.1	38.4	0.84	
6		17.0	1.68	24	1.10	30.2	69.8	276	6.23	
										.20

[1]Rainfall is the 48-hour total during April 11–12, 1994, recorded by the National Weather Service, Michiana Regional Airport.

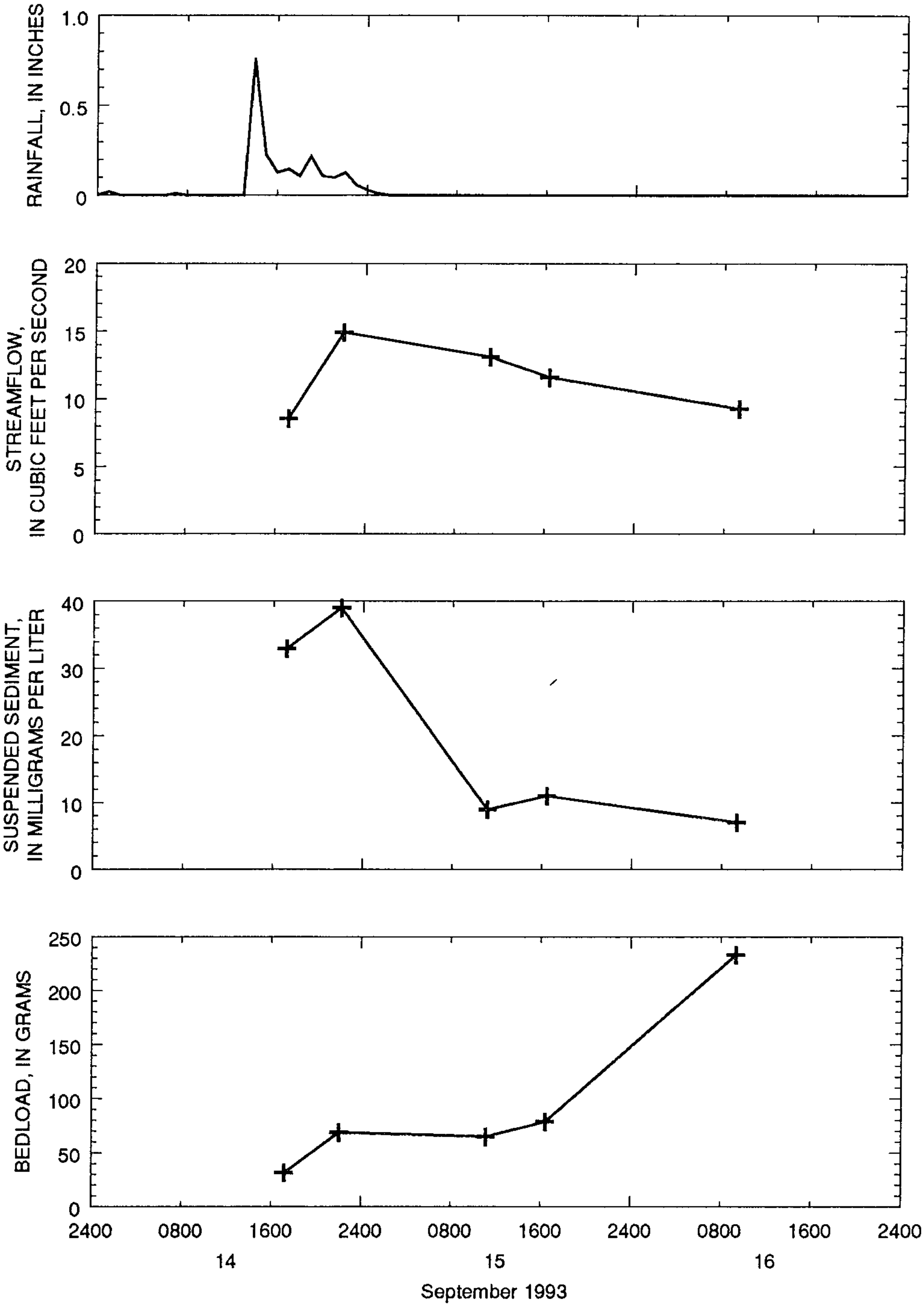

Figure 3. Relation of rainfall, streamflow, suspended-sediment concentration, and bedload at site 1 on Juday Creek, near South Bend, Indiana, for the September 14–16, 1993, sampling.

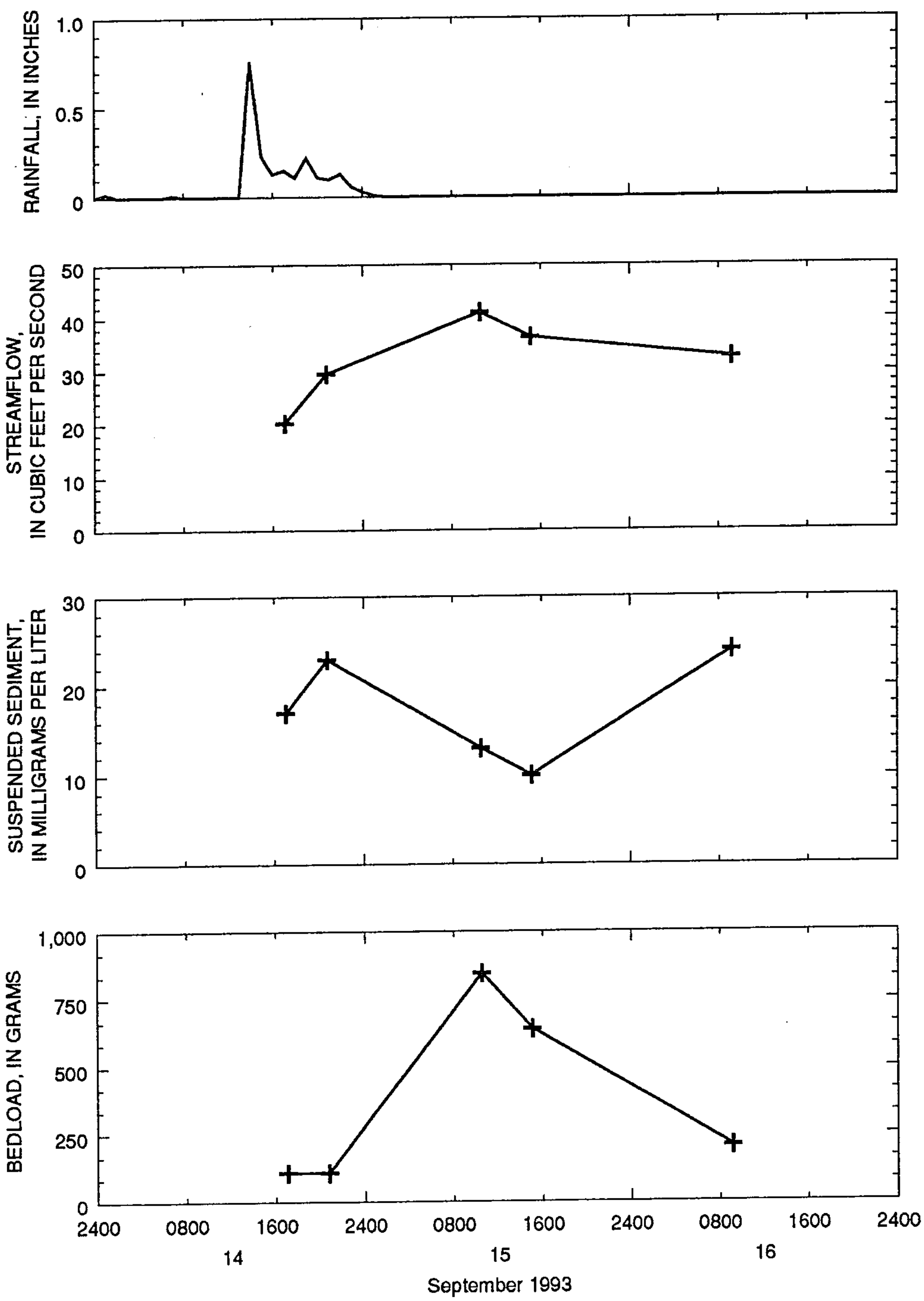

Figure 4. Relation of rainfall, streamflow, suspended-sediment concentration, and bedload at site 2 on Juday Creek, near South Bend, Indiana, for the September 14–16, 1993, sampling.

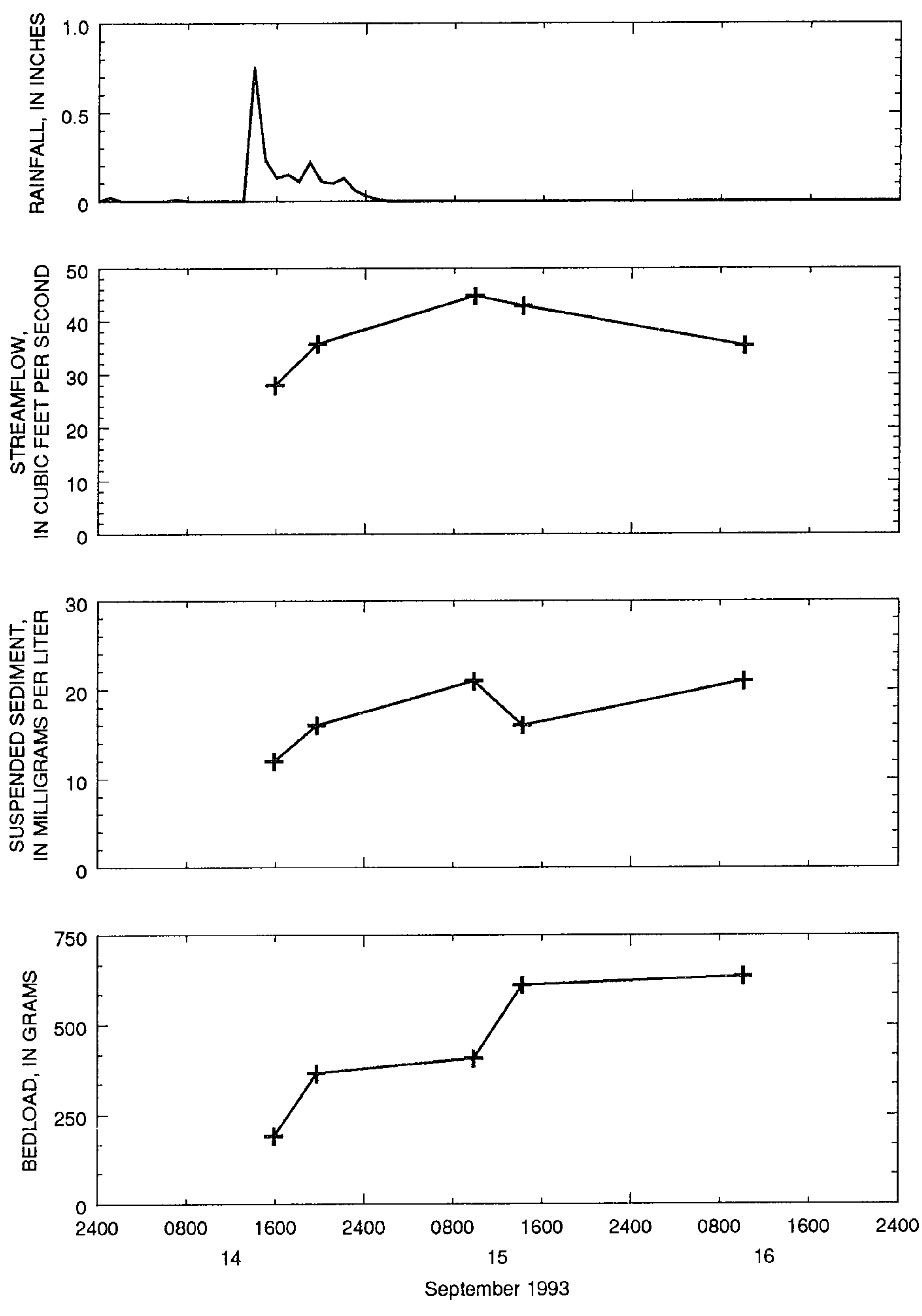

Figure 5. Relation of rainfall, streamflow, suspended-sediment concentration, and bedload at site 3 on Juday Creek, near South Bend, Indiana, for the September 14–16, 1993, sampling.

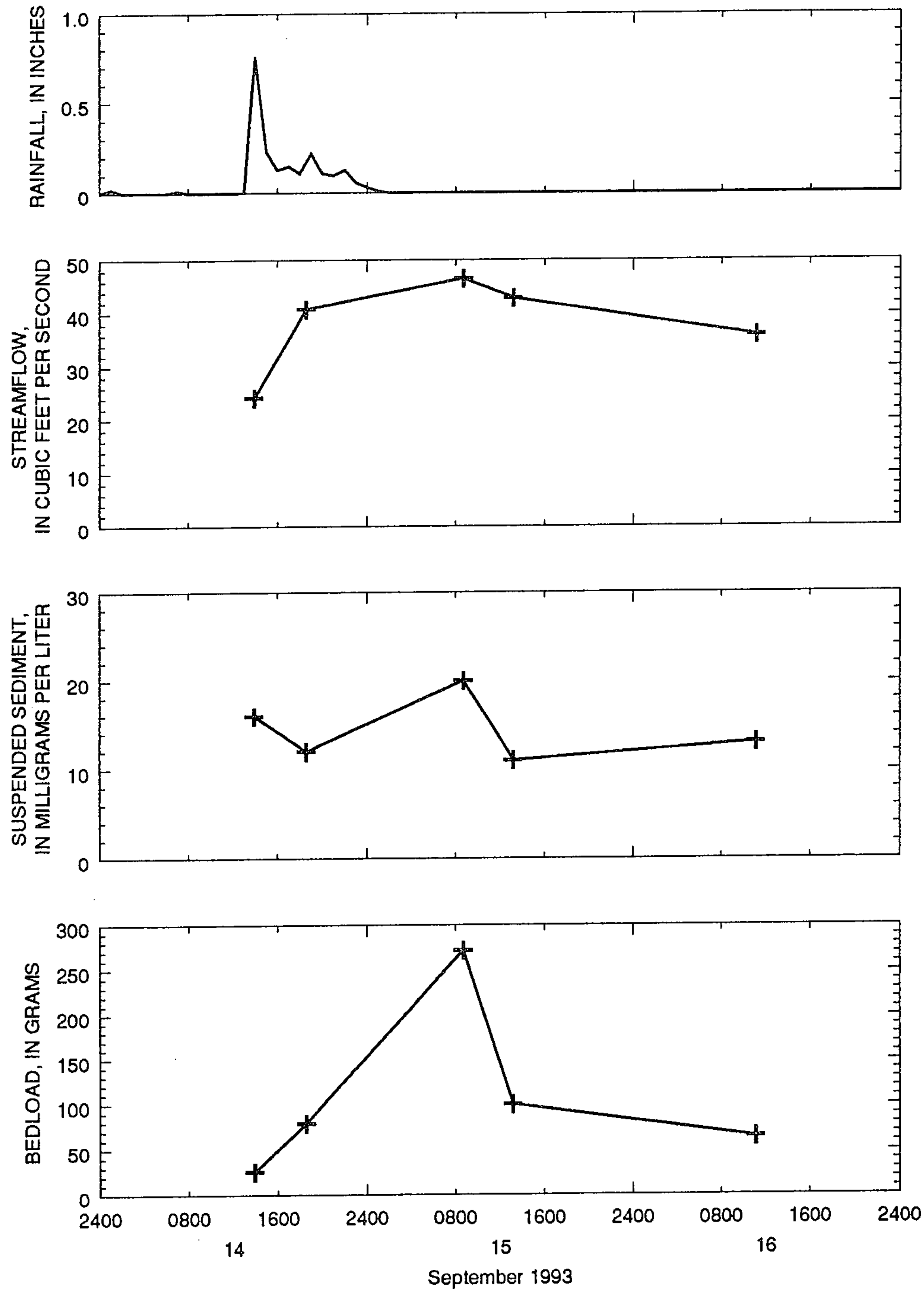

Figure 6. Relation of rainfall, streamflow, suspended-sediment concentration, and bedload at site 4 on Juday Creek, near South Bend, Indiana, for the September 14–16, 1993, sampling.

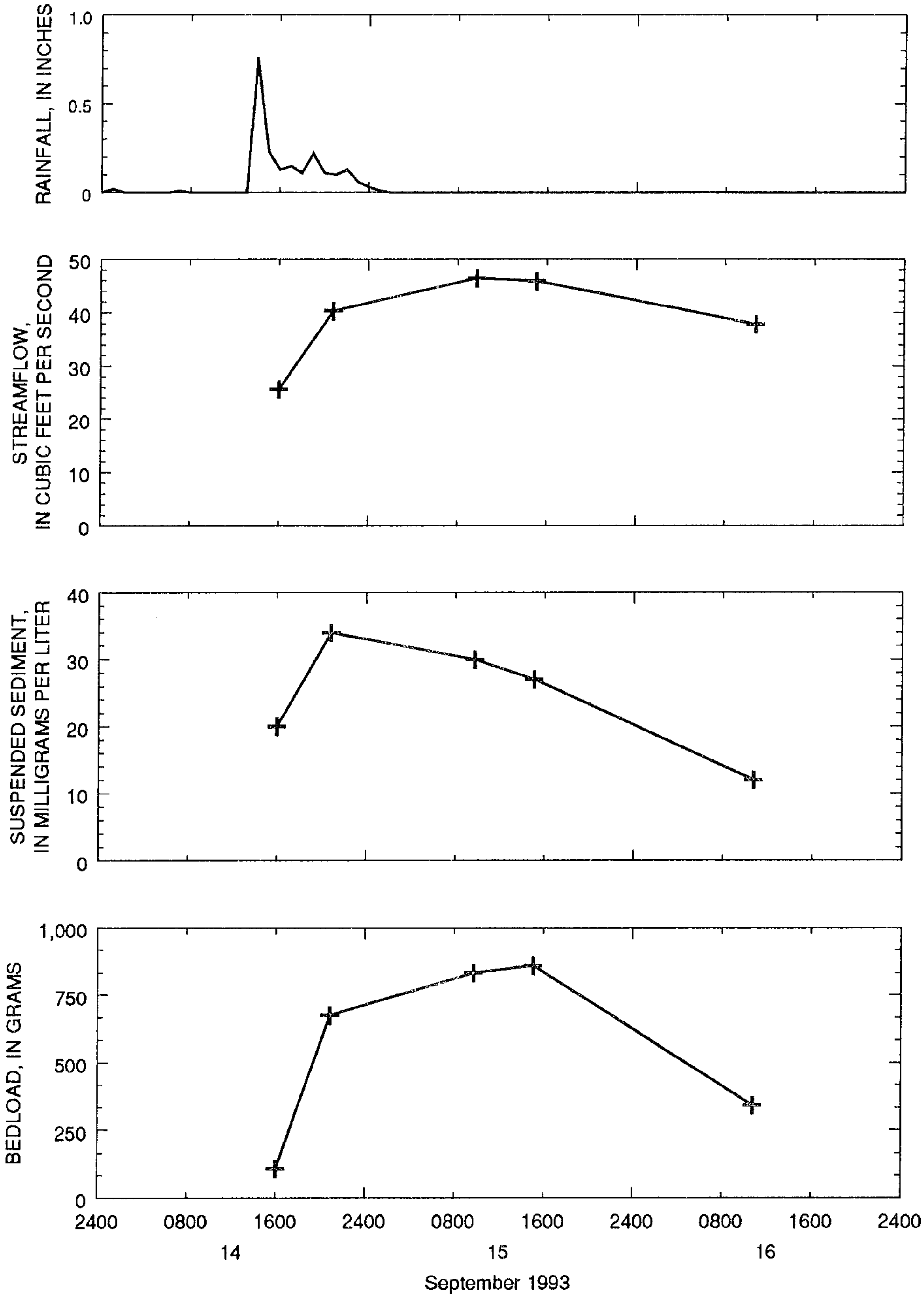

Figure 7. Relation of rainfall, streamflow, suspended-sediment concentration, and bedload at site 5 on Juday Creek, near South Bend, Indiana, for the September 14–16, 1993, sampling.

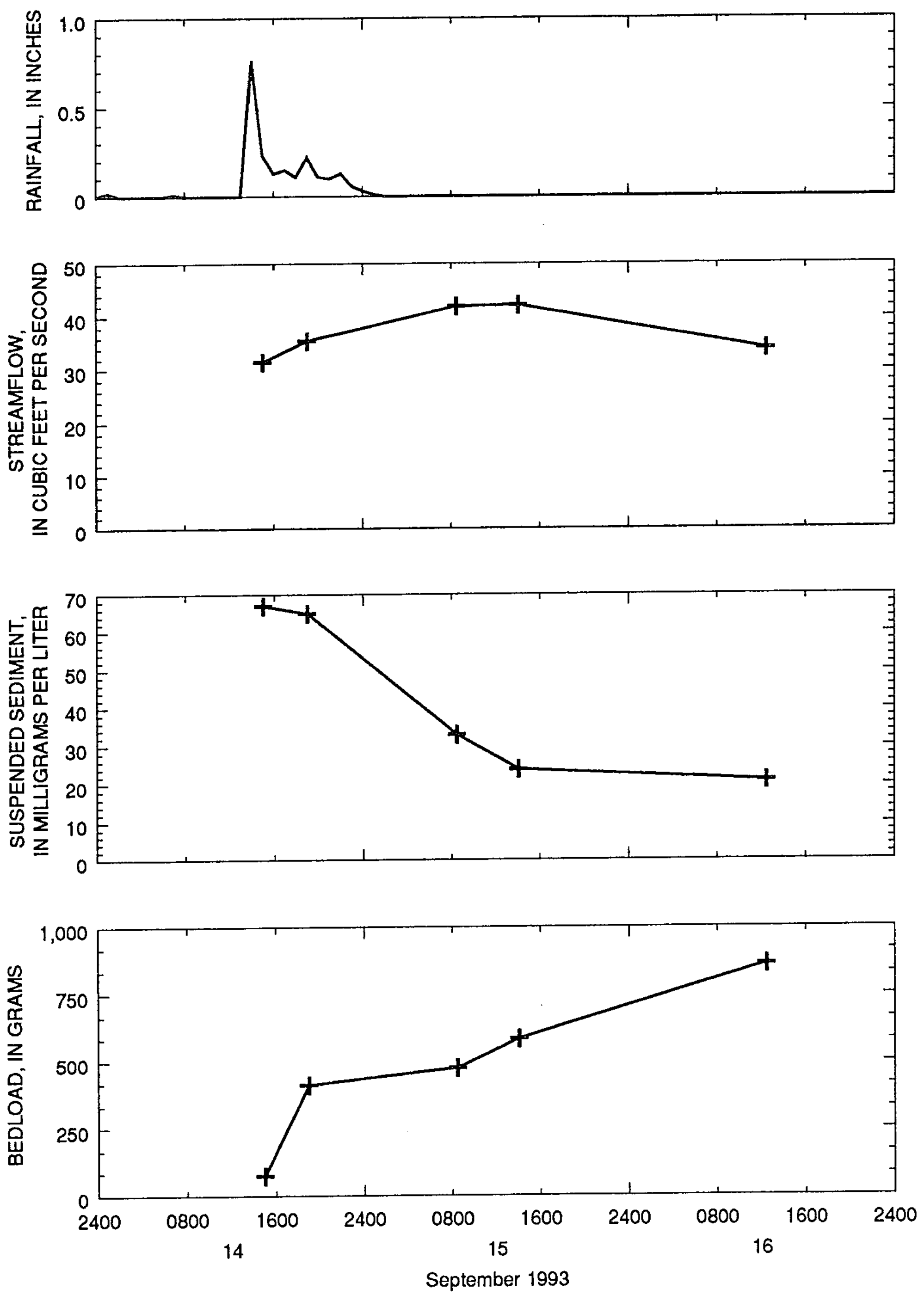

Figure 8. Relation of rainfall, streamflow, suspended-sediment concentration, and bedload at site 6 on Juday Creek, near South Bend, Indiana, for the September 14–16, 1993, sampling.

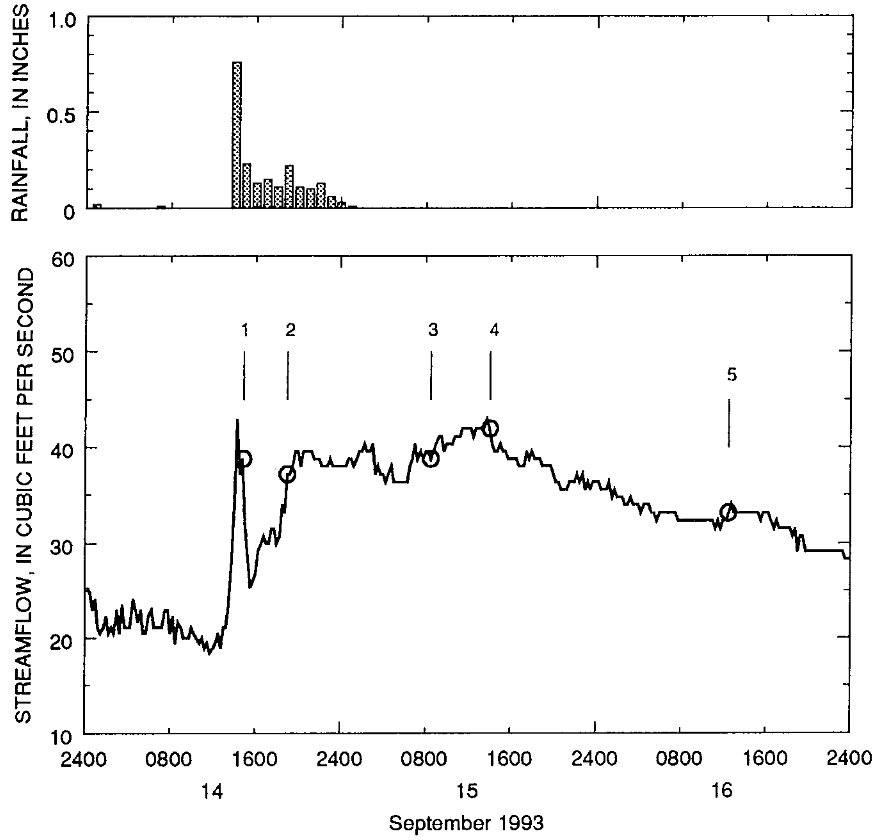

Figure 9. Storm hydrograph for Juday Creek near South Bend, Indiana (04101370), approximate sampling times, and rainfall record for South Bend (National Oceanic and Atmospheric Administration, 1993a).

Peaks in the concentrations of suspended sediment during storm event 1 typically occurred before or were coincident with the streamflow peaks (figs. 3–8). At sites 3 through 6, greater percentages of sand-size particles (>0.062 mm) were consistently in suspension than at sites 1 and 2. At site 1, the stream carried greater amounts of silt- and clay-size particles during the early stages of the storm, then more equal amounts of sand and fines for the duration of the storm. At site 2, the stream carried similar amounts of sand and fines until the third day of sampling, when the percentage of sand-size particles increased.

The bedload collected at each site ranged from 31.6 g at site 1 to 862 g at site 6 (table 6). The stream at site 1 tended to transport the least amount of bedload until the last sampling. This increase could have been caused by sampling a pulse of sediment, by the bank slumping upstream, or possibly by a minor inconsistency in sampling technique. Bedload transport at sites 2 through 5 followed the general shape of the streamflow hydrograph with peaks occurring between measurements 3 and 4 (figs. 4–7). At site 6, as at site 1, bedload increased throughout the rising limb of the hydrograph, and the maximum measured bedload occurred on the recession of the hydrograph (fig. 8). Between sites 3 and 4, a consistent reduction in bedload was noted (table 6). A likely cause of this reduction is the instream pond between the sites. Particles moving along the channel bottom probably would not pass through the pond, which is as deep as 8 ft. After site 4, however, the amount of bedload again increased. Between sites 4 and 5, bedload amounts increased from 99.4 to 859 g during the fourth set of measurements (table 6).

Velocity of bedload particles is generally lower than the mean velocity of water because of the frequent contact of the particles with the streambed. Bedload that passes through one section of Juday Creek may not appear at downstream sections for a few days or even a few storms later. This characteristic of bedload makes the comparison of bedload amounts between sites difficult during any one storm.

Suspended-sediment discharge and bedload discharge in ton/d were compared in figure 10. Only during samplings 1 and 2 was the suspended-sediment discharge ever greater than bedload discharge. The first storm sampling indicates that bedload discharge is the predominant mode of sediment transport along the entire stream.

The second measured storm began on April 11, 1994. By midnight of that day, 0.26 in. of rain had fallen. Two measurements were made at each of the six sites. The first set of measurements was started as the stage began to rise on the morning of April 12 (sampling 1, fig. 11). The second set of measurements was made about 6 hours later. Precipitation on April 12 was 0.67 in. Total precipitation for the storm was 0.93 in. Only two sets of samples were collected because the rainfall was less intense and of shorter duration than was predicted.

Suspended-sediment concentration ranged from a low of 8 mg/L to a high of 45 mg/L. During the first set of measurements, the highest concentration of sediment (45 mg/L) was at site 4, and the lowest concentration was at site 3 (downstream from Grape Road). For the second set of measurements, the highest concentration was at site 2 (20 mg/L), and the lowest concentration was at sites 3 and 5 (8 mg/L). Overall, suspended-sediment concentrations were low throughout the second event because of the smaller amount of rainfall and reduced runoff. Most of the sediment carried in suspension was greater than 0.062 mm at all sites (table 6).

Bedload collected at each site ranged from 9.9 g at site 2 to 407 g at site 5 (table 6). At sites 1, 4, and 5, greater amounts were recorded during the first measurement; whereas at sites 2, 3, and 6, greater amounts were recorded during the second measurement.

Bedload discharge and suspended-sediment discharge are shown in figure 12. Only at sites 2 and 4 during the first set of measurements was suspended-sediment discharge greater than bedload discharge. Again, in storm event 2, bedload discharge was significantly greater than suspended-sediment discharge.

The third sampling was June 23–25, 1994. Early on June 23, the National Weather Service at South Bend forecast as much as 2.0 in. of rainfall during the following 48-hour period. The sampling crew began the first of four sampling sets on the evening of June 23, as the stage began to rise (sampling 1, fig. 13). The last set of measurements was made on the morning of June 25, as the stage began its slow decline.

The suspended-sediment concentrations again were fairly low. The highest concentration measured was 44 mg/L at site 6. The lowest concentration was 4 mg/L at site 1. At most of the sites, concentration peaks were recorded during the early part of the storm, before or nearly coincident with the streamflow peak, which occurred within a few hours of the peak rainfall. The size of the sediment carried in suspension varied throughout the storm and from site to site (table 6). For example, at site 1, the first measurement showed that 88 percent of the particles were greater than 0.062 mm or sand size. By the last measurement, 94 percent of the particles in transport were silt and clay size. Measurements at the other sites showed less extreme variation. At low concentrations, a few particles of one size or another can affect the percentage breakdown.

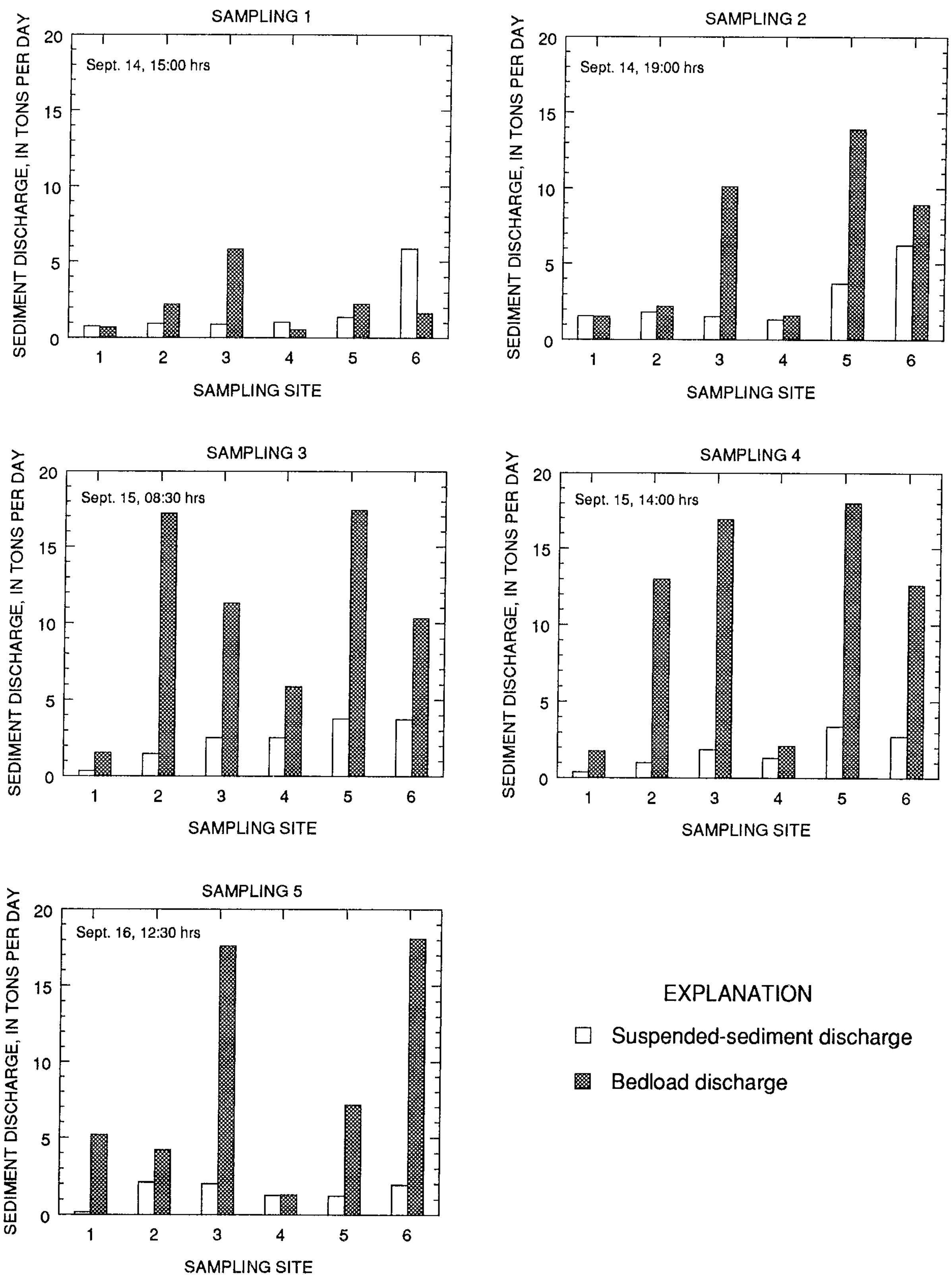

Figure 10. Suspended-sediment discharge and bedload discharge at the six sites for the September 14–16, 1993, sampling on Juday Creek, near South Bend, Indiana.

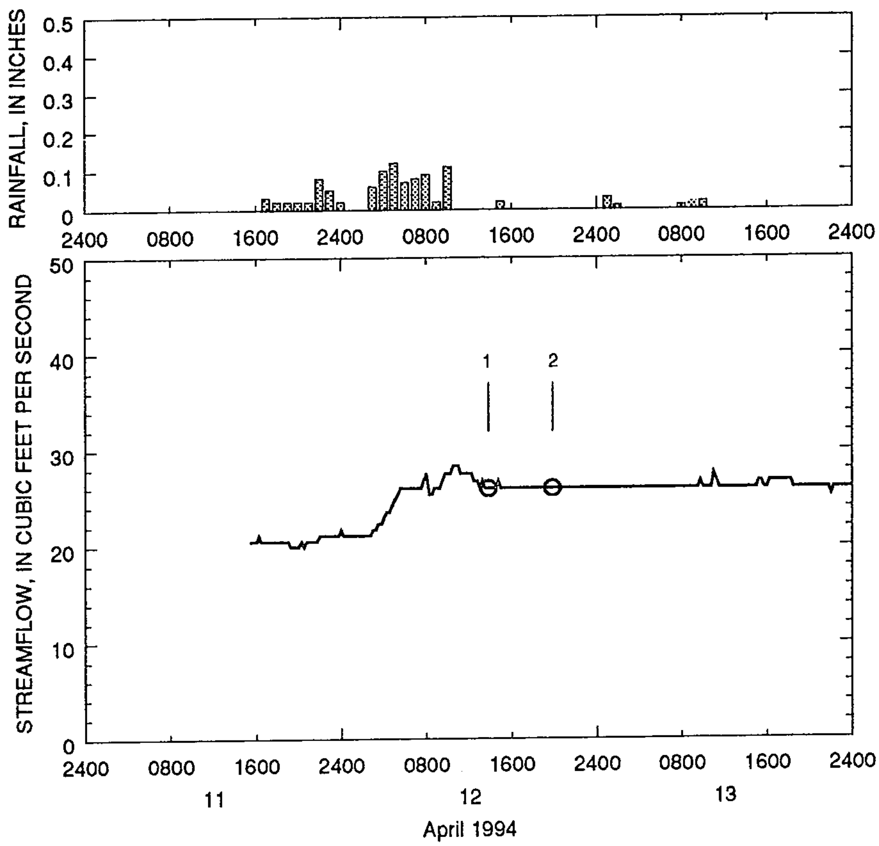

Figure 11. Storm hydrograph for Juday Creek near South Bend, Indiana (04101370), approximate sampling times, and rainfall record for South Bend (National Oceanic and Atmospheric Administration, 1994).

Bedload amounts for this rainfall event generally were less than those of the previous storms. The greatest amount, 483 g, was measured at site 4 during the second set of measurements. The least amount was 3.4 g, measured at site 1 during the first measurement; this measurement also corresponded to the smallest streamflow (3.24 ft^3/s). The bedload peaks generally occurred during the periods of highest streamflow on June 24 (figs. 13 and 14). This sampling did not show the reduction in bedload downstream from the instream pond, as did the previous events. This finding indicates that the supply of bedload to site 4 is controlled by the streambed and bank conditions of the upstream reach, even though the instream pond traps sediment.

Comparison of suspended-sediment discharge and bedload discharge in figure 14 shows the predominance of bedload in total sediment discharge. The graph shows some marked increases in bedload discharge from site 3 to site 4 (relative to the previous sampling events), whereas the graph of bedload discharge at site 5 shows a corresponding reduction.

The three sampled storms differed in many respects. The first event took place in early autumn. This event was characterized by intense rainfall on the first day and the highest suspended-sediment concentrations and bedloads. The second event

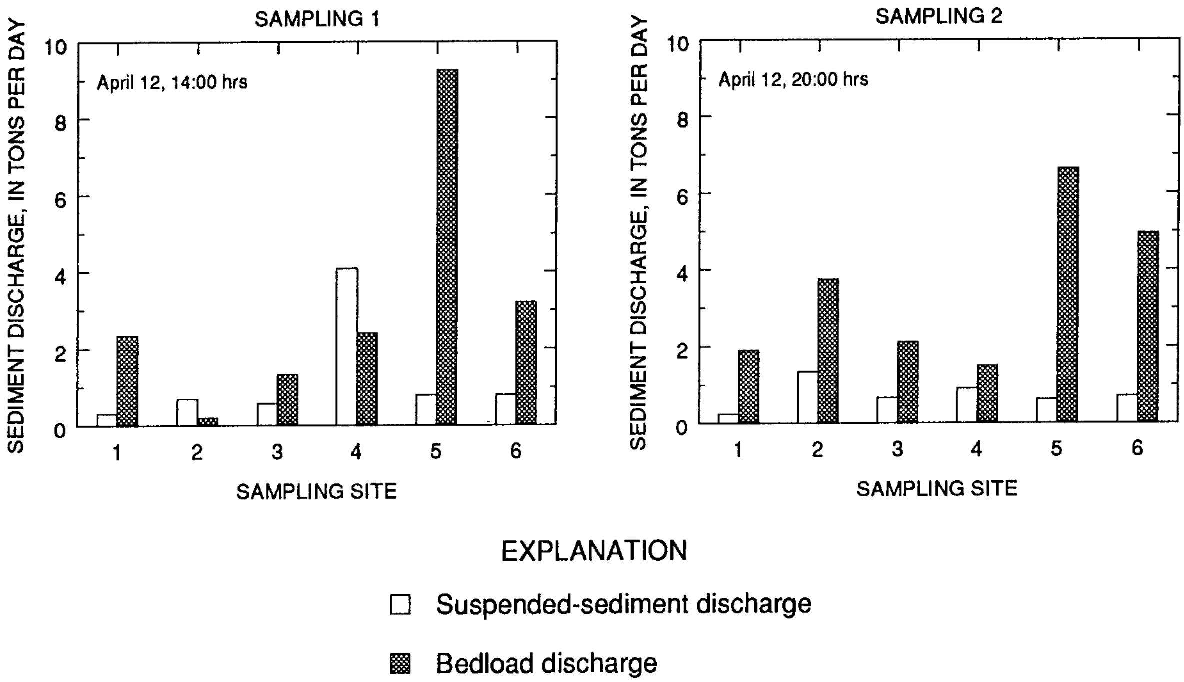

Figure 12. Suspended-sediment discharge and bedload discharge at the six sites for the April 12, 1994, sampling on Juday Creek, near South Bend, Indiana.

was a short-duration spring storm, with less runoff and smaller amounts of suspended sediment and bedload than the first event. The third event was sampled over 3 days in early summer. At the onset of the third storm, streamflow was about half of what it was at the beginning of the other two storms (figs. 9, 11, and 13). This condition could account for the much smaller bedloads at sites 1, 2, and 5.

Suspended-sediment concentrations for the storms ranged from 4 to 67 mg/L; in 85 percent of the samples, concentration was less than 30 mg/L. The median suspended-sediment concentration was 17 mg/L. This median concentration is within the range of medians (17 to 79 mg/L), reported by Crawford and Mansue (1988) for 15 streams in northern Indiana. The range in concentrations, however, is much narrower than for most streams. The narrow range of observed concentrations is likely due to the small drainage area and the narrow range of sampled flows on Juday Creek. As mentioned previously, Juday Creek maintains a narrow range of streamflow. Eighty percent of the time, the flow is 13 to 36 ft^3/s.

Suspended-sediment concentrations for Juday Creek do not correlate strongly with streamflow. Figure 15 shows the variations in suspended-sediment concentration and streamflow for all of the samples (66 storm samples and 6 low-flow samples). One reason for the variations may be that concentrations tend to peak before the streamflow peak and then gradually diminish. According to Crawford and Mansue (1988), most suspended-sediment loads in Indiana are transported in a short

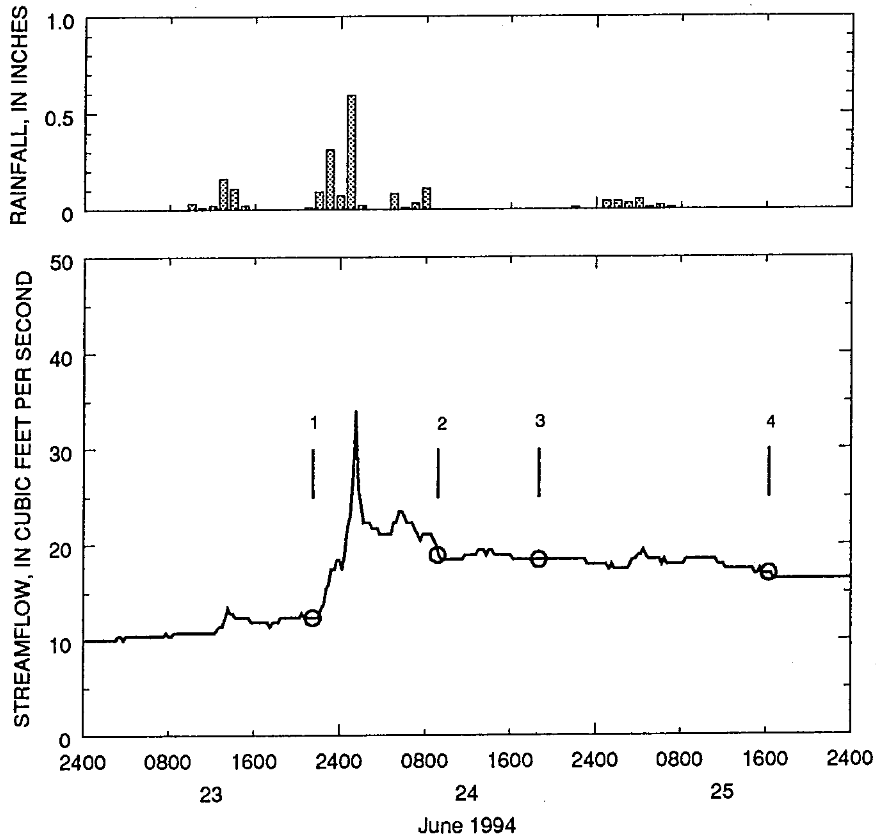

Figure 13. Storm hydrograph for Juday Creek near South Bend, Indiana (04101370), approximate sampling times, and rainfall record for South Bend (National Oceanic and Atmospheric Administration, 1994).

period of time during high flows (a few days a year). It is possible that much larger concentrations could occur but were not measured because of the sampling intervals. The sampling of the three storms did not include large streamflows; however, figure 2 shows that large streamflows did occur during the study period.

Little data on bedload are available for comparison with this study. Available literature suggests that bedload is highly variable in time and space (Gomez and others, 1991). Bedloads for the storms ranged from 3.4 to 862 g; the median bedload was 109 g and the mean was 242 g. Although it is variable, bedload does correlate somewhat with streamflow. Figure 16 shows the variations in bedload and streamflow for all the samples. Many of the smaller bedloads are at or below 20 ft^3/s. The samples collected at site 1, especially those collected at less than 10 ft^3/s, show a separate and more distinct pattern and correlate more strongly with streamflow. Bedload discharge exceeds suspended-sediment discharge in almost all comparisons (figs. 10, 12, and 14). The particle-size distributions of the bed material (table 3) indicate that most of the material available for transport is sand size, which will be transported mostly as bedload. These particles in transport could be a threat to the spawning of salmonids and to their food sources. The small amount of silt and clay in the bed-material samples may explain why the suspended-sediment concentrations are low and why 75 percent of the samples had mostly sand-size particles in suspension (more than 50 percent of sample >0.062mm).

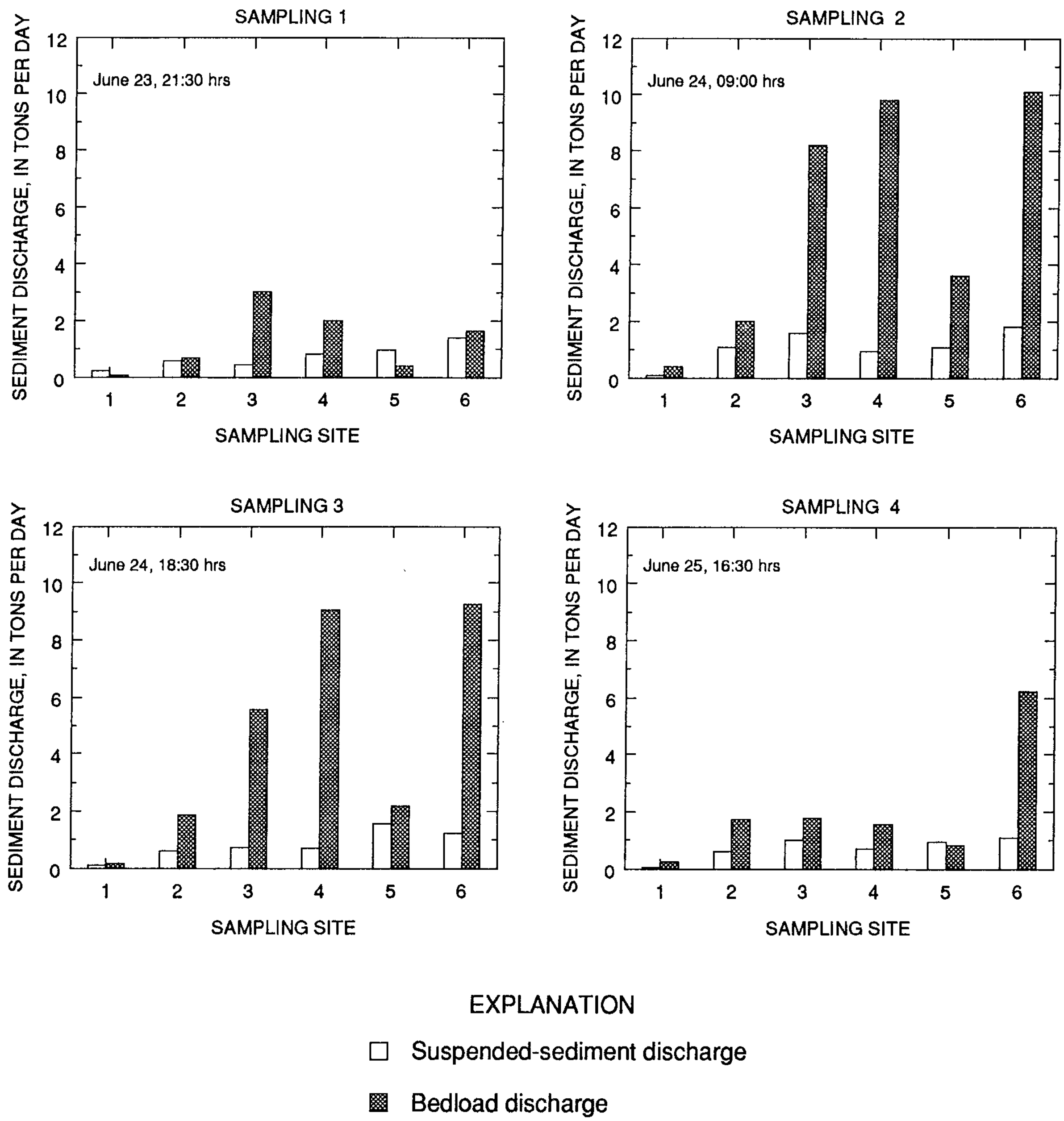

Figure 14. Suspended-sediment discharge and bedload discharge at the six sites for the June 23–25, 1994, sampling on Juday Creek, near South Bend, Indiana.

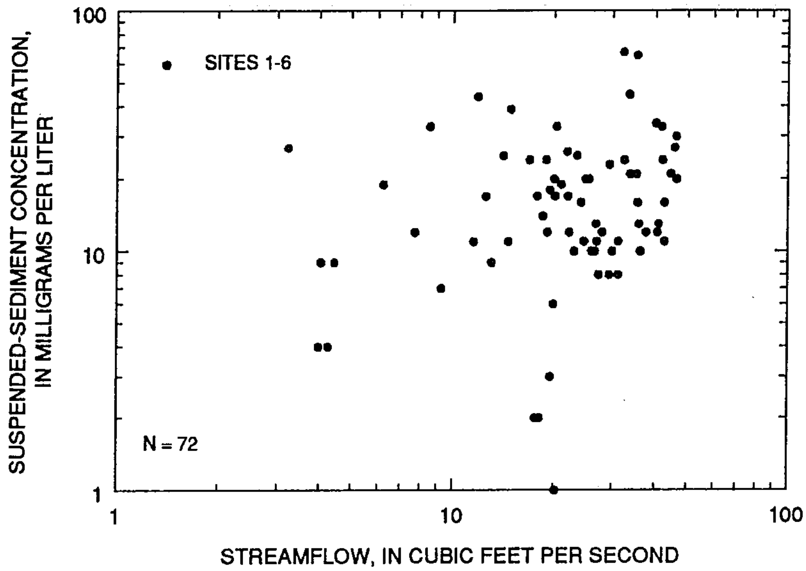

Figure 15. Variations in suspended-sediment concentration and streamflow in Juday Creek, near South Bend, Indiana.

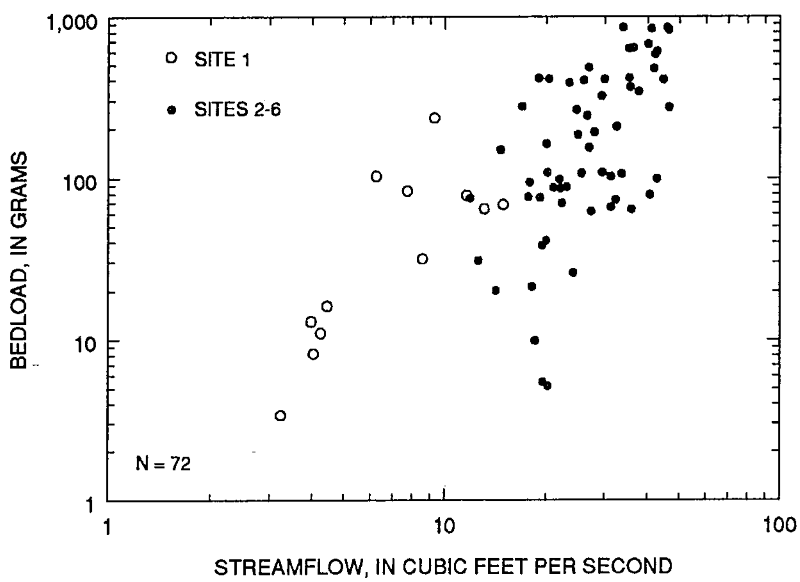

Figure 16. Variations in bedload and streamflow in Juday Creek, near South Bend, Indiana.

The relations of streamflow, suspended sediment, and bedload along the study reach of Juday Creek are summarized in figure 17. The medians for the 11 samples at each site are plotted. Suspended-sediment concentration increases from site 1 to site 2, remains fairly uniform through site 4, and then increases again through site 6. Bedload increases from site 1 to site 3, drops off sharply at site 4, and then increases through site 6. Streamflow increases steadily from site 1 to site 4 and then declines through site 6. This pattern, which also can be seen in most of the sampling events in table 6, shows that Juday Creek has a gaining reach and a losing reach. This trend also was noted by Silliman (1994). The upstream reach is affected by the inflow of ground water, whereas the downstream reach is losing flow to ground water (Arihood, 1994).

Variations in sediment discharge between sampling sites are shown in figure 18. Median suspended-sediment discharge, bedload discharge, and combined sediment discharge for the 11 storm samples are shown. Suspended-sediment discharge increases gradually along the entire reach. Bedload discharge increases from site 1 to site 3, then declines sharply downstream from the instream pond. Bedload discharge then increases from site 4 downstream to site 6. Figure 18, as well as figure 17, shows that bedload transport accounts for most of the sediment discharge.

Streamflow, suspended sediment, and bedload affect the overall sediment conditions in Juday Creek. Suspended sediment appears to have less effect on stream quality than does bedload. Bedload could alter the stream most significantly with respect to aquatic life.

Scour and Fill

Scour and fill, or changes in the streambed altitude, were measured by use of scour chains and with reference to surveyed channel cross sections. Scour chains are primarily a means for measuring streambed scour, but infilling over the chains also can be measured. Surveyed cross sections not only document areas of scour or fill, but also show (with time) changes in channel morphology.

Scour Chains

A scour chain is a short section of chain driven vertically into the streambed to record scour. As the streambed scours, the chain falls. The length of chain lying on the streambed equals the depth of scour at that point. The chain is buried with sediment if infilling occurs. Cycles of scour and fill can be recorded only with frequent measurement of scour chains. The use of scour chains, however, enables documentation of maximum scour at a site during a specific time period. During high flow, the streambed may scour to below pre-flood levels and then quickly refill. If the site were surveyed even a short time after the high flow, the maximum scour and subsequent fill may not be observed.

Scour chains were placed at each of the six sites along cross sections perpendicular to flow in straight reaches of channel. The chains were driven vertically into the streambed with a steel bar. The lower ends of the chains were driven below the level of anticipated scour, and the tops of the chains were level with the streambed. Flagging was attached to the top link to aid in locating the chains for recovery. The locations of the cross sections were marked and, by use of a tag line, the stationing of the chains (distance from the stream bank) was recorded. The tag-line stationing and a metal detector were used to pinpoint the locations of the scour chains for recovery when the measurements of scour and fill were made.

Thirty-one chains were placed in the stream channel, at least three chains at each site. Twenty-two of the chains were recovered at the end of the study. Table 7 lists the scour chains, by site, and the measured scour and fill. The scour chains are numbered from left to right looking downstream, so number 1 is always the closest to the left bank. At site 2, the scour chains were laid out in two cross sections about 30 ft apart.

The scour chain measurements indicate that the net change in streambed altitude for the study period (about 15 months) averaged about 0.1 ft at

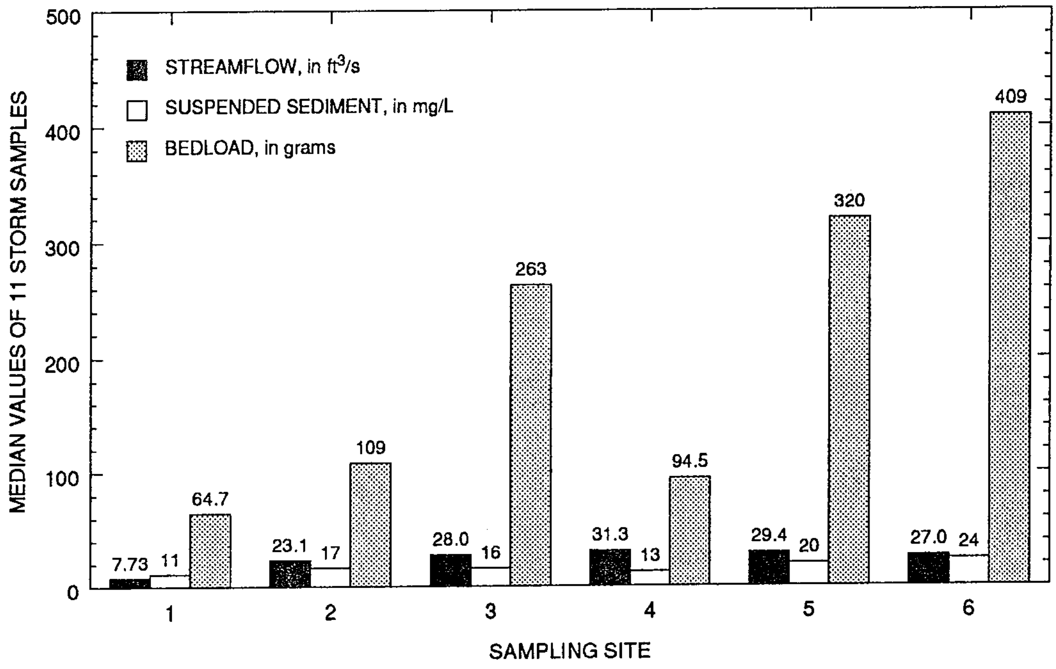

Figure 17. Relations of streamflow, suspended-sediment concentration, and bedload between sampling sites along Juday Creek, near South Bend, Indiana.

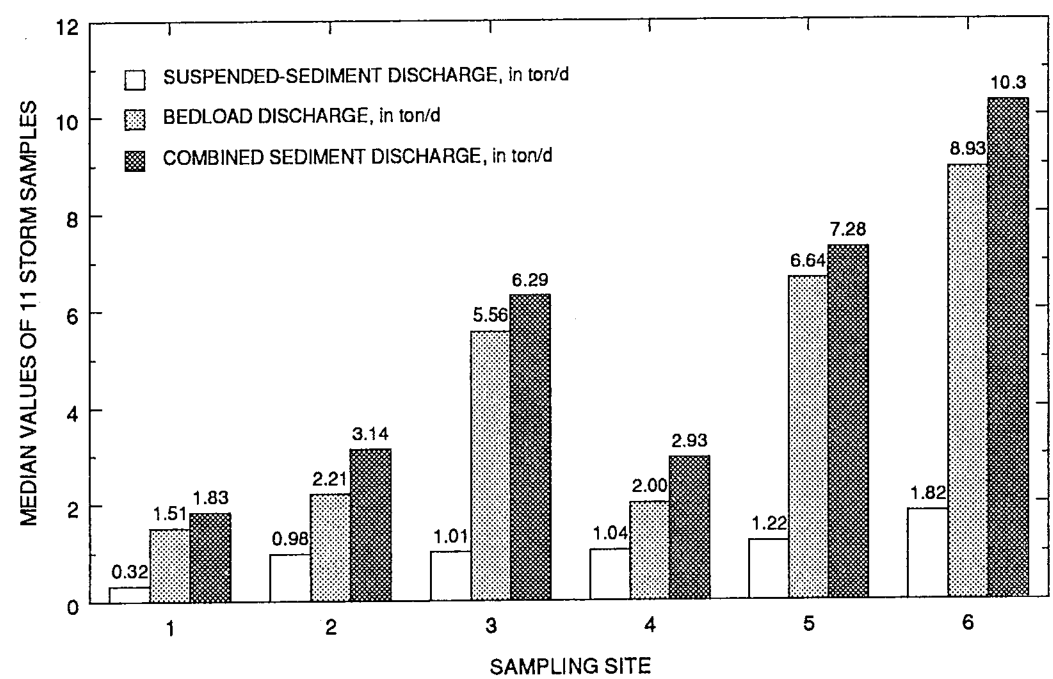

Figure 18. Variations in sediment discharge between sampling sites along Juday Creek, near South Bend, Indiana.

Table 7. Measurements of scour and fill by use of scour chains in Juday Creek, near South Bend, Indiana

[Chains were installed in April 1993 and remeasured in July 1994]

Chain number	Scour (feet)	Fill (feet)	Net change in streambed altitude (feet)	Streambed sediment type
1-1	0	0.07	0.07	
1-2	0	.28	.28	Sand
1-3	0	.43	.43	
2-1	.34	.46	.12	
2-2	.23	.40	.17	
2-3	*	*	*	Sand
2-4[1]	0	.08	.08	
2-5[1]	0	.17	.17	
2-6[1]	0	.14	.14	
3-1	.12	.10	–.02	
3-2	0	.08	.08	
3-3	.12	0	–.12	
3-4	0	.10	.10	Gravel
3-5	0	.08	.08	
3-6	0	.07	.07	
4-1	.12	0	–.12	
4-2	*	*	*	
4-3	*	*	*	Sand, gravel
4-4	.67	.69	.02	
4-5	.45	.11	–.34	
4-6	.12	.09	–.03	
5-1	0	.62	.62	
5-2	*	*	*	
5-3	*	*	*	Sand, gravel
5-4	*	*	*	
5-5	*	*	*	
5-6	*	*	*	
6-1	*	*	*	
6-2	0	0	0	Sand, gravel
6-3	0	.10	.10	
6-4	0	.17	.17	

*Chain was not recovered.

[1]Chain was located along a second cross section at site 2.

most of the study sites (table 7). Most of the scour chains indicated that the net change is infilling. At some sites, however, chains recorded a small amount of scour as the net change. Most of the chains that showed scour also showed subsequent infilling, a pattern that is consistent with the natural scour and fill cycles of a sandy streambed. The maximum observed scour was at site 4, near the center of the channel. Sites 1 and 5 show the most consistent pattern of infilling; no scour was observed. At site 5, only one of the scour chains was recovered. The infilling at site 5 also is documented in the surveyed cross sections (fig. 23).

Scour chains provide only point measurements of the changes in streambed altitude, and they may not represent streambed conditions for long reaches of channel.

Surveyed Cross Sections

Scour and fill at each site were also documented with reference to surveyed channel cross sections, which also record changes in channel morphology. Three separate cross sections were surveyed at each site. Their spacing ranged from about 25 to 165 ft. The cross sections were positioned so that they would not interfere with the scour chains. The locations of these cross sections were marked in the field so they could be resurveyed four times between April 1993 and April 1994. The surveying was done with a total station and a data logger that recorded the coordinates of the surveyed points and the land-surface altitude. Approximately 20 to 30 points were surveyed along each section to define the shape of the channel. With this number of points, the spacing was close enough to identify changes in the channel without having to resurvey the same points. An arbitrary datum was assumed at each site, and two reference marks were established so that horizontal and vertical control could be reproduced for all five surveys. Because the purpose of the surveyed cross sections was to document the relative changes in the streambed, the reference marks were not referenced to sea level.

A representative cross section from each site is included to show the relative changes in the channel throughout the study period (figs. 19–24). All the cross sections represent the view downstream. The survey of April 1993 represents the initial conditions. The survey of June 22–25, 1993, followed thunderstorms during which the South Bend area had almost 6 in. of rainfall (National Oceanic and Atmospheric Administration, 1993a). As a result of this heavy rainfall, Juday Creek reached an instantaneous peak flow of 226 ft^3/s at the USGS streamflow-gaging station on June 9 (Stewart and others, 1994, p. 217). The relative magnitude of this peak flow compared to the rest of the study period can be seen in the hydrograph for the study period (fig. 2). The November 1993 survey was an interim survey to monitor the streambed, and the April 1994 survey was the 1-year follow up to the initial survey. The channel cross sections also were surveyed in March 1994; however, they were not included in the figures because they were virtually the same as those for April 1994.

Site 1 is in an agricultural area where the channel has been dredged. The cross sections from site 1 show the trapezoidal shape of a dredged channel (fig. 19). Minimal bank loss and only minor fluctuations in the streambed altitude were noted at this site. The April 1994 cross section is close to the initial survey, showing some fill. The streambed is fairly stable, considering the sandy bed material (tables 3 and 4) and the straight reach. The stability probably can be attributed to the small drainage area, about 7.0 mi^2. Sufficient streamflows and velocities did not occur during the study period to induce significant sediment transport.

Site 2 also has a trapezoidal channel but not as symmetrical as the channel at site 1 (fig. 20). The high flows of June 1993 scoured the base of the left bank, which remained scoured through the final survey. The June 1993 survey also shows almost 1 ft of scour along some of the streambed; however, by November 1993, much of this area had refilled.

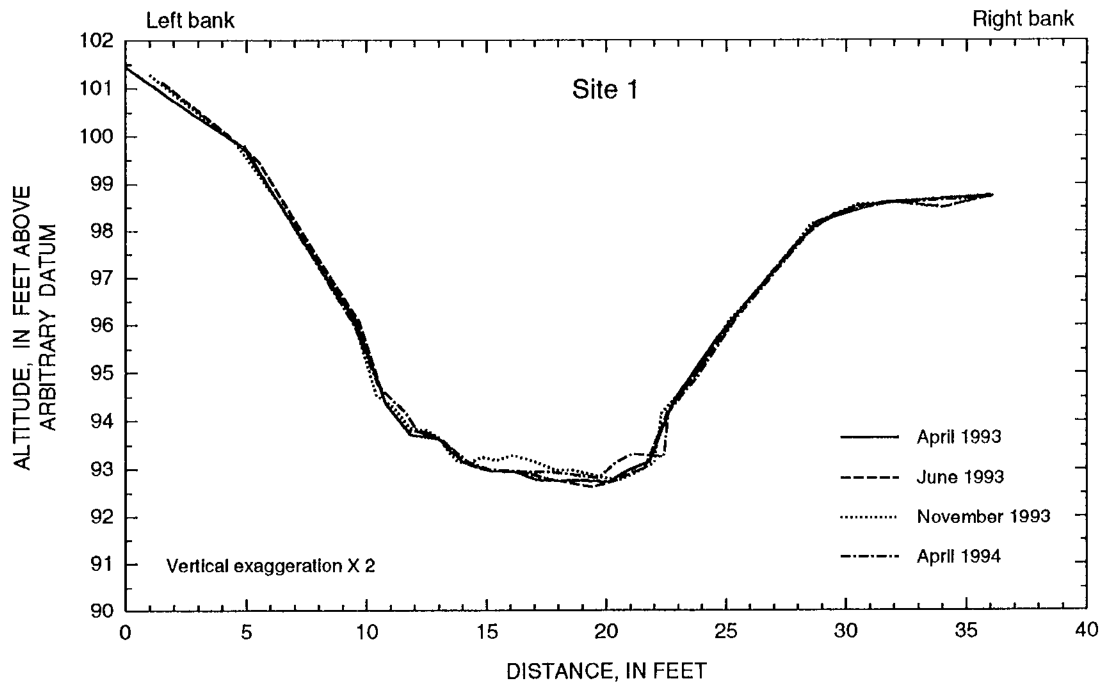

Figure 19. Channel cross sections from four surveys showing scour and fill at site 1 on Juday Creek, near South Bend, Indiana.

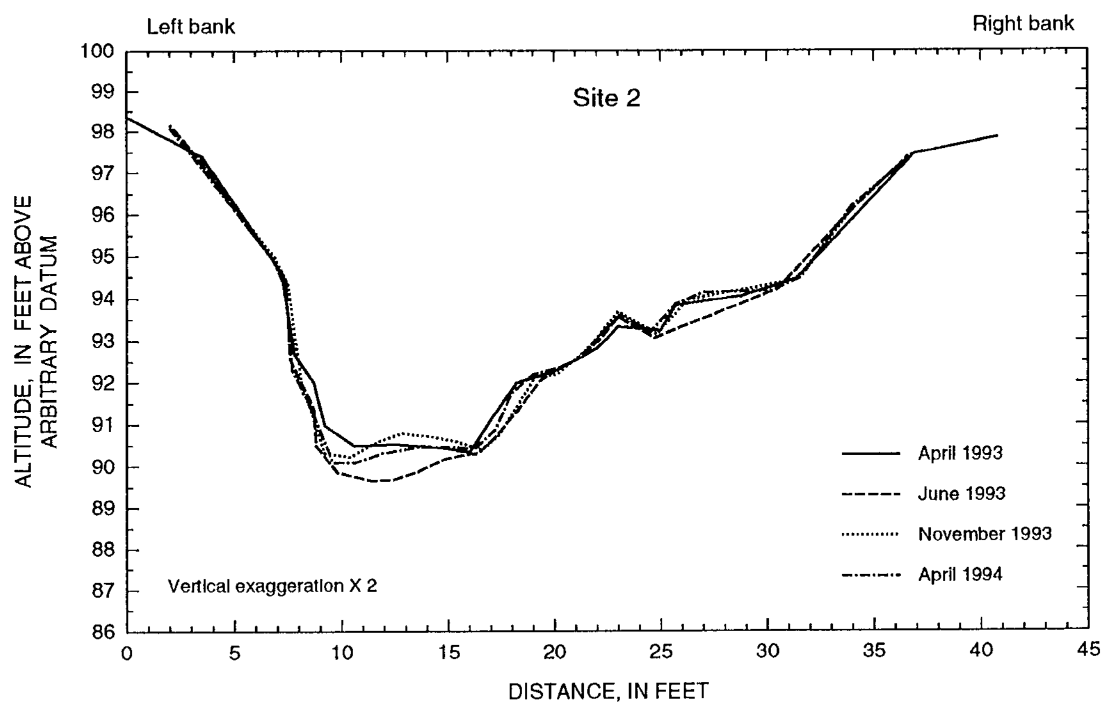

Figure 20. Channel cross sections from four surveys showing scour and fill at site 2 on Juday Creek, near South Bend, Indiana.

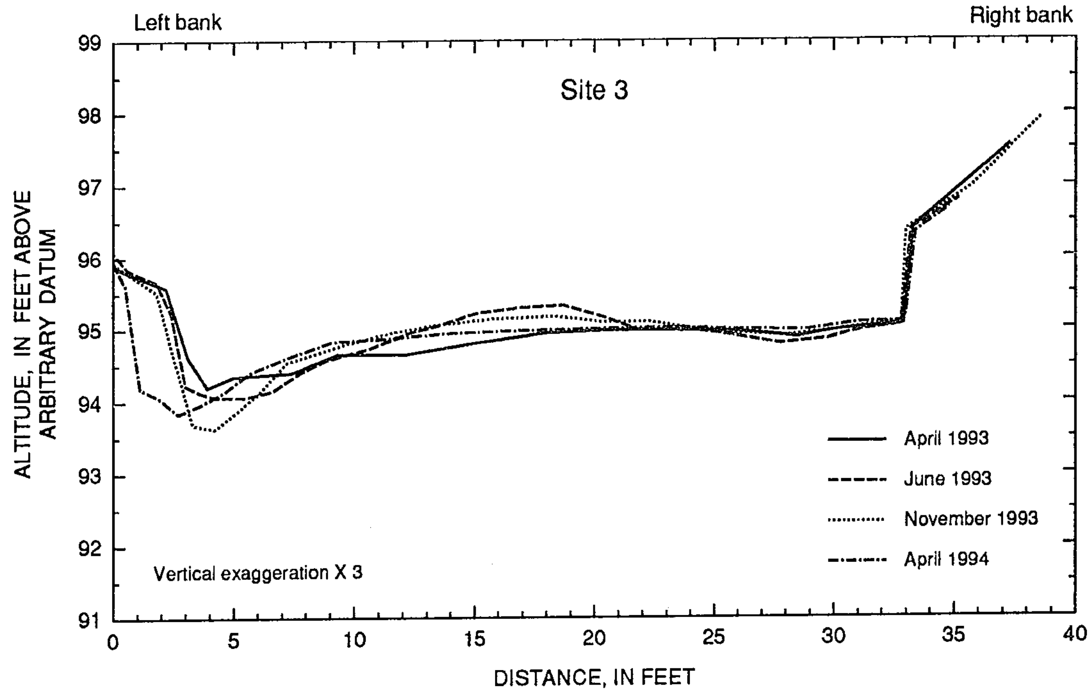

Figure 21. Channel cross sections from four surveys showing scour and fill at site 3 on Juday Creek, near South Bend, Indiana.

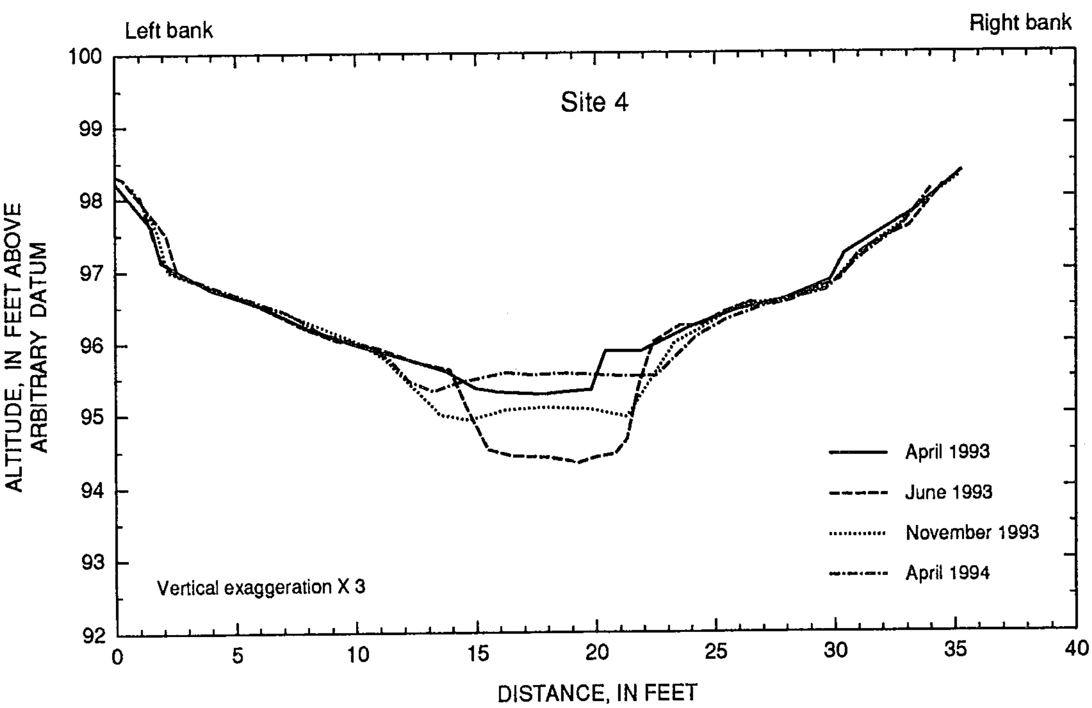

Figure 22. Channel cross sections from four surveys showing scour and fill at site 4 on Juday Creek, near South Bend, Indiana.

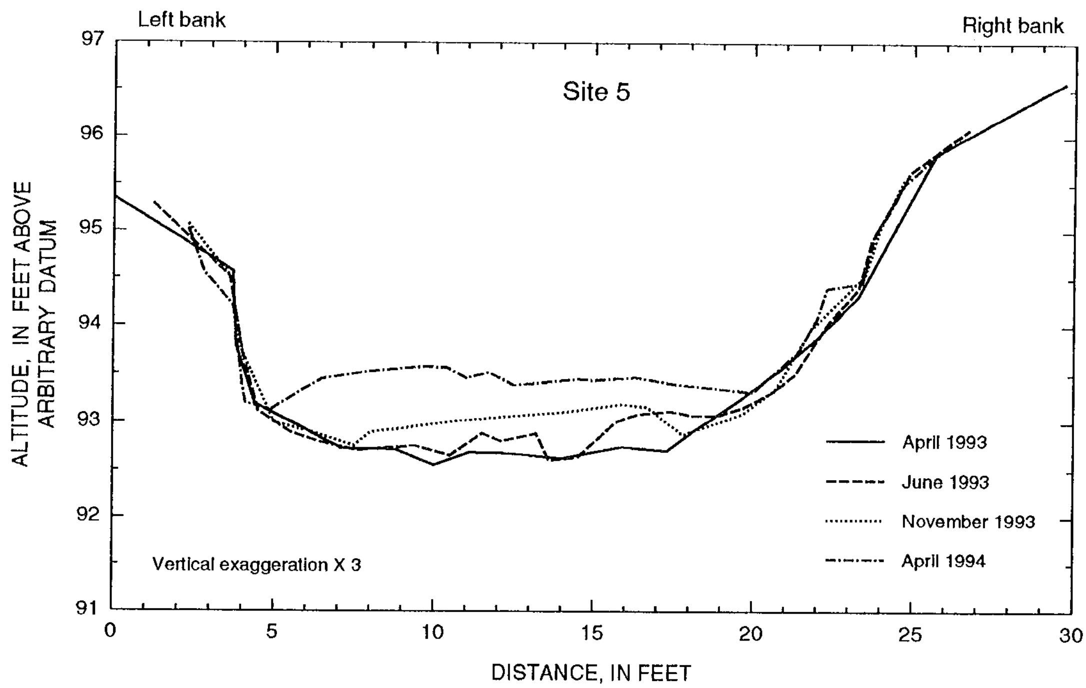

Figure 23. Channel cross sections from four surveys showing scour and fill at site 5 on Juday Creek, near South Bend, Indiana.

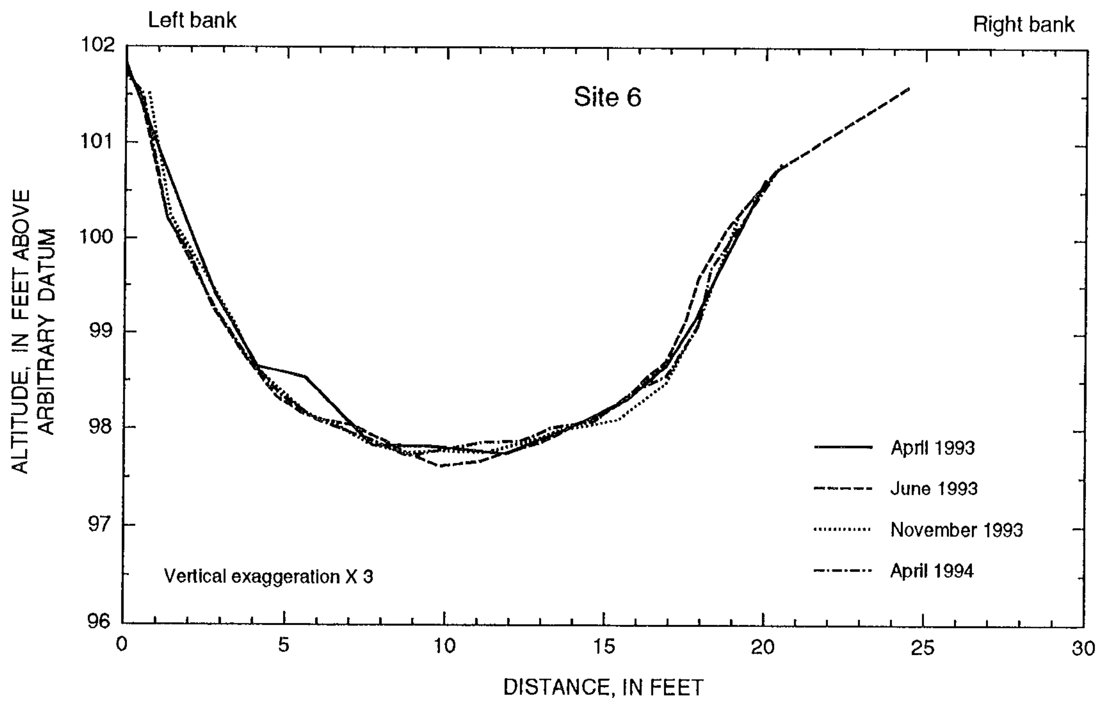

Figure 24. Channel cross sections from four surveys showing scour and fill at site 6 on Juday Creek, near South Bend, Indiana.

By April 1994, the streambed returned to virtually the same conditions as during the initial survey 1 year before, except for the left side of the channel which remained about one-half foot lower. This fluctuation of the streambed with changing streamflow can be expected where the streambed material is sand or finer particles.

Site 3 is at the inlet to the instream pond, where the channel is wider and the banks are lower (fig. 21). The streambed along this reach is mostly firm gravel. As Juday Creek flows into the instream pond, it meanders to the right; this meander explains the relatively stable right side of the channel and the scoured left bank. The fill near the middle of the channel is in response to the redistribution of flow to the left where the channel area is increasing. The scour and fill at this cross section is limited to only about one-half foot, but the base of the left bank has shifted about 3 ft to the left.

The maximum observed scour occurred at site 4 as a result of the heavy rains of June 1993 (fig. 22). The maximum scour below the April 1993 streambed level was about 1.4 ft. This cross section is just upstream from the scour chains, which recorded a maximum scour of 0.67 ft (table 7). The November 1993 and April 1994 surveys indicate that the streambed had been refilling since June 1993. Most of the scour and fill at site 4 has occurred near the middle of the channel, where the velocity is highest and the water is deepest. The particle-size analysis of the streambed material indicates that the streambed in the middle of the channel is mostly very fine pebbles; closer to the banks, the streambed is medium sand.

Site 5 is the only site where most of the channel has continuously infilled (fig. 23). The maximum fill is about 1 ft; at most places, the channel has filled about 0.7 ft to 0.8 ft. This accumulation of sand made recovery of the scour chains difficult. The sediment accumulation along this reach probably is caused by a stone dam just downstream from the study site. The stone dam pools the water and functions as a sediment trap for the bedload, which would otherwise probably continue to travel downstream. Parts of the reach between sites 4 and 5 were not accessible. Conditions along this reach could contribute to the increased sedimentation at site 5. The particle-size analysis of the streambed material shows that most of the streambed is gravel (tables 3 and 4). The bed-material samples, however, were collected in August 1993. The streambed was very firm when the scour chains were driven into the channel (April 1993). The bed-material samples and the firm conditions noted at that time indicate that the "normal" streambed is coarser and firmer than the loose sand that was found during the April 1994 survey.

This trapping of the sandy bedload also was observed at a rock riffle about 300 ft upstream from site 3. Sediment trapping observed at these sites indicates some bedload storage in the channel. Increased streamflow or changes in the riffles could facilitate a pulse of bedload transport.

The streambed at site 6 is a firm sand and gravel channel that has undergone little change during the study period (fig. 24). Site 6 is on the Izaak Walton League property just upstream from the confluence of Juday Creek and the St. Joseph River. The stream gradient along this reach is steeper than that of the upstream reaches. The particle-size analysis indicates that the streambed is sand and gravel, but there is coarser material along this reach that was too large for the sampler. Some of the irregularities in the cross sections at site 6 may be a result of the surveying rod resting on large cobbles for one survey but not for others.

YIELD OF SEDIMENT

Sediment yield was determined for the upper reach of Juday Creek, which includes the area upstream from the instream pond. The lower reach is from the Izaak Walton League sediment trap near the mouth, upstream to the instream pond. Sediment yield could not be calculated for the lower reach. The sediment trap was near full capacity at the original survey, and it was not dredged during the course of the study; therefore, a change in volume could not be calculated.

The bottom of the 6-acre instream pond was surveyed in April 1993 and April 1994 to determine the volume of sediment delivered to the pond during 1 year. Nineteen cross sections were surveyed, most of them traversing the delta where Juday Creek flows into the pond. The vertical and horizontal datum for the pond surveys were the same as those established for site 3. A total station was used to survey in the shallow water around the delta, and a fathometer was used to record continuous profiles where the water was deep. The total station recorded northing and easting coordinates as well as altitude. Coordinates and altitudes also were determined for the data points used from the fathometer records.

The surveyed data for the surface of the pond bottom was contoured by use of ARC/INFO[1], a geographic information system. The time periods represented by the contour maps are April 1993 and April 1994 (figs. 25 and 26). Juday Creek enters the pond in the southeast corner, where a delta has formed. A change in the shape of the delta can be seen between the two contour maps. The general shape of the delta is outlined by the 90- to 95-ft contour lines. The April 1994 map shows that the delta is broader and that it has prograded to the northwest. Away from the delta, in the deeper water, little change was detected, an indication that most of the sedimentation was at the delta. To identify the areas of sediment accumulation more closely, ARC/INFO was used to compute the difference between the April 1993 surface and the April 1994 surface (fig. 27). Figure 27 shows that most sediment accumulated around the delta where it drops off to deeper water. Some of the area in the southeast corner of the pond where sediment has not accumulated is above the water surface. The sediment accumulation along the north and south shorelines probably is from bank erosion.

[1]Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Areas of sedimentation and the changing shape of the delta also can be seen in cross sections (fig. 28). The locations of these cross sections are shown on the contour maps. Section E-E′ is closest to the inlet and shows the least amount of sedimentation. The water is shallow and swift as it flows through this area, and this condition is not conducive to deposition. The large trough at the left end of the section is in an area of backwater and does not receive much direct flow. Section E-G shows that sedimentation has occurred along most of the section, especially in the trough at the northeast edge of the delta. As much as 5 ft of sediment has accumulated here in a 1-year period. Section E-K also shows sedimentation along most of the section. The thickest accumulation of sediment is about 160 ft from endpoint E. Figure 27 shows a thick accumulation of sediment in this area just to the northwest of section E-K.

ARC/INFO was used to estimate the volume of sediment deposited between April 1993 and April 1994. A water-surface altitude of 96 ft was assumed, and pond volumes were computed for both surveys. The difference between the two was assumed to be the volume of sediment. The sediment accumulation along the north and south shorelines probably is from bank erosion and cannot be attributed to stream sediment transport (fig. 27). An analysis of the trend of sediment thickness showed that this sediment accumulation was not associated with the fluvial sedimentation near the delta. Therefore, this area of the pond was not included in the estimate of the volume of sediment. Only the area east of section E-N was used to estimate the volume of sediment. This assumption may underestimate the sediment yield, especially the suspended-sediment contribution, but it prevents the inclusion of sediment believed not to be derived from Juday Creek.

The volume of sediment deposited in the instream pond between April 1993 and April 1994 was estimated to be 26,500 ft^3, or about 0.6 acre-ft. The drainage area at the pond is approximately 27.9 mi^2. The sediment yield, in terms of volume, for the upper reach of Juday Creek from April 1993 to April 1994 was estimated to be about 950 ft^3/mi^2.

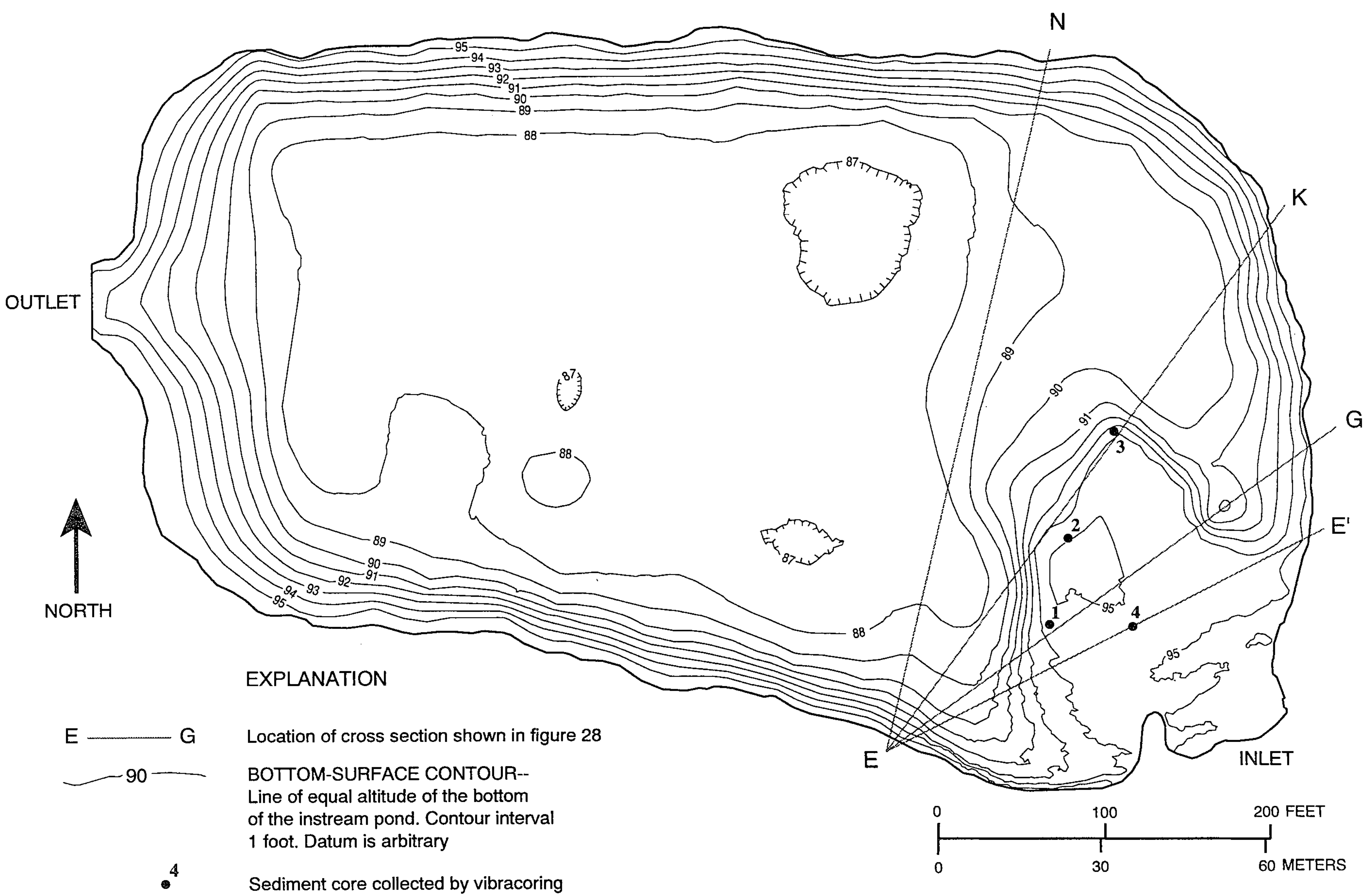

Figure 25. Configuration of the bottom of the instream pond on Juday Creek, near South Bend, Indiana, April 1993.

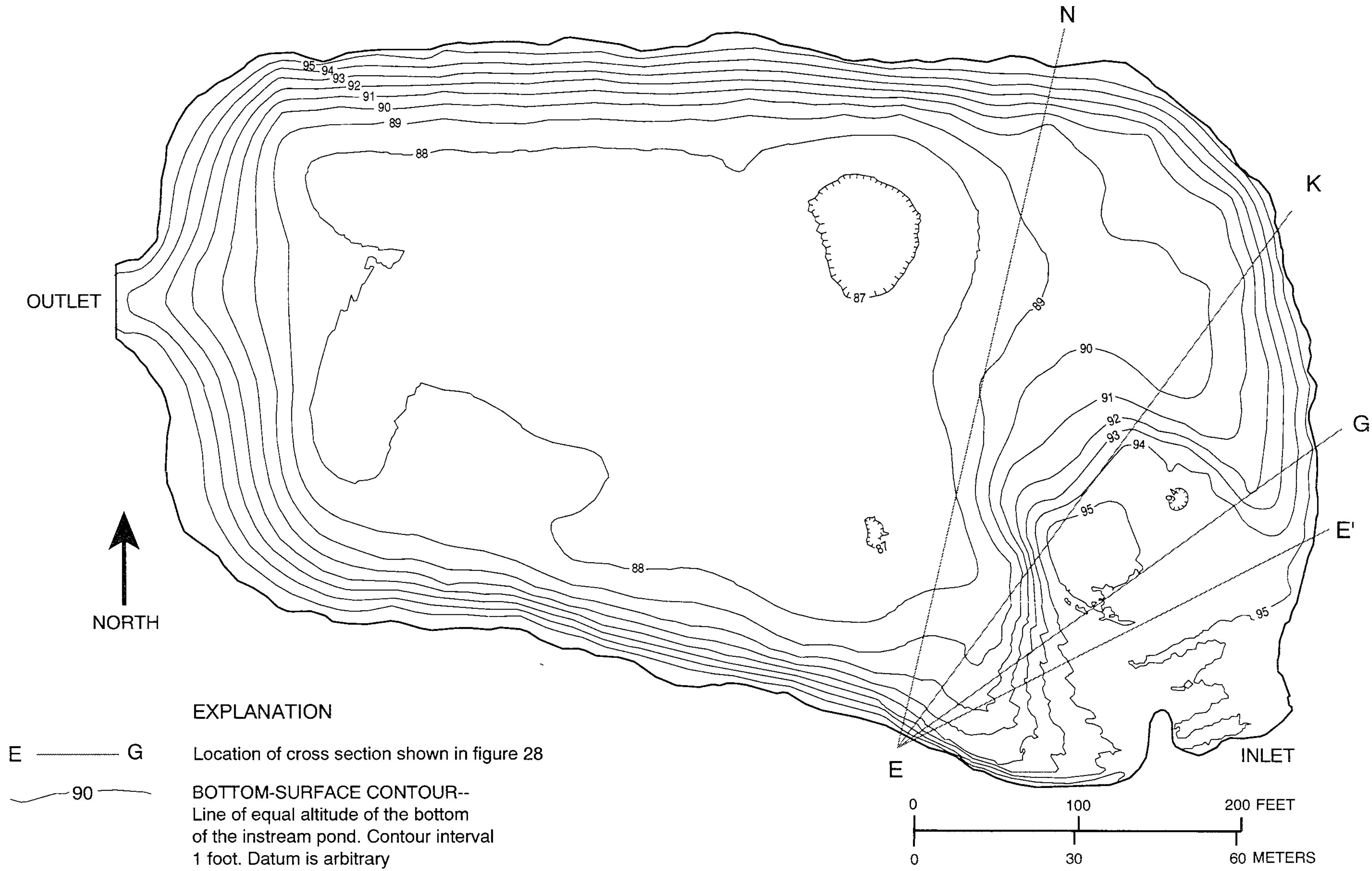

Figure 26. Configuration of the bottom of the instream pond on Juday Creek, near South Bend, Indiana, April 1994.

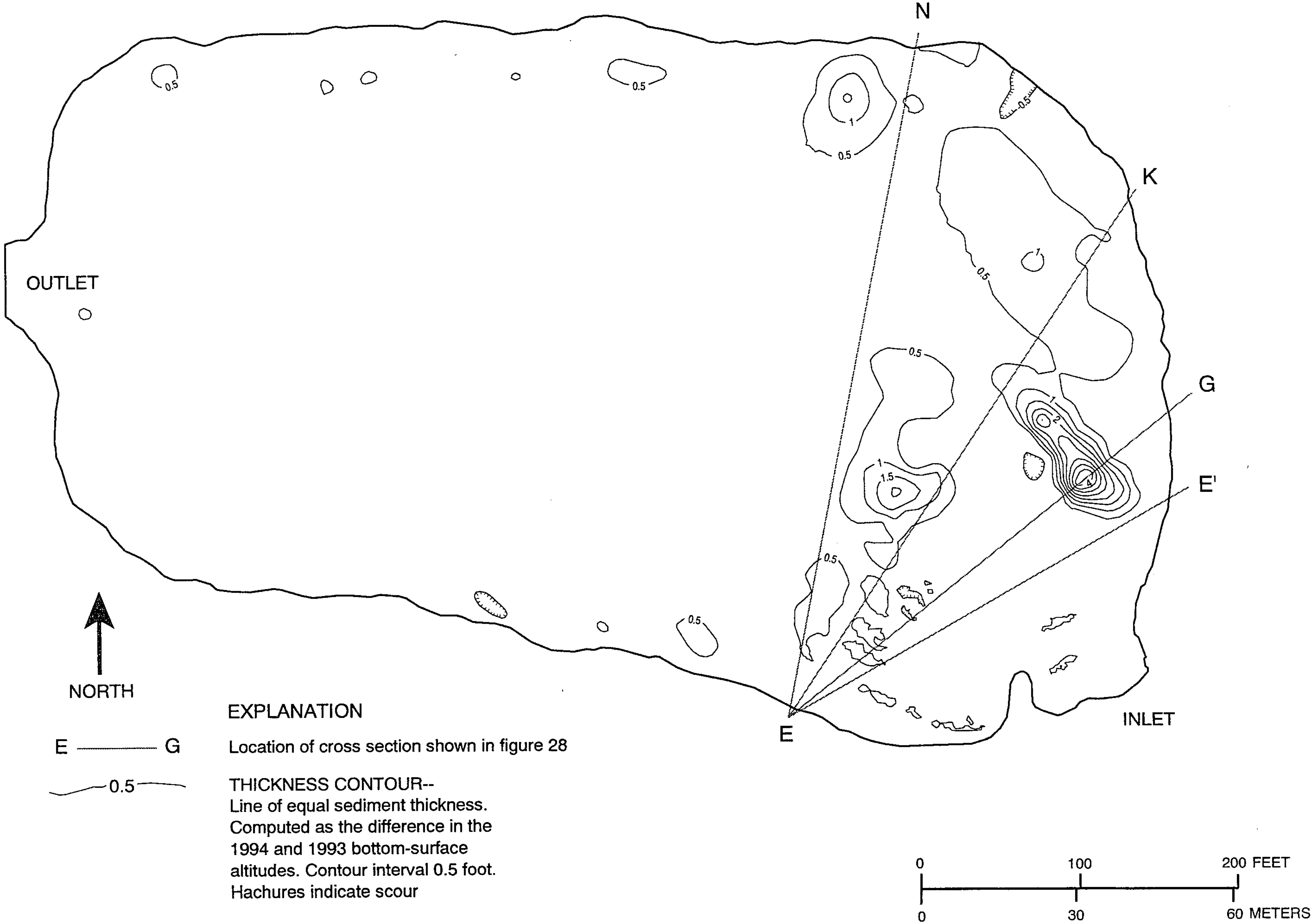

Figure 27. Sediment accumulation at the instream pond on Juday Creek, near South Bend, Indiana, April 1993 through April 1994.

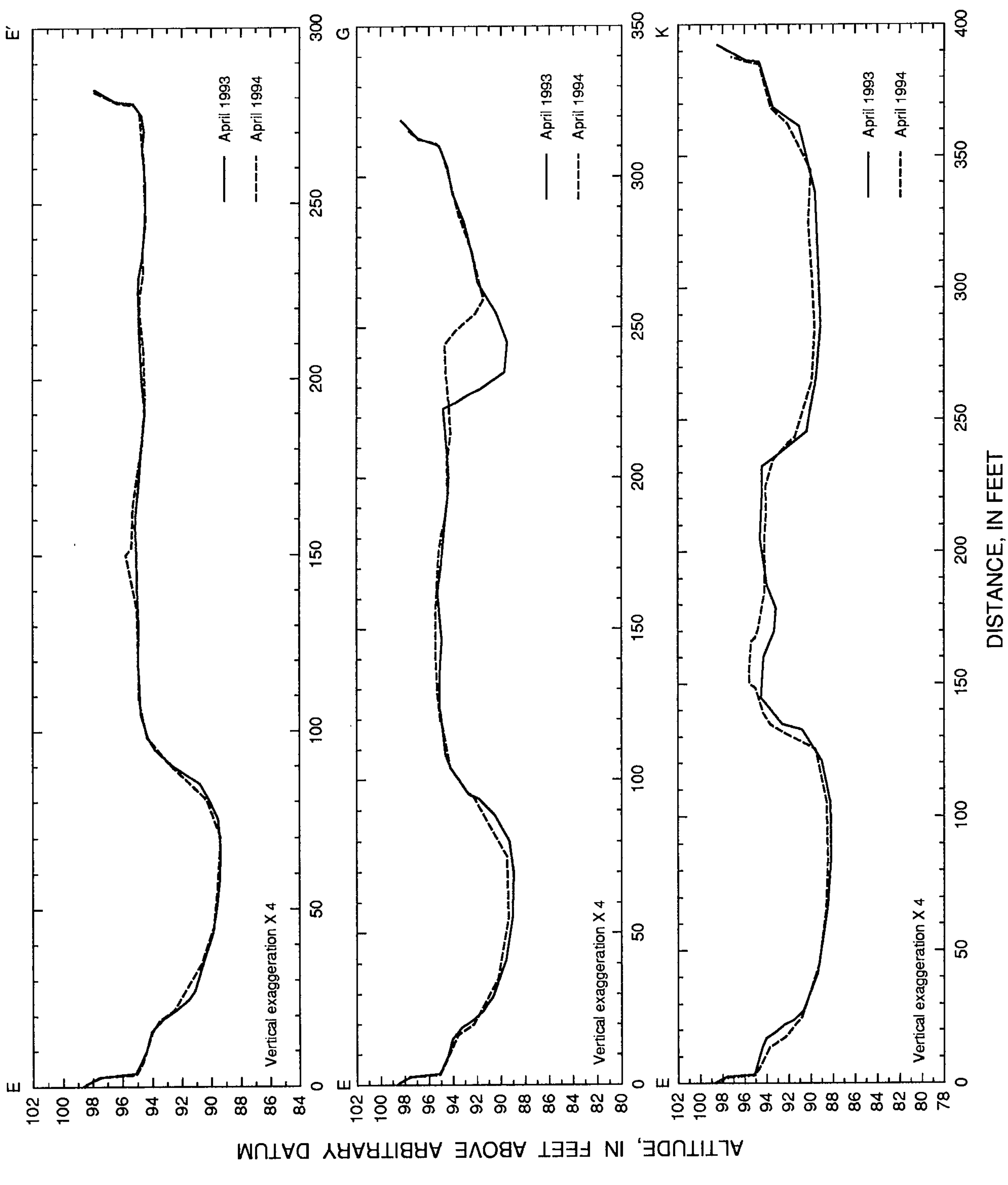

Figure 28. Cross sections of the instream pond on Juday Creek, near South Bend, Indiana, April 1993 and April 1994. Locations of the cross sections are shown in figures 25–27.

Sediment samples were collected along the delta edge for particle-size distribution analyses. The results show that the sediment being deposited on the delta is predominantly medium to coarse sand, with only a trace finer than 0.062 mm (table 3). Any finer grained material not deposited with the sand would have been deposited in deeper water. No significant accumulations of sediment are in the areas of deeper water (fig. 27). The graphs of sediment discharge show that bedload discharge usually is much higher than suspended-sediment discharge at site 3 (figs. 11, 13, and 15). Given the grain-size distributions and the data from site 3, it is assumed most of the sediment is transported onto the delta as bedload.

Estimation of the sediment yield in terms of weight required an estimate of the bulk density. The bulk density or volume weight of the sediments was estimated by collection of core samples with known volumes along the delta edge where sedimentation occurred. Three samples were collected in 1-foot long cylinders, and the volume weight ranged from 99 to 104 lb/ft^3. The average volume weight was estimated to be 102 lb/ft^3; therefore, the sediment load for the year was 1,350 tons. The sediment yield in terms of weight for the upper reach of Juday Creek from April 1993 to April 1994 was about 48 ton/mi^2. The daily average sediment load into the pond for the 1-year period was 3.7 ton, and the daily average sediment yield was 0.13 ton/mi^2.

The sediment yield cannot be compared directly to yields published for other streams in Indiana. No known sediment-yield data are available that include the contribution of bedload. Crawford and Jacques (1992) studied the suspended-sediment in Trail Creek at Michigan City, Ind. They estimated that the annual suspended-sediment yield for the 1981–90 water years ranged from 68 to 153 ton/mi^2 and averaged 114 ton/mi^2. A study of the suspended-sediment characteristics of streams in Indiana included 15 streams in the Northern Moraine and Lake Region (Crawford and Mansue, 1988, p. 67). Estimated average annual suspended-sediment yields of these streams ranged from 11 to 152 ton/mi^2; the median yield was 59 ton/mi^2. The estimated sediment yield for Juday Creek is in reasonable agreement with results from these studies; however, because the other studies do not account for bedload discharge, direct comparisons cannot be made.

SUMMARY AND CONCLUSIONS

Juday Creek is a small tributary to the St. Joseph River that drains 37.7 mi^2 of north-central Indiana. The sediment conditions of the stream were examined during 1993 and 1994 to determine the characteristics, transport, and yield of sediment in Juday Creek. This report includes analyses of bed material, suspended-sediment concentration, and bedload at six sampling sites. Sediment cores were collected from the pond delta and sediment trap. Cross sections were surveyed and scour chains were used to evaluate scour and fill at the six sites. An instream pond was surveyed in April 1993 and again in April 1994 to estimate the sediment yield for the upper reach of Juday Creek.

The particle-size distribution of the bed material and the sediment core descriptions document the sediment characteristics of the streambed of Juday Creek. The streambed along most of the channel is composed of medium sand. In the upper reaches of the stream, the streambed is primarily fine to medium sand. Near the instream pond, bed material becomes a mixture of sand and gravel. Bed-material and sediment cores collected from the pond delta indicate that medium to coarse sand is the predominant particle size being deposited at that location. The bed material in the lower reach of the stream is sand and gravel. The most downstream reach has a stable streambed of gravel and sand; this reach has the coarsest particles in the entire length. The particle-size distributions of all samples indicate that most of the bed material is coarser than 0.062 mm—that is, sand size and larger.

Measurements made during low flows and storms and additional measurements of scour and fill were analyzed to determine sediment transport in Juday Creek. Streamflow, suspended sediment, and bedload were measured during three storms and during a low-flow period. Scour and fill were measured by means of scour chains and surveyed cross sections. Changes in channel size and shape during the study period were determined from surveyed cross sections.

Sediment samples collected during the low flows provided data for comparison to those collected during storms. The median suspended-sediment concentration was 2.5 mg/L, and the median bedload was 17.1 g. These values, although low, indicate that some sediment transport occurred even during periods of low flow.

Measurements of streamflow during the storm sampling ranged from 3.24 to 46.5 ft^3/s. Streamflow measurements along Juday Creek indicate gaining and losing reaches. In the upper reach, the stream receives inflow of ground water; the downstream reach loses flow to ground water.

Suspended-sediment concentrations did not correlate strongly with streamflow. The concentrations tended to peak before the streamflow peak and then gradually diminish. Concentrations in storm samples analyzed were less than 70 mg/L, and in most samples were 30 mg/L or less. The median suspended-sediment concentration was 17 mg/L. These concentrations are below levels reported to have significant adverse effects on brown trout and other salmonids.

Bedload along Juday Creek was variable. During low flows loads ranged from 5.2 to 76.7 g. For the three storms, loads ranged from about 3.4 to 862 g; the median was 109 g. Although highly variable, bedload correlates with streamflow. Median values of bedload generally increased downstream. As streamflow increased, so did amounts of bedload. During almost all sampling events, bedload discharge exceeded suspended-sediment discharge. Bedload discharge is the predominant mode of sediment transport along the entire stream.

Measurements from the scour chains indicate that the net change in streambed altitude for the study period was minimal (–0.34 to 0.62 ft) but that some infilling occurred at most of the study sites. Surveyed cross sections documented that scour and fill has occurred at most of the sites, and that bank erosion occurred at two sites. Scour and fill tended to balance out; after a 1-year period, the average net change in the streambed altitude was about 0.1 ft. At one of the sites, the channel progressively filled throughout the study period. The infilling was likely caused by a low stone dam that functions as a bedload trap. The trapping of bedload at a rock riffle also was observed just upstream from the instream pond. This trapping indicates not only storage, but also movement of sediment along the stream.

Sediment yield for the upper reach of Juday Creek was estimated by determining the volume of sediment delivered to the instream pond during a 1-year period. The bottom of the pond was surveyed in April 1993 and in April 1994. A geographic information system was used to contour the bottom surface of the pond for both surveys and to compute the decrease in volume of the pond between the surveys. The difference in the volumes was assumed to be the volume of sediment delivered to the pond. The volume of sediment deposited in the pond was estimated to be 26,500 ft^3. Most of the sediment was sand deposited on a delta at the upstream end of the pond. The average volume weight of the sediment was estimated to be 102 lb/ft^3; therefore, the total weight of sediment deposited was 1,350 tons. The sediment yield from April 1993 to April 1994 was estimated to be about 48 ton/mi^2.

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DNR
INDIANA DEPARTMENT OF NATURAL RESOURCES
PATRICK R. RALSTON, DIRECTOR

Division of Soil Conservation
c/o Soil and Water Conservation District Office
60455 U. S. 31 South
South Bend, IN 46614
(219) 291-2300

December 6, 1994

Becky Moffett-Carey
c/o St. Joseph River Basin
1120 County City Bldg.
South Bend, IN 46601

Dear Becky,

This is a follow up to the site investigation into bank erosion along Juday Creek in the northeast 1/4 of section 32 of Clay township in St. Joseph County.

After walking the creek (county ditch) and looking at both banks, it is my opinion that there is active bank erosion occurring in this stretch of the stream. I feel this is a result of the existing soil type, the steepness of the banks, the lack of most of the natural vegetation and the tendency of the stream to try to return to it's natural meander.

The soil along the creek is mapped as a Maumee mucky loam. This soil is formed in sandy glacial outwash and there is a high percentage of organic matter in the surface layer. This soil is very prone to water erosion as a result of the instability and low density of the soil. The banks are vertical which increases erodibility discourages and supporting vegetation. Maumee soils have severe limitations and should be managed to reflect the high erodibility and wet conditions.

The areas with the largest degree of erosion were void of all natural vegetation at the soil/water interface. Since all banks are managed for yards and planted with grass, the vegetation ends at the top of the bank. Since the grasses are manicured and frequently mowed, the height of the vegetation provides little protection from stream flow. The root systems also have very little chance of becoming established in the saturated conditions and provide limited soil anchoring benefits.

Since Juday Creek is also considered a legal drain, this area has been channelized to increase flows during rain events. For development and landscaping purposes, several pond inlets have been excavated directly into the stream bank. The areas of the most severe erosion are occurring at the inlets of these ponds. The reason for this is the speed and velocity of the water flow, after a storm event, striking the unvegetated and unprotected soil at the inlets of these ponds.

Juday Creek Erosion
POSSIBLE SOLUTIONS
page 2

All erosion control techniques should be part of a plan consistence to the goals of the homeowners and the residential areas along the creek. The county drainage board should be involved, since the stream is considered a legal drain. All solutions may need approval from the IDNR, Division of Water, to meet permit requirements.

Several solutions to combat the stream bank erosion in this area include excavation of the stream banks to a gentle slope of 2:1 or 3:1 and vegetate the exposed soil surfaces with vegetation suited to the conditions present. Protecting the banks with energy dissipators such as riprap stone, or erosion blankets are a possibility.

Products or techniques such as coconut rolls, gabion baskets, wave breaks, concrete, etc. are possibilities, but may or may not be consistent with the goals of all the parties involved and should be investigated thoroughly.

It is important to remember that the stream will try to naturally meander and that erosion will be inevitable because of this soil type, so management is only temporary and will be ongoing and should be consistent with the goals of each group in the entire watershed, upstream as well as downstream.

I am sorry but I can not offer specific solutions to the stream bank erosion with out knowing all goals of the watershed or the individual landowner. I will be happy to offer specific technical assistance on any individual project.

Please call with any questions.

Sincerely,

John Law
Erosion Control Technician
IDNR, Division of Soil Conservation..

cc: John McNamara, County Surveyor
Debbie Knepp, DC, Natural Resources Conservation Service
Harold Doremire, APD, IDNR, Division of Soil Conservation

United States Department of the Interior

TAKE PRIDE IN AMERICA

GEOLOGICAL SURVEY
Water Resources Division
5957 Lakeside Boulevard
Indianapolis, Indiana 46278-1996
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MACOG

March 18, 1994

Ms. Karen Mackowiak
St. Joseph River Basin Commission
1120 County-City Building
South Bend, Indiana 46601

Dear Ms. Mackowiak:

Enclosed are the finalized 1993 water-year data for the U.S. Geological Survey Gage, Juday Creek at South Bend, Indiana ((04101370). I have included the following tables and curves:

Final discharge table.
Primary computation sheets which track the hourly stage, daily peak, and corresponding discharge, minimum stage, and corresponding discharge, and mean daily discharge.
Stage-discharge relationship table.
Water temperature hourly data and quality control data.
Discharge Measurement log.

Under separate cover I have enclosed the daily discharge hydrograph and the stage-discharge curve.

If you have further questions about this data or other matters, please call me at extension 153.

Sincerely,

James A. Stewart
Chief, Hydrologic Data Section

5 Enclosures

Separate Cover:
Daily Discharge Hydrograph
Stage-Discharge Curve

STATION NUMBER 04101370 JUDAY CREEK NEAR SOUTH BEND, IN STREAM SOURCE AGENCY USGS
LATITUDE 414343 LONGITUDE 0861546 DRAINAGE AREA 0.00 DATUM STATE 18 COUNTY 141
PROVISIONAL DATA SUBJECT TO REVISION

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1992 TO SEPTEMBER 1993
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	26	21	23	57	e27	22	39	33	20	e33	14	e14
2	22	42	23	48	27	22	38	32	20	e31	14	32
3	19	40	22	46	28	23	35	33	20	e32	14	35
4	23	23	21	71	27	26	34	33	21	e30	15	25
5	22	20	20	67	27	27	32	34	21	e29	15	22
6	21	18	21	57	27	26	31	32	20	e28	15	24
7	19	17	21	48	26	26	30	31	37	e27	14	22
8	18	16	20	43	26	28	30	29	103	e27	14	20
9	18	16	20	39	26	35	32	29	163	e26	e13	19
10	17	16	21	38	26	41	31	30	85	26	21	21
11	16	16	20	37	25	39	31	28	61	27	17	19
12	16	27	20	37	26	37	31	28	47	27	16	19
13	16	34	20	35	26	37	30	26	55	24	16	20
14	18	32	21	34	25	35	31	25	72	24	15	27
15	20	29	20	35	25	33	33	24	60	21	16	39
16	30	25	24	34	25	35	37	24	45	21	18	32
17	29	25	24	32	24	42	34	23	43	22	16	26
18	27	24	23	31	24	37	33	23	41	21	15	21
19	24	24	22	30	e23	34	35	23	42	21	15	19
20	24	24	22	29	23	33	56	23	41	20	20	19
21	22	24	21	32	24	32	49	22	37	20	e20	20
22	20	24	21	32	23	36	42	21	34	19	e19	18
23	20	26	21	37	23	49	39	22	e33	19	e16	18
24	20	25	20	35	e22	47	38	22	e32	19	e16	17
25	18	25	20	32	e21	42	39	20	e35	19	e17	19
26	e16	24	e20	30	e21	38	35	20	e33	19	e15	25
27	15	24	e19	e29	21	36	33	19	e32	17	e13	32
28	e15	23	e19	e29	21	34	33	20	e34	17	e13	37
29	e14	23	e26	e28	---	33	35	20	e32	16	e13	32
30	e14	23	46	e28	---	32	33	22	e33	15	e15	29
31	e15	---	71	e28	---	34	---	21	---	15	16	---
TOTAL	614	730	732	1188	689	1051	1059	792	1352	712	486	722
MEAN	19.8	24.3	23.6	38.3	24.6	33.9	35.3	25.5	45.1	23.0	15.7	24.1
MAX	30	42	71	71	28	49	56	34	163	33	21	39
MIN	14	16	19	28	21	22	30	19	20	15	13	14

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1993 - 1993, BY WATER YEAR (WY)

MEAN	19.8	24.3	23.6	38.3	24.6	33.9	35.3	25.5	45.1	23.0	15.7	24.1
MAX	19.8	24.3	23.6	38.3	24.6	33.9	35.3	25.5	45.1	23.0	15.7	24.1
(WY)	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993
MIN	19.8	24.3	23.6	38.3	24.6	33.9	35.3	25.5	45.1	23.0	15.7	24.1
(WY)	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993

SUMMARY STATISTICS	FOR 1993 WATER YEAR	
ANNUAL TOTAL	10127	
ANNUAL MEAN	27.7	
HIGHEST DAILY MEAN	163	Jun 9
LOWEST DAILY MEAN	13	Aug 9
ANNUAL SEVEN-DAY MINIMUM	14	Aug 26
INSTANTANEOUS PEAK FLOW	226	Jun 9
INSTANTANEOUS PEAK STAGE	3.39	Jun 9
10 PERCENT EXCEEDS	39	
50 PERCENT EXCEEDS	25	
90 PERCENT EXCEEDS	16	

STATISTICS COMPUTED BY: JRDAVIS DATE: 03/15/1994 AT: 13:55:56

e Estimated

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE RATINGS USED --
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL STNRD 1.0 10/01/92 (0001)
INPUT DD: FROM EDL-MOD

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS 0100 / 1300	0200 / 1400	0300 / 1500	0400 / 1600	0500 / 1700	0600 / 1800	0700 / 1900	0800 / 2000	0900 / 2100	1000 / 2200	1100 / 2300	1200 / 2400
10/01/92	2.27 30 <0030>	2.22 2.3 <0000>	2.25	26	-0.04W	0.00	225	226	226	227	225	226	226	225	225	226	225	225
							223	223	224	223	224	224	224	225	224	222	223	224
10/02/92	2.25 27 <0145>	2.17 18 <1800>	2.21	22	-0.07W	0.01	224	224	224	223	222	221	221	220	220	221	220	220
							220	220	219	219	220	217	219	219	218	221	220	219
10/03/92	2.20 21 <0015>	2.13 16 <2100>	2.18	19	-0.09W	0.01	220	219	218	218	218	219	220	217	217	217	217	219
							220	218	219	219	218	218	217	216	213	215	217	218
10/04/92	2.24 25 <0615>	2.18 19 <0000>	2.21	23	-0.07W	0.02	220	223	223	222	223	223	222	223	221	223	223	220
							223	221	221	219	220	220	221	220	220	220	219	220
10/05/92	2.22 24 <0330>	2.17 18 <0600>	2.20	22	-0.08W	0.02	221	221	221	221	221	217	221	222	221	221	220	221
							220	221	221	221	222	218	218	219	221	219	219	220
10/06/92	2.22 24 <1615>	2.15 17 <2400>	2.19	21	-0.09W	0.03	220	219	219	219	219	220	218	219	219	220	220	219
							221	219	220	221	221	221	220	220	219	218	218	215
10/07/92	2.20 21 <0215>	2.14 17 <0145>	2.18	19	-0.10W	0.03	219	219	219	218	217	218	218	218	217	218	219	219
							217	220	217	218	216	219	217	219	217	219	217	218
10/08/92	2.19 20 <0230>	2.11 15 <2300>	2.17	18	-0.10W	0.04	218	218	217	217	217	218	216	217	215	217	216	218
							217	217	216	216	215	215	218	216	217	218	211	213
10/09/92	2.20 21 <0945>	2.11 15 <1915>	2.16	18	-0.10W	0.04	217	214	217	214	215	214	216	214	217	219	217	217
							213	216	217	216	216	215	217	214	213	216	214	217
10/10/92	2.18 19 <0100>	2.11 15 <1500>	2.14	17	-0.10W	0.05	218	214	215	214	213	214	214	216	214	212	212	214
							212	214	211	213	213	214	213	213	214	213	213	213
10/11/92	2.15 17 <1400>	2.10 15 <0300>	2.13	16	-0.10W	0.05	212	213	210	213	214	213	213	213	212	212	213	213
							213	215	212	214	213	212	213	211	213	212	210	213
10/12/92	2.14 17 <0045>	2.09 14 <1045>	2.12	16	-0.10W	0.06	210	212	211	213	213	212	213	211	213	213	212	214
							211	212	214	213	213	213	214	211	212	213	214	213
10/13/92	2.16 18 <2200>	2.09 14 <1615>	2.12	16	-0.10W	0.07	212	211	212	211	212	213	211	213	211	212	210	211
							213	212	211	211	212	212	213	214	213	216	215	209
10/14/92	2.37 40 <1645>	2.08 14 <0700>	2.15	18	-0.09W	0.07	213	213	213	211	212	213	208	209	211	212	208	215
							213	214	212	219	236	228	219	217	215	218	217	215
10/15/92	2.25 27 <0745>	2.13 16 <0100>	2.18	20	-0.09W	0.07	213	214	213	215	217	219	223	224	223	222	219	221
							221	220	220	220	219	218	218	217	216	218	218	217

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL
INPUT DD: FROM EDL-MOD

STATE 18 DIST 18
RATINGS USED --
STNRD 1.0 10/01/92 (0001)

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS

	DATE --------	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
	10/16/92	2.32 36 <0945>	2.17 18 <0000>	2.27	30	-0.02W	0.08	224 229	223 226	223 227	222 227	227 230	228 230	229 231	227 230	227 230	230 228	229 228	230 228
	10/17/92	2.30 34 <0015>	2.22 22 <1045>	2.27	29	-0.03W	0.08	228 222	228 225	227 230	228 228	228 228	227 228	224 225	223 226	225 228	223 229	222 229	223 228
	10/18/92	2.28 32 <0000>	2.20 20 <1115>	2.25	27	-0.04W	0.08	227 220	226 223	227 224	226 226	226 224	226 226	226 225	227 226	225 224	227 224	225 226	225 226
	10/19/92	2.26 28 <0000>	2.17 17 <0100>	2.23	24	-0.07W	0.09	217 226	225 223	225 224	221 223	224 222	221 221	222 223	222 222	224 223	225 222	225 222	224 221
	10/20/92	2.28 32 <0615>	2.16 16 <1415>	2.23	24	-0.07W	0.09	222 224	222 223	223 224	224 223	223 222	226 222	224 222	224 224	223 225	225 221	222 223	224 222
	10/21/92	2.28 32 <1015>	2.13 14 <1530>	2.22	22	-0.09W	0.09	223 222	223 228	221 222	221 222	223 222	221 221	222 219	223 221	222 222	226 219	222 223	220 222
	10/22/92	2.24 24 <0200>	2.18 16 <0600>	2.21	20	-0.11W	0.09	221 224	224 222	221 220	222 221	221 221	218 219	221 219	221 219	220 221	223 223	221 222	221 223
	10/23/92	2.23 23 <0000>	2.15 14 <2115>	2.21	20	-0.12W	0.10	221 222	222 222	221 220	222 220	218 220	222 222	222 221	222 221	222 221	221 220	222 220	222 218
	10/24/92	2.24 24 <1645>	2.17 15 <1330>	2.21	20	-0.12W	0.10	220 220	221 221	222 221	219 223	220 221	219 223	222 222	222 221	220 221	222 221	220 223	221 221
	10/25/92	2.23 22 <0045>	2.09 11 <2215>	2.19	18	-0.14W	0.10	221 221	222 218	219 215	220 221	221 220	222 219	220 219	223 217	221 212	221 211	221 212	221 214
#	10/26/92	2.19 17 <1245>	2.11 12 <0145>	2.15	14	-0.17W	0.11	213 217	214 216	211 217	215 214	213 215	214 217	213 216	216 216	213 215	213 214	215 214	217 219
	10/27/92	2.26 27 <1415>	2.08 10 <2030>	2.16	15	-0.17W	0.10	217 218	219 221	219 221	218 215	219 215	216 213	217 213	221 209	220 210	220 210	219 212	219 212
#	10/28/92	2.25 28 <1200>	2.12 12 <0000>	2.19	21	-0.08W	0.08	214 220	214 219	217 219	217 221	217 220	220 219	217 222	219 221	218 218	219 221	220 220	223 219
#	10/29/92	2.22 28 <0730>	2.13 22 <1230>	2.19	25		0.07	219 219	221 218	220 219	219 219	219 218	217 219	219 220	220 219	221 219	221 217	221 218	218 218
#	10/30/92	2.20 26 <0845>	2.03 16 <2200>	2.13	22		0.07	217 216	219 215	217 214	219 209	215 207	217 208	219 205	218 205	218 205	216 203	217 204	217 204

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION   STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE   RATINGS USED --
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL   STNRD 1.0 10/01/92 (0001)
INPUT DD: FROM EDL-MOD

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060   STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:******   PUNCH INTERVAL: 15 MIN

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
# 10/31/92	2.05	1.98	2.02	16		0.07	204	204	204	204	205	204	203	203	204	203	204	205
	17	14					205	204	201	201	200	200	200	200	199	198	199	200
	<0345>	<1945>																
11/01/92	2.34	1.96	2.10	21		0.06	201	196	201	199	199	202	200	201	202	201	204	208
	37	13					208	210	207	208	211	220	225	218	234	234	234	231
	<2100>	<0200>																
11/02/92	2.53	2.21	2.39	42		0.06	235	236	234	232	235	247	243	247	241	245	243	242
	56	27					240	221	237	229	234	234	227	243	250	249	250	251
	<0745>	<1400>																
11/03/92	2.51	2.21	2.36	39		0.05	250	248	247	245	246	246	243	243	242	241	243	236
	53	27					234	232	233	231	229	227	224	224	222	222	221	222
	<0000>	<2300>																
11/04/92	2.22	2.10	2.16	23		0.05	220	219	220	220	219	219	218	217	218	218	216	214
	28	20					214	214	214	214	213	213	212	212	213	212	213	211
	<0000>	<2330>																
11/05/92	2.13	2.07	2.09	20		0.05	211	210	210	210	210	209	211	209	209	209	208	210
	22	18					211	210	209	210	209	209	207	208	207	207	207	208
	<0045>	<1815>																
11/06/92	2.08	2.04	2.06	18		0.04	206	207	207	207	208	207	207	206	206	206	206	206
	19	17					206	206	206	206	206	206	206	206	206	206	205	206
	<0000>	<2215>																
11/07/92	2.06	2.03	2.05	17		0.04	204	206	205	205	205	205	205	203	204	205	205	204
	18	16					204	204	205	204	204	205	205	205	204	205	205	205
	<0000>	<0800>																
11/08/92	2.06	2.00	2.03	16		0.03	205	204	204	204	205	203	204	202	203	203	203	202
	18	15					203	202	200	202	202	202	203	202	203	203	203	203
	<0045>	<1430>																
11/09/92	2.04	2.00	2.03	16		0.03	202	202	202	202	202	203	202	203	203	203	203	203
	17	15					203	203	202	202	203	203	203	203	203	203	203	203
	<0830>	<1845>																
11/10/92	2.05	2.01	2.02	16		0.03	203	202	203	202	202	202	202	202	203	202	202	203
	17	15					203	203	203	203	202	203	203	203	203	202	202	202
	<1230>	<1015>																
11/11/92	2.05	2.00	2.02	16		0.02	200	201	201	202	203	203	202	203	201	205	203	203
	17	15					203	202	201	202	202	202	201	202	202	202	203	202
	<0930>	<0100>																
11/12/92	2.34	2.02	2.20	27		0.02	202	202	203	204	213	219	216	216	219	223	221	220
	37	16					221	223	224	223	225	229	229	232	232	231	234	230
	<2300>	<0000>																
11/13/92	2.35	2.24	2.30	34		0.02	235	233	233	232	231	226	228	228	227	227	226	226
	38	29					228	230	228	230	234	234	233	232	232	229	229	231
	<0100>	<1115>																
11/14/92	2.31	2.24	2.27	32		0.01	231	230	229	228	228	228	228	227	229	227	227	225
	35	29					227	226	226	229	228	227	227	226	226	224	227	226
	<0000>	<2200>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION   STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE   RATINGS USED --
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL   STNRD 1.0 10/01/92 (0001)
INPUT DD: FROM EDL-MOD

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060   STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:******   PUNCH INTERVAL: 15 MIN

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
--------							STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS											
11/15/92	2.27	2.20	2.23	29		0.01	226	225	225	226	226	226	226	224	224	225	224	223
	32	26					222	223	221	223	221	222	220	221	220	221	220	221
	<0315>	<1900>																
11/16/92	2.21	2.16	2.19	25		0.00	220	220	219	218	219	218	219	219	218	219	217	218
	27	24					218	218	219	219	217	219	219	218	219	219	219	219
	<0545>	<1030>																
11/17/92	2.21	2.16	2.19	25		0.00	219	219	219	220	219	219	220	220	220	219	218	219
	27	24					220	219	218	218	219	216	218	219	218	218	218	218
	<0515>	<1800>																
11/18/92	2.18	2.15	2.17	24		0.00	217	217	218	217	217	218	218	218	218	217	217	217
	25	23					217	217	217	216	216	216	217	217	216	216	216	215
	<0000>	<1945>																
11/19/92	2.39	2.14	2.16	24		0.00	216	216	216	216	216	216	216	216	216	216	216	217
	41	22					217	216	215	215	215	216	215	216	215	216	216	217
	<1030>	<0630>																
11/20/92	2.18	2.14	2.16	24		0.00	216	216	216	216	216	216	215	216	214	216	215	216
	25	22					218	216	216	218	217	217	217	218	217	217	217	217
	<1245>	<0900>																
11/21/92	2.19	2.14	2.16	24		0.00	217	217	218	218	217	217	217	217	216	216	214	216
	25	22					216	215	215	215	215	216	215	215	215	216	215	216
	<0345>	<1045>																
11/22/92	2.19	2.14	2.16	24		0.00	214	216	214	216	215	215	214	214	215	215	214	216
	25	22					217	215	217	218	217	218	218	218	219	218	219	219
	<2030>	<0100>																
11/23/92	2.21	2.18	2.19	26		0.00	220	219	219	218	219	219	219	219	220	220	219	219
	27	25					220	220	220	219	219	220	220	220	220	221	220	220
	<1945>	<0015>																
11/24/92	2.21	2.17	2.19	25		0.00	220	219	219	219	219	219	219	218	219	219	218	219
	27	24					218	218	218	221	220	219	219	217	217	218	221	219
	<1600>	<1115>																
11/25/92	2.21	2.16	2.18	25		0.00	218	219	219	217	217	217	219	219	219	217	217	216
	27	24					216	217	218	217	218	217	218	218	218	217	218	217
	<0830>	<1200>																
11/26/92	2.18	2.16	2.17	24		0.00	217	218	217	218	218	218	217	217	217	217	217	217
	25	24					217	218	217	217	217	217	217	217	216	216	217	217
	<0130>	<0645>																
11/27/92	2.17	2.15	2.16	24		0.00	217	216	216	217	217	217	216	216	216	216	216	216
	24	23					215	215	216	216	216	216	216	216	216	216	216	216
	<0000>	<1045>																
11/28/92	2.16	2.15	2.16	23		0.00	216	216	216	215	216	216	216	216	216	215	215	215
	24	23					216	215	215	216	216	216	216	215	216	215	216	216
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11/29/92	2.16	2.14	2.15	23		0.00	216	216	216	216	215	215	214	215	214	214	214	215
	24	22					215	214	214	214	215	214	214	214	214	215	214	215
	<0000>	<0515>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL
INPUT DD: FROM EDL-MOD

STATE 18 DIST 18
RATINGS USED --
STNRD 1.0 10/01/92 (0001)

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
11/30/92	2.15	2.13	2.14	23		0.00	215	215	214	214	214	215	215	214	213	214	215	214
	23	22					214	214	214	214	214	214	214	214	214	215	214	214
	<0000>	<0900>																
12/01/92	2.16	2.13	2.14	23		0.01	214	214	214	214	214	214	214	214	214	214	214	215
	24	22					214	215	214	215	214	214	216	214	215	215	215	215
	<1900>	<0615>																
12/02/92	2.20	2.14	2.16	23		0.01	215	215	215	215	215	215	216	215	215	216	216	220
	26	22					217	217	216	216	216	216	216	216	216	216	215	215
	<1145>	<0030>																
12/03/92	2.15	2.11	2.13	22		0.01	215	215	215	214	215	214	214	214	214	214	214	214
	23	21					214	214	214	214	212	211	212	211	211	212	212	213
	<0000>	<1730>																
12/04/92	2.13	2.10	2.11	21		0.01	211	212	212	212	212	212	212	211	212	212	212	212
	22	20					212	212	212	212	211	212	211	211	212	212	211	211
	<0000>	<1530>																
12/05/92	2.12	2.08	2.11	20		0.01	211	211	211	210	210	211	211	211	211	210	210	210
	21	19					211	211	211	211	211	211	212	212	211	212	208	211
	<1430>	<2300>																
12/06/92	2.12	2.08	2.11	21		0.01	212	211	211	211	211	211	211	211	210	211	211	211
	21	19					211	211	211	211	211	210	211	211	211	211	211	211
	<0030>	<1030>																
12/07/92	2.12	2.09	2.11	21		0.01	211	212	211	212	211	211	211	212	211	212	211	211
	21	19					211	211	211	211	211	210	211	211	211	211	211	210
	<0015>	<0715>																
12/08/92	2.11	2.08	2.10	20		0.01	211	211	211	210	211	211	211	211	211	211	211	210
	21	19					210	209	210	210	210	210	210	210	210	210	210	210
	<0015>	<1415>																
12/09/92	2.12	2.09	2.10	20		0.01	211	211	211	210	210	210	210	211	210	210	210	210
	21	19					210	210	210	210	210	210	210	210	210	211	212	212
	<2300>	<0245>																
12/10/92	2.13	2.10	2.12	21		0.01	212	211	212	212	213	212	212	212	212	212	212	211
	22	20					212	211	211	211	211	211	211	210	211	211	211	211
	<0330>	<0615>																
12/11/92	2.11	2.08	2.10	20		0.01	211	210	210	210	209	210	211	211	211	211	210	210
	21	19					210	209	211	210	211	208	211	211	211	210	211	211
	<0000>	<1800>																
12/12/92	2.11	2.08	2.11	20		0.01	211	211	210	211	210	211	211	211	210	211	211	210
	21	19					210	211	210	210	211	211	210	210	211	210	210	211
	<0000>	<1345>																
12/13/92	2.12	2.08	2.11	20		0.01	210	210	210	210	211	211	210	211	208	210	210	210
	21	19					211	211	211	210	211	211	211	211	211	211	211	212
	<0045>	<0845>																
12/14/92	2.13	2.10	2.12	21		0.01	211	211	212	212	212	212	211	211	211	212	212	211
	22	20					212	212	212	212	212	212	211	212	212	212	212	212
	<1545>	<1245>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STA[illegible] 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE RATINGS USED --
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL STNRD 1.0 10/01/92 (0001)
INPUT DD: FROM EDL-MOD

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

	DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
	--------							STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS											
	12/15/92	2.15	2.06	2.11	20		0.00	213	212	212	212	213	213	212	212	211	210	208	210
		23	18					209	209	209	208	209	208	209	212	211	211	211	214
		<2345>	<1815>																
	12/16/92	2.25	2.12	2.17	24		-0.01	215	214	214	214	216	215	216	216	218	218	217	217
		30	21					218	218	216	217	217	217	215	218	223	224	225	223
		<2300>	<0345>																
	12/17/92	2.24	2.14	2.17	24		-0.01	218	218	217	218	217	218	217	216	216	215	216	217
		29	22					216	216	216	217	216	214	216	215	214	216	215	215
		<0030>	<1800>																
	12/18/92	2.17	2.12	2.14	23		-0.01	216	215	216	215	214	215	214	214	214	213	215	215
		24	21					215	215	215	213	214	214	215	214	213	215	213	214
		<0445>	<1945>																
	12/19/92	2.16	2.10	2.14	22		-0.01	214	214	215	213	213	214	215	213	214	214	213	213
		24	20					214	213	213	214	214	213	215	210	214	215	214	216
		<2215>	<2000>																
	12/20/92	2.16	2.11	2.13	22		-0.01	214	215	214	213	215	215	214	214	213	213	213	213
		24	21					213	213	213	212	213	212	213	212	212	212	212	213
		<0000>	<1815>																
	12/21/92	2.14	2.10	2.12	21		-0.01	212	212	212	212	211	211	212	212	212	211	211	212
		22	20					212	211	211	213	212	212	212	212	212	212	213	213
		<2215>	<0530>																
	12/22/92	2.14	2.09	2.12	21		0.00	213	213	212	212	213	213	212	213	212	213	212	212
		22	19					212	212	212	212	213	213	212	209	212	212	213	212
		<1945>	<2000>																
	12/23/92	2.13	2.10	2.11	21		0.00	213	212	212	212	212	212	212	212	212	211	211	211
		22	20					211	211	211	211	211	211	210	210	211	211	210	211
		<0045>	<1900>																
	12/24/92	2.11	2.07	2.10	20		0.00	211	210	211	210	210	211	211	211	210	210	210	210
		21	18					210	210	210	210	210	210	210	210	207	210	210	211
		<0000>	<2100>																
	12/25/92	2.12	2.09	2.10	20		0.00	210	210	210	210	211	211	211	210	211	210	211	212
		21	19					211	210	211	211	209	210	210	210	209	210	209	210
		<0530>	<1700>																
#	12/26/92	2.36	2.10	2.19	26		0.00	211	214	216	216	217	219	221	222	225	226	228	229
		39	20					232	231	230	229	232	210	210	210	210	210	210	210
		<1645>	<0000>																
#	12/27/92	2.29	2.09	2.14	22		0.00	210	210	210	209	214	216	218	219	221	224	225	228
		33	19					209	210	210	210	210	210	210	211	210	210	210	211
		<1145>	<0030>																
#	12/28/92	2.16	2.09	2.12	21		0.03	210	210	209	210	210	210	210	211	211	210	211	212
		24	19					212	212	212	213	213	213	214	214	216	215	216	216
		<2100>	<0130>																
#	12/29/92	2.29	2.16	2.23	29		0.11	216	216	217	217	218	218	218	221	226	226	224	223
		33	24					226	227	227	227	226	226	228	227	227	228	227	228
		<2345>	<0000>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE RATINGS USED --
04101370 DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL STNRD 1.0 10/01/92 (0001)
JUDAY CREEK NEAR SOUTH BEND, IN INPUT DD: FROM EDL-MOD
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
12/30/92	2.63	2.28	2.42	45		0.18	229	228	230	232	232	233	232	233	237	239	239	239
	69	32					238	239	241	245	249	262	251	258	258	260	258	258
	<1745>	<0000>																
12/31/92	2.73	2.54	2.64	71		0.19	258	259	258	263	260	263	262	259	271	269	271	269
	83	57					266	267	270	270	266	266	264	264	263	263	263	260
	<0915>	<0245>																
01/01/93	2.61	2.45	2.54	57		0.19	259	257	259	258	257	259	259	258	257	255	254	255
	66	47					253	253	251	251	251	252	252	250	249	250	250	250
	<0230>	<2345>																
01/02/93	2.50	2.42	2.46	48		0.19	249	247	247	249	246	247	245	247	247	247	245	245
	52	44					245	246	245	245	244	244	242	245	245	243	243	243
	<0000>	<1900>																
01/03/93	2.46	2.41	2.44	46		0.19	244	244	244	244	244	244	244	244	241	243	243	244
	48	43					241	244	245	244	245	245	245	245	246	245	245	244
	<0145>	<0900>																
01/04/93	2.89	2.44	2.64	71	0.00W	0.19	247	250	251	252	252	256	263	269	270	265	268	269
	108	46					270	271	271	273	274	272	279	261	265	275	283	269
	<2230>	<0000>																
01/05/93	2.70	2.47	2.59	67	0.03W	0.19	259	263	268	265	259	256	255	260	258	258	257	256
	79	53					260	258	259	258	265	262	258	256	254	249	250	257
	<0015>	<2245>																
01/06/93	2.65	2.44	2.50	57	0.04W	0.21	265	254	252	251	252	252	246	245	245	247	248	252
	72	50					249	247	250	249	246	250	249	250	246	247	244	248
	<0100>	<2300>																
01/07/93	2.49	2.34	2.42	48	0.03W	0.21	247	249	248	246	244	244	243	245	241	244	243	242
	56	39					240	240	243	239	237	239	238	241	238	238	240	237
	<0015>	<2345>																
01/08/93	2.46	2.34	2.38	42	0.03W	0.20	239	236	237	238	239	246	239	240	237	238	236	237
	52	39					239	237	239	238	238	236	238	238	238	235	237	237
	<0545>	<2245>																
01/09/93	2.37	2.31	2.34	39	0.02W	0.19	235	235	234	235	236	234	234	231	233	233	233	235
	41	36					233	232	233	232	234	234	234	233	234	234	234	233
	<0000>	<0800>																
01/10/93	2.36	2.29	2.33	38	0.02W	0.18	234	232	231	231	233	232	232	231	232	232	233	234
	40	34					232	233	233	234	234	233	231	233	234	234	233	232
	<0045>	<1545>																
01/11/93	2.34	2.28	2.32	37	0.02W	0.17	233	233	231	232	233	231	233	230	231	231	231	232
	39	33					232	231	230	232	232	230	232	232	230	233	230	233
	<0315>	<2130>																
01/12/93	2.35	2.29	2.32	37	0.02W	0.16	233	234	235	233	233	233	233	233	233	234	233	230
	40	34					232	233	233	231	231	230	230	229	230	230	231	232
	<0045>	<1630>																
01/13/93	2.33	2.24	2.30	35	0.01W	0.16	232	231	232	231	232	231	231	229	230	231	231	229
	38	30					231	227	230	230	229	228	228	229	229	228	227	230
	<0115>	<0845>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL
INPUT DD: FROM EDL-MOD

STATE 18 DIST 18
RATINGS USED --
STNRD 1.0 10/01/92 (0001)

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS

	DATE --------	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
	01/14/93	2.31 36 <1715>	2.25 31 <0800>	2.29	34	0.01W	0.15	230 228	229 228	227 227	229 228	228 227	230 230	230 231	225 228	229 230	229 227	230 230	228 228
	01/15/93	2.33 38 <0800>	2.25 31 <0945>	2.30	35	0.01W	0.14	230 230	231 231	230 233	229 233	229 231	228 231	231 227	233 230	231 230	231 227	232 229	233 230
	01/16/93	2.32 37 <0945>	2.24 30 <2030>	2.28	34	0.01W	0.13	229 229	229 231	226 230	229 229	229 228	228 228	228 231	228 225	229 229	231 228	228 229	230 227
	01/17/93	2.30 35 <0400>	2.21 27 <0215>	2.26	32	0.01W	0.12	227 226	228 228	228 225	230 227	227 226	227 226	229 227	225 224	228 226	225 223	226 226	227 225
	01/18/93	2.27 32 <0315>	2.22 28 <0615>	2.25	31	0.01W	0.11	225 225	223 224	226 224	226 223	225 225	223 226	224 227	226 225	225 226	225 225	227 226	224 224
	01/19/93	2.27 32 <1215>	2.22 28 <2045>	2.25	30	0.01W	0.10	226 226	225 225	226 224	225 225	225 225	224 224	224 225	225 224	226 225	226 223	223 225	224 225
	01/20/93	2.27 32 <1445>	2.21 27 <0300>	2.24	29	0.00W	0.09	224 223	222 223	221 224	224 222	223 223	223 222	225 223	225 224	224 224	225 225	223 224	225 223
	01/21/93	2.31 36 <2230>	2.23 28 <0000>	2.27	32	0.01W	0.08	224 227	223 226	225 226	225 226	223 227	226 228	227 228	226 226	226 230	227 229	228 227	225 228
	01/22/93	2.33 38 <0215>	2.21 27 <1000>	2.27	32	0.01W	0.07	226 223	227 227	228 226	227 225	231 223	229 227	225 228	228 225	224 228	221 226	225 226	224 227
	01/23/93	2.35 40 <0330>	2.25 31 <0030>	2.31	36	0.02W	0.06	225 230	233 231	234 228	231 233	231 228	233 230	232 229	232 230	234 233	233 232	233 232	231 234
	01/24/93	2.34 39 <0000>	2.25 31 <1830>	2.30	35	0.02W	0.05	231 230	233 229	228 227	229 227	233 229	234 227	233 225	232 228	229 227	230 229	232 232	232 230
	01/25/93	2.35 40 <0500>	2.20 26 <1800>	2.26	32	0.01W	0.04	230 225	231 224	232 224	231 225	235 223	227 220	226 226	227 225	225 222	230 226	228 222	223 228
	01/26/93	2.28 33 <0000>	2.20 26 <2230>	2.24	30	0.01W	0.04	226 224	227 222	226 222	226 224	224 225	228 223	225 225	227 223	226 224	225 223	225 224	224 224
#	01/27/93	2.28 32 <1600>	2.18 23 <0645>	2.24	27	-0.02W	0.03	221 223	220 227	220 227	223 228	223 225	221 225	222 224	221 226	222 225	222 225	225 226	227 225
#	01/28/93	2.39 41 <1545>	2.19 24 <0415>	2.33	36	-0.01W	0.02	226 237	221 235	223 237	223 237	224 237	235 233	237 233	235 235	235 234	235 234	238 235	236 234

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION — STATE 18 DIST 18

PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE — RATINGS USED --

DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL — STNRD 1.0 10/01/92 (0001)

INPUT DD: FROM EDL-MOD

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS

	DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 / 1300	0200 / 1400	0300 / 1500	0400 / 1600	0500 / 1700	0600 / 1800	0700 / 1900	0800 / 2000	0900 / 2100	1000 / 2200	1100 / 2300	1200 / 2400
#	01/29/93	2.34 37 <0000>	2.29 33 <1945>	2.32	36	0.00W	0.01	234	234	233	234	233	233	234	233	233	232	232	232
								233	232	232	232	232	232	231	230	231	231	231	231
#	01/30/93	2.32 36 <2000>	2.24 27 <0600>	2.28	32	-0.01W	0.00	230	230	231	230	226	224	226	226	224	228	229	229
								228	227	227	225	229	230	228	232	231	229	230	230
#	01/31/93	2.32 36 <1400>	2.28 32 <2330>	2.30	34	0.00W	-0.01	230	231	231	231	231	231	230	230	231	230	230	230
								230	232	230	230	230	230	229	230	229	230	231	228
#	02/01/93	2.30 34 <0015>	2.21 25 <1615>	2.25	28	-0.02W	-0.02	230	228	228	229	228	229	228	228	227	227	225	224
								223	223	223	222	223	224	223	221	223	223	221	223
	02/02/93	2.26 29 <1130>	2.19 24 <0145>	2.23	27	-0.03W	-0.03	223	221	221	222	221	220	221	221	220	225	225	226
								226	226	224	221	224	226	223	226	225	226	226	225
	02/03/93	2.27 30 <0930>	2.22 25 <1515>	2.25	28	-0.02W	-0.03	226	226	227	225	224	226	224	225	226	226	226	224
								226	225	227	226	223	226	226	224	224	223	226	224
	02/04/93	2.26 29 <1830>	2.22 25 <0715>	2.24	27	-0.03W	-0.03	225	224	225	223	223	224	224	225	225	225	224	222
								223	222	222	223	224	224	225	225	226	226	225	225
	02/05/93	2.26 29 <0045>	2.21 25 <1300>	2.24	27	-0.03W	-0.02	225	223	224	225	223	224	223	223	222	223	223	224
								221	225	225	225	224	224	225	224	224	225	225	225
	02/06/93	2.26 29 <0015>	2.22 25 <2345>	2.24	27	-0.03W	-0.02	225	225	224	223	225	225	224	225	225	225	225	224
								223	225	224	225	223	223	224	223	224	223	224	223
	02/07/93	2.25 28 <0215>	2.22 25 <0315>	2.23	26	-0.03W	-0.02	224	223	224	224	224	223	222	223	223	224	224	224
								224	223	223	223	223	223	223	223	223	223	223	224
	02/08/93	2.25 28 <0015>	2.20 24 <1630>	2.23	26	-0.03W	-0.02	223	224	225	224	224	222	222	222	222	221	222	222
								224	223	224	221	221	221	222	223	222	222	222	221
	02/09/93	2.24 27 <0530>	2.19 24 <1430>	2.22	26	-0.03W	-0.02	222	221	222	222	223	223	223	223	223	223	222	221
								222	221	220	221	221	222	224	223	223	223	223	224
	02/10/93	2.24 27 <0000>	2.21 25 <1130>	2.23	26	-0.03W	-0.02	223	224	223	223	223	223	223	223	222	223	223	222
								222	223	223	223	223	222	222	222	223	222	223	222
	02/11/93	2.24 27 <0300>	2.21 25 <0545>	2.22	25	-0.03W	-0.02	223	222	224	222	222	222	221	222	223	222	222	222
								222	222	221	222	221	222	222	221	222	222	222	223
	02/12/93	2.24 27 <0630>	2.22 25 <0015>	2.23	26	-0.03W	-0.02	222	223	222	223	222	223	223	223	223	222	223	223
								223	223	224	223	223	223	223	222	223	223	223	223

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL
INPUT DD: FROM EDL-MOD

STATE 18 DIST 18
RATINGS USED --
STNRD 1.0 10/01/92 (0001)

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

	DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
	--------							STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS											
	02/13/93	2.23	2.21	2.22	26	-0.03W	-0.02	223	222	222	221	222	223	222	222	222	222	222	222
		26	25					223	223	223	223	222	222	222	222	222	222	222	223
		<0000>	<0400>																
	02/14/93	2.23	2.21	2.22	25	-0.03W	-0.02	222	221	222	222	222	223	222	222	222	222	222	222
		26	25					222	222	223	222	222	222	222	221	221	222	222	222
		<0000>	<0130>																
	02/15/93	2.22	2.20	2.21	25	-0.03W	-0.02	221	222	221	221	222	221	222	220	221	221	221	220
		25	24					220	220	221	220	221	221	221	221	221	221	221	222
		<0000>	<0745>																
	02/16/93	2.23	2.20	2.21	25	-0.03W	-0.02	221	221	222	220	222	222	222	222	222	221	222	223
		26	24					222	222	221	222	221	221	221	221	221	220	220	220
		<1045>	<0400>																
	02/17/93	2.21	2.19	2.20	24	-0.03W	-0.02	220	221	220	220	220	220	221	221	220	220	220	221
		25	24					220	220	220	221	220	220	221	221	220	220	220	220
		<0045>	<0130>																
	02/18/93	2.25	2.18	2.20	24	-0.03W	-0.02	220	220	220	220	221	220	220	220	223	224	225	220
		28	23					219	218	219	219	219	219	219	219	219	219	219	219
		<1015>	<1400>																
#	02/19/93	2.49	2.17	2.23	~~27~~	-0.02W	-0.02	225	221	221	221	220	219	218	218	218	221	229	236
		51	22					249	239	226	220	218	217	219	218	218	218	218	218
		<1300>	<1645>																
	02/20/93	2.19	2.16	2.17	23	-0.03W	-0.02	218	218	217	218	218	218	217	217	216	218	217	218
		24	22					217	218	218	217	217	217	217	217	218	217	217	216
		<0115>	<0900>																
	02/21/93	2.22	2.16	2.19	24	-0.03W	-0.02	217	218	218	218	218	219	219	220	219	219	220	220
		25	22					220	221	220	219	220	220	219	221	220	219	220	220
		<2030>	<0000>																
	02/22/93	2.20	2.17	2.18	23	-0.03W	-0.02	219	219	218	218	219	218	218	219	219	219	218	218
		24	22					218	218	218	217	217	217	218	217	218	217	218	217
		<0000>	<1415>																
	02/23/93	2.19	2.16	2.18	23	-0.03W	-0.02	217	217	218	218	218	218	219	219	218	218	218	218
		24	22					218	218	218	217	218	219	217	217	217	217	218	217
		<0415>	<2015>																
#	02/24/93	2.26	2.15	2.17	~~23~~	-0.03W	-0.02	217	217	217	217	217	217	216	220	220	221	223	222
		29	21					216	216	216	216	216	216	216	216	215	215	216	216
		<0730>	<1345>																
#	02/25/93	2.49	2.14	2.25	~~29~~	-0.02W	-0.02	215	221	227	227	229	230	229	230	231	234	234	242
		51	21					249	233	222	214	214	216	216	216	217	216	216	217
		<1300>	<1545>																
#	02/26/93	2.17	2.15	2.16	~~22~~	-0.03W	-0.02	217	217	217	217	216	217	217	217	216	216	216	215
		22	21					216	216	216	215	216	216	216	216	215	215	215	215
		<0000>	<0515>																
	02/27/93	2.16	2.14	2.15	21	-0.03W	-0.02	216	215	215	215	215	215	215	215	215	215	216	215
		22	21					215	215	215	215	215	215	215	215	215	215	215	215
		<0015>	<0515>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE

DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL

INPUT DD: FROM EDL-MOD

STATE 18 DIST 18

RATINGS USED --

STNRD 1.0 10/01/92 (0001)

04101370

JUDAY CREEK NEAR SOUTH BEND, IN

OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003

PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS 0100 / 1300	0200 / 1400	0300 / 1500	0400 / 1600	0500 / 1700	0600 / 1800	0700 / 1900	0800 / 2000	0900 / 2100	1000 / 2200	1100 / 2300	1200 / 2400
02/28/93	2.16 22 <0030>	2.15 21 <0000>	2.15	21	-0.03W	-0.02	215	215	216	216	216	216	216	216	216	215	215	215
							215	215	216	215	215	215	215	215	215	216	215	216
03/01/93	2.18 23 <2115>	2.14 21 <0530>	2.16	22	-0.03W	-0.02	215	215	215	215	215	216	215	215	216	216	215	216
							216	216	216	217	216	216	217	217	217	217	217	217
03/02/93	2.18 23 <0030>	2.15 21 <0830>	2.17	22	-0.03W	-0.02	217	217	217	216	217	217	216	216	216	216	216	216
							217	217	217	216	217	216	217	216	217	217	217	217
03/03/93	2.19 24 <1715>	2.15 21 <1115>	2.17	23	-0.03W	-0.02	216	217	217	217	217	216	216	217	217	217	216	215
							216	218	216	217	218	218	218	218	218	219	219	219
03/04/93	2.26 29 <2145>	2.19 24 <0000>	2.22	26	-0.03W	-0.02	219	221	222	220	221	221	220	222	222	221	221	222
							223	222	224	223	223	223	224	223	225	225	225	226
03/05/93	2.26 29 <0000>	2.23 26 <0600>	2.24	27	-0.03W	-0.02	225	225	225	225	224	223	223	223	223	223	224	224
							223	224	223	223	223	224	223	224	224	223	223	223
03/06/93	2.24 27 <0100>	2.21 25 <1100>	2.22	26	-0.03W	-0.02	224	222	222	223	223	223	223	222	222	222	221	223
							223	222	222	222	222	222	222	222	223	223	223	223
03/07/93	2.25 28 <2130>	2.21 25 <0015>	2.23	26	-0.03W	-0.02	222	223	222	222	222	223	224	223	223	222	223	223
							224	224	223	223	224	223	223	223	224	224	224	225
03/08/93	2.28 32 <2245>	2.23 26 <0115>	2.25	28	-0.02W	-0.02	225	223	224	223	224	226	224	225	226	225	225	225
							225	225	225	226	227	226	227	227	227	226	228	228
03/09/93	2.34 37 <2315>	2.28 32 <0000>	2.31	35	0.00W	-0.02	229	229	231	230	230	231	230	233	232	232	232	232
							230	230	231	231	232	231	232	232	232	233	233	234
03/10/93	2.45 47 <1215>	2.33 36 <0030>	2.38	40	0.00W	-0.02	234	234	235	235	234	234	235	235	234	235	236	235
							242	243	243	242	242	243	241	240	239	239	238	238
03/11/93	2.39 41 <0015>	2.34 37 <1645>	2.36	39		-0.02	239	238	238	237	237	237	236	235	236	236	236	235
							235	236	235	235	236	235	236	234	235	235	235	234
03/12/93	2.35 38 <0015>	2.32 36 <1230>	2.33	37		-0.02	235	234	234	233	234	234	234	233	233	233	234	233
							233	232	232	232	232	233	233	232	233	234	234	234
03/13/93	2.35 38 <0245>	2.32 36 <0615>	2.33	37		-0.02	233	234	234	234	234	233	233	234	234	233	233	233
							233	232	233	232	233	233	233	233	232	232	232	233
03/14/93	2.33 36 <0000>	2.29 33 <0630>	2.31	35		-0.02	231	232	231	231	231	232	231	231	232	231	231	231
							232	232	231	231	231	229	230	230	230	230	229	229

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL
INPUT DD: FROM EDL-MOD

STATE 18 DIST 18
RATINGS USED --
STNRD 1.0 10/01/92 (0001)

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS 0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
03/15/93	2.30	2.27	2.28	33		-0.02	230	228	230	229	228	229	228	228	228	228	229	229
	34	32					228	228	228	229	228	229	228	228	228	228	228	228
	<0100>	<0745>																
03/16/93	2.38	2.27	2.32	35		-0.02	229	228	228	227	228	228	228	229	229	231	231	231
	40	32					231	234	234	235	235	234	235	238	236	235	236	237
	<1945>	<0145>																
03/17/93	2.42	2.36	2.39	41		-0.02	238	237	237	238	240	241	242	241	242	240	240	239
	44	39					237	238	238	240	239	237	237	239	237	236	236	237
	<0545>	<0045>																
03/18/93	2.37	2.31	2.33	37		-0.02	236	235	235	235	233	234	234	233	234	234	234	234
	40	35					233	233	233	232	233	232	231	233	232	231	231	232
	<0000>	<1900>																
03/19/93	2.32	2.28	2.30	34		-0.02	231	230	230	230	230	229	230	230	229	229	230	229
	36	32					230	229	229	228	229	229	228	230	230	230	229	230
	<0000>	<0845>																
03/20/93	2.31	2.27	2.29	33		-0.02	230	229	229	229	229	229	229	228	229	228	229	228
	35	32					229	229	228	228	229	229	228	228	228	228	228	228
	<0030>	<1845>																
03/21/93	2.29	2.26	2.27	32		-0.02	228	228	228	228	229	228	228	227	227	228	227	227
	33	31					227	227	226	227	226	227	227	227	227	227	229	228
	<0045>	<0830>																
03/22/93	2.39	2.28	2.33	36		-0.02	228	229	230	231	232	232	232	233	234	233	234	234
	41	32					233	234	234	233	234	233	233	234	234	235	237	239
	<2400>	<0000>																
03/23/93	2.54	2.33	2.46	49		-0.02	239	239	244	240	240	242	242	243	247	246	245	249
	57	36					247	248	251	250	251	252	251	253	251	252	250	252
	<1715>	<0545>																
03/24/93	2.53	2.36	2.44	46		-0.02	252	251	252	251	247	243	248	245	246	245	242	243
	56	39					244	244	241	240	237	241	239	238	243	239	241	242
	<0015>	<1530>																
03/25/93	2.43	2.34	2.39	42		-0.01	242	242	243	242	240	241	241	240	241	241	241	240
	45	37					239	238	240	241	236	236	237	237	234	236	238	237
	<0145>	<2100>																
03/26/93	2.40	2.31	2.35	38		0.00	237	239	239	240	235	239	236	236	235	236	234	234
	42	35					235	235	235	235	234	232	233	232	233	232	233	232
	<0345>	<1745>																
03/27/93	2.35	2.29	2.32	36		0.01	232	233	232	233	232	232	232	233	234	235	232	233
	38	33					232	232	230	231	232	231	232	232	230	232	230	232
	<0815>	<1315>																
03/28/93	2.32	2.26	2.29	34		0.01	229	230	230	229	229	229	226	229	227	230	228	229
	36	31					231	230	231	230	230	230	230	228	230	230	229	229
	<1445>	<0700>																
03/29/93	2.31	2.27	2.29	33		0.02	228	229	228	230	228	228	229	228	229	228	229	229
	35	32					229	228	227	228	228	228	230	230	230	227	230	230
	<2230>	<2200>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL
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STATE 18 DIST 18
RATINGS USED --
STNRD 1.0 10/01/92 (0001)

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
							STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS											
03/30/93	2.30	2.25	2.28	32		0.04	229	229	228	227	229	229	229	229	229	229	229	227
	34	30					227	227	229	229	228	227	228	226	228	227	228	228
	<0000>	<1215>																
03/31/93	2.39	2.26	2.30	34		0.05	229	228	227	228	227	230	228	227	229	229	229	231
	41	31					229	229	229	231	231	232	235	234	235	236	237	238
	<2330>	<0115>																
04/01/93	2.40	2.32	2.36	39		0.04	236	235	236	235	235	234	234	236	234	235	236	237
	42	36					235	238	237	239	237	238	239	237	239	240	238	238
	<2045>	<0545>																
04/02/93	2.39	2.32	2.35	38		0.04	237	236	236	237	237	236	238	236	236	236	235	236
	41	36					236	235	235	235	236	234	236	235	233	234	233	235
	<0345>	<2330>																
04/03/93	2.35	2.29	2.31	35		0.03	232	233	233	233	231	233	234	233	232	232	231	231
	38	33					230	231	230	230	229	230	231	229	231	231	230	229
	<0000>	<1445>																
04/04/93	2.31	2.27	2.29	34		0.03	230	230	229	230	229	231	230	230	230	230	231	229
	35	32					229	227	229	229	230	229	230	229	228	228	229	227
	<0115>	<1400>																
04/05/93	2.30	2.25	2.28	32		0.03	229	229	229	230	228	228	229	229	229	229	227	227
	34	30					228	228	228	227	227	228	228	229	227	227	227	225
	<0015>	<1530>																
04/06/93	2.28	2.25	2.26	31		0.02	226	227	228	226	226	226	226	227	228	227	227	226
	32	30					225	226	227	227	226	225	227	225	226	227	227	226
	<0030>	<0000>																
04/07/93	2.27	2.23	2.26	30		0.02	226	225	226	225	226	226	226	226	225	226	226	227
	32	28					226	226	227	225	226	225	225	226	226	225	225	226
	<0115>	<2245>																
04/08/93	2.27	2.23	2.25	30		0.02	225	225	226	226	226	226	226	224	224	225	227	226
	32	28					224	224	225	225	226	225	224	223	225	224	225	225
	<0245>	<2000>																
04/09/93	2.31	2.24	2.28	32		0.01	225	226	226	227	227	226	226	230	230	229	229	228
	35	29					228	229	229	228	227	227	228	228	228	227	227	227
	<0815>	<0015>																
04/10/93	2.28	2.25	2.27	31		0.01	227	227	225	226	227	227	227	227	227	227	226	227
	32	30					226	225	226	227	225	227	227	226	227	226	227	226
	<0015>	<0300>																
04/11/93	2.29	2.24	2.27	31		0.00	226	227	227	227	227	226	224	227	227	225	229	227
	33	29					228	228	226	228	227	227	228	227	228	227	225	227
	<0130>	<0545>																
04/12/93	2.28	2.24	2.26	31		0.00	227	226	227	227	227	226	226	226	226	226	224	226
	32	29					226	226	226	225	225	226	225	224	225	224	225	226
	<0115>	<0230>																
04/13/93	2.27	2.23	2.25	30		0.00	225	225	226	226	225	226	225	227	225	226	225	225
	32	28					226	226	225	225	225	224	225	224	224	225	225	224
	<0430>	<2030>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION   STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE   RATINGS USED --
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL   STNRD 1.0 10/01/92 (0001)
INPUT DD: FROM EDL-MOD

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
04/14/93	2.31 35 <1900>	2.23 28 <0015>	2.26	31		-0.01	224	224	225	225	226	226	223	225	226	225	226	225
							226	226	225	225	225	225	231	228	228	227	229	229
04/15/93	2.38 40 <2330>	2.25 30 <1215>	2.29	33		-0.01	227	228	228	227	228	226	226	227	226	227	228	227
							228	227	227	231	235	233	231	230	230	230	237	237
04/16/93	2.37 40 <0000>	2.31 35 <2345>	2.34	37		-0.02	237	235	235	236	234	235	235	234	234	234	234	234
							232	234	233	233	234	235	233	234	232	233	233	233
04/17/93	2.33 36 <0000>	2.27 32 <2045>	2.31	34		-0.02	231	233	231	231	232	232	232	231	231	231	232	231
							231	230	230	229	231	230	230	229	228	229	231	229
04/18/93	2.30 34 <0015>	2.27 32 <1415>	2.29	33		-0.02	229	229	229	230	228	229	229	229	228	230	228	229
							229	228	228	228	229	227	228	228	228	228	228	227
04/19/93	2.46 48 <2115>	2.25 30 <1015>	2.31	35		-0.03	228	228	227	228	227	227	227	226	226	228	226	227
							230	230	230	230	230	230	229	238	244	241	243	244
04/20/93	2.62 68 <1230>	2.44 46 <0000>	2.53	56		-0.01	246	246	245	247	247	249	250	250	250	256	257	259
							260	259	258	257	256	257	255	255	257	255	254	252
04/21/93	2.54 57 <0045>	2.41 43 <2230>	2.47	49		0.00	252	254	251	250	251	250	250	248	248	246	246	245
							245	247	245	244	245	244	243	244	243	243	242	243
04/22/93	2.43 45 <0000>	2.37 40 <1230>	2.39	41		0.00	242	240	242	240	241	240	240	240	239	239	239	238
							238	239	239	239	238	238	238	238	239	237	238	238
04/23/93	2.39 41 <0130>	2.34 37 <1430>	2.36	39		0.00	238	237	237	238	235	236	237	235	236	238	236	236
							237	236	236	235	235	235	235	236	235	236	235	235
04/24/93	2.39 41 <2045>	2.33 36 <0515>	2.35	38		0.00	235	235	235	235	235	234	235	234	235	235	234	235
							235	235	234	234	234	233	233	234	238	235	234	233
04/25/93	2.41 43 <1245>	2.32 36 <0130>	2.36	39		-0.01	234	233	232	234	236	236	235	236	238	238	240	239
							241	237	237	235	234	235	235	235	235	235	235	234
04/26/93	2.36 39 <0030>	2.28 32 <1700>	2.32	35		-0.01	234	234	234	235	234	234	233	233	233	233	233	233
							232	232	231	230	228	229	229	230	229	229	229	229
04/27/93	2.32 36 <0915>	2.26 31 <1700>	2.29	33		-0.01	229	229	228	230	228	229	229	228	231	230	230	229
							229	228	229	229	226	227	228	229	227	228	227	228
04/28/93	2.32 36 <2345>	2.27 32 <0130>	2.28	33		-0.01	228	228	227	228	228	228	228	228	231	230	230	228
							228	228	228	229	229	228	227	227	228	228	230	232

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL
INPUT DD: FROM EDL-MOD

STATE 18 DIST 18
RATINGS USED --
STNRD 1.0 10/01/92 (0001)

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
04/29/93	2.34 37 <0015>	2.28 32 <2345>	2.31	35		-0.01	231 233	231 232	231 230	232 232	231 230	231 234	231 232	230 230	230 230	230 230	230 231	231 230
04/30/93	2.32 36 <1615>	2.27 32 <0245>	2.29	33		-0.01	229 229	228 228	228 229	228 229	228 232	231 230	230 230	230 230	231 230	229 230	230 229	230 229
05/01/93	2.30 34 <0015>	2.26 31 <2245>	2.28	33		-0.01	229 228	229 229	229 228	229 228	229 228	229 227	229 227	229 228	229 228	228 227	228 227	227 227
05/02/93	2.30 34 <1315>	2.26 31 <0330>	2.28	32		-0.01	227 229	228 230	227 228	228 227	228 228	227 228	228 228	228 228	228 230	228 228	228 228	228 229
05/03/93	2.32 36 <0500>	2.27 32 <2315>	2.29	33		-0.01	228 229	229 230	228 230	229 229	232 229	230 229	229 229	230 229	230 229	231 228	232 228	231 228
05/04/93	2.31 35 <1345>	2.26 31 <0430>	2.28	33		-0.02	227 227	227 231	228 229	227 229	228 229	227 228	228 229	227 230	228 231	227 230	227 230	228 231
05/05/93	2.32 36 <0030>	2.29 33 <1100>	2.30	34		-0.02	232 230	231 229	231 229	230 230	230 231	230 230	230 231	230 229	231 229	230 229	229 230	231 229
05/06/93	2.30 34 <0030>	2.25 30 <1645>	2.28	32		-0.02	229 228	229 227	228 227	230 227	229 226	229 226	228 227	228 226	229 226	228 226	227 226	228 227
05/07/93	2.29 33 <0945>	2.24 29 <1730>	2.26	31		-0.02	226 226	226 227	226 226	226 226	227 226	227 225	226 225	227 225	226 224	228 225	227 225	227 224
05/08/93	2.26 31 <0715>	2.22 28 <2230>	2.24	29		-0.02	225 224	224 225	225 224	224 223	225 224	224 224	225 224	225 223	225 223	225 224	224 223	225 224
05/09/93	2.25 30 <0615>	2.22 28 <0630>	2.23	29		-0.02	223 224	223 223	224 224	224 223	224 222	224 222	224 222	223 224	224 223	223 222	224 223	223 222
05/10/93	2.27 32 <0530>	2.21 27 <0215>	2.24	30		-0.02	223 225	222 224	224 224	225 223	226 223	227 224	226 223	226 224	226 224	225 223	225 224	225 223
05/11/93	2.24 29 <0015>	2.21 27 <1600>	2.22	28		-0.02	222 223	223 223	222 223	222 221	223 222	222 223	222 223	222 222	222 223	223 223	222 222	223 222
05/12/93	2.25 30 <0915>	2.20 26 <1730>	2.22	28		-0.02	223 222	222 223	222 222	222 222	223 221	223 220	223 220	222 222	223 220	225 221	223 221	223 220
05/13/93	2.23 28 <0945>	2.17 24 <1545>	2.19	26		-0.03	220 220	220 220	220 218	220 218	221 217	220 219	220 218	220 218	221 219	223 219	221 218	220 217

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE RATINGS USED --
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL STNRD 1.0 10/01/92 (0001)
INPUT DD: FROM EDL-MOD

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS 0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
05/14/93	2.22	2.17	2.19	25		-0.03	219	218	219	218	219	219	219	219	219	219	219	221
	28	24					220	219	218	221	219	218	218	218	218	218	218	217
	<1130>	<0000>																
05/15/93	2.18	2.15	2.17	24		-0.03	217	217	217	217	217	218	217	217	217	217	216	217
	25	23					217	216	217	216	217	217	216	218	217	217	216	217
	<0045>	<2245>																
05/16/93	2.18	2.15	2.17	24		-0.03	217	217	217	217	217	216	218	216	217	217	217	217
	25	23					217	216	216	216	216	216	217	216	216	217	217	216
	<0645>	<1715>																
05/17/93	2.17	2.14	2.15	23		-0.03	216	216	216	216	215	215	215	214	214	214	214	215
	24	22					215	215	216	215	215	216	215	215	215	216	215	215
	<0030>	<0745>																
05/18/93	2.17	2.14	2.16	23		-0.03	215	215	216	216	217	217	216	216	216	216	217	216
	24	22					216	216	216	216	216	216	216	216	215	216	216	215
	<0500>	<0115>																
05/19/93	2.17	2.13	2.15	23		-0.03	215	216	215	216	216	215	217	215	215	215	215	215
	24	22					215	213	214	214	214	215	215	214	213	214	213	214
	<0700>	<1345>																
05/20/93	2.17	2.12	2.14	23		-0.03	214	214	214	215	215	215	215	215	214	214	217	216
	24	21					215	215	215	212	214	213	213	214	214	214	215	214
	<1030>	<1600>																
05/21/93	2.17	2.12	2.14	22		-0.03	214	215	214	214	214	215	215	213	217	215	215	214
	24	21					214	214	214	214	213	213	213	213	213	214	213	212
	<0900>	<1815>																
05/22/93	2.13	2.10	2.12	21		-0.04	212	211	212	212	212	212	211	212	212	212	212	212
	22	20					212	212	211	211	211	210	210	211	211	211	212	212
	<0015>	<1730>																
05/23/93	2.17	2.12	2.13	22		-0.04	212	213	213	213	212	213	213	213	214	215	213	213
	24	21					213	213	212	212	212	213	212	214	213	215	215	214
	<2230>	<0000>																
05/24/93	2.17	2.10	2.13	22		-0.04	214	215	217	215	215	215	215	216	216	214	213	213
	24	20					213	212	211	211	211	212	211	211	210	211	211	211
	<0300>	<1645>																
05/25/93	2.13	2.08	2.11	20		-0.04	211	211	210	211	209	211	209	210	210	209	210	211
	22	19					212	212	212	211	211	211	211	211	211	211	212	212
	<1245>	<1030>																
05/26/93	2.12	2.08	2.10	20		-0.04	211	211	212	212	211	211	211	210	211	212	212	210
	21	19					208	208	209	208	209	209	208	208	209	209	209	209
	<0000>	<1215>																
05/27/93	2.14	2.06	2.08	19		-0.04	209	208	208	207	208	208	208	209	209	213	210	208
	22	18					207	207	207	208	208	209	208	208	208	208	209	209
	<0945>	<1245>																
05/28/93	2.14	2.07	2.10	20		-0.04	210	209	210	209	210	210	209	209	209	213	209	209
	22	18					209	210	210	210	210	210	210	210	210	209	210	209
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UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL
INPUT DD: FROM EDL-MOD

STATE 18 DIST 18
RATINGS USED --
STNRD 1.0 10/01/92 (0001)

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 / 1300	0200 / 1400	0300 / 1500	0400 / 1600	0500 / 1700	0600 / 1800	0700 / 1900	0800 / 2000	0900 / 2100	1000 / 2200	1100 / 2300	1200 / 2400
							STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS											
05/29/93	2.14	2.09	2.11	20		-0.04	209	210	211	211	211	210	214	211	210	210	210	210
	22	19					211	210	210	214	211	212	211	210	210	210	210	210
	<0700>	<0000>																
05/30/93	2.25	2.09	2.14	22		-0.04	210	210	211	211	212	212	211	211	210	211	210	212
	30	19					213	215	215	214	214	216	218	222	222	218	215	215
	<2015>	<0345>																
05/31/93	2.17	2.09	2.12	21		-0.04	217	216	215	214	214	213	212	212	213	212	212	212
	24	19					211	211	212	210	211	211	210	209	210	209	210	210
	<0100>	<2000>																
06/01/93	2.12	2.08	2.10	20		-0.04	211	210	209	211	209	211	211	209	209	209	209	209
	21	19					211	211	208	210	210	209	209	209	208	209	209	209
	<0615>	<1500>																
06/02/93	2.13	2.07	2.09	20		-0.04	208	209	209	213	210	210	211	209	209	210	209	207
	22	18					209	209	209	207	208	210	210	209	212	210	211	210
	<0400>	<0930>																
06/03/93	2.14	2.07	2.10	20		-0.04	210	211	211	214	213	212	212	210	210	209	213	210
	22	18					210	211	211	208	209	209	209	208	208	208	208	208
	<0400>	<1715>																
06/04/93	2.21	2.07	2.11	21		-0.04	207	207	209	207	208	209	210	210	209	211	212	211
	27	18					210	212	212	212	211	211	212	219	214	213	214	216
	<1430>	<0015>																
06/05/93	2.20	2.09	2.12	21		-0.04	220	218	216	215	213	214	213	214	213	212	213	211
	26	19					211	209	210	212	210	210	210	210	209	210	211	210
	<0045>	<1400>																
06/06/93	2.12	2.07	2.09	20		-0.04	209	211	211	209	209	212	210	209	210	209	212	212
	21	18					211	209	209	208	209	208	208	209	210	207	209	207
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06/07/93	2.63	2.07	2.29	37		-0.03	212	210	208	208	212	210	209	209	209	211	208	210
	69	18					210	218	260	256	256	258	262	257	260	260	261	263
	<2400>	<0000>																
06/08/93	3.22	2.58	2.84	103		0.05	269	269	268	261	267	271	274	279	270	271	281	271
	180	62					300	294	289	277	279	295	298	301	312	311	318	316
	<2015>	<0445>																
06/09/93	3.39	2.79	3.14	163		0.14	318	321	312	308	313	319	319	321	320	304	313	319
	226	92					305	314	323	324	331	331	320	293	321	295	285	297
	<1715>	<2130>																
06/10/93	3.00	2.44	2.73	85		0.16	289	281	260	244	258	246	247	268	260	275	278	292
	130	46					278	273	295	295	270	272	267	276	275	278	275	278
	<0015>	<0400>																
06/11/93	2.78	2.39	2.56	61		0.16	274	276	272	275	273	269	272	272	267	257	245	245
	90	41					240	252	248	248	246	244	241	243	242	244	247	245
	<0000>	<2030>																
06/12/93	2.55	2.37	2.44	46		0.16	246	249	247	245	249	247	246	245	253	244	243	243
	58	40					241	241	241	244	243	244	245	242	241	242	242	237
	<0915>	<2400>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE RATINGS USED --
04101370 DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL STNRD 1.0 10/01/92 (0001)
JUDAY CREEK NEAR SOUTH BEND, IN INPUT DD: FROM EDL-MOD
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

	DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS 0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400

	06/13/93	2.58	2.37	2.52	55		0.16	242	255	255	256	252	252	254	253	254	253	253	257
		62	40					253	254	252	251	253	253	253	252	248	252	250	253
		<0215>	<0000>																
	06/14/93	2.75	2.48	2.65	72		0.16	250	249	250	252	252	252	261	264	263	265	266	272
		86	50					272	273	273	272	272	273	273	274	273	272	271	270
		<1330>	<0245>																
	06/15/93	2.71	2.41	2.56	59		0.16	270	267	264	263	264	262	261	257	257	257	256	254
		80	43					254	251	254	254	252	251	248	246	245	244	241	246
		<0045>	<2245>																
	06/16/93	2.47	2.35	2.42	44		0.16	244	244	247	243	244	241	241	245	240	241	241	244
		49	38					244	244	243	241	242	245	245	243	243	241	243	241
		<0300>	<0615>																
	06/17/93	2.47	2.34	2.40	42		0.20	241	242	241	241	239	241	240	242	241	240	236	235
		49	37					241	236	239	238	241	242	240	247	242	242	241	240
		<2000>	<1330>																
	06/18/93	2.41	2.34	2.38	40		0.22	237	237	239	241	238	240	237	238	237	240	236	237
		43	37					238	237	239	238	237	238	238	236	237	235	235	236
		<0645>	<2130>																
	06/19/93	2.47	2.33	2.40	42		0.22	235	236	240	244	241	240	243	241	246	238	240	242
		49	36					239	239	238	239	238	240	241	241	238	241	242	239
		<0845>	<2315>																
	06/20/93	2.44	2.33	2.38	40		0.21	239	239	238	237	238	238	244	240	240	239	239	240
		46	36					240	238	239	236	237	237	236	235	236	235	234	235
		<0700>	<2345>																
	06/21/93	2.38	2.30	2.34	37		0.20	234	237	235	236	236	236	235	235	234	233	237	234
		40	34					233	234	233	234	232	232	231	233	231	231	232	231
		<0015>	<2030>																
	06/22/93	2.33	2.26	2.30	34		0.20	229	230	229	231	232	230	231	231	233	231	230	231
		36	31					230	231	229	229	230	231	230	229	230	227	227	226
		<0515>	<1130>																
#	06/23/93	2.41	2.26	2.34	37		0.19	228	228	230	232	233	229	232	232	231	234	233	234
		43	31					234	234	235	234	234	235	237	238	238	240	239	237
		<2330>	<0000>																
#	06/24/93	2.43	2.32	2.38	41		0.19	241	238	239	241	241	239	241	241	243	242	234	238
		45	36					234	235	236	236	237	232	237	235	237	238	239	240
		<0330>	<1800>																
#	06/25/93	2.48	2.31	2.41	43		0.18	239	239	239	241	243	244	243	243	244	244	243	242
		50	35					242	236	240	241	241	239	239	237	237	237	239	240
		<0515>	<1315>																
#	06/26/93	2.42	2.32	2.36	39		0.17	240	239	239	238	239	242	236	237	239	236	235	236
		44	36					234	234	236	234	234	234	235	235	235	234	234	235
		<0600>	<0930>																
#	06/27/93	2.38	2.26	2.35	38		0.17	234	236	237	236	237	235	237	234	237	236	236	236
		40	31					235	235	236	233	233	235	234	232	235	234	235	236
		<0145>	<2230>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE RATINGS USED --
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL STNRD 1.0 10/01/92 (0001)
INPUT DD: FROM EDL-MOD

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

	DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
	---------							STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS											
#	06/28/93	2.47	2.33	2.39	42		0.16	233	235	236	236	234	234	237	244	246	243	245	247
		49	36					247	247	244	242	241	240	238	238	238	237	234	234
		<0830>	<0015>																
#	06/29/93	2.38	2.25	2.33	37		0.15	236	237	238	237	235	235	235	231	225	230	232	233
		40	30					232	233	233	229	232	234	233	233	233	234	233	232
		<0215>	<0900>																
#	06/30/93	2.41	2.26	2.36	39		0.15	234	234	235	234	227	236	239	237	241	240	238	240
		43	31					239	240	237	238	238	237	238	236	237	234	235	235
		<0845>	<0515>																
#	07/01/93	2.40	2.26	2.35	38		0.14	235	235	236	237	233	235	233	234	235	238	235	236
		42	31					235	237	238	234	235	233	234	230	232	234	232	232
		<1015>	<1930>																
#	07/02/93	2.36	2.22	2.32	35		0.13	233	233	231	233	232	233	232	233	233	230	231	231
		39	28					229	231	231	231	230	232	231	231	231	232	236	228
		<2300>	<0245>																
#	07/03/93	2.36	2.23	2.32	36		0.13	232	230	230	232	232	230	233	231	233	233	232	234
		39	28					234	232	234	234	232	235	234	225	231	231	231	231
		<1215>	<2015>																
#	07/04/93	2.36	2.23	2.27	31		0.12	228	228	227	227	226	227	225	226	225	227	226	227
		39	28					229	227	229	228	224	227	226	226	227	226	225	229
		<0045>	<0315>																
#	07/05/93	2.31	2.22	2.26	31		0.12	226	228	227	228	227	227	226	227	227	227	225	229
		35	28					227	227	226	224	225	226	224	228	226	224	226	225
		<0345>	<1430>																
#	07/06/93	2.32	2.22	2.25	30		0.11	226	226	226	228	225	227	228	227	227	226	226	226
		36	28					226	226	225	226	225	225	222	224	223	223	224	224
		<0645>	<1900>																
#	07/07/93	2.27	2.17	2.24	29		0.10	222	225	223	224	224	224	225	224	224	226	223	224
		32	24					225	222	223	223	223	223	225	222	224	225	224	224
		<0945>	<1630>																
#	07/08/93	2.28	2.18	2.23	29		0.10	223	224	223	225	223	223	224	224	225	224	223	225
		32	25					222	222	224	223	222	222	224	222	221	221	223	222
		<0715>	<1730>																
#	07/09/93	2.28	2.16	2.21	27		0.09	223	222	225	223	221	223	228	222	222	220	218	221
		32	24					220	220	221	222	220	220	220	221	219	222	222	223
		<0700>	<1745>																
	07/10/93	2.24	2.17	2.20	26		0.08	221	221	221	221	222	220	219	219	220	222	222	220
		29	24					222	221	219	219	220	219	219	219	219	219	217	219
		<2130>	<2030>																
	07/11/93	2.26	2.18	2.21	27		0.08	220	221	218	220	220	219	220	221	221	221	219	218
		31	25					220	222	222	226	222	222	224	222	226	223	223	223
		<1545>	<0300>																
	07/12/93	2.30	2.16	2.21	27		0.07	222	222	224	223	224	226	225	227	222	228	224	223
		34	24					220	218	218	219	218	218	217	218	217	217	217	218
		<0615>	<2030>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION   STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE   RATINGS USED --
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL   STNRD 1.0 10/01/92 (0001)
INPUT DD: FROM EDL-MOD

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:******   PUNCH INTERVAL: 15 MIN

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS 0100 / 1300	0200 / 1400	0300 / 1500	0400 / 1600	0500 / 1700	0600 / 1800	0700 / 1900	0800 / 2000	0900 / 2100	1000 / 2200	1100 / 2300	1200 / 2400
07/13/93	2.22 28 <0830>	2.15 23 <1945>	2.17	24		0.06	218	217	217	218	219	218	218	218	220	219	218	217
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07/15/93	2.14 22 <0045>	2.10 20 <2000>	2.12	21		0.05	214	212	213	213	213	213	213	213	212	212	213	212
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07/16/93	2.14 22 <2215>	2.08 19 <1430>	2.12	21		0.05	211	212	212	212	212	213	212	212	212	212	212	210
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07/17/93	2.17 24 <1000>	2.13 22 <0000>	2.14	22		0.04	214	213	214	215	214	215	214	214	215	217	215	215
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07/18/93	2.14 22 <0015>	2.10 20 <2100>	2.12	21		0.03	214	214	213	214	213	213	213	213	213	213	214	213
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07/19/93	2.14 22 <0445>	2.11 21 <0000>	2.12	21		0.03	212	213	213	213	213	213	212	214	213	213	213	213
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07/20/93	2.12 21 <0100>	2.07 18 <1315>	2.10	20		0.04	212	211	211	211	211	211	212	212	211	210	209	210
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07/21/93	2.11 21 <1430>	2.08 19 <0030>	2.10	20		0.04	210	210	210	210	210	209	210	210	209	209	209	209
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07/22/93	2.12 21 <1645>	2.06 18 <1615>	2.08	19		0.02	209	209	210	209	209	209	208	208	208	207	207	207
							208	207	208	208	211	209	208	208	207	208	207	208
07/23/93	2.10 20 <0630>	2.05 17 <2330>	2.08	19		0.02	207	208	208	207	208	209	209	209	209	209	209	209
							206	207	207	208	207	207	208	209	207	207	207	206
07/24/93	2.13 22 <1500>	2.05 17 <0045>	2.08	19		0.01	205	206	207	207	207	207	207	207	208	207	212	209
							209	209	213	212	212	209	209	209	209	208	208	208
07/25/93	2.11 21 <1045>	2.06 18 <1430>	2.08	19		0.01	208	208	209	209	208	209	208	209	208	209	211	209
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07/26/93	2.09 19 <0330>	2.04 17 <2200>	2.07	19		0.01	208	208	208	209	209	209	209	209	208	209	208	209
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07/27/93	2.08 19 <1630>	2.02 16 <2030>	2.05	17		0.00	205	206	205	205	205	204	206	206	203	204	204	204
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UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE RATINGS USED --
04101370 DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL STNRD 1.0 10/01/92 (0001)
JUDAY CREEK NEAR SOUTH BEND, IN INPUT DD: FROM EDL-MOD
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

	DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
	--------							STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS											
	07/28/93	2.05	2.02	2.04	17		0.00	205	204	205	204	204	205	205	204	204	204	205	204
		17	16					204	203	204	203	205	203	203	203	203	203	203	202
		<0100>	<1945>																
	07/29/93	2.04	1.98	2.01	16		-0.01	203	203	203	203	203	202	202	202	201	203	202	202
		17	14					202	202	201	201	201	200	199	198	199	198	199	200
		<0215>	<1930>																
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		16	14					201	201	201	201	201	200	199	200	200	201	200	201
		<0645>	<1730>																
	07/31/93	2.02	1.97	2.00	15		-0.01	200	200	201	200	201	201	201	201	201	201	201	201
		16	13					201	200	201	200	200	200	199	198	199	199	198	198
		<0730>	<2315>																
	08/01/93	1.99	1.96	1.98	14		-0.02	197	198	198	198	198	198	198	198	198	198	199	198
		14	13					198	197	197	197	197	197	196	197	197	197	196	197
		<0515>	<1900>																
	08/02/93	1.99	1.96	1.97	13		-0.02	198	198	197	197	197	198	197	197	197	197	197	197
		14	13					196	198	198	197	197	197	197	197	196	196	196	197
		<1345>	<0430>																
	08/03/93	2.01	1.97	1.98	14		-0.02	197	197	198	197	198	198	198	198	199	198	198	198
		15	13					199	199	198	198	198	199	199	200	200	200	200	201
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		15	14					200	200	200	200	200	200	200	200	199	200	200	200
		<0000>	<1815>																
	08/05/93	2.01	2.00	2.00	15		-0.03	200	201	200	200	201	201	201	201	200	200	200	200
		15	15					201	201	200	200	200	200	200	200	200	200	200	200
		<0200>	<0000>																
	08/06/93	2.03	1.98	2.00	15		-0.04	200	200	200	201	200	200	201	200	201	202	202	201
		16	14					201	201	200	200	199	199	199	199	199	198	199	199
		<0930>	<1945>																
	08/07/93	1.99	1.97	1.98	14		-0.04	199	199	199	199	199	199	198	198	198	198	199	197
		14	13					197	197	198	197	197	198	197	197	197	197	197	197
		<0000>	<1145>																
	08/08/93	2.00	1.95	1.97	13		-0.04	197	198	197	197	198	198	197	197	197	197	197	197
		15	12					197	197	200	199	197	196	196	196	196	196	196	196
		<1500>	<1730>																
#	08/09/93	1.96	1.92	1.95	~~12~~		-0.05	196	196	195	196	196	196	196	195	196	196	196	196
		13	11					196	194	194	193	193	193	193	193	192	193	193	193
		<0000>	<1745>																
	08/10/93	2.26	1.93	2.05	21	0.05W	-0.05	193	194	194	208	215	211	208	215	220	222	214	210
		32	11					207	205	203	202	202	201	200	199	199	199	198	198
		<0430>	<0000>																
	08/11/93	1.98	1.94	1.97	17	0.07W	-0.05	198	198	198	198	198	198	198	197	197	197	197	197
		17	15					197	196	196	196	196	196	194	195	195	195	195	195
		<0000>	<1900>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE RATINGS USED --
04101370 DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL STNRD 1.0 10/01/92 (0001)
JUDAY CREEK NEAR SOUTH BEND, IN INPUT DD: FROM EDL-MOD
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

	DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
	---------							STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS											
	08/12/93	1.95	1.94	1.95	16	0.07W	-0.05	195	195	195	195	195	195	195	195	194	194	195	195
		16	15					194	195	194	194	194	194	194	194	194	194	194	194
		<0000>	<0230>																
	08/13/93	1.95	1.93	1.94	16	0.07W	-0.05	194	194	194	195	195	195	195	195	195	195	195	195
		16	15					195	195	194	194	194	193	193	193	193	193	193	193
		<0330>	<1800>																
	08/14/93	1.93	1.91	1.93	15	0.07W	-0.05	193	193	193	193	193	193	193	193	193	193	193	193
		15	14					193	192	191	192	192	192	192	192	192	192	192	192
		<0000>	<1415>																
	08/15/93	2.19	1.91	1.95	16	0.07W	-0.05	192	192	192	192	192	192	192	192	192	192	192	192
		29	14					192	192	193	192	191	192	204	213	202	200	202	209
		<1945>	<1630>																
	08/16/93	2.10	1.96	2.00	18	0.07W	-0.05	210	207	204	202	201	200	200	200	199	197	198	198
		24	16					198	198	198	198	197	197	197	197	197	197	197	196
		<0015>	<2245>																
	08/17/93	1.97	1.94	1.96	16	0.07W	-0.05	197	196	197	196	196	196	196	196	196	196	196	196
		17	15					196	196	196	195	195	195	195	195	195	194	195	195
		<0030>	<2200>																
	08/18/93	1.98	1.90	1.94	15	0.07W	-0.05	195	195	195	195	195	195	195	195	195	198	196	195
		17	13					195	194	193	193	192	191	191	191	191	190	190	190
		<0945>	<2115>																
	08/19/93	2.11	1.90	1.93	15	0.07W	-0.04	190	191	191	191	191	191	191	191	191	191	191	191
		25	13					191	191	191	191	191	205	201	198	196	196	196	197
		<1815>	<0000>																
	08/20/93	2.03	1.97	2.02	20	0.07W		198	199	200	201	202	202	203	203	203	203	203	203
		20	17					203	203	203	203	203	203	203	203	203	203	203	203
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#	08/21/93	2.03	2.03	2.03	20	0.07W		203	203	203	203	203	203	203	203	203	203	203	203
		20	20					203	203	203	203	203	203	203	203	203	203	203	203
		<0000>	<0000>																
#	08/22/93	2.03	2.03	2.03	20	0.07W		203	203	203	203	203	203	203	203	203	203	203	203
		20	20					203	203	203	203	203	203	203	203	203	203	203	203
		<0000>	<0000>																
#	08/23/93	2.03	2.03	2.03	20	0.07W		203	203	203	203	203	203	203	203	203	203	203	203
		20	20					203	203	203	203	203	203	203	203	203	203	203	203
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#	08/24/93	2.03	2.03	2.03	20	0.07W		203	203	203	203	203	203	203	203	203	203	203	203
		20	20					203	203	203	203	203	203	203	203	203	203	203	203
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#	08/25/93	2.03	2.03	2.03	20	0.07W		203	203	203	203	203	203	203	203	203	203	203	203
		20	20					203	203	203	203	203	203	203	203	203	203	203	203
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#	08/26/93	2.03	2.03	2.03	20	0.07W		203	203	203	203	203	203	203	203	203	203	203	203
		20	20					203	203	203	203	203	203	203	203	203	203	203	203
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UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION   STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE   RATINGS USED --
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL   STNRD 1.0 10/01/92 (0001)
INPUT DD: FROM EDL-MOD

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060   STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993   TEST DIFF:******   PUNCH INTERVAL: 15 MIN

	DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400
#	08/27/93	2.03	2.03	2.03	~~20P~~	0.07W		203	203	203	203	203							
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		<0000>	<0000>																
M	08/28/93																		
M	08/29/93																		
#	08/30/93	2.03	1.92	1.95	16P	0.07W						194	193	193	193	192	192	192	192
		20	14					192	192	192	192	192	192	203	203	203	203	203	203
		<1900>	<0515>																
	08/31/93	2.03	1.91	1.94	16	0.07W		203	203	203	203	203	192	192	192	192	192	192	192
		20	14					192	191	191	191	191	191	191	191	191	191	191	191
		<0000>	<1315>																
#	09/01/93	1.92	1.91	1.91	14P	0.07W		191	191	191							192	192	192
		14	14					192	192	192	192	191	191	191	191	191	191	191	191
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	09/02/93	2.47	1.91	2.21	31	0.03W		191	191	191	191	191	191	191	191	199	215	242	231
		49	14					234	240	245	246	246	244	243	243	242	242	243	242
		<1615>	<0000>																
	09/03/93	2.42	2.21	2.31	35			242	240	240	238	238	237	235	234	233	232	231	229
		44	27					229	227	227	226	226	227	225	224	224	223	222	221
		<0000>	<2345>																
	09/04/93	2.26	2.14	2.18	25			221	221	220	220	221	220	220	219	219	220	223	222
		31	22					221	216	216	216	215	215	215	214	215	214	214	214
		<1015>	<2000>																
	09/05/93	2.20	2.10	2.13	22			214	214	213	214	214	213	213	213	213	213	213	213
		26	20					213	212	212	212	211	211	215	213	213	210	211	211
		<2115>	<2200>																
	09/06/93	2.23	2.10	2.16	24			210	210	210	210	212	213	215	220	221	220	221	221
		28	20					220	219	218	217	216	216	216	216	216	216	216	216
		<0815>	<0100>																
	09/07/93	2.16	2.11	2.14	22			216	215	215	215	215	215	215	215	214	214	214	214
		24	21					213	213	213	214	213	214	213	213	212	212	212	211
		<0000>	<2345>																
	09/08/93	2.15	2.08	2.10	20			211	211	211	211	211	213	211	210	210	210	209	211
		23	19					210	210	210	209	210	209	209	209	209	209	210	213
		<2345>	<2030>																
	09/09/93	2.17	2.07	2.09	19		0.00	211	209	209	209	209	209	209	209	209	209	210	209
		24	18					208	208	208	208	207	207	207	208	207	208	208	208
		<0015>	<1630>																
	09/10/93	2.20	2.07	2.11	21		0.01	207	208	207	207	209	213	211	212	210	211	212	212
		26	18					211	212	212	211	211	212	214	213	214	216	212	215
		<0745>	<0030>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE RATINGS USED --
04101370 DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL STNRD 1.0 10/01/92 (0001)
JUDAY CREEK NEAR SOUTH BEND, IN INPUT DD: FROM EDL-MOD
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	0100 1300	0200 1400	0300 1500	0400 1600	0500 1700	0600 1800	0700 1900	0800 2000	0900 2100	1000 2200	1100 2300	1200 2400

09/11/93	2.15	2.05	2.07	19		0.01	211	211	210	210	209	209	207	206	206	206	206	206
	23	17					207	207	206	209	208	206	206	206	205	205	206	205
	<0000>	<2100>																
09/12/93	2.16	2.05	2.08	19		0.02	206	206	207	207	208	208	209	209	207	207	207	207
	24	17					207	208	213	208	207	206	208	208	210	211	210	216
	<1915>	<0000>																
09/13/93	2.17	2.06	2.10	20		0.02	209	213	210	212	215	217	208	209	213	214	208	208
	24	18					207	207	206	206	206	209	210	209	208	210	215	216
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	43	18					212	230	228	221	225	225	234	237	237	236	236	235
	<1415>	<1145>																
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	43	36					240	240	238	236	235	237	235	234	232	233	232	233
	<1345>	<2045>																
09/16/93	2.33	2.24	2.28	32	0.00W	0.03	232	231	230	230	230	229	229	228	228	228	228	228
	36	28					229	229	229	229	228	227	225	225	225	225	225	224
	<0000>	<2330>																
09/17/93	2.24	2.18	2.21	26	-0.02W	0.03	224	224	224	223	224	224	223	222	222	222	222	222
	28	22					222	220	221	221	221	220	220	220	219	218	219	218
	<0000>	<2200>																
09/18/93	2.19	2.15	2.17	21	-0.05W	0.03	218	218	219	218	218	218	218	217	217	217	217	217
	23	19					217	216	217	216	216	216	216	216	215	215	216	215
	<0030>	<1815>																
09/19/93	2.16	2.12	2.14	19	-0.06W	0.03	215	216	215	214	214	215	215	214	214	214	214	214
	21	18					213	214	213	213	213	213	213	214	213	213	213	213
	<0200>	<2030>																
09/20/93	2.20	2.12	2.14	19	-0.06W	0.03	213	212	213	213	213	213	213	213	212	214	213	214
	24	18					213	213	212	213	213	214	213	214	218	216	217	216
	<2045>	<0030>																
09/21/93	2.19	2.13	2.15	20	-0.06W	0.03	218	219	218	216	215	215	214	214	214	213	213	214
	23	18					214	213	213	214	213	214	215	215	215	215	215	215
	<0115>	<0830>																
09/22/93	2.15	2.11	2.12	18	-0.06W	0.03	215	215	214	212	212	212	213	212	212	212	213	212
	19	17					212	212	212	211	212	211	212	212	212	212	212	212
	<0000>	<1545>																
09/23/93	2.12	2.10	2.11	18	-0.06W	0.03	211	212	211	212	212	212	212	212	212	212	212	212
	18	17					212	212	211	212	211	211	211	211	211	210	211	211
	<0000>	<2045>																
09/24/93	2.11	2.10	2.11	17	-0.06W	0.03	210	211	211	211	211	211	211	211	210	211	211	210
	17	17					210	210	210	210	211	210	210	210	211	210	210	210
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09/25/93	2.24	2.10	2.13	19	-0.05W	0.03	210	210	210	210	210	210	210	210	210	210	210	211
	28	17					211	212	213	212	212	214	220	220	221	221	222	222
	<2330>	<0000>																

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF GAGE HEIGHT AND DISCHARGE RATINGS USED --
DATE PROCESSED: 03-18-1994 @ 10:00 BY LEHAMMIL STNRD 1.0 10/01/92 (0001)
INPUT DD: FROM EDL-MOD

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OUTPUT PARAMETER 00060 STORE STATISTIC(S) 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993

TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX GH /DISCH <TIME>	MIN GH /DISCH <TIME>	MEAN GH	MEAN DISCH	SHIFT ADJ	DATUM CORR	STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS											
--------							0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200
							1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
09/26/93	2.22	2.18	2.21	25	-0.03W	0.03	222	221	220	219	219	219	219	219	220	221	221	222
	26	22					221	222	222	221	222	222	221	222	221	221	221	220
	<0000>	<0615>																
09/27/93	2.38	2.19	2.29	32	-0.01W	0.03	220	221	220	219	220	220	221	224	225	226	226	233
	40	23					237	231	233	234	235	236	233	237	236	236	235	237
	<1315>	<0130>																
09/28/93	2.40	2.27	2.33	37	0.00W	0.03	234	239	239	240	239	236	237	234	234	234	235	235
	42	32					231	234	230	231	231	229	230	228	230	229	228	230
	<0245>	<2130>																
09/29/93	2.31	2.25	2.28	32	0.00W	0.03	229	229	229	230	230	230	230	230	230	229	229	229
	35	29					229	228	228	227	227	227	227	227	227	226	226	227
	<0030>	<1815>																
09/30/93	2.28	2.21	2.25	29	-0.01W	0.03	227	226	227	226	227	225	226	225	226	226	226	226
	32	25					226	226	225	223	222	224	223	223	224	224	223	222
	<0145>	<1745>																
PERIOD	3.39	1.90																
	226	2.3																

TIME CORRECTION 0.0

NOTE. SYMBOLS USED ABOVE HAVE THE FOLLOWING MEANINGS --
P - DAILY SUMMARY IS FOR AN INCOMPLETE DAY
W - SHIFT VARIES BY TIME AND VALUE - V SHIFT
- ONE OR MORE DISPLAYED DAILY VALUES NOT STORED/FILE(S) CONTAINS WRITE-PROTECTED VALUE(S)
M - NO UNIT VALUES AVAILABLE FOR THIS DAY

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		VALUES AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
10-01	17.8	5.3	11.0	AM	7.4	7.0	6.6	6.4	6.1	5.7	5.4	5.3	5.9	7.4	9.4	11.9
				PM	14.6	16.4	17.6	17.7	17.4	16.7	15.8	14.6	13.5	12.6	11.9	11.5
10-02	20.3	9.7	14.4	AM	11.2	11.0	10.7	10.5	10.1	9.9	9.7	9.7	10.3	11.4	13.0	15.2
				PM	17.6	19.2	20.1	20.2	19.9	19.2	18.3	17.2	16.3	15.6	15.2	14.8
10-03	21.4	12.0	16.2	AM	14.4	14.1	13.8	13.4	13.0	12.6	12.2	12.0	12.4	13.3	14.7	16.5
				PM	18.6	20.2	21.2	21.4	21.0	20.4	19.6	18.5	17.7	16.9	16.2	15.4
10-04	18.1	9.2	14.4	AM	14.8	14.3	14.2	14.2	13.9	13.3	12.7	12.4	12.4	13.1	14.1	15.4
				PM	16.4	17.1	17.9	18.1	17.8	17.0	15.7	14.2	12.7	11.3	10.1	9.2
10-05	15.8	4.4	9.6	AM	8.4	7.5	6.8	6.1	5.7	5.2	4.7	4.5	5.1	6.7	8.7	10.8
				PM	13.0	14.5	15.6	15.8	15.4	14.7	13.4	11.7	10.4	9.2	8.2	7.3
10-06	16.4	3.0	9.1	AM	6.5	5.9	5.3	4.7	4.2	3.7	3.2	3.0	3.6	5.5	7.9	10.4
				PM	12.9	14.7	16.1	16.4	16.0	15.3	14.1	12.4	10.9	9.7	8.8	8.0
10-07	18.2	5.4	11.3	AM	7.5	7.0	6.7	6.6	6.2	5.7	5.5	5.5	6.0	7.4	9.5	12.1
				PM	14.7	16.7	17.9	18.2	17.9	17.4	16.6	15.6	14.7	13.8	13.0	12.2
10-08	16.3	10.3	12.8	AM	11.5	11.2	11.1	11.1	11.1	11.0	11.0	11.3	11.9	12.9	13.9	14.2
				PM	14.3	14.6	15.3	16.0	16.3	16.0	14.4	13.4	12.6	11.5	10.6	10.3
10-09	11.1	8.2	10.0	AM	10.3	10.2	10.0	9.9	9.9	9.8	9.5	9.0	8.4	8.2	8.6	9.4
				PM	10.4	10.9	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.4	10.4
10-10	14.0	8.3	10.4	AM	10.0	9.5	9.2	9.0	8.9	8.8	8.7	8.4	8.4	8.9	9.9	11.4
				PM	13.1	13.9	14.0	13.6	13.0	12.3	11.5	10.5	9.7	9.0	8.7	8.7
10-11	12.7	6.9	9.8	AM	8.8	8.9	8.9	8.9	8.9	8.8	8.6	8.5	8.7	9.6	10.6	11.3
				PM	11.5	11.9	12.4	12.7	12.6	12.1	11.0	9.7	8.6	7.8	7.3	6.9
10-12	14.8	5.3	8.9	AM	6.5	6.1	5.7	5.4	5.3	5.5	5.9	6.3	7.2	8.3	9.6	11.4
				PM	13.1	14.1	14.8	14.4	13.5	12.4	10.9	9.3	8.2	7.3	6.4	5.8
10-13	13.1	2.7	7.8	AM	5.6	5.4	5.2	4.6	4.0	3.5	3.0	2.7	3.2	4.7	7.0	9.1
				PM	10.7	11.9	12.9	13.1	12.8	12.2	11.2	10.4	9.7	8.9	8.5	8.3
10-14	18.7	8.3	12.5	AM	8.3	8.3	8.4	8.6	8.7	8.9	9.0	9.1	9.5	10.5	12.8	15.9
				PM	17.2	18.2	18.7	17.4	15.4	14.5	14.1	13.9	13.8	13.8	13.7	13.0
10-15	15.5	11.9	13.1	AM	12.5	12.2	12.1	12.1	12.0	11.9	11.9	12.0	12.3	12.5	12.7	12.9
				PM	13.3	13.6	13.7	13.9	14.1	14.0	13.9	13.8	13.8	14.3	15.0	15.5
10-16	15.7	5.6	9.5	AM	15.3	14.4	13.9	13.5	13.2	12.4	11.6	10.5	9.3	8.7	8.4	8.4
				PM	8.7	8.3	8.3	8.1	7.7	7.1	6.6	6.2	6.0	5.9	5.7	5.6
10-17	9.1	1.3	4.9	AM	5.5	5.2	4.5	3.8	3.3	2.4	1.8	1.3	1.7	3.2	4.9	6.6
				PM	7.9	8.5	9.1	8.8	8.1	7.3	5.9	4.6	3.7	3.2	2.8	2.6
10-18	6.9	2.4	.4.5	AM	2.8	3.2	3.7	4.1	4.3	4.4	4.6	4.7	5.0	5.2	5.4	6.1
				PM	6.5	6.7	6.9	6.2	5.4	4.8	4.1	3.4	3.0	2.8	2.6	2.4
10-19	7.4	1.1	3.9	AM	2.3	2.1	1.8	1.7	1.5	1.4	1.2	1.2	1.6	2.7	4.1	5.8
				PM	6.6	6.5	7.1	7.4	7.3	6.8	6.0	5.2	4.5	3.7	3.0	3.0
10-20	8.7	.6	4.2	AM	3.1	3.1	3.1	2.0	1.3	.9	.7	.7	.9	1.1	1.7	2.6
				PM	4.1	5.9	7.4	8.3	8.7	8.5	7.8	6.9	6.1	5.6	5.3	5.5
10-21	11.7	4.4	7.7	AM	6.0	6.4	6.5	6.5	6.4	6.3	6.1	6.0	6.5	7.2	8.2	9.1
				PM	9.7	10.5	11.3	11.7	11.5	10.5	9.0	7.7	6.6	5.6	4.9	4.4
10-22	17.6	2.4	9.1	AM	4.0	3.7	3.3	3.1	2.8	2.6	2.5	2.5	3.1	4.8	7.4	10.3
				PM	12.8	14.8	16.9	17.6	17.3	16.4	15.2	14.0	13.0	12.1	11.5	11.1
10-23	22.1	9.5	15.3	AM	10.8	10.5	10.2	9.9	9.6	9.5	9.5	9.8	10.6	12.3	14.4	17.3
				PM	19.7	21.3	22.0	22.1	22.0	21.3	20.0	18.7	17.9	17.2	16.4	15.6

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		VALUES AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
10-24	18.6	6.9	13.3	AM	14.9	14.2	13.5	13.2	13.0	13.1	12.7	12.1	12.1	12.5	13.3	15.5
				PM	16.4	17.4	18.5	17.2	15.5	13.7	12.1	10.9	10.0	9.0	7.9	6.9
10-25	17.6	1.8	8.2	AM	5.9	4.9	4.1	3.5	2.9	2.5	2.1	1.8	2.1	3.6	6.0	10.2
				PM	12.7	15.1	17.6	16.9	15.7	14.1	12.2	10.4	9.1	8.2	7.7	7.3
10-26	17.0	4.1	10.6	AM	7.0	7.4	8.2	9.0	9.2	9.2	8.9	8.7	10.0	11.6	13.2	15.2
				PM	15.8	16.8	16.8	15.8	14.3	12.6	10.7	9.0	7.5	6.3	5.1	4.1
10-27	18.1	-.7	6.0	AM	3.2	2.4	1.6	1.0	.4	.0	-.5	-.7	-.3	1.2	4.3	9.3
				PM	12.0	14.9	17.8	15.8	14.2	12.2	9.9	7.8	6.1	4.7	3.5	2.7
10-28	19.4	.5	7.6	AM	2.1	1.6	1.2	.8	.7	.7	.6	.5	1.3	3.3	6.2	10.8
				PM	13.8	17.3	19.4	18.7	17.3	15.2	12.8	10.6	8.7	7.4	6.7	6.2
10-29	12.8	4.6	8.6	AM	6.2	6.5	6.9	7.3	7.5	7.7	7.7	7.6	7.6	8.1	9.3	11.3
				PM	12.5	12.7	12.2	12.0	11.4	10.3	9.0	7.7	6.9	6.3	5.6	4.6
10-30	10.2	3.2	5.9	AM	4.1	3.5	3.2	3.2	3.3	3.3	3.4	3.5	3.9	4.8	6.0	7.3
				PM	8.3	8.7	10.2	9.7	9.3	8.4	7.5	7.2	6.9	6.2	5.7	5.3
10-31	13.1	2.6	6.9	AM	4.7	4.2	3.8	3.5	3.2	3.3	3.0	2.6	2.9	4.1	6.1	8.5
				PM	10.3	11.3	13.1	12.5	11.5	10.3	9.2	8.5	8.2	7.9	7.6	7.4
11-01	7.4	4.8	5.5	AM	7.0	6.8	6.2	5.7	5.3	5.3	5.3	5.4	5.2	5.0	5.0	4.9
				PM	4.8	4.9	5.0	5.0	5.0	5.1	5.2	5.4	5.7	5.9	6.1	6.4
11-02	15.2	5.8	10.0	AM	6.7	7.2	7.8	8.4	9.3	10.1	10.6	12.0	12.6	13.1	13.8	14.6
				PM	15.0	13.1	12.3	11.6	10.9	9.7	8.6	7.7	6.9	6.5	6.0	5.8
11-03	11.7	3.5	7.1	AM	5.4	4.7	4.2	4.0	4.0	4.0	3.8	3.5	4.1	5.4	7.4	9.7
				PM	11.4	11.7	11.4	10.8	10.4	9.7	8.9	7.9	7.3	6.9	6.7	6.7
11-04	6.7	1.7	3.6	AM	6.6	5.7	5.3	4.8	4.4	4.0	3.6	3.1	2.9	3.2	3.8	3.5
				PM	3.6	3.5	3.4	3.3	3.3	2.9	2.6	2.3	2.1	2.0	1.8	1.7
11-05	2.6	1.0	1.5	AM	1.6	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	1.0	1.3	1.7
				PM	1.6	2.1	2.6	2.4	2.1	1.6	1.3	1.1	1.1	1.1	1.2	1.1
11-06	2.2	.0	.7	AM	.7	.4	.2	.1	.1	.1	.0	.0	.1	.4	.9	1.1
				PM	1.2	1.7	2.0	2.2	2.1	1.5	1.0	.6	.4	.2	.1	.0
11-07	5.9	-.7	1.8	AM	-.1	-.2	-.4	-.5	-.6	-.6	-.7	-.7	-.3	.8	2.2	3.2
				PM	4.0	4.8	5.8	5.4	4.9	4.0	3.0	2.4	2.0	1.7	1.6	1.6
11-08	7.9	1.2	3.2	AM	1.5	1.5	1.6	1.6	1.6	1.6	1.5	1.3	1.3	2.3	3.5	4.5
				PM	6.2	7.3	7.6	6.6	5.2	3.9	3.1	2.7	2.5	2.7	2.9	3.1
11-09	11.3	3.0	7.1	AM	3.0	3.2	3.9	4.7	5.0	5.2	5.2	5.2	5.2	5.5	6.3	7.2
				PM	8.3	9.6	10.9	11.3	10.8	10.1	9.5	9.0	8.8	8.8	8.8	8.9
11-10	9.8	8.0	9.0	AM	8.9	9.0	8.3	8.0	8.2	8.5	8.7	9.0	9.2	9.7	9.5	8.9
				PM	8.8	8.8	9.0	9.1	9.1	9.1	9.1	9.1	9.2	9.3	9.4	9.5
11-11	9.6	6.8	8.1	AM	9.6	9.6	9.6	9.6	9.6	9.1	8.0	7.2	6.9	6.8	7.1	7.4
				PM	7.8	8.5	8.7	8.7	8.4	8.0	7.6	7.3	7.1	6.9	7.0	7.1
11-12	12.8	2.4	7.6	AM	7.4	7.8	8.3	8.7	9.0	9.2	9.6	9.9	11.1	11.9	12.4	12.7
				PM	12.2	10.0	7.8	5.9	4.7	3.9	3.4	3.1	2.9	2.8	2.7	2.4
11-13	2.8	-1.5	.4	AM	1.8	1.0	.3	-.1	-.5	-.8	-.6	-.4	-.3	.3	.8	1.4
				PM	2.5	2.7	2.4	1.8	1.0	.1	-.2	-.7	-1.1	-1.4	-1.4	-1.4
11-14	1.4	-2.4	-.9	AM	-1.5	-1.5	-1.5	-1.6	-1.7	-2.0	-2.2	-2.3	-2.3	-1.5	.0	.5
				PM	1.1	1.3	.7	.7	.4	-.1	-.5	-.9	-1.3	-1.5	-1.6	-1.7
11-15	5.1	-3.2	-.2	AM	-1.7	-1.8	-2.0	-2.1	-2.0	-2.0	-1.9	-1.9	-1.8	-1.0	.2	2.3
				PM	3.1	4.6	4.9	4.2	2.8	1.4	-.1	-1.1	-1.9	-2.6	-3.1	-3.1

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		VALUES AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
11-16	7.3	-3.1	2.1	AM	-2.7	-2.3	-1.9	-1.5	-1.2	-1.0	-.8	-.5	-.1	.9	2.3	3.9
				PM	5.2	6.5	7.0	7.1	7.2	6.0	4.3	3.0	2.6	3.0	3.5	4.1
11-17	9.4	3.5	6.0	AM	4.9	5.8	6.4	6.4	5.5	4.7	3.9	3.5	3.7	5.4	7.1	8.2
				PM	9.1	9.4	9.3	8.8	7.8	6.8	5.9	5.2	4.6	4.1	3.7	3.5
11-18	4.9	1.9	3.1	AM	3.3	3.1	3.0	2.8	2.5	2.3	2.1	2.0	1.9	2.0	2.3	2.7
				PM	3.4	4.1	4.8	4.8	4.7	4.2	3.8	3.5	3.3	3.1	2.8	2.4
11-19	5.6	2.0	3.4	AM	2.3	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.1	2.7	3.5	4.7
				PM	5.4	5.5	5.0	4.5	4.3	4.0	3.9	4.0	4.1	4.1	4.1	4.1
11-20	17.2	4.1	10.1	AM	4.2	4.4	4.6	4.7	4.8	4.9	5.0	5.2	5.6	6.3	8.0	11.0
				PM	13.6	16.3	17.2	17.0	16.1	15.1	14.3	13.8	13.5	13.5	13.6	13.8
11-21	14.3	7.1	11.5	AM	12.8	11.8	11.6	11.8	12.0	12.2	12.5	12.7	12.7	12.9	13.6	14.0
				PM	14.3	13.8	12.9	12.4	11.2	9.9	9.0	8.5	8.1	7.7	7.4	7.1
11-22	7.1	5.4	6.0	AM	6.7	6.4	6.2	6.0	5.8	5.5	5.4	5.4	5.5	5.7	5.6	5.6
				PM	5.8	6.0	6.0	6.1	6.1	6.2	6.2	6.3	6.4	6.4	6.4	6.5
11-23	7.3	3.5	5.5	AM	6.9	7.2	7.3	7.3	6.8	6.2	5.7	5.3	4.9	4.8	5.0	5.7
				PM	5.8	5.9	6.1	5.8	5.5	5.1	4.7	4.4	4.1	3.8	3.6	3.5
11-24	5.7	3.1	4.2	AM	3.4	3.3	3.2	3.2	3.2	3.2	3.1	3.1	3.3	3.7	4.1	4.9
				PM	5.5	5.7	5.6	5.5	5.2	4.9	4.7	4.5	4.3	4.2	4.2	4.2
11-25	6.9	4.1	5.4	AM	4.2	4.3	4.3	4.3	4.3	4.2	4.2	4.1	4.2	4.5	5.2	6.2
				PM	6.3	6.3	6.2	6.1	6.1	6.4	6.7	6.5	6.5	6.9	6.5	6.1
11-26	6.1	.4	2.9	AM	5.7	5.5	5.3	5.2	5.1	4.9	4.7	4.6	4.3	3.8	3.4	2.7
				PM	2.1	1.6	1.3	1.1	.9	.8	.8	.7	.6	.5	.4	.4
11-27	.9	-.7	.0	AM	.3	.3	.1	.0	-.1	-.3	-.5	-.6	-.7	-.6	-.4	.0
				PM	.5	.9	.8	.7	.3	.0	-.1	-.2	-.3	-.3	-.4	-.5
11-28	.8	-1.3	-.5	AM	-.6	-.8	-.9	-1.0	-1.1	-1.1	-1.2	-1.2	-1.2	-1.1	-.8	-.2
				PM	.3	.7	.8	.7	.5	.1	-.2	-.4	-.6	-.9	-1.2	-1.3
11-29	7.6	-2.2	1.5	AM	-1.3	-1.2	-1.2	-1.2	-1.5	-1.8	-2.1	-2.2	-2.0	-1.1	.3	2.3
				PM	4.5	6.7	7.6	7.3	6.4	4.9	3.5	2.4	2.0	2.0	1.7	1.1
11-30	1.1	.1	.5	AM	.7	.3	.5	.7	.7	.5	.4	.2	.2	.2	.2	.4
				PM	.7	.9	1.0	1.0	.8	.7	.5	.4	.3	.2	.2	.1
12-01	.1	-1.5	-.6	AM	.0	-.1	-.4	-.6	-.7	-.7	-.8	-.9	-.9	-.7	-.4	.0
				PM	.0	.0	.0	-.1	-.3	-.7	-1.1	-1.5	-1.5	-1.3	-1.1	-.9
12-02	2.0	-.9	.3	AM	-.6	-.4	-.3	-.2	-.1	-.2	-.2	-.1	-.1	.2	.7	1.4
				PM	1.7	1.9	2.0	1.6	1.2	.8	.5	.2	.0	-.3	-.6	-.7
12-03	13.5	-1.6	-1.4	AM	-.8	-.9	-1.0	-1.2	-1.3	-1.4	-1.5	-1.6	-1.5	-1.1	-.4	.4
				PM	1.0	2.0	2.0	1.5	5.7	4.8	4.7	4.6	4.4	4.4	4.3	4.3
12-04	4.7	3.2	4.3	AM	4.3	4.2	4.2	4.3	4.3	4.4	4.4	4.4	4.5	4.5	4.6	4.7
				PM	4.7	4.7	4.7	4.6	4.6	4.4	4.2	4.0	3.8	3.5	3.4	3.2
12-05	3.2	1.3	2.5	AM	3.1	3.0	2.8	2.7	2.6	2.5	2.3	2.3	2.2	2.3	2.4	2.6
				PM	2.9	3.0	3.0	3.0	2.9	2.7	2.4	2.2	1.9	1.7	1.5	1.3
12-06	2.3	1.1	1.8	AM	1.2	1.2	1.1	1.1	1.1	1.2	1.2	1.3	1.3	1.5	1.6	1.8
				PM	2.0	2.1	2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2
12-07	3.4	2.2	3.0	AM	2.2	2.3	2.4	2.5	2.6	2.6	2.7	2.8	2.8	2.9	2.9	3.1
				PM	3.2	3.3	3.3	3.4	3.4	3.4	3.3	3.3	3.3	3.2	3.2	3.2
12-08	4.0	3.2	3.5	AM	3.2	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.3	3.4
				PM	3.6	3.7	3.9	4.0	3.9	3.9	3.9	3.8	3.7	3.7	3.6	3.5

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		VALUES AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
12-09	4.1	2.3	3.5	AM	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.4	3.4	3.6
				PM	3.9	4.0	4.1	4.1	4.1	4.0	3.9	3.9	3.3	2.8	2.4	2.3
12-10	3.7	1.8	2.8	AM	2.2	1.8	1.9	2.0	1.9	1.9	2.0	2.1	2.2	2.4	2.7	2.9
				PM	3.0	3.3	3.4	3.6	3.6	3.6	3.6	3.7	3.7	3.7	3.7	3.7
12-11	5.4	3.7	4.6	AM	3.8	3.9	3.9	3.9	4.0	4.0	4.0	4.1	4.1	4.2	4.3	4.5
				PM	4.8	5.1	5.3	5.3	5.4	5.4	5.4	5.3	5.2	5.1	4.9	4.8
12-12	5.8	4.0	4.9	AM	4.7	4.6	4.5	4.4	4.2	4.1	4.0	4.0	4.1	4.2	4.5	4.9
				PM	5.2	5.5	5.7	5.8	5.8	5.8	5.7	5.6	5.5	5.5	5.4	5.4
12-13	5.6	4.9	5.4	AM	5.4	5.4	5.3	5.3	5.3	5.3	5.4	5.4	5.4	5.4	5.4	5.4
				PM	5.5	5.6	5.6	5.6	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9
12-14	4.9	4.0	4.4	AM	4.8	4.7	4.6	4.4	4.3	4.2	4.1	4.0	4.0	4.1	4.2	4.3
				PM	4.4	4.6	4.6	4.7	4.6	4.6	4.6	4.5	4.5	4.4	4.4	4.4
12-15	6.6	4.4	5.3	AM	4.4	4.4	4.4	4.4	4.5	4.5	4.6	4.6	4.7	4.9	5.0	5.2
				PM	5.4	5.6	5.7	5.8	5.9	6.0	6.0	6.1	6.1	6.2	6.4	6.6
12-16	6.8	6.1	6.4	AM	6.8	6.8	6.7	6.7	6.6	6.5	6.4	6.4	6.3	6.3	6.3	6.3
				PM	6.3	6.3	6.3	6.3	6.3	6.3	6.2	6.2	6.2	6.1	6.1	6.1
12-17	6.1	5.6	6.0	AM	6.1	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	6.0	6.0
				PM	6.1	6.1	6.1	6.1	6.0	5.9	5.9	5.8	5.7	5.7	5.6	5.6
12-18	5.6	5.1	5.3	AM	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.1
				PM	5.3	5.4	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.1	5.1	5.1
12-19	5.9	4.9	5.3	AM	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.2	5.2	5.4	5.5
				PM	5.6	5.8	5.8	5.9	5.8	5.7	5.4	5.2	5.1	5.0	4.9	4.9
12-20	4.9	2.5	4.0	AM	4.9	4.9	4.8	4.6	4.4	4.3	4.1	4.0	3.8	3.8	3.8	4.0
				PM	4.1	4.2	4.4	4.3	4.1	3.9	3.7	3.4	3.1	2.9	2.7	2.5
12-21	3.3	1.6	2.4	AM	2.4	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.6	1.7	1.9	2.2
				PM	2.5	2.8	3.1	3.3	3.3	3.2	3.1	3.0	2.8	2.7	2.6	2.6
12-22	4.2	2.3	3.2	AM	2.5	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.5	2.7	3.1
				PM	3.5	3.9	4.1	4.2	4.2	4.1	4.1	4.1	4.0	4.0	4.0	4.0
12-23	5.1	2.8	4.3	AM	4.0	4.1	4.1	4.2	4.3	4.3	4.3	4.3	4.3	4.4	4.6	4.7
				PM	4.8	5.0	5.1	5.1	5.1	4.8	4.5	4.2	3.8	3.4	3.1	2.8
12-24	2.8	.7	1.7	AM	2.6	2.3	2.2	2.0	1.9	1.8	1.8	1.7	1.6	1.5	1.6	1.7
				PM	1.8	1.8	1.9	1.8	1.7	1.6	1.6	1.5	1.3	1.0	.9	.7
12-25	1.2	-.1	.5	AM	.5	.3	.2	.2	.1	.1	.0	.1	.2	.2	.5	.8
				PM	1.1	1.2	1.2	1.2	1.0	.8	.6	.4	.3	.1	.0	-.1
12-26	.3	-.1	.0	AM	-.1	-.1	-.1	-.1	-.1	-.1	-.1	-.1	-.1	-.1	-.1	-.1
				PM	-.1	-.1	-.1	-.1	-.1	.3	.3	.2	.1	.1	.0	.0
12-27	1.9	-.1	.7	AM	.0	.0	-.1	-.1	-.1	-.1	-.1	-.1	-.1	-.1	-.1	-.1
				PM	.7	1.2	1.5	1.7	1.9	1.9	1.9	1.8	1.8	1.7	1.8	1.8
12-28	4.9	1.8	3.6	AM	2.0	2.1	2.2	2.4	2.5	2.7	2.8	3.0	3.1	3.3	3.5	3.7
				PM	4.0	4.3	4.5	4.6	4.7	4.7	4.7	4.8	4.7	4.8	4.8	4.9
12-29	6.2	4.9	5.5	AM	4.9	4.9	5.0	5.1	5.1	5.1	5.2	5.2	5.0	4.9	5.1	5.5
				PM	5.6	5.7	5.8	5.8	5.9	5.9	5.9	6.0	6.1	6.1	6.1	6.2
12-30	8.8	6.2	7.3	AM	6.3	6.4	6.5	6.5	6.5	6.6	6.7	6.7	6.8	6.7	6.8	7.0
				PM	7.2	7.4	7.6	7.8	7.9	8.3	8.2	8.2	8.3	8.5	8.6	8.8
12-31	8.9	5.7	7.6	AM	8.9	8.9	8.8	8.7	8.6	8.4	8.3	8.2	8.1	8.0	7.9	7.8
				PM	7.6	7.5	7.3	7.1	6.9	6.7	6.5	6.4	6.2	6.0	5.9	5.7

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		VALUES AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
01-01	5.7	4.2	4.7	AM	5.6	5.4	5.3	5.2	5.0	4.9	4.8	4.7	4.6	4.5	4.4	4.4
				PM	4.5	4.5	4.5	4.5	4.5	4.4	4.3	4.3	4.2	4.2	4.2	4.2
01-02	4.6	3.7	4.1	AM	4.1	4.1	4.0	3.9	3.9	3.8	3.7	3.7	3.7	3.7	3.9	4.0
				PM	4.2	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.5	4.6
01-03	7.6	4.6	6.0	AM	4.7	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.7	5.9
				PM	6.1	6.2	6.4	6.5	6.7	6.8	7.0	7.1	7.2	7.3	7.4	7.6
01-04	9.6	7.6	8.9	AM	7.8	8.0	8.2	8.4	8.6	8.8	9.1	9.2	9.2	9.2	9.2	9.3
				PM	9.4	9.5	9.6	9.6	9.5	9.4	9.2	9.1	8.9	8.7	8.5	8.4
01-05	8.4	6.7	7.2	AM	8.3	8.2	8.0	7.9	7.7	7.6	7.5	7.3	7.2	7.1	7.0	7.0
				PM	7.0	7.0	7.0	7.0	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.7
01-06	6.7	5.9	6.4	AM	6.6	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.2	6.2	6.2	6.3
				PM	6.4	6.6	6.6	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9
01-07	6.5	5.6	6.0	AM	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.6	5.6	5.6	5.7	5.9
				PM	6.1	6.2	6.4	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1
01-08	6.1	4.7	5.6	AM	6.0	6.0	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.4	5.4	5.5
				PM	5.8	5.9	5.9	5.9	5.6	5.5	5.4	5.2	5.1	4.9	4.8	4.7
01-09	4.7	3.5	4.2	AM	4.6	4.6	4.6	4.5	4.3	4.2	4.1	4.0	4.0	4.0	4.1	4.2
				PM	4.3	4.5	4.5	4.4	4.4	4.2	4.1	3.9	3.8	3.6	3.6	3.5
01-10	3.5	2.0	2.8	AM	3.4	3.3	3.1	2.7	2.4	2.2	2.0	2.0	2.1	2.2	2.4	2.5
				PM	2.7	2.9	3.0	3.1	3.2	3.1	3.1	3.0	2.9	2.8	2.7	2.7
01-11	4.2	2.6	3.4	AM	2.6	2.6	2.6	2.7	2.7	2.7	2.7	2.6	2.6	2.7	3.0	3.3
				PM	3.6	3.8	4.0	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.2
01-12	5.3	4.2	4.8	AM	4.2	4.3	4.3	4.3	4.4	4.4	4.4	4.4	4.4	4.5	4.6	4.8
				PM	4.9	5.1	5.2	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.2
01-13	5.4	4.5	5.0	AM	5.3	5.3	5.4	5.4	5.4	5.4	5.4	5.4	5.3	5.4	5.2	5.0
				PM	5.0	4.9	4.9	4.9	4.8	4.7	4.6	4.5	4.5	4.5	4.5	4.5
01-14	5.2	4.1	4.6	AM	4.5	4.4	4.4	4.3	4.3	4.2	4.2	4.1	4.1	4.1	4.2	4.4
				PM	4.7	4.9	5.1	5.2	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.6
01-15	5.1	4.2	4.6	AM	4.5	4.4	4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.4	4.5
				PM	4.7	4.8	5.0	5.1	5.1	5.0	4.9	4.8	4.7	4.6	4.6	4.5
01-16	4.6	4.1	4.4	AM	4.5	4.5	4.4	4.4	4.3	4.2	4.2	4.2	4.1	4.1	4.2	4.3
				PM	4.4	4.5	4.6	4.6	4.6	4.6	4.5	4.4	4.4	4.3	4.3	4.4
01-17	4.6	3.7	4.3	AM	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.2	4.2	4.2	4.3
				PM	4.4	4.5	4.6	4.6	4.6	4.4	4.2	4.1	3.9	3.8	3.7	3.7
01-18	4.1	2.6	3.4	AM	3.6	3.6	3.6	3.6	3.5	3.4	3.3	3.1	3.0	3.0	3.1	3.3
				PM	3.5	3.8	4.0	4.1	4.0	3.8	3.6	3.4	3.2	2.9	2.8	2.6
01-19	3.4	1.3	2.4	AM	2.4	2.2	2.1	1.9	1.8	1.7	1.5	1.4	1.3	1.4	1.7	2.1
				PM	2.6	3.0	3.2	3.4	3.4	3.3	3.2	3.0	2.8	2.7	2.6	2.5
01-20	4.2	2.0	3.0	AM	2.5	2.4	2.3	2.3	2.2	2.2	2.1	2.0	2.0	2.1	2.3	2.6
				PM	3.0	3.4	3.7	3.9	4.0	4.1	4.1	4.0	4.0	4.1	4.1	4.2
01-21	6.0	4.2	5.2	AM	4.3	4.4	4.4	4.5	4.6	4.6	4.7	4.7	4.6	4.8	4.9	5.1
				PM	5.3	5.4	5.6	5.8	5.9	5.9	6.0	6.0	6.0	6.0	5.9	5.9
01-22	5.9	5.2	5.7	AM	5.9	5.9	5.9	5.9	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7
				PM	5.7	5.7	5.8	5.8	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.2
01-23	6.6	4.9	5.7	AM	5.1	5.0	5.0	4.9	4.9	4.9	4.9	5.0	5.0	5.2	5.3	5.4
				PM	5.6	5.9	6.2	6.5	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.4

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18

PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS

DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370

JUDAY CREEK NEAR SOUTH BEND, IN

(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003

PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

	DATE	MAX	MIN	MEAN		1	2	3	4	5	6	7	8	9	10	11	12
										VALUES AT INDICATED HOURS							
	01-24	6.4	4.7	5.9	AM	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.2	6.2	6.1	6.1
					PM	6.1	6.0	6.1	6.1	5.9	5.7	5.5	5.3	5.1	5.0	4.8	4.7
	01-25	4.7	3.4	4.1	AM	4.6	4.4	4.3	4.2	4.0	3.9	3.8	3.7	3.7	3.8	3.9	4.1
					PM	4.3	4.5	4.7	4.6	4.5	4.4	4.2	4.0	3.8	3.7	3.6	3.4
	01-26	4.5	3.0	3.7	AM	3.3	3.3	3.2	3.1	3.1	3.0	3.0	3.0	3.0	3.1	3.2	3.4
					PM	3.6	3.8	4.1	4.2	4.3	4.2	4.3	4.3	4.3	4.4	4.4	4.5
	01-27	6.0	4.5	5.2	AM	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.6	4.7	5.0
					PM	5.5	5.8	6.0	6.0	6.0	5.9	5.7	5.7	5.6	5.6	5.6	5.6
	01-28	6.7	5.4	5.9	AM	5.5	5.6	5.6	5.6	5.7	5.6	5.6	5.5	5.4	5.4	5.6	5.8
					PM	6.2	6.4	6.6	6.7	6.6	6.5	6.4	6.1	5.9	5.7	5.6	5.4
	01-29	5.4	2.4	3.9	AM	5.2	5.0	4.9	4.6	4.5	4.2	4.0	3.8	3.6	3.5	3.5	3.6
					PM	3.8	4.1	4.1	4.1	3.9	3.6	3.4	3.1	2.9	2.7	2.6	2.4
	01-30	3.5	1.3	2.4	AM	2.2	2.1	1.9	1.8	1.7	1.7	1.5	1.4	1.3	1.4	1.6	2.0
					PM	2.5	3.0	3.3	3.5	3.4	3.3	3.2	3.0	2.9	2.7	2.6	2.6
	01-31	5.0	2.5	3.6	AM	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.6	2.8	3.1	3.5
					PM	4.0	4.5	4.9	5.0	5.0	4.9	4.7	4.6	4.5	4.4	4.4	4.4
	02-01	5.0	3.3	4.1	AM	4.4	4.3	4.2	4.1	3.9	3.8	3.6	3.4	3.3	3.3	3.5	3.8
					PM	4.3	4.7	5.0	5.0	4.9	4.7	4.4	4.1	3.9	3.6	3.4	3.3
P	02-02	4.6	2.5	3.5	AM	3.1	3.0	2.9	2.8	2.7	2.7	2.6	2.5	2.5	2.5	2.8	3.2
					PM	3.7	4.2			4.6	4.6	4.4	4.2	4.1	4.0	3.9	3.8
	02-03	5.8	3.3	4.3	AM	3.7	3.7	3.6	3.5	3.5	3.4	3.4	3.3	3.4	3.5	3.8	4.3
					PM	4.7	5.2	5.6	5.8	5.7	5.5	5.4	5.1	4.8	4.6	4.3	4.2
	02-04	6.6	3.8	5.0	AM	4.1	4.1	4.1	4.0	4.0	4.0	3.9	3.9	3.8	3.9	4.2	4.7
					PM	5.3	5.9	6.4	6.5	6.6	6.5	6.2	6.0	5.7	5.4	5.2	5.1
	02-05	7.0	4.4	5.5	AM	5.0	4.9	4.9	4.7	4.6	4.6	4.5	4.4	4.4	4.5	4.9	5.3
					PM	6.0	6.5	6.8	6.9	7.0	6.9	6.6	6.3	6.1	5.9	5.7	5.6
	02-06	5.9	4.7	5.4	AM	5.6	5.6	5.6	5.6	5.5	5.5	5.4	5.3	5.2	5.2	5.3	5.4
					PM	5.5	5.6	5.8	5.9	5.9	5.7	5.6	5.4	5.2	5.0	4.8	4.7
	02-07	5.3	3.3	4.4	AM	4.4	4.2	4.0	3.8	3.7	3.5	3.4	3.3	3.3	3.3	3.5	3.8
					PM	4.2	4.6	5.0	5.2	5.3	5.3	5.3	5.3	5.2	5.1	5.1	5.0
	02-08	5.5	4.9	5.1	AM	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0	5.1
					PM	5.3	5.4	5.4	5.5	5.5	5.4	5.3	5.2	5.1	5.0	5.0	4.9
	02-09	5.4	4.4	4.9	AM	4.9	4.8	4.8	4.7	4.7	4.6	4.5	4.5	4.4	4.4	4.5	4.6
					PM	4.8	5.0	5.2	5.3	5.4	5.4	5.4	5.4	5.3	5.2	5.1	5.0
	02-10	6.6	4.9	5.7	AM	4.9	4.9	5.0	5.0	5.0	5.1	5.2	5.2	5.3	5.4	5.5	5.7
					PM	5.9	6.1	6.3	6.4	6.6	6.5	6.4	6.3	6.2	6.1	5.9	5.8
	02-11	5.8	4.2	5.2	AM	5.8	5.7	5.7	5.6	5.6	5.5	5.4	5.3	5.2	5.1	5.2	5.2
					PM	5.3	5.4	5.4	5.4	5.3	5.2	5.0	4.9	4.7	4.5	4.4	4.2
	02-12	4.2	2.9	3.5	AM	4.1	4.0	3.8	3.7	3.5	3.4	3.1	3.0	2.9	2.9	3.0	3.1
					PM	3.4	3.6	3.7	3.7	3.8	3.8	3.7	3.7	3.6	3.5	3.5	3.5
	02-13	5.3	3.4	4.2	AM	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.5	3.8	4.1
					PM	4.6	5.0	5.2	5.3	5.2	5.1	4.9	4.7	4.6	4.4	4.4	4.3
	02-14	5.4	4.2	4.6	AM	4.3	4.3	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.3	4.5	4.7
					PM	4.9	5.1	5.3	5.4	5.3	5.2	5.1	4.9	4.8	4.6	4.5	4.4
	02-15	4.9	3.8	4.3	AM	4.3	4.2	4.1	4.1	4.0	3.9	3.9	3.8	3.8	3.9	4.1	4.3
					PM	4.5	4.8	4.8	4.9	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		1	2	3	4	5	6	7	8	9	10	11	12
					VALUES AT INDICATED HOURS											
02-16	4.4	3.0	3.6	AM	4.0	3.8	3.5	3.3	3.2	3.1	3.0	3.0	3.0	3.1	3.1	3.3
				PM	3.6	3.9	4.1	4.4	4.4	4.3	4.1	3.8	3.6	3.4	3.3	3.2
02-17	3.5	1.3	2.8	AM	3.2	3.1	3.0	2.9	2.8	2.7	2.6	2.4	2.4	2.4	2.7	2.9
				PM	3.1	3.3	3.4	3.5	3.4	3.2	2.9	2.6	2.2	1.8	1.5	1.3
02-18	1.3	-.2	.4	AM	1.1	.8	.6	.5	.3	.2	.0	-.2	-.2	-.2	-.2	.1
				PM	.3	.7	.9	1.1	1.2	1.0	.8	.5	.2	-.1	-.2	-.2
02-19	1.4	-.2	.3	AM	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2
				PM	-.2	-.2	-.2	-.1	1.0	1.4	1.4	1.3	1.2	1.1	1.1	1.1
02-20	3.9	1.1	2.5	AM	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.8	2.0	2.4
				PM	2.9	3.3	3.6	3.8	3.9	3.9	3.8	3.7	3.6	3.4	3.4	3.3
02-21	3.3	1.9	2.7	AM	3.0	2.8	2.8	2.6	2.6	2.6	2.2	1.9	2.0	2.0	2.1	2.3
				PM	2.5	2.7	2.8	2.9	3.0	3.0	3.1	3.0	2.9	2.9	2.8	2.8
02-22	3.4	2.1	2.8	AM	2.7	2.7	2.7	2.7	2.6	2.5	2.4	2.4	2.3	2.5	2.8	3.1
				PM	3.4	3.4	3.3	3.4	3.3	3.1	2.9	2.6	2.5	2.3	2.2	2.1
02-23	2.8	.7	1.7	AM	2.1	2.0	1.5	1.3	.8	.9	.7	.7	.8	1.0	1.2	1.5
				PM	1.9	2.3	2.5	2.8	2.6	2.7	2.5	2.3	2.1	1.7	1.4	1.2
02-24	1.9	-.2	.7	AM	1.0	.7	.5	.3	.2	.0	-.1	-.2	-.2	-.2	-.2	-.2
				PM	.6	1.3	1.7	1.9	1.9	1.8	1.5	1.2	.9	.6	.3	.0
02-25	1.7	-.2	.3	AM	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2
				PM	-.2	-.2	-.2	1.4	1.7	1.7	1.5	1.3	1.1	.9	.7	.6
02-26	3.7	.6	1.8	AM	.6	.6	.6	.6	.7	.7	.7	.7	.9	1.1	1.3	1.9
				PM	2.5	3.0	3.4	3.7	3.7	3.4	3.1	2.7	2.4	2.0	1.7	1.4
02-27	4.0	-.1	1.9	AM	1.0	.9	.7	.6	.4	.3	.1	-.1	.0	.4	.8	1.5
				PM	2.4	3.1	3.7	3.9	4.0	3.9	3.7	3.4	3.2	2.8	2.5	2.2
02-28	4.7	.8	2.6	AM	2.0	1.7	1.6	1.4	1.2	1.1	.9	.8	.8	1.1	1.6	2.3
				PM	3.2	3.9	4.4	4.7	4.7	4.4	4.1	3.8	3.5	3.2	2.9	2.6
03-01	5.9	1.9	3.6	AM	2.5	2.3	2.3	2.2	2.1	2.1	2.0	1.9	2.0	2.2	2.7	3.3
				PM	4.1	4.9	5.5	5.8	5.9	5.8	5.5	5.1	4.8	4.5	4.3	4.1
03-02	7.3	3.9	5.4	AM	4.1	4.1	4.0	4.0	4.0	3.9	3.9	3.9	4.0	4.3	4.7	5.2
				PM	5.8	6.4	6.9	7.2	7.3	7.2	7.1	6.9	6.8	6.6	6.5	6.4
03-03	8.0	6.3	7.0	AM	6.4	6.4	6.3	6.4	6.3	6.3	6.3	6.3	6.3	6.5	6.8	7.3
				PM	7.6	7.9	7.9	8.0	8.0	7.9	7.6	7.5	7.2	7.0	6.8	6.6
03-04	6.6	3.9	5.4	AM	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.8	5.8	5.7	5.6
				PM	5.5	5.5	5.3	5.0	4.9	4.7	4.4	4.2	4.0	3.9	3.9	3.9
03-05	6.2	3.8	4.6	AM	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.9	4.1	4.4
				PM	4.8	5.5	5.9	6.2	6.2	5.9	5.6	5.3	5.0	4.7	4.4	4.1
03-06	7.7	3.3	5.3	AM	4.0	3.8	3.8	3.7	3.6	3.5	3.4	3.3	3.4	3.7	4.3	5.1
				PM	6.0	6.8	7.4	7.7	7.7	7.6	7.2	6.9	6.6	6.3	6.1	6.0
03-07	7.1	5.7	6.3	AM	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.8	6.0	6.5	6.8
				PM	6.9	7.0	7.1	7.0	6.8	6.7	6.6	6.4	6.3	6.2	6.1	6.1
03-08	6.6	5.8	6.1	AM	6.1	6.1	6.2	6.2	6.1	6.1	6.0	5.8	5.8	5.9	5.9	6.0
				PM	6.2	6.4	6.6	6.6	6.6	6.5	6.3	6.2	6.1	6.0	5.9	5.8
03-09	8.2	5.6	6.6	AM	5.8	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.7	6.0	6.5
				PM	7.0	7.5	7.9	8.2	8.2	8.0	7.8	7.5	7.2	7.1	7.0	6.8
03-10	6.8	5.2	5.9	AM	6.6	6.6	6.5	6.5	6.4	6.2	5.7	5.5	5.3	5.3	5.3	5.5
				PM	5.7	5.9	6.0	6.1	6.1	5.9	5.7	5.6	5.5	5.4	5.3	5.2

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION   STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE   STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993   TEST DIFF:******   PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		VALUES AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
03-11	6.5	4.5	5.4	AM	5.1	5.0	5.0	4.9	4.8	4.7	4.6	4.5	4.6	4.7	4.9	5.3
				PM	5.8	6.2	6.4	6.5	6.4	6.2	6.0	5.8	5.6	5.4	5.3	5.2
03-12	6.6	4.0	5.2	AM	5.1	5.0	4.9	4.7	4.5	4.3	4.1	4.0	4.0	4.2	4.6	5.3
				PM	5.8	6.2	6.4	6.6	6.5	6.3	6.0	5.8	5.5	5.3	5.1	4.9
03-13	5.6	2.7	4.6	AM	4.9	4.8	4.8	4.7	4.6	4.5	4.4	4.3	4.3	4.4	4.6	4.9
				PM	5.2	5.5	5.6	5.6	5.4	5.1	4.8	4.4	3.9	3.5	3.1	2.7
03-14	4.2	1.3	2.5	AM	2.4	2.2	2.0	1.9	1.7	1.6	1.4	1.3	1.3	1.4	1.7	2.3
				PM	2.9	3.5	3.9	4.2	4.2	3.8	3.4	3.1	2.7	2.4	2.1	1.9
03-15	5.1	1.0	3.0	AM	1.7	1.6	1.5	1.4	1.2	1.1	1.0	1.1	1.3	1.6	2.2	2.6
				PM	3.1	3.8	4.4	4.8	5.0	5.1	5.1	5.0	4.9	4.8	4.8	4.8
03-16	5.1	4.8	4.9	AM	4.8	4.9	4.9	4.9	5.0	4.9	5.0	4.9	4.9	4.8	4.8	4.9
				PM	4.9	4.9	4.9	5.0	5.0	5.1	5.1	5.1	5.0	5.0	5.0	5.0
03-17	6.2	3.9	4.8	AM	4.9	4.8	4.6	4.5	4.4	4.2	4.1	3.9	3.9	3.9	4.3	4.8
				PM	5.3	5.7	5.9	6.2	6.0	5.6	5.3	4.9	4.6	4.3	4.2	4.0
03-18	6.7	3.1	4.7	AM	3.9	3.8	3.7	3.6	3.5	3.3	3.2	3.1	3.1	3.4	3.9	4.6
				PM	5.3	6.0	6.5	6.7	6.6	6.4	6.0	5.7	5.4	5.1	4.8	4.6
03-19	5.0	3.8	4.3	AM	4.4	4.3	4.1	4.1	4.0	3.9	3.8	3.8	3.9	4.0	4.1	4.4
				PM	4.7	4.8	5.0	5.0	4.9	4.7	4.5	4.4	4.1	4.1	4.1	4.2
03-20	6.1	4.2	5.3	AM	4.3	4.4	4.5	4.6	4.7	4.7	4.8	4.8	4.9	5.0	5.1	5.4
				PM	5.6	5.9	6.0	6.1	6.1	6.1	6.0	5.9	5.9	5.9	5.9	5.9
03-21	8.0	5.6	6.8	AM	5.9	6.0	5.9	5.9	5.8	5.7	5.6	5.6	5.6	6.0	6.4	6.7
				PM	7.3	7.6	7.8	8.0	8.0	8.0	7.9	7.7	7.6	7.4	7.4	7.3
03-22	7.8	6.2	7.0	AM	7.2	7.2	7.1	6.8	6.6	6.4	6.3	6.2	6.3	6.4	6.5	6.8
				PM	7.2	7.5	7.8	7.8	7.8	7.7	7.5	7.4	7.2	7.0	6.9	6.7
03-23	6.9	6.2	6.6	AM	6.6	6.5	6.3	6.4	6.4	6.3	6.2	6.2	6.2	6.3	6.4	6.5
				PM	6.7	6.8	6.9	6.8	6.8	6.8	6.7	6.7	6.7	6.7	6.8	6.8
03-24	8.8	6.8	7.8	AM	6.9	6.9	6.9	7.0	7.0	7.0	7.0	7.0	7.1	7.2	7.4	7.7
				PM	7.8	8.2	8.6	8.7	8.8	8.8	8.7	8.7	8.6	8.6	8.6	8.6
03-25	9.4	8.4	8.8	AM	8.6	8.6	8.6	8.5	8.5	8.4	8.4	8.4	8.4	8.4	8.5	8.6
				PM	8.8	9.1	9.4	9.4	9.4	9.3	9.2	9.1	9.0	8.9	8.9	8.8
03-26	10.3	8.3	9.1	AM	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.3	8.3	8.3	8.4	8.7
				PM	8.8	9.3	9.8	10.1	10.3	10.3	10.1	9.9	9.6	9.3	9.1	9.0
03-27	11.9	8.2	9.7	AM	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.2	8.3	8.7	9.3
				PM	10.1	10.8	11.4	11.8	11.9	11.7	11.3	10.9	10.5	10.3	10.0	9.9
03-28	12.2	9.1	10.5	AM	9.8	9.7	9.7	9.6	9.4	9.3	9.2	9.1	9.2	9.5	10.0	10.7
				PM	11.3	11.6	12.1	12.2	12.1	12.0	11.7	11.5	11.2	10.9	10.7	10.6
03-29	13.7	9.6	11.4	AM	10.5	10.4	10.2	10.1	9.9	9.8	9.7	9.6	9.7	10.0	10.6	11.5
				PM	12.2	12.6	13.4	13.6	13.7	13.6	13.2	12.8	12.4	12.1	11.8	11.5
03-30	14.2	10.2	12.0	AM	11.3	11.1	10.9	10.7	10.5	10.3	10.2	10.2	10.3	10.5	10.8	11.6
				PM	12.4	13.2	13.9	14.1	14.2	14.0	13.7	13.3	13.0	12.7	12.5	12.3
03-31	12.3	9.6	11.2	AM	12.1	11.9	11.8	11.6	11.5	11.5	11.4	11.4	11.3	11.3	11.4	11.5
				PM	11.5	11.6	11.6	11.5	11.4	11.1	10.9	10.5	10.3	10.0	9.8	9.6
04-01	9.6	6.1	7.8	AM	9.4	9.2	9.0	8.9	8.7	8.6	8.3	8.1	7.9	7.7	7.7	7.7
				PM	7.7	7.6	7.5	7.4	7.2	7.1	6.9	6.7	6.5	6.4	6.3	6.1
04-02	7.1	5.5	6.2	AM	6.0	5.9	5.8	5.7	5.7	5.6	5.5	5.5	5.7	5.9	6.0	6.4
				PM	6.5	6.7	6.9	7.1	7.1	7.0	6.8	6.6	6.5	6.3	6.2	6.2

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		VALUES AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
04-03	9.5	5.8	7.3	AM	6.2	6.1	6.1	6.0	5.9	5.9	5.8	5.8	5.9	6.3	6.9	7.7
				PM	8.2	8.9	9.4	9.5	9.5	9.2	8.7	8.2	7.9	7.6	7.4	7.3
04-04	10.5	6.3	8.3	AM	7.2	7.1	7.0	6.8	6.6	6.5	6.3	6.3	6.5	6.9	7.5	8.4
				PM	9.3	10.0	10.5	10.5	10.4	10.2	10.0	9.6	9.4	9.1	8.9	8.7
04-05	9.2	8.1	8.7	AM	8.6	8.6	8.5	8.5	8.4	8.2	8.1	8.1	8.2	8.5	8.6	8.8
				PM	9.0	9.2	9.2	9.2	9.2	9.2	9.0	8.8	8.7	8.5	8.4	8.4
04-06	11.3	8.1	9.6	AM	8.3	8.3	8.2	8.2	8.2	8.1	8.1	8.1	8.2	8.4	9.1	9.8
				PM	10.4	11.0	11.1	11.1	11.3	11.3	11.1	10.9	10.7	10.5	10.4	10.3
04-07	11.7	9.3	10.4	AM	10.1	10.0	9.8	9.6	9.5	9.4	9.3	9.3	9.4	9.6	9.8	10.1
				PM	10.5	11.1	11.4	11.5	11.7	11.6	11.5	11.2	11.0	10.9	10.8	10.7
04-08	11.4	10.3	10.9	AM	10.6	10.6	10.5	10.5	10.4	10.4	10.3	10.3	10.4	10.5	10.6	10.7
				PM	10.9	11.1	11.2	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3
04-09	11.6	9.9	11.1	AM	11.4	11.3	11.3	11.2	11.1	11.1	11.1	11.0	11.0	10.9	10.9	10.9
				PM	10.9	11.0	11.3	11.5	11.6	11.5	11.4	11.1	10.8	10.5	10.2	9.9
04-10	13.3	8.5	10.7	AM	9.7	9.5	9.2	9.0	8.8	8.6	8.5	8.5	8.8	9.3	9.9	10.9
				PM	11.8	12.6	13.1	13.3	13.3	13.0	12.5	12.0	11.6	11.2	10.9	10.7
04-11	10.7	9.1	10.0	AM	10.6	10.5	10.3	10.3	10.2	10.0	9.9	9.9	9.8	9.9	9.9	10.0
				PM	10.2	10.3	10.3	10.3	10.2	10.0	9.9	9.8	9.6	9.4	9.2	9.1
04-12	9.6	8.4	8.9	AM	8.9	8.8	8.7	8.7	8.6	8.5	8.4	8.4	8.4	8.4	8.5	8.7
				PM	9.0	9.2	9.3	9.5	9.6	9.6	9.5	9.3	9.2	9.0	8.9	8.8
04-13	12.9	8.5	10.4	AM	8.8	8.7	8.7	8.7	8.6	8.5	8.6	8.6	8.6	8.9	9.5	10.3
				PM	11.1	12.0	12.5	12.8	12.9	12.7	12.4	12.1	11.7	11.5	11.2	11.0
04-14	11.5	9.7	10.6	AM	10.8	10.6	10.5	10.3	10.2	10.0	9.9	9.7	9.7	9.8	10.0	10.4
				PM	11.2	11.3	11.4	11.5	11.5	11.3	11.0	10.9	10.7	10.5	10.4	10.3
04-15	12.3	9.9	11.0	AM	10.2	10.1	10.0	10.0	10.0	9.9	9.9	10.0	10.1	10.4	10.9	11.1
				PM	11.4	11.6	11.9	12.0	12.3	12.1	12.0	11.8	11.7	11.6	11.6	11.5
04-16	11.5	8.3	9.9	AM	11.3	11.0	10.8	10.5	10.3	10.0	9.8	9.7	9.7	9.7	9.7	9.9
				PM	10.2	10.2	10.1	10.0	9.9	9.6	9.4	9.2	8.9	8.7	8.5	8.3
04-17	11.6	7.2	9.1	AM	8.1	7.9	7.8	7.6	7.5	7.3	7.2	7.2	7.3	7.7	8.3	9.1
				PM	10.0	10.8	11.3	11.6	11.5	11.2	10.9	10.4	10.0	9.7	9.6	9.6
04-18	12.2	9.3	10.6	AM	9.5	9.5	9.5	9.5	9.4	9.4	9.3	9.3	9.6	9.9	10.1	10.7
				PM	11.5	11.9	12.0	12.1	12.2	12.1	11.9	11.6	11.4	11.2	11.0	10.9
04-19	11.2	10.3	10.9	AM	10.8	10.7	10.7	10.6	10.5	10.3	10.3	10.4	10.5	10.7	10.9	11.0
				PM	11.1	11.2	11.2	11.2	11.2	11.1	11.1	11.1	11.1	11.2	11.1	11.1
04-20	12.3	10.3	11.3	AM	11.0	11.0	11.0	11.0	11.1	11.1	11.1	11.1	11.1	11.3	11.5	12.0
				PM	12.3	12.3	12.2	12.0	11.8	11.5	11.3	11.1	10.9	10.7	10.5	10.3
04-21	11.8	8.4	9.9	AM	10.1	9.9	9.6	9.3	9.0	8.7	8.4	8.4	8.5	8.6	9.1	9.8
				PM	10.5	11.1	11.6	11.8	11.5	11.3	10.9	10.4	10.0	9.6	9.4	9.2
04-22	13.2	8.4	10.5	AM	9.1	9.0	9.0	8.8	8.7	8.5	8.4	8.4	8.7	9.2	10.0	10.9
				PM	11.8	12.5	13.0	13.2	13.1	12.8	12.3	11.8	11.4	11.1	11.0	10.9
04-23	14.6	9.6	12.0	AM	10.8	10.6	10.5	10.2	10.0	9.8	9.6	9.7	10.0	10.5	11.2	12.2
				PM	13.0	13.7	14.4	14.6	14.4	14.2	13.9	13.6	13.3	13.1	12.9	12.8
04-24	14.4	12.0	13.2	AM	12.7	12.6	12.5	12.4	12.2	12.1	12.1	12.0	12.2	12.4	12.6	13.0
				PM	13.6	14.0	14.1	14.3	14.4	14.4	14.2	14.1	14.0	13.8	13.7	13.5
04-25	14.7	12.3	13.3	AM	13.4	13.2	13.1	13.0	12.8	12.6	12.5	12.4	12.4	12.3	12.4	13.0
				PM	13.6	14.2	14.5	14.7	14.7	14.4	14.0	13.6	13.2	12.9	12.6	12.4

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18

PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS

DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370

JUDAY CREEK NEAR SOUTH BEND, IN

(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003

PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

					VALUES AT INDICATED HOURS											
DATE	MAX	MIN	MEAN		1	2	3	4	5	6	7	8	9	10	11	12
04-26	15.2	11.0	12.9	AM	12.2	12.0	11.9	11.7	11.5	11.3	11.1	11.0	11.1	11.5	12.1	13.0
				PM	13.8	14.5	15.0	15.2	15.2	15.0	14.5	14.0	13.5	13.0	12.6	12.2
04-27	15.1	10.6	12.6	AM	11.9	11.6	11.4	11.2	11.0	10.7	10.6	10.6	10.8	11.1	11.8	12.6
				PM	13.5	14.2	14.8	15.0	15.1	14.8	14.4	14.0	13.6	13.3	13.1	12.9
04-28	15.6	12.1	13.8	AM	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.1	12.1	12.6	13.3	14.2
				PM	15.0	15.5	15.6	15.6	15.5	15.4	15.2	15.0	14.8	14.6	14.5	14.5
04-29	14.5	12.4	13.6	AM	14.4	14.3	14.2	14.0	13.9	13.8	13.7	13.6	13.6	13.6	13.6	13.6
				PM	13.7	13.8	13.8	13.7	13.6	13.6	13.5	13.3	13.0	12.8	12.6	12.4
04-30	16.6	11.5	13.8	AM	12.2	12.0	11.9	11.8	11.7	11.6	11.5	11.5	11.7	12.0	12.8	13.7
				PM	14.7	15.6	16.2	16.6	16.6	16.4	16.1	15.7	15.4	15.0	14.7	14.4
05-01	17.6	12.8	14.9	AM	14.1	13.8	13.6	13.4	13.2	13.0	12.8	12.8	13.0	13.5	14.1	14.9
				PM	15.9	16.6	17.2	17.5	17.6	17.3	16.9	16.4	16.0	15.5	15.1	14.8
05-02	15.5	13.5	14.4	AM	14.5	14.3	14.1	13.9	13.7	13.6	13.5	13.5	13.6	13.8	13.9	14.1
				PM	14.2	14.5	15.1	15.4	15.4	15.5	15.3	15.1	14.8	14.5	14.3	14.1
05-03	14.5	13.6	14.0	AM	14.0	13.9	13.8	13.7	13.7	13.6	13.6	13.6	13.6	13.7	13.9	14.0
				PM	14.1	14.1	14.3	14.4	14.5	14.5	14.4	14.2	14.1	14.0	13.9	13.7
05-04	15.1	13.3	14.2	AM	13.7	13.6	13.5	13.5	13.4	13.4	13.3	13.4	13.6	13.6	13.8	14.3
				PM	14.7	15.0	14.8	15.1	15.1	15.1	15.0	14.8	14.6	14.4	14.3	14.2
05-05	17.2	13.7	15.0	AM	14.1	14.0	14.0	13.9	13.9	13.8	13.7	13.7	13.7	13.8	13.9	14.2
				PM	15.0	15.7	16.4	17.0	17.2	17.0	16.7	16.2	15.8	15.5	15.2	15.0
05-06	19.2	14.0	16.3	AM	14.7	14.6	14.4	14.3	14.2	14.1	14.0	14.0	14.2	14.8	15.5	16.4
				PM	17.3	18.2	18.8	19.1	19.2	18.8	18.5	18.0	17.5	17.1	16.7	16.3
05-07	17.8	14.6	16.3	AM	16.0	15.8	15.5	15.3	15.0	14.8	14.6	14.7	15.0	15.5	16.0	16.3
				PM	16.8	17.4	17.7	17.8	17.8	17.7	17.5	17.2	16.9	16.6	16.2	15.9
05-08	19.4	14.5	16.8	AM	15.6	15.4	15.1	15.0	14.8	14.6	14.5	14.5	14.7	15.2	15.8	16.7
				PM	17.7	18.5	19.0	19.3	19.4	19.3	19.0	18.6	18.2	17.8	17.4	17.0
05-09	20.5	15.3	17.8	AM	16.7	16.4	16.1	15.9	15.6	15.4	15.3	15.3	15.5	16.0	16.8	17.7
				PM	18.7	19.5	20.2	20.4	20.5	20.5	20.2	19.9	19.5	19.1	18.8	18.5
05-10	21.2	17.0	19.0	AM	18.2	18.0	17.8	17.6	17.4	17.2	17.1	17.0	17.2	17.6	18.1	18.9
				PM	19.6	20.4	20.9	21.2	21.2	21.0	20.8	20.5	20.1	19.7	19.4	19.0
05-11	21.5	17.5	19.1	AM	18.8	18.5	18.2	18.0	17.8	17.6	17.5	17.5	17.7	18.0	18.6	19.2
				PM	20.0	20.7	21.2	21.5	21.3	20.9	20.6	20.1	19.6	19.1	18.6	18.2
05-12	19.9	15.8	17.6	AM	17.8	17.5	17.2	16.9	16.6	16.3	16.2	16.1	16.2	16.6	17.2	17.8
				PM	18.6	19.3	19.7	19.9	19.7	19.4	18.8	18.2	17.5	16.8	16.3	15.8
05-13	17.4	13.4	15.2	AM	15.4	15.0	14.6	14.3	14.0	13.7	13.5	13.4	13.5	14.0	14.5	15.2
				PM	16.0	16.7	17.3	17.4	17.3	16.9	16.4	15.7	15.2	14.7	14.2	13.9
05-14	17.2	12.4	14.7	AM	13.5	13.3	13.0	12.9	12.6	12.5	12.4	12.4	12.6	13.0	13.5	14.4
				PM	15.2	16.1	16.7	17.2	17.2	17.2	17.0	16.7	16.4	16.1	15.9	15.6
05-15	18.4	14.5	16.2	AM	15.5	15.3	15.2	15.0	14.8	14.6	14.5	14.5	14.6	15.0	15.5	16.2
				PM	17.0	17.7	18.2	18.4	18.4	18.1	17.7	17.2	16.8	16.5	16.1	15.8
05-16	16.7	14.0	15.2	AM	15.5	15.3	15.1	14.9	14.7	14.6	14.4	14.3	14.1	14.0	14.2	14.6
				PM	15.1	15.8	16.4	16.7	16.7	16.5	16.2	15.7	15.3	14.8	14.4	14.0
05-17	15.7	12.3	14.0	AM	13.7	13.4	13.1	12.9	12.7	12.5	12.3	12.4	12.6	13.1	13.6	14.1
				PM	14.7	15.1	15.6	15.7	15.6	15.5	15.2	14.9	14.6	14.3	14.0	13.8
05-18	15.0	12.4	13.6	AM	13.6	13.4	13.2	13.1	13.0	12.9	12.8	12.8	13.0	13.2	13.6	14.1
				PM	14.5	14.8	14.9	15.0	14.9	14.5	14.1	13.9	13.5	13.1	12.7	12.4

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18

PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS

04101370 DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

JUDAY CREEK NEAR SOUTH BEND, IN

(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003

PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		VALUES AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
05-19	15.1	10.8	12.8	AM	12.1	11.8	11.6	11.4	11.1	10.9	10.8	10.9	11.1	11.5	12.1	12.9
				PM	13.6	14.4	14.8	15.0	15.1	14.9	14.6	14.2	13.7	13.3	13.0	12.7
05-20	14.7	11.8	13.0	AM	12.5	12.4	12.2	12.1	12.0	11.9	11.8	11.8	12.1	12.4	12.8	13.0
				PM	13.3	13.8	14.1	14.6	14.7	14.6	14.2	14.0	13.7	13.3	13.0	12.7
05-21	16.4	11.7	13.8	AM	12.5	12.3	12.1	12.0	11.9	11.7	11.7	11.7	11.9	12.5	13.0	13.7
				PM	14.6	15.4	16.0	16.3	16.4	16.3	16.0	15.6	15.1	14.7	14.2	13.8
05-22	17.7	12.0	14.8	AM	13.4	13.1	12.8	12.6	12.3	12.1	12.0	12.1	12.4	13.0	13.6	14.5
				PM	15.6	16.5	17.2	17.6	17.7	17.5	17.2	16.9	16.6	16.3	16.2	15.9
05-23	15.9	14.5	15.1	AM	15.6	15.5	15.3	15.1	15.0	14.9	14.8	14.7	14.6	14.5	14.5	14.5
				PM	14.5	14.7	14.8	15.0	15.2	15.4	15.5	15.5	15.4	15.4	15.5	15.3
05-24	18.3	14.9	16.3	AM	15.2	15.1	15.1	15.1	15.0	14.9	14.9	14.9	15.1	15.5	16.0	16.8
				PM	17.5	18.0	18.3	18.3	18.1	17.7	17.3	16.9	16.5	16.2	15.9	15.7
05-25	17.3	14.4	15.7	AM	15.5	15.3	15.1	15.0	14.8	14.7	14.5	14.5	14.4	14.4	14.6	15.0
				PM	15.6	16.3	16.9	17.2	17.3	17.2	17.0	16.7	16.3	16.0	15.7	15.5
05-26	19.1	13.7	16.3	AM	15.2	14.9	14.7	14.4	14.1	13.9	13.7	13.8	14.0	14.4	15.0	15.8
				PM	16.9	17.8	18.5	18.9	19.1	19.0	18.8	18.4	18.0	17.5	17.1	16.7
05-27	17.6	15.2	16.3	AM	16.3	16.0	15.8	15.6	15.4	15.3	15.3	15.2	15.2	15.5	15.6	15.8
				PM	15.9	16.2	16.8	17.2	17.5	17.6	17.6	17.4	17.2	17.0	16.7	16.4
05-28	16.8	14.0	15.8	AM	16.2	16.0	15.8	15.6	15.5	15.4	15.4	15.4	15.5	15.8	16.2	16.5
				PM	16.7	16.8	16.8	16.6	16.2	16.0	15.6	15.2	14.8	14.6	14.3	14.0
05-29	17.7	12.4	14.9	AM	13.8	13.5	13.3	13.0	12.8	12.5	12.4	12.4	12.6	13.0	13.5	14.3
				PM	15.3	16.2	17.0	17.4	17.7	17.7	17.6	17.3	16.9	16.6	16.2	15.9
05-30	16.1	13.8	15.0	AM	15.5	15.1	14.8	14.6	14.3	14.1	13.9	13.8	14.0	14.4	14.6	14.8
				PM	15.0	15.1	15.5	15.4	15.5	15.5	15.5	15.7	16.1	15.7	15.5	15.5
05-31	15.5	13.0	14.0	AM	15.4	15.3	15.0	14.7	14.4	14.0	13.7	13.4	13.2	13.1	13.1	13.2
				PM	13.5	13.7	13.9	14.3	14.5	14.5	14.4	14.3	14.1	13.8	13.4	13.0
06-01	16.3	11.2	13.7	AM	12.7	12.4	12.1	11.8	11.5	11.3	11.2	11.3	11.5	12.0	12.6	13.4
				PM	14.4	15.2	15.8	16.2	16.3	16.3	16.0	15.7	15.4	15.2	14.9	14.6
06-02	15.5	13.8	14.5	AM	14.5	14.3	14.2	14.0	13.9	13.8	13.8	13.8	13.8	13.9	13.9	14.0
				PM	14.4	14.8	15.0	15.3	15.5	15.5	15.5	15.4	15.2	15.0	14.9	14.7
06-03	15.2	13.8	14.5	AM	14.5	14.4	14.2	14.1	14.0	13.9	13.9	13.8	13.8	13.9	14.0	14.2
				PM	14.4	14.6	14.8	15.0	15.2	15.2	15.2	15.1	14.9	14.7	14.6	14.4
06-04	14.4	13.0	13.6	AM	14.1	13.9	13.7	13.5	13.4	13.2	13.1	13.1	13.1	13.2	13.3	13.5
				PM	13.5	13.6	13.8	14.0	14.0	14.0	13.9	13.8	13.6	13.4	13.2	13.0
06-05	17.0	12.2	14.3	AM	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.2	12.4	12.7	13.1	13.9
				PM	14.8	15.6	16.3	16.7	16.9	17.0	16.8	16.5	16.2	15.8	15.5	15.2
06-06	18.6	13.8	16.1	AM	14.9	14.7	14.5	14.2	14.0	13.8	13.8	13.9	14.2	14.6	15.2	16.0
				PM	16.9	17.7	18.2	18.5	18.6	18.5	18.3	18.1	17.8	17.6	17.3	17.1
06-07	17.1	15.6	16.1	AM	16.8	16.5	16.4	16.2	16.1	15.9	15.9	15.8	15.8	15.8	15.9	16.1
				PM	16.0	16.1	16.7	16.8	16.5	16.4	16.1	16.0	15.8	15.8	15.7	15.6
06-08	17.2	15.5	16.0	AM	15.5	15.5	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.7	15.6	15.7
				PM	15.7	15.7	15.9	16.2	16.4	16.5	16.5	16.7	17.2	17.0	17.0	17.1
06-09	20.9	17.1	19.2	AM	17.2	17.4	17.6	17.8	18.0	18.1	18.2	18.3	18.5	18.8	19.2	19.7
				PM	20.2	20.5	20.8	20.9	20.8	20.7	20.5	20.2	20.0	19.7	19.5	19.3
06-10	19.3	16.3	17.3	AM	19.0	18.7	18.5	18.1	17.7	17.4	17.1	16.9	16.7	16.6	16.5	16.7
				PM	17.0	17.3	17.4	17.4	17.4	17.3	17.2	17.0	16.8	16.7	16.5	16.3

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION   STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE   STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993   TEST DIFF:******   PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		VALUES AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
06-11	17.5	15.0	16.3	AM	16.2	16.0	15.9	15.7	15.5	15.3	15.1	15.0	15.1	15.2	15.5	15.9
				PM	16.3	16.7	17.2	17.4	17.5	17.5	17.4	17.3	17.2	17.0	16.8	16.6
06-12	18.5	15.3	16.9	AM	16.5	16.3	16.2	16.0	15.8	15.6	15.5	15.4	15.3	15.6	16.0	16.6
				PM	17.2	17.8	18.2	18.4	18.5	18.5	18.2	18.1	17.9	17.7	17.5	17.2
06-13	18.5	16.0	17.3	AM	17.0	16.9	16.7	16.5	16.3	16.2	16.1	16.0	16.0	16.2	16.7	17.3
				PM	17.8	18.0	18.3	18.5	18.5	18.4	18.3	18.3	18.1	17.9	17.7	17.5
06-14	17.5	16.2	16.8	AM	17.4	17.2	17.0	16.9	16.7	16.6	16.7	16.9	16.6	16.4	16.2	16.4
				PM	16.6	16.7	16.9	17.1	17.2	17.1	17.0	16.9	16.8	16.7	16.5	16.3
06-15	17.0	15.0	16.0	AM	16.2	16.0	15.8	15.6	15.4	15.2	15.1	15.0	15.0	15.1	15.4	15.8
				PM	16.2	16.5	16.9	17.0	17.0	16.9	16.8	16.5	16.3	16.1	15.9	15.7
06-16	17.6	14.3	15.9	AM	15.4	15.2	15.0	14.8	14.6	14.4	14.3	14.3	14.4	14.6	15.0	15.7
				PM	16.4	17.1	17.4	17.6	17.6	17.5	17.3	17.1	16.9	16.7	16.5	16.4
06-17	19.6	15.3	17.4	AM	16.2	16.0	15.9	15.7	15.5	15.4	15.3	15.3	15.4	15.7	16.3	16.9
				PM	17.7	18.4	19.0	19.4	19.6	19.6	19.5	19.3	19.2	19.1	19.0	18.8
06-18	19.9	17.5	18.7	AM	18.6	18.4	18.3	18.2	18.0	17.8	17.6	17.5	17.5	17.5	17.7	18.1
				PM	18.7	19.1	19.5	19.7	19.8	19.9	19.8	19.6	19.4	19.2	19.0	18.9
06-19	19.7	17.7	18.8	AM	18.8	18.7	18.5	18.6	18.2	18.0	17.8	17.7	17.8	18.0	18.2	18.7
				PM	19.1	19.5	19.6	19.7	19.6	19.5	19.4	19.2	19.1	19.0	18.8	18.6
06-20	20.3	17.7	18.8	AM	18.4	18.2	18.2	18.1	18.0	17.8	17.9	17.8	17.7	17.8	18.1	18.4
				PM	19.1	19.5	19.9	20.2	20.3	20.2	20.0	19.8	19.5	19.3	19.1	18.9
06-21	18.9	16.6	17.7	AM	18.7	18.5	18.3	18.2	18.0	17.8	17.6	17.5	17.4	17.3	17.2	17.2
				PM	17.3	17.5	17.7	17.9	18.0	18.0	17.8	17.6	17.3	17.1	16.9	16.6
06-22	19.9	15.4	17.6	AM	16.4	16.1	16.0	15.8	15.6	15.5	15.4	15.5	15.6	16.0	16.5	17.3
				PM	18.1	18.8	19.4	19.8	19.9	19.9	19.7	19.5	19.3	19.0	18.8	18.5
06-23	20.7	17.2	18.8	AM	18.3	18.2	18.0	17.8	17.6	17.5	17.3	17.2	17.2	17.4	17.7	18.3
				PM	19.0	19.7	20.2	20.6	20.7	20.7	20.5	20.2	19.9	19.5	19.1	18.8
06-24	20.7	17.0	18.9	AM	18.5	18.1	17.8	17.6	17.3	17.2	17.0	17.0	17.2	17.4	17.9	18.5
				PM	19.3	20.0	20.3	20.5	20.7	20.7	20.6	20.3	20.1	19.8	19.6	19.3
06-25	19.4	17.4	18.5	AM	19.0	18.8	18.6	18.5	18.5	18.6	18.3	18.2	18.2	18.2	18.3	18.5
				PM	18.8	19.0	19.4	18.9	18.8	18.8	18.5	18.3	18.2	17.9	17.6	17.4
06-26	19.4	16.1	17.7	AM	17.2	17.0	16.7	16.5	16.3	16.1	16.1	16.1	16.1	16.5	16.9	17.5
				PM	18.1	18.8	19.0	19.3	19.4	19.2	19.1	19.0	18.7	18.5	18.2	18.0
06-27	20.5	16.9	18.5	AM	17.8	17.7	17.5	17.2	17.1	17.0	16.9	16.9	17.0	17.2	17.5	18.0
				PM	18.7	19.4	20.0	20.3	20.5	20.4	20.3	20.0	19.8	19.6	19.3	19.1
06-28	19.1	16.6	17.9	AM	18.8	18.7	18.5	18.3	18.1	18.0	17.8	17.9	18.0	17.7	17.6	17.7
				PM	17.8	18.0	18.2	18.2	18.1	18.0	17.9	17.7	17.4	17.1	16.9	16.6
06-29	19.1	15.5	17.0	AM	16.4	16.2	16.0	15.8	15.7	15.5	15.5	15.5	15.6	15.7	16.0	16.4
				PM	17.0	17.6	18.3	18.7	19.0	19.1	19.0	18.7	18.4	18.1	17.8	17.6
06-30	17.6	15.6	16.2	AM	17.3	17.0	16.7	16.5	16.4	16.2	16.1	16.0	15.9	15.9	15.9	15.9
				PM	15.9	16.0	16.0	16.0	16.1	16.1	16.1	16.0	15.9	15.8	15.7	15.6
07-01	16.2	14.7	15.4	AM	15.4	15.2	15.1	15.0	14.9	14.8	14.7	14.7	14.7	14.9	15.0	15.2
				PM	15.4	15.6	15.9	16.0	16.2	16.2	16.2	16.2	16.0	15.9	15.7	15.6
07-02	18.5	15.0	16.6	AM	15.4	15.3	15.2	15.1	15.0	15.0	15.0	15.1	15.2	15.6	16.0	16.5
				PM	17.2	18.0	18.3	18.4	18.5	18.4	18.4	18.1	17.9	17.7	17.5	17.3
07-03	20.3	16.8	18.3	AM	17.2	17.1	17.0	16.9	16.9	16.8	16.8	16.8	16.9	17.0	17.2	17.8
				PM	18.5	19.0	19.5	19.9	20.3	20.3	20.2	20.1	19.9	19.7	19.5	19.3

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		1	2	3	4	5	6	7	8	9	10	11	12
					VALUES AT INDICATED HOURS											
07-04	22.7	18.1	20.3	AM	19.1	18.9	18.7	18.5	18.3	18.2	18.1	18.1	18.3	18.6	19.1	19.8
				PM	20.7	21.5	22.1	22.5	22.7	22.7	22.5	22.2	22.0	21.8	21.5	21.3
07-05	23.8	20.0	21.8	AM	21.1	20.9	20.7	20.5	20.2	20.1	20.0	20.0	20.1	20.4	20.9	21.5
				PM	22.3	23.0	23.4	23.7	23.8	23.8	23.6	23.3	23.0	22.7	22.5	22.2
07-06	23.0	20.5	21.7	AM	22.0	21.8	21.6	21.4	21.1	20.9	20.7	20.5	20.5	20.7	20.9	21.5
				PM	22.1	22.7	22.9	23.0	23.0	22.8	22.5	22.3	22.0	21.6	21.3	21.0
07-07	21.4	19.4	20.5	AM	20.7	20.5	20.2	20.0	19.8	19.6	19.5	19.4	19.4	19.8	20.1	20.5
				PM	21.0	21.1	21.2	21.3	21.4	21.3	21.2	21.0	20.8	20.6	20.4	20.2
07-08	21.8	19.0	20.4	AM	20.0	19.8	19.6	19.4	19.2	19.1	19.0	19.0	19.1	19.3	19.7	20.2
				PM	20.7	21.1	21.5	21.7	21.8	21.8	21.7	21.5	21.3	21.1	20.9	20.7
07-09	23.0	19.5	21.2	AM	20.5	20.3	20.1	19.9	19.8	19.6	19.5	19.6	19.7	20.1	20.5	21.3
				PM	22.1	22.7	22.9	23.0	22.8	22.8	22.6	22.3	22.0	21.6	21.3	21.0
07-10	21.2	19.3	20.1	AM	20.7	20.4	20.2	19.9	19.7	19.5	19.3	19.3	19.3	19.3	19.3	19.4
				PM	19.5	19.8	20.3	20.7	21.0	21.2	21.2	21.0	20.8	20.6	20.3	20.1
07-11	20.7	18.7	19.7	AM	19.9	19.6	19.3	19.1	18.9	18.8	18.7	18.7	18.8	19.0	19.1	19.6
				PM	20.1	20.2	20.3	20.6	20.7	20.5	20.5	20.2	20.0	19.9	19.8	19.6
07-12	21.6	18.3	19.7	AM	19.4	19.2	19.0	18.8	18.6	18.5	18.4	18.3	18.3	18.5	18.9	19.4
				PM	20.1	20.8	21.3	21.6	21.6	21.5	21.2	20.9	20.5	20.1	19.7	19.3
07-13	21.8	17.4	19.5	AM	19.0	18.6	18.3	18.0	17.7	17.5	17.4	17.4	17.7	17.9	18.3	18.9
				PM	19.7	20.4	20.9	21.4	21.7	21.8	21.7	21.4	21.1	20.8	20.5	20.2
07-14	20.2	18.9	19.4	AM	20.0	19.8	19.5	19.3	19.2	19.1	19.0	18.9	18.9	18.9	18.9	19.0
				PM	19.2	19.3	19.4	19.6	19.8	19.9	19.9	19.8	19.6	19.4	19.2	18.9
07-15	21.5	17.7	19.4	AM	18.7	18.5	18.3	18.2	18.0	17.9	17.7	17.7	17.8	18.1	18.5	19.0
				PM	19.4	20.0	20.5	21.1	21.3	21.5	21.4	21.2	20.9	20.6	20.2	19.9
07-16	21.5	17.9	19.8	AM	19.5	19.2	18.9	18.6	18.4	18.2	18.0	17.9	18.1	18.4	18.9	19.5
				PM	20.2	20.6	21.0	21.3	21.4	21.5	21.4	21.2	21.0	20.7	20.5	20.2
07-17	20.3	18.4	19.4	AM	19.9	19.6	19.3	19.1	18.9	18.7	18.5	18.4	18.4	18.5	18.7	18.9
				PM	19.1	19.4	19.7	20.0	20.2	20.3	20.3	20.2	20.1	19.9	19.7	19.5
07-18	21.5	17.9	19.5	AM	19.3	19.0	18.8	18.6	18.3	18.2	18.1	18.0	17.9	17.9	18.2	18.6
				PM	19.2	19.8	20.5	21.1	21.4	21.5	21.3	21.1	20.8	20.6	20.3	20.0
07-19	20.0	18.5	19.0	AM	19.8	19.6	19.4	19.2	19.1	19.0	18.8	18.7	18.6	18.5	18.5	18.5
				PM	18.5	18.5	18.7	18.9	19.2	19.3	19.3	19.3	19.2	19.0	18.9	18.7
07-20	20.9	17.0	18.9	AM	18.4	18.2	18.0	17.7	17.5	17.2	17.1	17.0	17.2	17.5	17.9	18.5
				PM	19.1	19.9	20.4	20.8	20.9	20.8	20.6	20.3	20.0	19.7	19.4	19.1
07-21	21.1	17.6	19.2	AM	18.8	18.6	18.4	18.2	18.0	17.8	17.6	17.6	17.6	17.9	18.3	18.8
				PM	19.5	20.1	20.7	21.0	21.1	21.0	20.8	20.5	20.0	19.6	19.2	18.9
07-22	19.1	16.9	18.0	AM	18.5	18.1	17.8	17.5	17.2	17.0	16.9	16.9	17.0	17.2	17.4	17.7
				PM	18.0	18.4	18.7	18.9	19.1	19.1	19.0	18.8	18.6	18.4	18.2	17.9
07-23	19.0	16.5	17.7	AM	17.7	17.4	17.2	17.0	16.8	16.6	16.5	16.5	16.5	16.7	17.1	17.4
				PM	17.6	17.8	18.2	18.6	18.9	19.0	18.9	18.8	18.7	18.6	18.4	18.2
07-24	19.0	17.1	18.0	AM	18.0	17.8	17.6	17.4	17.3	17.2	17.1	17.1	17.1	17.2	17.3	17.8
				PM	18.1	18.5	18.5	18.7	18.9	18.9	19.0	18.9	18.7	18.6	18.5	18.3
07-25	21.0	17.4	18.9	AM	18.2	18.1	17.9	17.8	17.7	17.5	17.5	17.4	17.4	17.4	17.6	17.7
				PM	17.8	18.6	19.2	19.8	20.3	20.7	20.9	21.0	21.0	20.8	20.7	20.5

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		VALUES AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
07-26	22.7	19.0	20.7	AM	20.3	20.1	19.9	19.6	19.4	19.2	19.0	19.0	19.0	19.2	19.6	20.2
				PM	20.9	21.6	22.1	22.5	22.7	22.6	22.5	22.2	21.9	21.6	21.4	21.1
07-27	23.2	19.4	21.2	AM	20.8	20.5	20.3	20.0	19.8	19.6	19.4	19.4	19.5	19.6	20.0	20.6
				PM	21.4	22.0	22.5	23.0	23.2	23.2	23.0	22.8	22.6	22.4	22.2	22.0
07-28	23.3	20.7	21.9	AM	21.8	21.6	21.4	21.2	21.0	20.9	20.7	20.7	20.8	21.0	21.3	21.5
				PM	22.0	22.7	23.0	23.3	23.3	23.2	23.0	22.8	22.4	22.0	21.7	21.3
07-29	21.3	19.3	20.1	AM	21.0	20.7	20.4	20.2	19.9	19.7	19.5	19.4	19.4	19.4	19.5	19.8
				PM	19.9	20.2	20.4	20.5	20.5	20.6	20.6	20.4	20.2	19.9	19.6	19.3
07-30	21.2	17.3	19.1	AM	19.0	18.7	18.4	18.1	17.8	17.6	17.4	17.3	17.5	17.7	18.1	18.6
				PM	19.4	20.1	20.7	21.0	21.2	21.1	20.9	20.5	20.1	19.7	19.3	18.9
07-31	21.2	16.6	18.9	AM	18.5	18.1	17.7	17.4	17.1	16.8	16.6	16.6	16.8	17.2	17.7	18.4
				PM	19.2	20.0	20.6	21.0	21.2	21.2	21.1	20.9	20.6	20.2	19.9	19.6
08-01	21.8	18.3	19.9	AM	19.4	19.1	18.9	18.8	18.6	18.5	18.3	18.3	18.4	18.6	18.9	19.2
				PM	19.8	20.4	21.0	21.4	21.7	21.8	21.7	21.6	21.4	21.2	20.9	20.7
08-02	21.5	18.7	20.1	AM	20.5	20.2	19.9	19.6	19.3	19.0	18.8	18.7	18.7	18.9	19.2	19.7
				PM	20.2	20.7	21.0	21.4	21.5	21.4	21.1	20.9	20.6	20.2	19.9	19.6
08-03	20.7	18.0	19.3	AM	19.4	19.1	18.9	18.6	18.4	18.2	18.0	18.0	18.1	18.4	18.9	19.4
				PM	20.1	20.7	20.5	20.7	20.7	20.5	20.3	20.0	19.7	19.4	19.2	18.9
08-04	19.6	17.0	18.2	AM	18.7	18.4	18.1	17.9	17.6	17.3	17.1	17.0	17.1	17.3	17.5	17.9
				PM	18.5	19.0	19.3	19.5	19.6	19.5	19.2	18.9	18.5	18.2	17.8	17.4
08-05	18.2	15.4	16.9	AM	17.0	16.7	16.4	16.1	15.8	15.6	15.4	15.4	15.5	15.8	16.2	16.6
				PM	17.1	17.5	17.9	18.1	18.2	18.1	18.0	17.8	17.6	17.4	17.3	17.1
08-06	17.6	16.0	16.7	AM	16.9	16.7	16.6	16.4	16.3	16.2	16.1	16.1	16.0	16.0	16.2	16.2
				PM	16.5	16.8	17.2	17.4	17.6	17.6	17.5	17.3	17.1	16.8	16.6	16.3
08-07	18.8	15.0	16.7	AM	16.0	15.8	15.6	15.4	15.3	15.1	15.0	15.0	15.2	15.5	15.9	16.3
				PM	16.9	17.5	18.1	18.6	18.8	18.8	18.7	18.4	18.1	17.8	17.5	17.2
08-08	19.6	15.4	17.3	AM	16.9	16.6	16.3	16.1	15.8	15.6	15.4	15.4	15.5	15.9	16.4	16.8
				PM	17.8	18.3	19.0	19.6	19.5	19.2	19.0	18.9	18.5	18.2	17.9	17.6
08-09	19.4	16.1	17.8	AM	17.3	17.0	16.8	16.6	16.4	16.2	16.1	16.1	16.2	16.5	17.0	17.5
				PM	18.0	18.5	19.0	19.2	19.3	19.4	19.4	19.3	19.1	18.9	18.7	18.5
08-10	21.5	17.7	19.5	AM	18.3	18.1	18.0	18.0	19.0	18.3	17.8	17.9	17.7	18.0	18.4	18.9
				PM	19.6	20.2	20.7	21.1	21.3	21.4	21.5	21.3	21.1	20.8	20.6	20.3
08-11	22.4	18.4	20.4	AM	20.0	19.7	19.4	19.2	18.9	18.7	18.5	18.4	18.4	18.7	19.1	19.7
				PM	20.4	21.1	21.7	22.3	22.4	22.4	22.3	22.2	22.0	21.7	21.4	21.0
08-12	21.1	19.1	20.2	AM	20.7	20.3	20.1	19.8	19.6	19.4	19.2	19.1	19.2	19.3	19.3	19.7
				PM	20.0	20.3	20.5	20.9	21.1	21.1	21.1	21.0	20.8	20.5	20.3	20.1
08-13	21.6	18.5	20.0	AM	19.8	19.5	19.2	19.0	18.8	18.7	18.5	18.5	18.5	18.7	19.0	19.2
				PM	19.7	20.3	20.8	21.2	21.4	21.5	21.6	21.5	21.3	21.2	21.0	20.8
08-14	22.5	18.9	20.6	AM	20.5	20.1	19.9	19.6	19.4	19.2	19.0	18.9	19.0	19.2	19.6	20.1
				PM	20.7	21.3	21.8	22.3	22.5	22.5	22.4	22.1	21.8	21.5	21.3	21.0
08-15	21.9	19.5	20.4	AM	20.7	20.5	20.2	20.0	19.9	19.7	19.5	19.5	19.6	19.9	20.0	20.1
				PM	20.3	20.4	20.5	20.5	20.8	20.8	20.8	21.9	21.4	20.7	20.4	20.1
08-16	21.4	18.9	20.1	AM	19.9	19.9	19.7	19.5	19.3	19.1	19.0	18.9	18.9	19.1	19.2	19.5
				PM	19.8	20.3	20.9	21.2	21.3	21.4	21.4	21.3	21.1	20.9	20.6	20.4
08-17	22.1	19.0	20.4	AM	20.1	19.9	19.6	19.5	19.3	19.2	19.1	19.0	19.0	19.1	19.3	19.6
				PM	20.0	20.5	21.2	21.6	22.0	22.0	22.1	21.9	21.6	21.3	21.1	20.8

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

						VALUES AT INDICATED HOURS											
	DATE	MAX	MIN	MEAN		1	2	3	4	5	6	7	8	9	10	11	12
	08-18	22.8	19.0	20.8	AM	20.4	20.2	19.9	19.7	19.5	19.2	19.0	19.0	19.0	19.2	19.9	20.4
					PM	20.9	21.3	21.9	22.3	22.7	22.8	22.6	22.5	22.3	22.1	21.8	21.5
	08-19	22.6	19.5	20.6	AM	21.1	20.8	20.5	20.2	20.0	19.8	19.7	19.6	19.5	19.5	19.6	19.7
					PM	20.0	20.7	21.2	21.3	21.5	21.7	22.6	21.8	21.4	21.3	21.0	20.7
P	08-20	20.7	19.4	19.6	AM	20.5	20.2	20.0	19.8	19.7	19.6	19.4					
					PM												
M	08-21																
M	08-22																
M	08-23																
M	08-24																
M	08-25																
M	08-26																
M	08-27																
M	08-28																
M	08-29																
M	08-30																
M	08-31																
M	09-01																
M	09-02																
M	09-03																
M	09-04																
M	09-05																
M	09-06																
M	09-07																
M	09-08																
P	09-09	17.4	16.3	17.3	AM												
					PM				17.4	17.4	17.4	17.3	17.2	17.0	16.7	16.5	16.3

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993 TEST DIFF:****** PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN		VALUES AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
09-10	16.3	14.2	15.3	AM	16.2	15.9	15.7	15.5	15.4	15.1	14.9	14.7	14.6	14.5	14.6	14.8
				PM	15.2	15.5	15.7	15.9	16.0	15.8	15.6	15.3	15.0	14.7	14.5	14.2
09-11	15.7	12.5	14.1	AM	13.9	13.6	13.4	13.2	13.0	12.8	12.6	12.5	12.6	12.8	13.2	13.6
				PM	14.3	14.9	15.2	15.5	15.7	15.7	15.5	15.4	15.2	15.1	14.9	14.8
09-12	16.8	14.2	15.3	AM	14.7	14.5	14.4	14.4	14.3	14.2	14.2	14.2	14.2	14.2	14.3	14.5
				PM	15.0	15.6	16.2	16.5	16.7	16.8	16.8	16.7	16.5	16.4	16.3	16.2
09-13	19.5	15.7	17.3	AM	16.1	16.0	16.0	15.9	15.9	15.8	15.7	15.7	15.9	16.1	16.5	17.1
				PM	17.4	17.9	18.4	18.8	19.0	19.2	19.5	19.1	19.0	18.9	18.7	18.6
09-14	20.5	17.8	18.8	AM	18.5	18.4	18.4	18.4	18.4	18.3	18.4	18.4	18.5	18.7	19.0	19.2
				PM	19.4	19.7	20.5	19.9	19.7	19.4	18.9	18.7	18.5	18.2	18.0	17.8
09-15	17.8	14.5	15.9	AM	17.5	17.2	17.0	16.8	16.6	16.4	16.2	16.1	16.0	15.8	15.8	15.8
				PM	15.8	15.7	15.8	15.7	15.6	15.5	15.4	15.2	15.0	14.9	14.7	14.5
09-16	14.5	13.6	14.0	AM	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.7	13.6	13.7	13.8
				PM	14.0	14.0	14.1	14.3	14.4	14.4	14.4	14.2	14.1	14.0	13.9	13.8
09-17	14.0	13.2	13.6	AM	13.7	13.6	13.5	13.4	13.4	13.3	13.3	13.2	13.2	13.3	13.4	13.5
				PM	13.6	13.7	13.8	13.9	14.0	14.0	14.0	13.9	13.8	13.5	13.3	13.2
09-18	14.2	12.0	13.2	AM	13.0	12.8	12.6	12.5	12.3	12.2	12.1	12.0	12.1	12.3	12.7	13.1
				PM	13.5	13.8	14.1	14.2	14.2	14.2	14.1	14.1	14.0	13.9	13.8	13.7
09-19	15.2	12.7	14.0	AM	13.6	13.5	13.4	13.3	13.1	12.9	12.8	12.7	12.7	12.9	13.2	13.7
				PM	14.2	14.5	14.8	15.1	15.2	15.2	15.2	15.0	14.8	14.6	14.4	14.2
09-20	15.0	13.4	14.1	AM	14.1	13.9	13.8	13.7	13.6	13.6	13.5	13.4	13.4	13.4	13.4	13.5
				PM	13.8	14.2	14.4	14.7	15.0	15.0	15.0	15.0	15.0	14.8	14.6	14.6
09-21	15.1	14.3	14.6	AM	14.4	14.4	14.4	14.4	14.4	14.3	14.3	14.3	14.3	14.3	14.4	14.5
				PM	14.7	14.9	15.1	15.1	15.1	15.1	15.0	15.0	14.9	14.7	14.5	14.3
09-22	15.2	13.4	14.3	AM	14.1	13.9	13.7	13.6	13.5	13.4	13.4	13.4	13.5	13.6	13.9	14.1
				PM	14.4	14.7	14.9	15.0	15.1	15.2	15.2	15.1	15.0	14.9	14.9	14.8
09-23	15.5	13.8	14.8	AM	14.8	14.8	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.7	14.7
				PM	15.0	15.2	15.4	15.5	15.4	15.3	15.1	14.9	14.6	14.3	14.1	13.8
09-24	15.1	12.0	13.6	AM	13.5	13.2	13.0	12.7	12.5	12.3	12.1	12.0	12.0	12.2	12.6	13.0
				PM	13.6	14.1	14.5	14.9	15.1	15.1	15.0	14.9	14.6	14.4	14.2	14.0
09-25	14.0	12.7	13.2	AM	13.8	13.6	13.4	13.2	13.1	13.0	12.9	12.9	12.9	12.9	13.0	13.1
				PM	13.1	13.2	13.4	13.4	13.4	13.3	13.3	13.3	13.1	13.0	12.8	12.7
09-26	13.7	12.4	13.0	AM	12.6	12.6	12.6	12.5	12.5	12.5	12.4	12.4	12.4	12.5	12.6	12.7
				PM	13.0	13.3	13.4	13.6	13.7	13.7	13.7	13.6	13.5	13.4	13.3	13.1
09-27	13.1	11.4	12.5	AM	13.1	13.0	13.0	13.0	12.9	12.9	12.8	12.7	12.7	12.6	12.5	12.5
				PM	12.5	12.4	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.6	11.5	11.4
09-28	12.1	10.9	11.4	AM	11.3	11.2	11.2	11.1	11.1	11.0	10.9	10.9	10.9	11.0	11.1	11.3
				PM	11.6	11.8	12.0	12.0	12.1	12.0	11.9	11.8	11.7	11.6	11.6	11.5
09-29	11.7	10.8	11.3	AM	11.4	11.4	11.3	11.2	11.1	11.0	11.0	10.9	11.0	11.0	11.2	11.4
				PM	11.6	11.7	11.7	11.7	11.7	11.6	11.5	11.3	11.2	11.0	10.9	10.8
09-30	12.0	10.0	11.0	AM	10.7	10.6	10.5	10.5	10.4	10.3	10.1	10.0	10.0	10.1	10.3	10.6
				PM	11.1	11.5	11.8	12.0	12.0	12.0	11.9	11.8	11.6	11.5	11.3	11.2

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION   STATE 18 DIST 18
PRIMARY COMPUTATIONS OF QUALITY OF WATER DIGITAL MONITOR RECORDS
DATE PROCESSED: 03-18-1994 @ 07:44 BY MSREHMEL

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
(00010) WATER TEMPERATURE   STORE STATISTIC(S) 00001, 00002, 00003
PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1993   TEST DIFF:******   PUNCH INTERVAL: 15 MIN

DATE	MAX	MIN	MEAN	VALUES AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
PERIOD	23.8	-3.2													

NOTE. SYMBOLS USED ABOVE HAVE THE FOLLOWING MEANINGS --
P - DAILY SUMMARY IS FOR AN INCOMPLETE DAY
M - NO UNIT VALUES AVAILABLE FOR THIS DAY

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

SUMMARY OF DISCHARGE MEASUREMENT DATA

04101370 DATE PROCESSED: 18-MAR-94 09:20

JUDAY CREEK NEAR SOUTH BEND, IN 1993 WATER YEAR

NO.	DATE TIME	MADE BY	WIDTH	AREA	MEAN VEL.	GAGE HEIGHT	DISCHARGE CFS	SHIFT ADJ.	PCT. DIFF.	NO. SECT.	GHT. CHG.	TIME	RATED	CONTROL
								RATING NO. 1.0						
1	10/14/92 1045	TJE	14.5	12.3	1.29	2.12	15.9	-0.10		30	0.00	0.6	G	LGT DEBRIS
2	10/27/92 1525	JRD	16.0	13.2	1.15	2.18	15.1	-0.18		27	-0.01	0.0	F	LGT DEBRIS
3	11/17/92 1000	LEH	16.0	22.3	1.16	2.20	25.7		-1.2	17	-0.01	0.4	F	CLEAR
4	12/15/92 1350	JRD	15.5	11.3	1.73	2.10	19.5		-2.5	27	0.00	0.4	G	LGT DEBRIS
5	01/06/93 1145	LEH	20.0	29.2	2.18	2.54	63.6	+0.05		21	0.00	0.4	F	LGT DEBRIS
6	02/02/93 0014	JRD	14.5	1011.	2.53	2.25	27.5	-0.03		28	0.00	0.5	G	CLEAR
7	02/05/93 1045	TJE	14.0	10.6	2.46	2.23	26.0	-0.03		28	0.00	0.5	F	CLEAR
8	03/30/93 1030	TJE	16.0	15.5	2.22	2.29	34.4		+3.6	22	-0.01	0.5	G	CLEAR
		REMARKS: SOME AQUATIC GROWTH ON CHANNEL BOTTOM												
9	04/20/93 0910	LEH	20.0	26.6	2.02	2.54	54.0		-4.9	21	0.00	0.4	F	CLEAR
10	05/26/93 1215	TJE	17.0	9.30	2.02	2.08	18.8		-1.1	18	0.00	0.3	G	CLEAR
11	06/17/93 1035	LEH	20.0	19.7	2.06	2.37	40.6		+1.8	21	0.00	0.5	F	CLEAR
12	07/20/93 1055	TJE	18.0	9.82	2.12	2.10	20.9		+4.5	27	0.00	0.7	F	CLEAR
13	08/10/93 0820	LEH	18.0	13.5	1.95	2.15	26.3	+0.07	-4.7	19	0.00	0.2	F	CLEAR
		REMARKS: ALL OK HANDAR 560 INSTALLED TODAY												
INSP	08/10/93 1020	JHI				2.17								
14	08/20/93 0830	KKF	14.5	9.86	2.02	2.02	19.9	+0.07	+2.1	23	0.00	0.7	G	CLEAR
15	09/14/93 1415	KKF/DER	17.5	18.9	1.66	2.27	31.5		0.0	14	+0.06	0.7	F	

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
EXPANDED RATING TABLE
DATE PROCESSED: 03-18-1994 @ 09:54 BY LEHAMMIL

TYPE: LOG

04101370
JUDAY CREEK NEAR SOUTH BEND, IN
OFFSET: 1.00

DD: 1 TYPE: 001 RATING NO: 1.0
START DATE/TIME: 10-01-92 (0001)

BASED ON _______ DISCHARGE MEASUREMENTS, NOS ________, AND ________, AND IS ______ WELL DEFINED BETWEEN ______ AND ______ CFS
COMP BY _____ DATE _________ CHK. BY _____ DATE _________

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION) .00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
1.70			6.000*	6.164	6.331	6.500*	6.665	6.831	7.000*	7.247	1.875
1.80	7.500*	7.747	8.000*	8.248	8.500*	8.825	9.158	9.500*	9.700*	10.09	3.000
1.90	10.50*	10.83	11.16	11.50*	11.96	12.43	12.92	13.42	13.93	14.46	4.500
2.00	15.00*	15.48	15.97	16.47	16.98	17.50*	17.98	18.47	18.97	19.48	5.000
2.10	20.00*	20.58	21.17	21.77	22.38	23.00*	23.58	24.17	24.77	25.38	6.000
2.20	26.00*	26.77	27.55	28.35	29.17	30.00*	30.77	31.56	32.36	33.17	8.000
2.30	34.00*	34.78	35.56	36.36	37.18	38.00*	38.78	39.57	40.37	41.18	8.000
2.40	42.00*	42.98	43.98	45.00*	45.99	47.00*	47.97	48.96	49.96	50.97	10.00
2.50	52.00*	53.16	54.34	55.54	56.76	58.00*	59.35	60.73	62.13	63.55	13.00
2.60	65.00*	66.36	67.74	69.14	70.56	72.00*	73.32	74.65	76.00	77.37	13.76
2.70	78.76	80.16	81.57	83.00	84.45	85.92	87.40	88.90	90.42	91.96	14.75
2.80	93.51	95.08	96.66	98.27	99.89	101.5	103.2	104.9	106.6	108.3	16.49
2.90	110.0*	111.9	113.8	115.8	117.7	119.7	121.7	123.8	125.8	127.9	20.00
3.00	130.0*	132.0	134.1	136.2	138.2	140.4	142.5	144.7	146.8	149.0	21.30
3.10	151.3	153.5	155.8	158.1	160.4	162.7	165.1	167.5	169.9	172.3	23.50
3.20	174.8	177.3	179.8	182.3	184.9	187.4	190.0	192.7	195.3	198.0	25.90
3.30	200.7	203.4	206.1	208.9	211.7	214.5	217.4	220.3	223.2	226.1	28.30
3.40	229.0	232.0	235.0	238.0	241.1	244.2	247.3	250.4	253.6	256.8	31.00*
3.50	260.0*										

UNITED STATES DEPARTMENT OF THE INTERIOR - GEOLOGICAL SURVEY - WRD INDIANA 03/18/94

STATION NUMBER 04101370 JUDAY CREEK NEAR SOUTH BEND, IN STREAM SOURCE AGENCY USGS
LATITUDE 414343 LONGITUDE 0861546 DRAINAGE AREA DATUM STATE 18 COUNTY 141
GAGE HEIGHT FROM EDL-MOD, IN (FEET)
RATING LIST
RATING ID: 1.0 STANDARD RATING TYPE: LOG
LAST UPDATED BY LEHAMMIL ON 03-18-1994 @ 09:53:32 REMARKS:

BASED ON ______ DISCHARGE MEASUREMENTS, NOS ________, AND ________, AND IS ______ WELL DEFINED BETWEEN ______ AND ______ CFS
COMP BY _____ DATE ________ CHK. BY _____ DATE ________

RATING VALUE IN	RATING VALUE OUT	RATING VALUE IN	RATING VALUE OUT	RATING VALUE IN	RATING VALUE OUT	RATING VALUE IN	RATING VALUE OUT	RATING VALUE IN	RATING VALUE OUT	RATING VALUE IN	RATING VALUE OUT
1.72	6	1.84	8.5	2	15	2.25	30	2.45	47	2.9	110
1.75	6.5	1.87	9.5	2.05	17.5	2.3	34	2.5	52	3	130
1.78	7	1.88	9.7	2.1	20	2.35	38	2.55	58	3.5	260
1.8	7.5	1.9	10.5	2.15	23	2.4	42	2.6	65		
1.82	8	1.93	11.5	2.2	26	2.43	45	2.65	72		

RATING START DATE	RATING START TIME		LOG OFFSETS				
10-01-1992	00:01	BREAKPOINTS:		---		---	
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JUDAY CREEK
STORMWATER FEASIBILITY STUDY

FOR

ST. JOSEPH COUNTY, INDIANA

SEPTEMBER 1994

Prepared for:
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Introduction

Juday Creek is a tributary of the St Joseph River with its watershed located in St Joseph County, Indiana and adjacent Cass County, Michigan. The creek is 12 miles long with an average gradient of 8 feet per mile. The Juday Creek watershed covers 37.7 square miles (24,130 acres) with 80 percent (19,000 acres) in Indiana. Agricultural, residential and commercial land uses dominate the watershed influencing the management of the stream.

There are three distinct, natural reaches along Juday Creek. The upper reach extends from the headwaters to about one-half mile west of Grape Road, and is a low gradient stream with a silt/sand bottom. In this reach the stream gains ground water and is strongly influenced by ground water response to storm events. The middle reach, from one-half mile west of Grape Road to Ironwood Road, has a higher gradient and has a sand/gravel bottom. In this reach the stream recharges ground water and does not show as strong a response to ground water fluctuations. The lower reach, from Ironwood Road to the St. Joseph River, is trout habitat with a gravel bottom. While not native to Indiana, there has been a resident reproducing population of brown trout (*Salmo trutta*). The stream gains flow from ground water and springs in the last half mile before the mouth of the stream at the St. Joseph River.

The entire watershed consists of unconsolidated, chiefly glaciofluvial sand, overlying clay till with shale and limestone bedrock. There is a bedrock river valley bordering the south side of the Juday Creek watershed. The till, especially along the bedrock valley, contains a major aquifer while the overlying glaciofluvial sand forms a surficial water table. Except for the last half mile of the creek, the watershed is flat (elevations 710 - 820 feet Mean Sea Level). In the lowest half mile the creek drops down to the banks of the St. Joseph River (about 650 feet Mean Sea Level). Land use in the upper reach of the watershed was primarily agricultural prior to 1979. By 1992, over 2,750 acres had been converted to residential and commercial land uses and development is continuing. Land use in the middle and lower reaches is primarily residential with a private park (Izaac Walton League) bordering the creek in the last half mile.

The management goals for Juday Creek have been established by the land use patterns in the watershed. Prior to 1979 the primary management goal was to control soil moisture conditions in the agricultural areas. After 1979 storm water collection in the urban areas was added to the management goals. In 1988-89 flood control in the residential areas was added as another management goal. Finally, in 1992 multiple use stream management was proposed.

Project Objectives

The primary objective of this project was to preliminarily investigate sound alternatives to the direct discharge of stormwater into Juday Creek. This task was multifaceted in that reduction of thermal pollution, soluble chemicals, and sedimentation are all of primary concern. Partially due to commercial and residential development water quality in Juday Creek has declined in the past decade, however, innovative alternatives for stormwater treatment may play a role in reversing this decline. The project has been funded by the St. Joseph County Drainage Board.

Temperatures in Juday Creek have risen significantly in the past five to ten years due to increased stormwater runoff. Development, including roads and storm sewers, along the stream has increased the amount of impermeable area which has created a significant rise in surface runoff. The greater volume of water enters the creek at a faster rate via roofs, parking lots and storm sewers. Rain water carried through storm sewers often originates on asphalt parking lots or roads exposed to sunlight resulting in dramatically increased water temperature. Recent land use developments have included storm water detention ponds. These detention ponds frequently store water long enough to cause a rise in water temperature prior to discharge into the creek. Additionally, the continuing change in land use along the reach of Juday Creek has reduced the amount of trees and brush that shade the stream. This loss of in canopy has also played a role in increasing the temperature of the creek and reducing the area for wildlife habitat.

The increase in water temperature is particularly important in Juday Creek due to an introduced Brown Trout population that has been naturally reproducing for many years. Juday Creek is considered to be one of Indiana's only cold water streams. Brown trout are intolerant of warm water and water temperatures in the creek are currently near the fish's maximum tolerance level. The most critical area of the stream in regards to temperature is from Ironwood Road to the mouth of Juday Creek. This stretch of the stream is the primary spawning habitat for the brown trout.

Sedimentation is another detrimental impact that continues to affect the quality of Juday Creek. A major contributor to the increase of sedimentation is, again, the direct discharge of storm sewers to the stream. Direct stormwater discharge into a creek has several negative sedimentation impacts. Storm sewers discharge water to the stream at high velocities, causing scouring and erosion along the banks thus, creating more suspended solids in the creek. Additionally, wildlife habitat is degraded as a result from loss of stream banks. A significant amount of benthic life is destroyed by the turbulence due to runoff velocity. Stormwater itself carries sediments and associated toxic substances from development areas and roadways increasing the sediment load of the creek.

In addition to generally degrading the creek, sedimentation also impacts the trout directly by silting in spawining beds and decreasing the benthic invertebrates which are an important component of the trout's diet thus, with increased sediment loads the Brown Trout will be unable to maintain a viable population irrespective of temperature concerns.

Primary Objective Solutions

One common thread linking thermal pollution and sediment loading is the direct discharge of storm lines into Juday Creek. Therefore, the primary retrofitting design objective was to eliminate storm lines running directly into the creek. The design for each stormwater discharge was customized based on location along the stream, volume of water to be treated and land availability.

The design goal for eliminating direct discharge into the creek is to route the storm lines into a natural or constructed wetland or a deep detention pond for primary treatment. Essentially, we are utilizing the ability of natural systems (wetlands and ponds) to improve water quality. Woodard-Clyde Consultants (1991) found that the greatest concentration of metals in sediments occurred at the location nearest the stormwater inlet. Additionally, it is known that the first flush of stormwater contains the warmest water and heaviest contaminants. Sediments typically constitute the most significant store of toxic substances available to organisms in a wetland (Mitsch and Gosselink 1986). Metals and toxic organic compounds can be taken up by plants from the sediments and can be introduced into the food web (Kadlec and Kadlec 1979; Kreiger et al. 1986; Kadlec and Tilton 1979). These two factors, warm water and sediment contamination, need to be addressed in each existing and proposed stormwater discharge to Juday Creek.

To control sedimentation problems we propose the storm lines be directed into a sediment trap for initial treatment of stormwater runoff. The traps should be designed to be several feet deep and contain side to side strips of wetland vegetation (Figure 1). The traps would take the initial surge of stormwater before it enters the wetland filter area or detention ponds. The sediment traps, with the aid of wetland vegetation, would force some of the larger suspended solids to settle out before entering the wetland or other body of water. The traps would begin to lose their cleansing ability once they become half full of silt deposits, however, they can be maintained using a back hoe to remove the accumulated silt.

For reaches of the stream where thermal pollution is a major concern (Ironwood Road to the mouth of Juday Creek) the storm lines are directed from the sediment traps to specially designed detention ponds prior to entering the creek. The detention ponds have a bottom water discharge pipe taking advantage of the fact that cold water is more dense than warm water and will settle to the bottom of the basin. The bottom of the basins will also be in contact with ground water to provide additional cold water. The pipe is designed so the invert elevation in the pond is several feet below the invert elevation at the outlet to the second body of water (Figure 2). In addition to thermal moderation, the detention ponds allow the further settling of sediments from the stormwater before moving on to the next treatment stage. In locations that were feasible, the detention basins were designed in a linear fashion instead of a typical circular design. Trees can be planted along the linear layout and form a canopy that would cover the majority of ponded surface area. Bottom water discharge from the detention pond along with a vegetative canopy will maximize reduction of thermal impacts.

Stormwater contains many pollutants in addition to sediments which can be reduced with the aid of a wetland. When thermal pollution is less of a concern, water will flow from the sediment traps to either a natural or constructed wetland. The proposed wetland treatment areas will be enhanced by dense plantings of wetland vegetation. The wetland filter areas that have been proposed in are an important step in the secondary treatment of stormwater.

Wetlands increase the residence time and promotes the sheet flow. Martin and Smoot (1986) reported that residence time and turbulence were the most important factors affecting sedimentation. Morris et al. (1981) reported that sheet flow, as opposed to channelized flow, was the most important factor affecting settling. The longer residence time for water in a wetland allows for further settling of suspended solids and efficient plant uptake of nutrients and pollutants. There is more friction between vegetation and moving water than between moving water and a smooth bottom, therefore, the vegetation acts as a screen and filters the sediments and pollutants from the stormwater (Figure 3). Wetland vegetation also reduces water temperature by absorbing solar radiation that would otherwise be absorbed by the water.

In addition to filtering benefits of wetlands, the increased residence time of stormwater in wetlands will allow for some percolation, particularly where there is underlying porous soils. The percolation of stormwater into the soil will add further treatment for removing pollutants while also reducing direct discharge flows into the creek.

Improvement of water quality is a major concern throughout Juday Creek and particularly the reach of the stream that recharges the groundwater. Studies preformed by The University of Notre Dame have found that the creek west of Grape Road to the Izaak Walton League is feeding the ground water supply. Therefore, it becomes increasingly important in downstream reaches to not only reduce sediment loading but reduce the pollutants entering the Juday Creek. Through wetland filtration, not only will the quality of the stream improve, but the groundwater quality will be enhanced and protected as well.

The use of sediment traps, detention basins, and wetlands to treat stormwater runoff will serve to relieve flood events. These three treatment mechanisms will reduce the rate at which runoff travels, intercept stormwater runoff and provide additional storage for flood waters. As a result, there will be a reduction in the volume of runoff entering the stream and the velocity at which Juday Creek would travel during storm events.

SITE REMEDIES

In this report twelve sites have been identified for possible retrofitting of storm lines that feed into Juday Creek (Figure 5). A checklist of functions addressed at each site are contained on Figure 6.

Site 1

The area designated as site 1 is the intersection of US31 and Juday Creek (Appendix A). This site will address the primary concern of thermal pollution due to its location along the portion of the stream which is considered brown trout spawning habitat.

The exact length of the storm sewers were not known by the South Bend City Engineer, however, the lines do carry a considerable amount of runoff from roads and heavy development along US 31. A significant portion of development in this area was built prior to county storm detention regulations, therefore, these areas have no on-site treatment of stormwater, resulting in increased peak volumes of runoff.

The only treatment area available is on the northeast corner of Juday Creek and US31. It receives the stormwater runoff from northeast of Juday Creek. The landlocked piece of property is between Juday Creek, US 31 and the Indiana Toll Road. The feasibility of land acquisition is relatively high due to the potentially low commercial value of the small land locked tract of property.

The remaining corners of the US31 and Juday Creek intersection have not been addressed due to heavy development in this area and a lack of suitable land available to develop an effective treatment site.

Treatment Area A

In this location both the cities' stormwater systems and the Toll Road runoff may be treated. A cold water discharge pond that incorporates the existing open channel may be excavated in the landlocked area. The treatment area would cover approximately 1.2 acres.

The storm line would discharge into a one to two foot baffle area that will be heavily vegetated along the strip. This creates a filter that will allow a significant portion of sediments to settle, pollutant uptake to occur and decrease the velocity of the runoff.

Next, the water will flow to the deep detention basin for treatment of thermal pollution. The deep pool is not conducive for wetland vegetation, but allows room for colder, denser water to sink. The discharge pipe from the detention basin to Juday Creek would be designed to extract the cooler water from the bottom of the pond. Additionally, the ponded area would be planted with native trees to provide a canopy over the surface area of the basin, reducing the amount exposure to solar radiation.

This treatment site is fairly close to the mouth of the stream and does not incorporate a sizeable quantity of watershed. Also, with the availability of only one of four corners at the intersection of Juday Creek and US31 the cost has to be weighed against a site that could have multiple treatment areas. As a positive, the site would incorporate sizeable drainage from development to the north of the creek.

Site 2

The site is at the proposed Cleveland Road storm line project (Appendix B). The storm sewers will run from the east and west of Ridgewood Street along Cleveland and continue down Ridgewood to Juday Creek. The storm line will surface discharge prior to entering the creek.

After field investigation it was found that there is no available land to use as a potential treatment area. There is residential housing along the north side of the creek and the Toll Road is directly south leaving virtually no accessible land.

It is recommended that from the point of surface discharge, wetland vegetation be planted as a small filter. This will help to dissipate the channelized runoff into more of a sheet flow. The vegetation will reduce the velocity of the runoff and allow filtering of sediments and pollutants.

Site 3

The site is at the intersection of Juniper Street and Juday Creek (Appendix C). Upon field inspection no point source discharges were found in the proximity of this potential treatment area. County officials were unclear of any direct discharge into the creek at the Juniper Road location. Therefore, this site was dismissed as a possible storm sewer retrofitting location.

Site 4

This site is the intersection of Ironwood Road and Juday Creek (Appendix D). In this region of Ironwood, there is considerable residential development that eventually becomes commercial development north of the creek. The northwest and southwest corners were found to have suitable land and topography for retrofitting storm lines. The northeast and southeast corners contain residential housing making an unacceptable retrofitting location.

The length of the storm lines were unknown making it difficult to asses the watershed for the sewers. However, a 3 foot culvert was found on the northwest corner and a 1 foot culvert was found on the southwest corner. Based on culvert carrying capacity, it can be assumed that the line from the north is carrying a large amount of runoff from roads and development.

The brown trout spawning habitat begins at Ironwood and continues downstream to the St. Joseph River making thermal pollution a major concern at site 4. It was stated in the Saint Joseph River Basin Commission Study Summary (FY 1992-94) that chloride contamination is present in the creek near the Notre Dame property. This information, in addition to other potential contaminants, emphasizes the need to address pollutants at this site as well.

Treatment Area A

This site has existing wetlands present along the stream that can be put to use for treating stormwater. To protect the natural wetlands, the storm lines would initially discharge into a linear sediment trap. The trap would aid in silt dropout and reduction in runoff velocity. The runoff would then flow to a linear, deep bottom, detention pond. A basin would be created by excavation in the detention area and using the spoil to create an earthen berm. Trees planted on the margins provide shade to the surface area of the pond reducing the temperature. A bottom water discharge pipe would be installed to release the cooler water from the basin. A spillway along the berm would be designed to carry runoff from major storm events. After the first flush of a major storm event, thermal concerns become less of a factor.

Use of the natural wetland can be put to optimized use by using earthen berms. The hydraulic residence time would be regulated by a weir structure discharging water into Juday Creek. The regulation of detention time in the wetland allows for further settling of suspended solids, filtering of pollutants and uptake of nutrients by vegetation.

The wetland can be enhanced by planting additional vegetation that will aid in the filtering process. The wetland vegetation also provides suitable habitat for many species of wildlife. The berms would be planted with shading trees such as silver maple and sycamore to provide additional canopy for the stream and habitat.

Treatment Area B

This site has existing wetlands that also can be enhanced to treat stormwater runoff. Since the largest accumulation of sediment occurs around the inlet of the storm line, a sediment trap has been designed to take the initial volume of stormwater. The trap would prevent larger particles from entering the wetland. In time, the sediment trap would fill up with solids require dredging to ensure that the trap remains functional. The trap can be located near Ironwood Road for easy access for maintenance. The topography of treatment area B does not allow construction of a deep water basin with bottom discharge.

Once the runoff built up enough head to spill out of the sediment trap, it would flow through a heavily vegetated strip. The vegetation would reduce the speed at which the water is traveling causing sheet flow and diminishing the amount of erosion in the floodplain and along stream banks. Additionally, vegetation will shade the water in the natural wetland, providing some thermal moderation.

The runoff would then travel into a natural wetland for final treatment. Earthen berms would be pushed up along the stream banks and tied into existing topography to increase residence time. Again, this allows for further settling of solids, plant breakdown of pollutants and reduction of runoff velocity. A weir would be used to discharge the treated water into Juday Creek.

Due to several factors including stream location, topography and availability of land, the Ironwood Road treatment site has the potential to be highly effective in the treatment of thermal pollution, sedimentation, nutrient loading and overall water quality.

Site 5

Site 5 is the intersection of Douglas Road and Juday Creek (Appendix E). There are point source discharges on the north and south sides of Douglas Road. The storm line on the north side discharges runoff directly into the creek. The storm sewer on the south side discharges prior to entering the creek and travels along a concrete slab that extends to the creek.

The area to the north of Douglas Road has considerable residential development and leaves virtually no availability for potential treatment facilities. However, the southwest corner of the intersection is an open field with an existing wetland which provide for treatment opportunities.

The length of the storm line on the south side that extends west was not known making it difficult to asses the drainage area that is encompassed. The diameter of the outlet pipe and an assumption of the slope at which the pipe is laid can give an estimate of the carrying capacity. A 12 inch culvert was found, indicating a relatively low volumetric capacity of the pipe. Therefore, it can be assumed that the southwest storm line is draining a relatively small watershed.

Treatment Area A

The primary goal of this site is to utilize the existing wetland for treatment of stormwater runoff. The factors to be addressed are reduction in runoff velocity, sedimentation, nutrient loading and bank erosion.

The storm lines would be directed into a sediment trap for initial treatment as discussed in previous sections. Next, the runoff would flow through a heavily vegetated strip to create sheet flow action and provide additional filtering prior to being routed to the existing wetland via earthen berm. The berm would be created by excavated material from the sediment trap and additional grading in the vegetated strip. The wetland could be enhanced by planting a variety of wetland plants, improving the overall quality of stormwater runoff.

While this site would treat a relatively small volume of water, each site adds incrementally to the degradation of Juday Creek. Construction was kept to a minimum on site 5 conceptual plans to control costs while still providing quality treatment of runoff. In essence minimal costs would provide effective treatment for the overall improvement of water at this site. Instead of ignoring a smaller site, a design has been proposed to try and reverse the incremental degradation that occurs moving downstream.

Site 6

Site 6 is the intersection of State Road 23 and Juday Creek (Appendix F). The east side of State Road 23 has extensive residential development making this area unsuitable for retrofitting design. The west side of the road contains existing wetlands and is an ideal location for treating stormwater.

Point source discharge pipes were found on the northwest and southwest corners of the intersection feeding directly into Juday Creek. The diameter of existing storm sewers indicate that lines have been sized for a relatively large carrying capacity. The extent of the lines is not known but runoff can be assumed to be generated primarily from roads and residential development.

The State Road 23 intersection is upstream of the brown trout spawning habitat but the issue of thermal pollution is still of concern throughout the stream. Thermal pollution, like other pollutants, are cumulative in nature and need to be brought under control whenever possible. The topography and availability of land at the northwest and southwest corners enable possible design alternatives for treating sedimentation, nutrient loading and thermal pollution.

Treatment Area A

The main function of the northwest corner would be reducing thermal pollution, sedimentation and nutrient loading. The treatment would be enhanced by the presence of high quality wetlands at this site.

The storm line would be directed to a sediment trap that would handle the more concentrated flow. The trap can be located near State Road 23 for easy equipment access for maintenance. The runoff would flow from the trap into a cold water detention basin for the second phase of treatment. The pond would be created by constructing a berm using excavated material from the basin area. A bottom water discharge pipe would be installed to displace cold water to Juday Creek during storm events. An earthen spillway is proposed which would discharge the remainder of runoff into the wetland for filtering of pollutants. The first flush of runoff is the primary thermal concern during a storm event. After the first flush of runoff, the objective shifts to filtering the water.

The wetland would be regulated by constructing a berm and with a weir structure as an outlet to Juday Creek. The wetland would be the final stage of treatment for the stormwater runoff. The wetland would be planted with wetland vegetation to increase residence time, filtering, settling and nutrient uptake.

Treatment Area B

The storm water would be directed to a sediment trap for initial treatment. Next, the water would travel through a vegetated strip and into a wetland for the final treatment phase. The existing wetland would be bermed and the water level controlled with a weir to improve wetland functions.

A cold water detention basin is not possible at this site due to steep slopes that create a limited treatment area. While reduction of thermal pollution should be addressed whenever possible, this site does not appear to offer any feasible options.

Site 7

Site 7 is the pond located within the stream at Lake Shore Estates (Appendix G). The pond is at the stream location where Juday Creek is feeding the ground water supply. The pond was originally intended to help alleviate problems of sedimentation overloading within the stream. With the excavation of the pond, additional storage for flood waters was created as well.

After inspection of the site, the pond was found to contain a natural delta that has formed from silt deposits. The pond is helping to reduce sediments however, implementation of a filtering system can make the settling process more effective.

The primary drawback to the pond is that temperatures of the water have risen. This is due to increased residence time and the fact that groundwater is no longer flushing through the stream. The pond has created more surface area for the water to be exposed to solar radiation.

Treatment

A three stage process has been proposed for the improvement of water quality from upstream waters of Juday Creek. The upstream portion of the pond would contain a sediment trap to enhance the existing delta for initial treatment of the stream water. This site is accessible to back hoes needed to maintain the traps in order to keep their effectiveness high.

Next, the water would flow into a wetland constructed in the pond that would be approximately one to two feet in depth. The final phase of treatment would be water filtering out of the wetland area and into a deep detention basin. The basin would be approximately ten feet deep with a bottom water discharge pipe. The excavated material from the detention pond would be used to create the sediment trap and wetland area. The pipe would pull the water off of the bottom, which is the denser cold water, and discharge at the channel elevation.

Excavation of a sub channel within the stream channel has been proposed to lay the pipe-arch so the top of pipe is at the same elevation of the existing stream bed. The pipe-arch would discharge where the grade of the stream is below the invert elevation to provide a positive outlet.

Plantings of sycamores, cottonwoods, silver maples and other shade trees are recommended to provide cover to aid in reducing temperatures. Also, wetland and sediment trap plantings would improve filtering and shade the water.

The pond is preforming the task of reducing sediments as it was originally intended with some degree of effectiveness, however, quality of water discharging from the pond can be significantly improved with the proposed treatment design. The existing pond along with the availability of land, makes this site an excellent location. The pond would be treating water not only from storm lines, but from agricultural runoff and urban runoff as well. Therefore, the impacts of the proposed treatment will prove highly beneficial to the water quality further downstream of Juday Creek.

Site 8

Site 8 is the intersection of Grape Road and Juday Creek (Appendix H). There are point source discharges at the northwest, southwest and southeast corners. The storm line to the north begins at University Park Shopping Center and runs south along the east side of the road. Then several hundred feet prior to the creek, the line goes under Grape Road to the west side and continues to the edge of the stream. The lines carrying runoff on the south side of the stream extend to McKinley Boulevard.

The diameter of the pipes indicate the storm lines carry a significant amount of runoff from roads and development. Grape Road has been a source of heavy commercial development, which is expected to continue upstream. This development has caused significant reduction in the availability of permeable land. The increase in pavement, roads and roofs have escalated the amount of runoff that occurs during storm events. Also, some commercial developments do not have adequate stormwater handling facilities increasing the volume of water the storm lines must handle.

All four corners of the intersection have suitable topography and land available. The northwest and northeast corners are potential sites for treating the storm line to the north of Juday Creek. Since the storm line crosses Grape Road, either site may be used but only one is necessary.

The storm line at the southeast corner discharges approximately 100 feet south of Juday Creek. The distance from the outlet to the stream has been heavily vegetated with cattails, bulrush and other wetland vegetation. This vegetated strip is currently providing treatment of stormwater runoff.

Grape Road and many associated acres of impervious land increase the temperature of runoff due to solar radiation. Therefore, thermal reduction becomes a significant factor at this site. Also, the high concentration of contaminants and nutrients present in stormwater must be confronted as well.

Treatment Area A

The storm line would be directed into a sediment trap for phase I of reducing pollutants. Next, the runoff would flow to a primary filtration strip. The flow is directed through the vegetated strip via earthen berm. The runoff would then spill into a deep detention basin. The basin would be approximately ten feet deep to allow the cold water to fall out due to higher density. A bottom water discharge would be installed to carry the cooler water to Juday Creek.

The sediment trap and filtration strip would be planted with wetland vegetation to increase efficiency. The detention basin would be planted with native shade trees to aid in the reduction of exposure to solar radiation.

Treatment Area B

The storm sewer would be directed into a sediment trap for initial handling of stormwater. From there the runoff would travel through a vegetated strip that is slightly graded to direct hydrology into the existing wetland. The wetland would be intensified by pushing up a berm and installing a weir flow outlet. These structures increase the residence time of runoff and regulate the elevation within the wetland.

The water elevation in the wetland would be approximately one to two feet in order to sustain wetland vegetation. Additional vegetation would be recommended to increase sieve-like action and provide habitat. Shading trees are recommended for planting along the stream for canopy and additional habitat.

This treatment area is limited in space due to an access road and development. Therefore, it was not feasible to design a deep detention pond for thermal reduction. However, additional shade trees were suggested to provide some treatment for this limited area.

Treatment Area C

The storm lines would initially be routed to sediment traps to handle the first flush of contaminants. The runoff would then travel through a filter strip before discharging into a deep detention basin. The basin contains a bottom water discharge pipe which would release colder water from the bottom.

The basin has been designed in a linear fashion to reduce the width of the surface area. The edge of the pond would be planted with native shade trees, forming a canopy over the linear area to aid in reducing thermal pollution.

The storm lines associated with Grape Road carry a significant amount of runoff which makes retrofitting an important design concept for this area. The availability of land and flat topography allow for treatment of all primary functions. Comparing water quality improvement effectiveness to cost effectiveness, this site is primary location for retrofitting storm lines.

Site 9

Site 9 is the intersection of Main Street and Juday Creek (Appendix I). Storm lines have a point source discharge at the northeast and southeast corners of the intersection. The pipes have a positive outlet that discharges directly into Juday Creek.

Development is beginning to spread from Grape Road to Main Street and continuing west. Extension of west bound roads from Grape has increased the amount of runoff present at this location. However, new development has and future development will be regulated by county storm detention regulations. The county is requiring development projects to handle storm water runoff on site.

It is still necessary to treat runoff from roads that have been captured by storm sewer lines. The runoff would be carrying contaminants but the volume of water being handled is reduced by on site treatment.

Treatment Area A &B

The storm line would outlet into a sediment trap that would capture the initial surge of contaminants. The water would then spill over into a man made wetland created by a berm and an outlet control structure. These mechanisms would provide additional residence time of the runoff before spilling over the notch structure into Juday Creek.

A baffle has been proposed in the wetland to direct the flow of hydrology in a parabolic path instead of a linear route to the creek. This aides in increasing the occupancy time of the water in the manmade wetland. The wetland would be improved by providing a heavy population of hydric vegetation.

The treatment areas were intensely farmed in the years passed which lead to clearing of land. Therefore, very little permanent vegetation exists in this stretch of the creek. It is recommended that several native trees and vegetation be planted along the creek for protection from solar penetration which contributes to increased stream temperatures.

These retrofitting sites are less involved than treatment areas further downstream but still play an important role. Construction costs would be economical and effective results would be achieved through stormwater treatment.

Site 10

Site 10 is the intersection of Edison Lakes Parkway and Juday Creek (Appendix J). The only known point source storm line is at the southeast corner of the intersection. The southwest corner has a gully formed by channelized flow along an agricultural field running to Juday Creek.

The Edison Lakes Parkway development has been regulated by St. Joseph County storm detention regulations. Therefore, the runoff from parking and buildings is being handled on site. The stormwater from development has been cared for in the original site design unlike downstream where no regard for increased runoff was given thus creating the need for retrofitted storm lines.

However, the need for handling storm runoff from roads and adjacent agricultural fields prior to entering Juday Creek still exists. Improvement techniques should be examined to improve the quality of water in order to reduce the snowball effect of pollutants that occur moving downstream.

Treatment Area A

The presence of a gully leading to the stream indicates the advanced stages of channel flow. A sediment trap containing vegetated strips has been proposed to combat the effects of gully erosion. The trap would serve to reduce the velocity at which the runoff is traveling to the stream. The plants would act as a sieve for silt deposits acquired from agricultural and urban runoff. Also, the vegetation can uptake the overabundance of nutrients present in the water.

Major clearing of trees and vegetation has occurred from agricultural practices throughout this region. It is recommended to plant native vegetation and trees along the stream for shading, habitat and stabilization of banks.

Treatment Area B

The storm line would be directed to discharge into a sediment trap for preliminary phase of treatment. The runoff would then travel to a manmade wetland for final cleansing of stormwater. The wetland would be created by pushing up an earthen berm which contained a notch structure which serves as a spillway for stormwater to enter the creek.

A baffle is proposed in the wetland to extend the route at which hydrology would flow. This would increase detention time and provide additional filtering of stormwater. These are important factors in the treatment of sedimentation and nutrient loading.

Again, the wetland and associated berms would need heavy plantings of trees and hydric vegetation. Plantings would assist in the filtering process and reduction of exposure to sunlight. Also, the anchoring of plants and trees provide stabilization of stream banks which reduce scouring and erosion.

These treatment areas would be easy to construct and provide a significant benefit to the overall quality of Juday Creek. The treatment designs will be a nice compliment to the existing systems of storm detention ponds.

Site 11

Site 11 is the intersection of Fir Road and Juday Creek (Appendix K). Upon investigation of the site, the only storm line discharging directly to the stream was at the southwest corner of the intersection. The pipe had a 12" diameter which indicates a relatively low carrying capacity.

The availability of land in close proximity to the stream is very limited in this area. The only possible treatment area is on the northeast corner of the intersection. As evident by pipe dimensions, there is not a large volume of water being handled. This would not constitute a major retrofitting design. Also, this stream location is not in need of urgent care in comparison to sites further downstream. The Fir Road crossing is fairly close to the headwaters of Juday Creek, therefore, significant amounts of sediments and nutrients have not had a chance to accumulate.

However, being closer to the headwaters does not mean the site should be neglected. There are some simple preventative methods to improve the stream that are not labor intensive or costly. The stream banks should be planted with vegetation to anchor the sediment and reduce scouring and erosion. The vegetation would also uptake nutrients and provide habitat beneficial to the creek. Also, interplantings of native trees would aid in reducing the exposure of sunlight on the stream causing temperatures to rise.

Site 12

Site 12 is the 'T' intersection of Capitol Avenue and Cleveland Road (Appendix L). Open ditches are along the east and west sides of Capitol Avenue and run north to south. The ditches run under Cleveland Road via 18 inch corrugated metal pipes and continue to a west to east ditch. The water flows through a series of agricultural ditches that eventually feed into Juday Creek. The 18 inch culverts are presently filled with gabion rocks that virtually seal off the pipes.

The clarity of the water is very low indicating a high concentration of sediments and other pollutants. It is recommended that silt traps be placed in the ditches just prior to outflow into Juday Creek. Therefore, the larger sediments that have been carried by the water would settle out in the traps instead of the creek. The presence of vegetation in the trap would help to reduce the velocity and uptake some of the nutrients present in the water.

PERMITTING

As with any project of this nature several permits will be required prior to construction. The primary agencies involved are the Army Corps of Engineers, Indiana Department of Environmental Management, Indiana Department of Natural Resources (IDNR) and St. Joseph County Drainage Board.

The U.S. Army Corps of Engineers has jurisdiction over streams and wetlands essentially all work within Juday Creek and associated wetlands will have to be permitted under Section 404 of the Clean Water Act. The U.S. Environmental Protection Agency, U.S. Fish & Wildlife Service, Indiana Department of Natural Resources, and local environmental groups and citizens will have the opportunity to comment on any permit application. Additionally, water quality certification from the Indiana Department of Environmental Management will also have to be obtained as required under Section 401 of the Clean Water Act.

The IDNR has jurisdiction over any construction within the floodway portion of a site through Indiana Code 13-2-22 (1945 Flood Control Act). This would include the construction of berms, sediment traps, manmade wetlands, outlet structures and detention basins. To qualify for a floodway permit from the IDNR, the proposed project must meet the following standards:

a.) The project does not restrict the carrying capacity of the floodway or cause increased flood hazards.

b.) The project does not result in an unreasonable risk to life or property.

c.) The project does not result in an unreasonably detrimental impact on fish, wildlife and botanical resources.

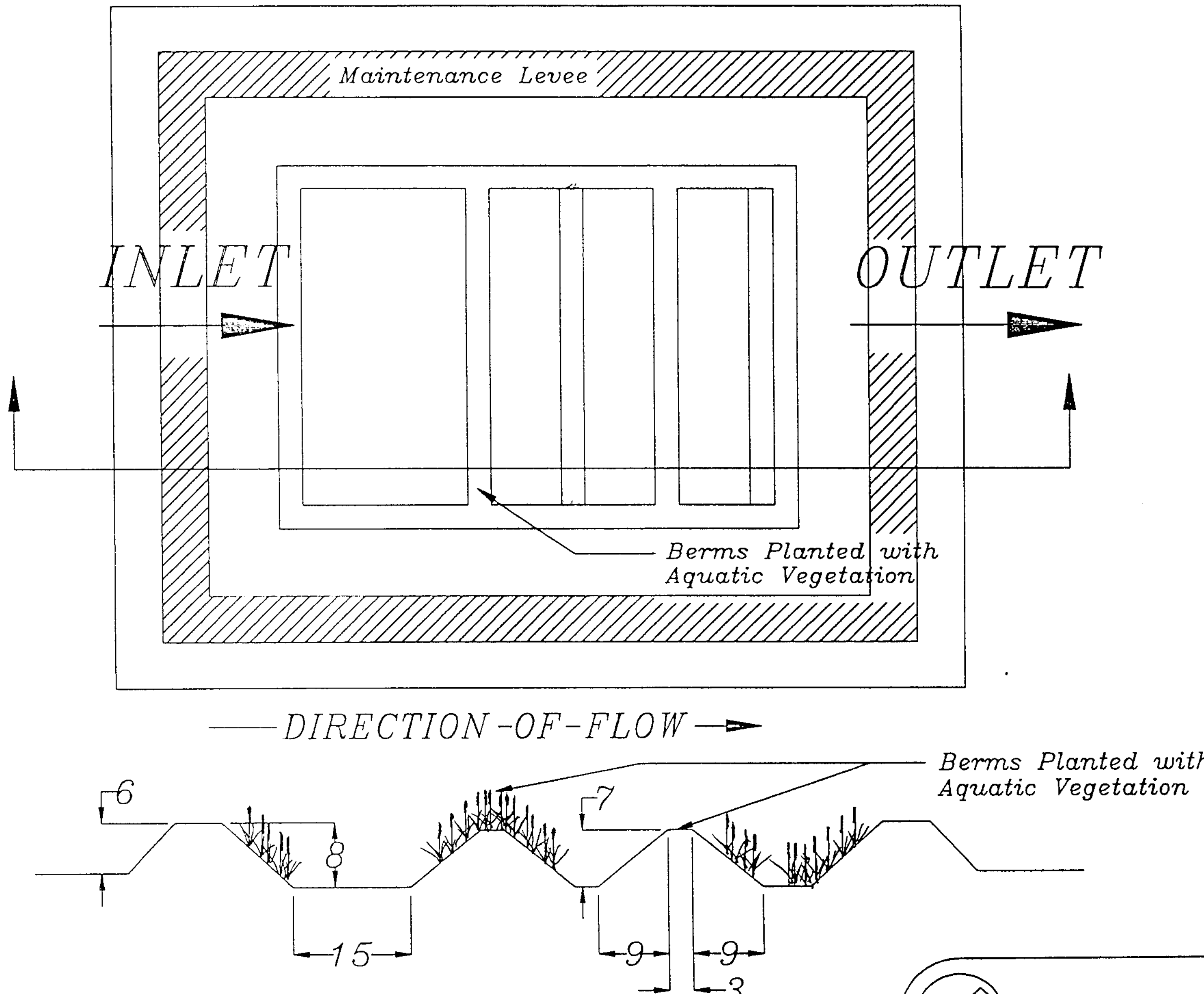
The IDNR has detailed technical standards to be followed in both the initial floodplain data development phase and subsequent proposed project assessment of the phase of the computer flood model.

SUMMARY

This stormwater discharge feasibility study represents an innovative effort by St. Joseph County to improve the water quality in Juday Creek through the use of engineering and biological solutions. Although the study is conceptual in nature, its findings demonstrate a number of potential solutions to moderate the negative impacts of urban and agricultural stormwater discharge.

As with any project, a cost benefit analysis must be considered prior to proceeding with design and construction solutions. Even with the prioritization of twelve sites and the use of existing wetlands and ponds, there are certainly some sites discussed in this report which may not be economical or feasible for a variety of reasons. Further prioritization will need to be done including investigation of land acquisition costs, construction costs, existing utility restrictions, and permitting feasibility.

In summary, there are exciting opportunities available for St. Joseph County to pursue in improving the quality of stormwater inflows to Juday Creek. In combination with watershed management efforts, the implementation of point source treatment systems could have a significant impact on the quality of Juday Creek as a recreational, aesthetic, and functional resource. Based on these opportunities, we recommend choosing a top priority site from a cost benefit standpoint to be pursued for design and construction. Monitoring of this "pilot" system will provide data as to the measurable benefits provided from the project and the value of pursuing additional sites.



Typical Sediment Trap (Plan and Section)
Scale: 1"=20'

J.F. New & Associates, Inc.
708 Roosevelt Road
P.O. Box 243
Walkerton, IN 46574
Phone: 219-586-3400
FAX: 219-586-3446
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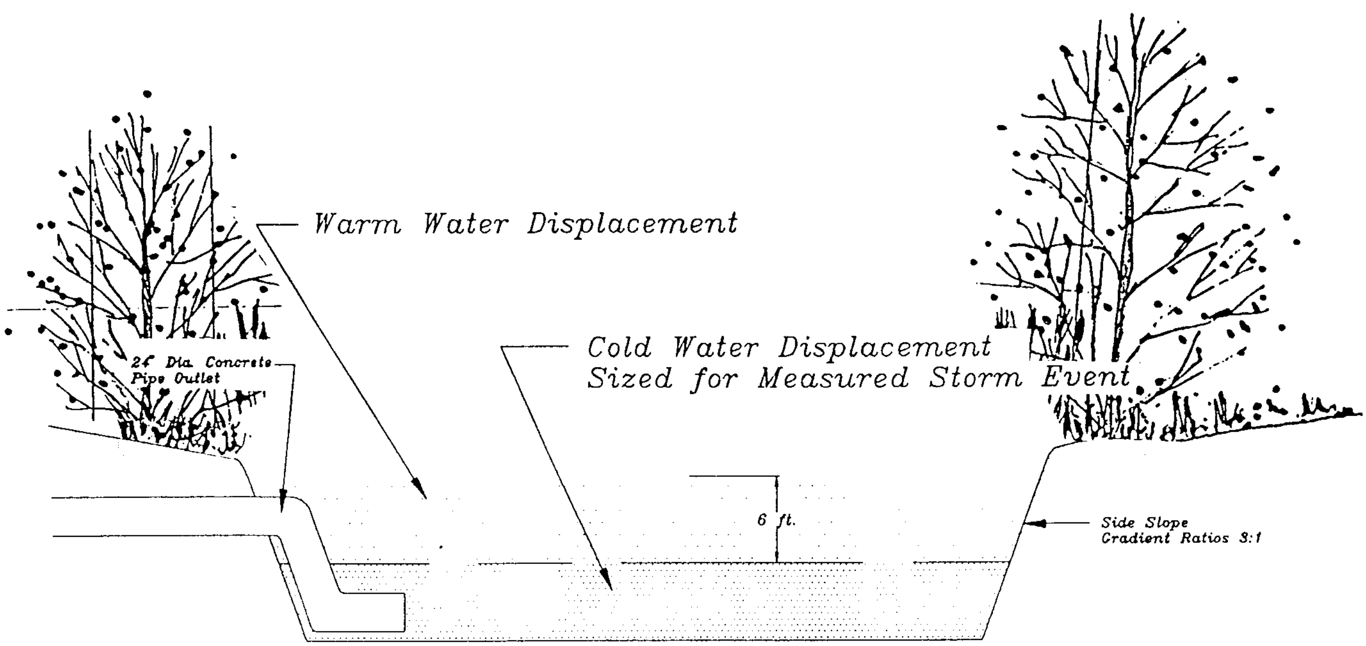
Figure 1



Typical Section of Cold Water Discharge
Not to Scale

Figure 2

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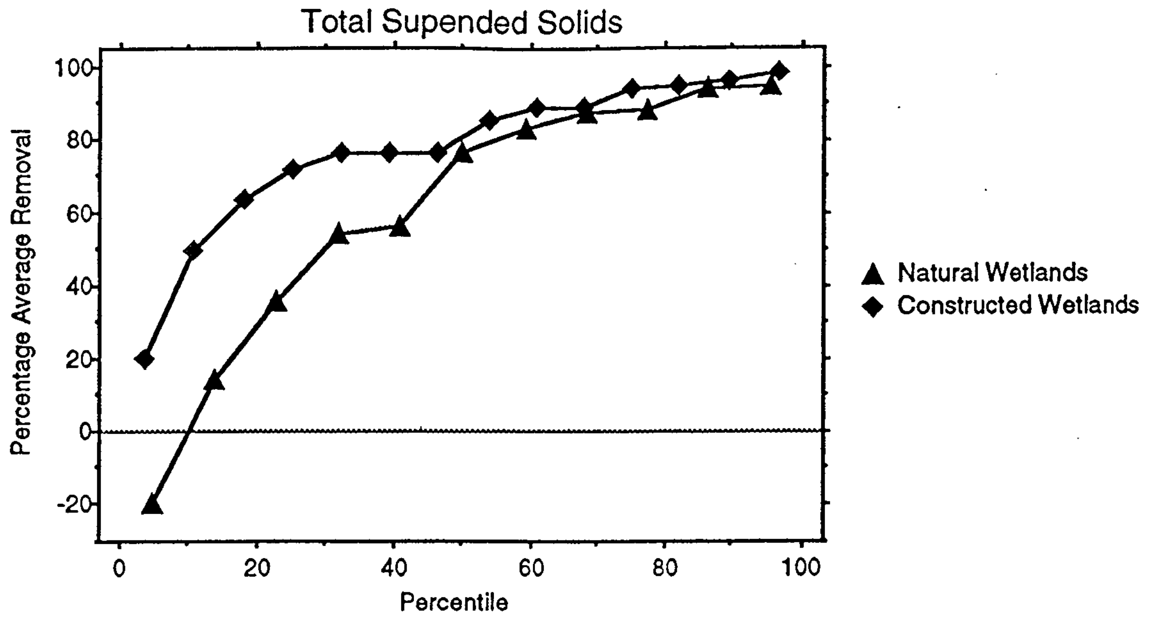

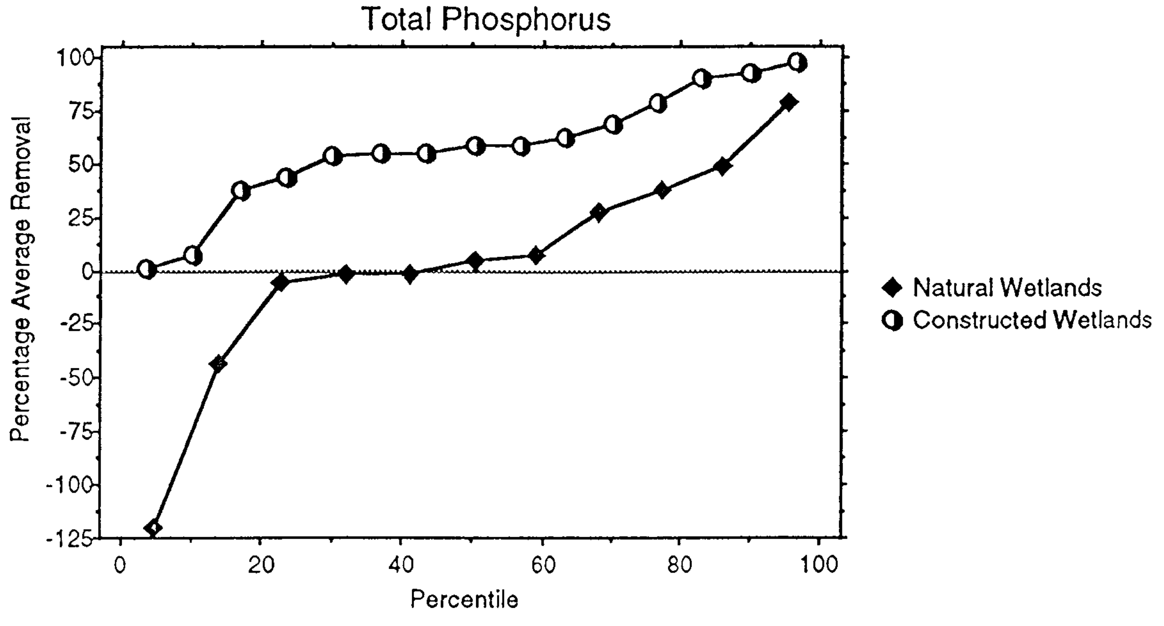

*Source: The Use of Wetlands for Controlling Stormwater Pollution. 1992.

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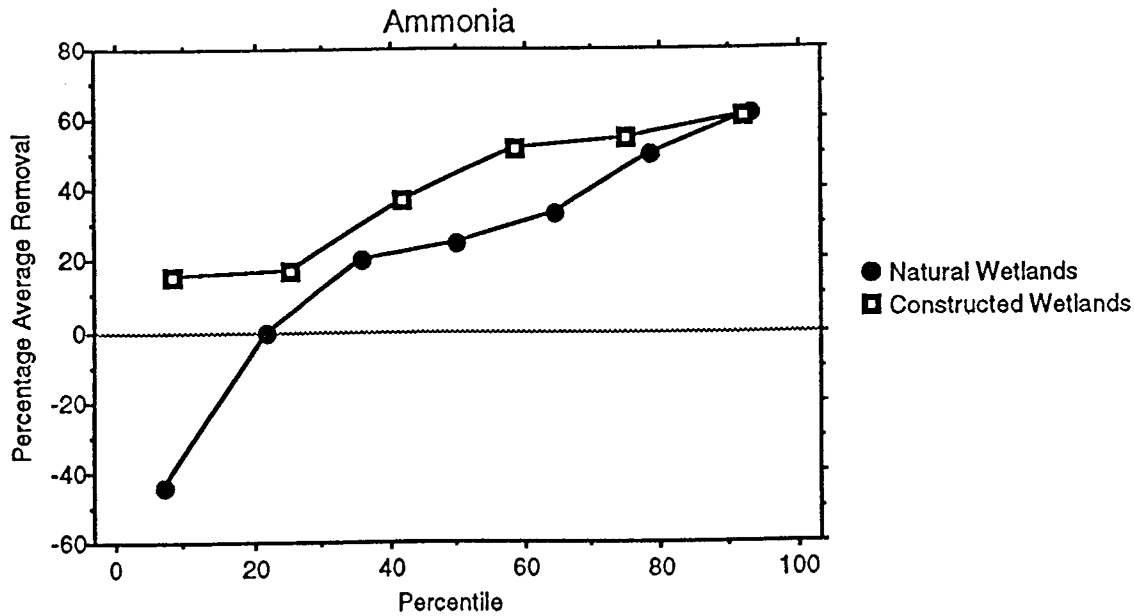
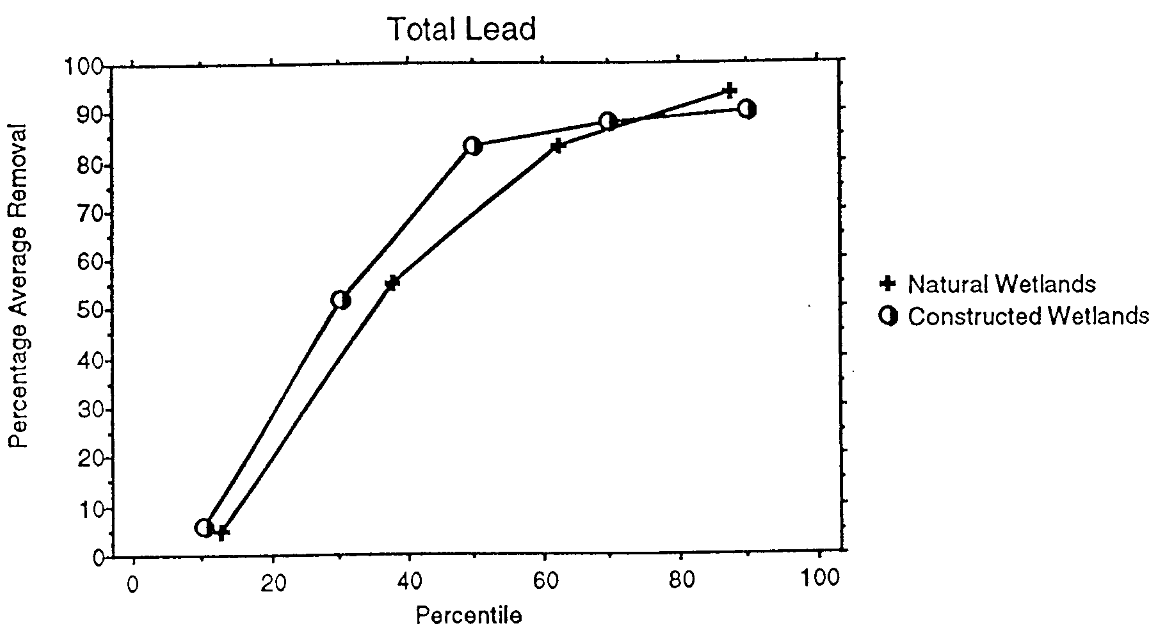
Figure 3A





*Source: The Use of Wetlands for Controlling Stormwater Pollution. 1992.

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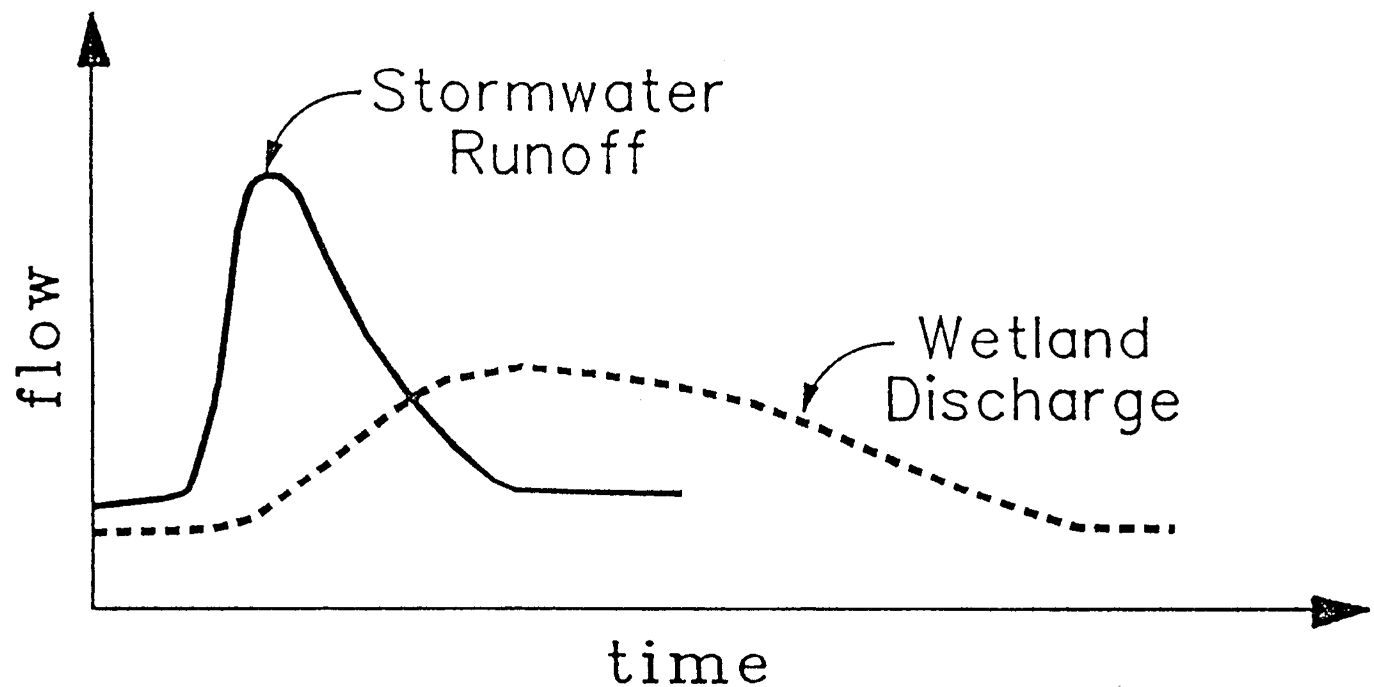
Figure 3B



*Source: U.S. Environmental Protection Agency. 1990. Use of Wetlands in Stormwater Management.

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Figure 4

FUNCTIONS OF PROPOSED TREATMENT AREAS

SITE	THERMAL MODERATION	SEDIMENT FILTER	NUTRIENT FILTER	EROSION CONTROL	FLOOD RELIEF
1-A	✓	✓	✓	✓	✓
4-A	✓	✓	✓	✓	✓
4-B		✓	✓	✓	✓
5-A		✓	✓	✓	✓
6-A	✓	✓	✓	✓	✓
6-B		✓	✓	✓	✓
7	✓	✓	✓	✓	✓
8-A	✓	✓	✓	✓	✓
8-B		✓	✓	✓	✓
8-C	✓	✓	✓	✓	✓
9-A		✓	✓	✓	✓
9-B		✓	✓	✓	✓
10-A		✓	✓	✓	
10-B		✓	✓	✓	✓
12		✓	✓	✓	

NOTE: No treatment areas are available at Sites 2, 3 and 11.

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Figure 6

Limno-Tech, Inc.
Environmental Engineering
2395 Huron Parkway
Ann Arbor, Michigan 48104

Cole - Roger Nawrot

EVALUATION OF POTENTIAL IMPACTS ON JUDAY CREEK FROM PROPOSED DETENTION BASINS

Prepared by:

LTI, Limno-Tech, Inc.
Ann Arbor, Michigan

Prepared for:

St. Joseph County Drainage Board
South Bend, Indiana

October 23, 1991

TABLE OF CONTENTS

SUMMARY

A storm water detention basin was proposed to be built on Juday Creek for flood control. Limno-Tech, Inc. (LTI) conducted field monitoring and a modeling analysis to investigate the possible impacts of this basin on Creek temperatures and the brown trout population downstream. The modeling analysis included simulations of water temperature changes due to the proposed detention basin under normal and storm flows.

This evaluation demonstrated that the proposed detention basin would cause Creek temperatures to exceed State Water Quality Standards during the more restrictive spring imprinting period and during peak summer conditions. Predicted temperature increases exceeded both the maximum temperature limits and allowable temperature increases over natural conditions. Predicted temperature increases due to the proposed detention basin in the downstream area of trout habitat were similar under normal flows and storm flows. Storm flows did result in higher predicted temperatures in the middle sections of the study area.

INTRODUCTION

Construction of storm water detention basins on Juday Creek has been proposed for the purpose of flood control. The proposed detention basins are wet ponds that will contain water at an average depth of seven feet during non-storm periods. Depending on meteorological conditions and times between storms, temperatures in these ponds could become elevated above those in Juday Creek, and water flowing out of these basins could influence the temperature regime of Juday Creek. As Juday Creek supports a resident, reproducing trout population in the downstream reaches, concerns have been expressed about the potential for elevated temperatures that may affect continued trout viability.

SCOPE

Limno-Tech, Inc. (LTI) conducted an assessment of potential impacts on Juday Creek due to discharges from the proposed storm water detention basin. The assessment focused on temperature impacts, and included field monitoring and computer modeling of water and temperature in Juday Creek and the proposed detention basin. A field monitoring program examined flow, temperature, dissolved oxygen, nutrients, chlorophyll *a*, and sediment oxygen demand. Modeling was conducted to predict potential temperature impacts on the creek from the proposed detention basin. Data from the monitoring and the modeling were then examined to determine if there would be any detrimental impacts to the trout fishery in the creek. Water quality data were qualitatively assessed to evaluate the potential for adverse impacts besides temperature.

SITE DESCRIPTION

Juday Creek originates in Cass County, Michigan and flows south and west for 12 miles, entering the St. Joseph River near South Bend, Indiana. Almost 80% of the 37-square mile Juday Creek drainage area lies in St. Joseph County, Indiana. The relatively flat upper sections of the stream drain agricultural land. The lower half of the stream has a steeper gradient and drains primarily residential and urban areas. The last half-mile flows through forested property owned by the Izaak Walton League. The section of Juday Creek examined for this study was the reach between the location of the proposed detention basin upstream of Fir Road to the mouth of the Creek (Figure 1).

Juday Creek is one of the few streams in Indiana to support a resident, naturally reproducing brown trout population. While the best habitat is within the Izaak Walton League property, areas of suitable substrate with fish are found upstream to Ironwood Road, 3.4 miles above the mouth of the creek. A silt trap on the Creek prevents migration of other species of trout and salmon farther than one-half mile up the creek.

CRITICAL CONDITIONS

Critical conditions were selected at which the combination of biological, climatic, and hydrological factors would most likely cause the specified parameter to exceed the water quality standard under consideration. For temperature modeling of Juday Creek the critical conditions are the periods when stream and climatic conditions, examined at peak temperatures and at vulnerable periods in the trouts' life cycle, have the greatest probability of affecting trout survival.

The scientific literature and Indiana's Water Quality Standards were reviewed to determine critical stream temperatures and periods for brown trout survival. The review of scientific literature (Attachment A) determined that adult brown trout mortality would be caused by exposure for more than 24 hours to a stream temperature of $76^{o}F$ in spring and $80^{o}F$ in summer. Indiana Water Quality Standards were designed to protect trout eggs and young fish as well as to allow for healthy trout populations. Since the proposed detention basins will have to comply with State regulations, the State standards were used as critical temperatures in this analysis. Indiana's Water Quality Standards designate Juday Creek as a salmonid water that is protected for cold water fish (Title 327 IAC 2-1-6(c) (1) (F)). For these waters the State standards (Title 327 IAC 2-1-6(c) (3)) specify water temperature limits that prohibit:

- temperatures above $70^{o}F$
- temperatures above $65^{o}F$ during spawning and imprinting periods
- temperature rises of more than $2^{o}F$ above natural conditions

For streams where temperatures naturally rise above $70^{o}F$, or $65^{o}F$ during spawning and imprinting periods, the IDEM's standard procedure is to not allow any additional temperature increase above what occurs naturally (Dennis Clark, IDEM, personal communication, 1991).

Based upon a review of climatic and hydrologic conditions, two months were selected at which the critical temperatures were most likely to be exceeded. Brown trout spawn in the late fall, when stream temperatures are expected to be below the State's $65^{o}F$ standard. However the eggs hatch and the young fish are vulnerable to high temperatures in the spring. May was selected as the most likely month in which environmental conditions would create the warmest stream temperatures while young fish are still susceptible to higher temperatures, thus the more restrictive $65^{o}F$ limit would apply. July is the most likely month of the year that the $70^{o}F$ maximum stream temperature limit would be exceeded. The limit of a $2^{o}F$ artificial rise in stream temperature was evaluated for both months.

DATA ASSESSMENT

Historical Data

No previous studies of Juday Creek have measured temperature and flow over the entire study area. Previous studies, mostly by University of Notre Dame researchers, have focused on the lower portion of the stream containing the trout population, with apparently few studies conducted upstream of Ironwood Road. The University of Notre Dame's aquatic ecology class has periodically measured water quality, and the USGS obtained occasional flow measurements near U.S. Highway 31 during the 1970's (Schwenneker, 1985).

Field Monitoring

The existing data base for Juday Creek was not extensive enough for conducting the modeling evaluation, and a limited field monitoring program was implemented to provide the necessary data. Dr. Martin B. Berg, of the University of Notre Dame, and LTI conducted surveys on May 14 and July 30, 1991. Five Creek locations were selected along the area that would be affected by the proposed basins (Figure 1):

Location	Miles from Mouth
Fir Road	6.5
outflow of Lakeshore Estates Pond	4.4
Douglas Road	3.4
bridge upstream of Juniper Road	2.2
U.S. 31	1.5

The Lakeshore Estates Pond was included since conditions in the pond may resemble those in the proposed detention basins. At each location depth, width, flow, dissolved oxygen, and temperature were measured. Water samples were analyzed for total phosphorus and soluble orthophosphate (nutrients necessary for plant and algal growth) by EIS, Inc. of South Bend. Water samples were also analyzed for chlorophyll *a* concentrations (an indicator of algal growth) at the University of Notre Dame. Dr. Stephen E. Silliman of the University of Notre Dame conducted longitudinal Creek temperature surveys throughout the summer, as well as temperature monitoring of the Lakeshore Estates pond and monitoring of stream water and sediment temperatures. Continuous temperature monitoring was not possible in the Lakeshore Estates pond because of the risk of vandalism to equipment. LTI measured sediment oxygen demand (SOD) in the Lakeshore Estates pond on July 30, 1991 to determine possible impacts of the detention basins on dissolved oxygen levels in the basins and the Creek.

The longitudinal temperature and flow surveys conducted throughout the summer (Attachment B), and temperature and flow measurements during the spring and summer surveys (Attachment C) support the following conclusions;

1. The lower sections of Juday Creek, including the area of trout habitat, exceeded State temperature limits. The spawning/imprinting period limit of 65^oF was exceeded during late May, and the 70^oF limit during late June and all of July.

2. Juday Creek apparently gains significant flow from ground water along the reach from Bittersweet Road through the inflow to Lakeshore Estates pond,

3. The Creek is apparently neutral and/or loses water to the ground water from the outflow of this pond through the bridge on the Izaak Walton League property (located off of Darden Road),

4. The Creek gains substantial ground water via springs along the lower reach of the Izaak Walton League property,

5. The pond at Lakeshore Estates has provided consistent warming of the creek water, approximately 2^oF, throughout June and July.

Flows measured at U.S. 31 are similar, although slightly higher, than USGS-measured flows taken from 1973 to 1978 for the same season (Schwenneker, 1985).

Ground water inputs are vital to the ecology of the stream system. Ground water temperature ranges from approximately 53^oF to 57^oF, and this cold water inflow counters the water temperature increases caused by solar radiation. Water temperature in the Creek drops as it flows through sections where there is substantial ground water inflow. In sections where the Creek is losing water to the ground water table or is neutral, water temperature remains constant or increases due to the warmer ambient air temperature and to solar inputs. The buffering of the stream temperature by ground water enables trout to survive in Juday Creek. Even with this buffering, Juday Creek is a marginal trout stream with respect to temperature. Stream temperatures exceeded the 65^oF State temperature that would be likely to apply in May (Figure 2). The maximum temperature limit of 70^oF was exceeded during late June and all of July (Figure 3, Figure 4). The highest temperature measured was 75^oF, which was below the 80^oF temperature determined from the literature search to cause adult mortality.

Dissolved oxygen, nutrients, and chlorophyll *a* concentrations in Juday Creek were typical for a small stream (Attachment C). Dissolved oxygen concentrations were high for both surveys, which is expected in a small, turbulent system. The spring phosphorus concentrations were analyzed with too high of a detection limit to provide much information other than that concentrations were not excessive. The summer survey found total phosphorus concentrations ranging from 0.08 to 0.13 mg/L, increasing towards the downstream stations. These concentrations are within the expected range for a stream flowing through an agricultural and urban area, and are similar to the limited previous data that are available (Schwenneker, 1985). Soluble orthophosphate concentrations were below the laboratory detection limit in summer. Chlorophyll *a* levels were low at all sites except for those immediately downstream of the Lakeshore Estates pond. Concentrations were high coming out of the pond, but quickly dropped at the downstream stations. There was evidence of sediment accumulation in the Creek. Sediment accumulation in the area of trout habitat has increased within the last 5 to 6 years (M. Berg, personal communication). However, as construction activities decreased in the last year, sediment has been flushed out of some sections. Attachment F contains some observations of general watershed conditions. Overall, the surveys of Juday Creek found acceptable water quality. These surveys were conducted under dry weather conditions however, and it is likely that substantial increases in nutrients and sediment occur during higher flows from storm runoff.

Sediment oxygen demand (SOD) in the Lakeshore Estates pond averaged 4.0 $g/m^2/day$ @ 20^oC (Attachment D). This value is toward the high end of the expected range for lakes and streams (Bowie *et al.* 1985). This oxygen demand is probably caused by organic materials from upstream areas settling out in the pond, and similar values are likely in the proposed detention basins. Under a long period of hot weather with little wind, a serious depletion of dissolved oxygen could occur in the basins, affecting fish in the basin and possibly resulting in a release of nutrients downstream.

TEMPERATURE MODELING

Approach and Assumptions

The primary focus of this study was to evaluate the possible changes in stream temperature that would occur if the proposed detention basin was constructed. The only basin considered was the Fir Road Pond. Design specifications for this detention basin were those from the *Final Report on Detention Basin Study for Juday Creek East of Grape Road, St. Joseph County, Indiana* by Cole Associates, Inc. This basin was proposed to be built on Juday Creek between Fir Road and the Grand Trunk Railroad trestle. The basin was designed as two wet ponds covering approximately 60 acres, having an average depth of 7 feet under normal flow conditions. The pond would hold an additional 2 feet of storm water, releasing the extra flow to Juday Creek at a maximum of 53.2 cfs.

The U.S. EPA-supported model QUAL2E was selected to model the temperature impacts of the proposed detention basin (Brown and Barnwell 1987). The model was run at steady state, which is acceptable for a small stream that tends to quickly stabilize. Juday Creek is a relatively small, shallow stream, and thus is very sensitive to environmental conditions such as weather, flows, and ground water interactions. This sensitivity must be kept in mind when interpreting results from a steady state model of such a system.

The model was calibrated to the May 14, July 16, and July 30, 1991 survey results (the spring and summer surveys, and one of the longitudinal temperature surveys). Stream geometry was based upon survey data, and other model parameters were chosen from literature. A more complete description of the model and calibration is included in Attachment E.

After QUAL2E was calibrated, model scenarios were run to predict the changes in stream temperature that would occur under certain conditions if the proposed detention basin was constructed. Three model runs were evaluated for each of the chosen critical months:

- baseline conditions
- baseline conditions with the detention basin
- storm flow conditions with the detention basin

Baseline conditions were chosen as the flows and temperatures found during the field surveys and average climatic conditions for the month. While it would be preferable to model a worst case, standard $_7Q_{10}$ low flow, the complex hydrology of Juday Creek makes modeling of flows unreliable without specific field data. Under the summer 1991 flows of 14 to 23 cfs, the upper sections of the stream gained water from ground water, the middle sections lost water to ground water, and the farthest downstream section again gained water. The ground water contribution to the total flow has a profound effect on moderating stream temperatures. Without field data during an actual once-in-10-year drought it is impossible to predict if this hydrologic pattern will exist or if the ground water inflow would change under a $_7Q_{10}$ low flow of 2.4 cfs (from Schwenneker, 1985). The simulations with the proposed detention basin were also conducted with 1991 survey conditions. The storm flow was assumed to be that from a once-in-3-year storm, released from the proposed detention basin at its design rate of 53.2 cfs. It was also assumed that the proposed detention basin and storm flows would not have an effect on ground water flows.

Results

In the modeling runs for May conditions, scenarios with the proposed detention basin resulted in temperatures exceeding the State's 65^{o}F standard (Figure 5). The modeled baseline stream temperature stayed below 65^{o}F, although approached it near the stream mouth (while field measurements in late May exceeded 65^{o}F, the model represents average monthly conditions). Adding the detention pond to the simulation increased water temperatures over the 65^{o}F criteria along the entire stream. Stream temperatures in the vicinity of the detention basin increased over 6^{o}F. The warmer basin water cooled as it mixed with ground water downstream, but projected temperatures near the beginning of the trout habitat at Ironwood Road were still 2.5^{o}F over the baseline. One-half mile from the Creek mouth temperatures were still nearly 2^{o}F warmer. When storm flow was added to the simulations, predicted stream temperatures in the trout habitat area ranged approximately 1.5-3^{o}F higher than baseline temperatures. While the storm flow simulation did not greatly increase temperatures in the area of trout habitat above those of the simulation with the basin only, temperatures in the middle sections of the Creek did not fall as quickly due to increased storm flow volumes.

All three simulations for July exceeded the 70^{o}F State Water Quality Standard (Figure 5). The baseline simulation was calibrated to field data that exceeded 70^{o}F in the lower sections of the Creek. When the detention basin was added to the model runs, with and without storm flow, predicted stream temperature increased above 70^{o}F for nearly the entire Creek downstream of the detention basin. These increases were approximately 7^{o}F near the basin, 1.5-2^{o}F at the upstream boundary of the trout habitat, and 1^{o}F warmer than baseline near the stream mouth. Temperature changes with distance downstream were similar to those of the May simulation, with the storm flow maintaining elevated temperatures through the middle sections of the Creek.

CONCLUSIONS

The field surveys and modeling analysis indicate that, based upon current IDEM standard practice, the proposed detention basin would cause unacceptable temperature increases in Juday Creek. The field surveys found that the Lakeshore Estates pond increased water temperatures $2^{o}F$ between inflow and outflow. The proposed detention basin has the same depth but a much greater surface area than the Lakeshore Estates pond, and would be expected to raise the Creek temperature more than the $2^{o}F$ allowed by State standards for salmonid waters. The modeling analysis also shows that the proposed detention basin, under dry weather as well as storm flow conditions, would increase Creek temperatures more than the $2^{o}F$ allowed. Although sections of the Creek currently exceed maximum State water temperature limits for cold water fish, the proposed basin would increase water temperature in additional sections above the applicable State limits during both the more restrictive spring period and the peak of summer. The proposed detention basin would not raise stream temperatures to levels that would cause trout mortality under the relatively normal stream conditions modeled. However, under drought conditions the increase in stream temperatures due to the proposed detention basin may be significantly greater. A complete ground water survey and a field survey under near-drought conditions would be necessary in order to make reliable projections under more extreme conditions.

State Water Quality Standards do not specifically address several situations unique to Juday Creek. Where the Standards do not specifically apply the IDEM has standard practices that it follows. While these practices would allow State standards to be met for some situations, the standards would still not be met in all locations.

Technically, the State Water Quality Standards designate the entire length of Juday Creek in Indiana as protected for trout. However, only the lower 3.4 miles of the Creek actually have a trout population. If previous documentation exists, the IDEM may only consider the sections of the river currently inhabited by trout as protected for trout and salmon, and thus the cold water standards would only apply to the lower sections of the Creek. This would allow the middle section of the study area to meet the less restrictive standards for non-salmonid waters. However, the section immediately downstream of the proposed detention basin had predicted temperature increases of 6^{o}-$7^{o}F$ over natural conditions, exceeding the $5^{o}F$ increase allowed for non-salmonid waters (Title 327 IAC 2-1-6(b)(4). During the forecasted July storm flows Creek temperatures would increase greater than the allowable $5^{o}F$ for up to 2.6 miles downstream of the detention basin.

Violations are also predicted in the trout habitat downstream of Ironwood Road, where the more restrictive standards for salmonid waters would apply. The May simulations indicated that the proposed detention basin would increase stream temperatures enough to violate both the $2^{o}F$ increase limit and the $65^{o}F$ maximum temperature. Storm flows from the pond would cause similar violations. During July, the proposed basin would not increase stream temperatures much more than $2^{o}F$ in the area of trout habitat. However, the baseline temperature already exceeds the 70^{o} standard, and IDEM standard practice is to not allow any additional temperature increase above natural temperatures in these cases.

RECOMMENDATIONS

It is unlikely that the proposed detention basin will meet current State Water Quality Standards and IDEM interpretation of these standards. The County may want to investigate the feasibility of "dry storage" for floodwater detention. A dry pond could provide the same floodwater and sediment control of a "wet pond", yet would not increase stream temperatures. Dry retention may or may not have the aesthetic attraction of a wet pond, depending on construction.

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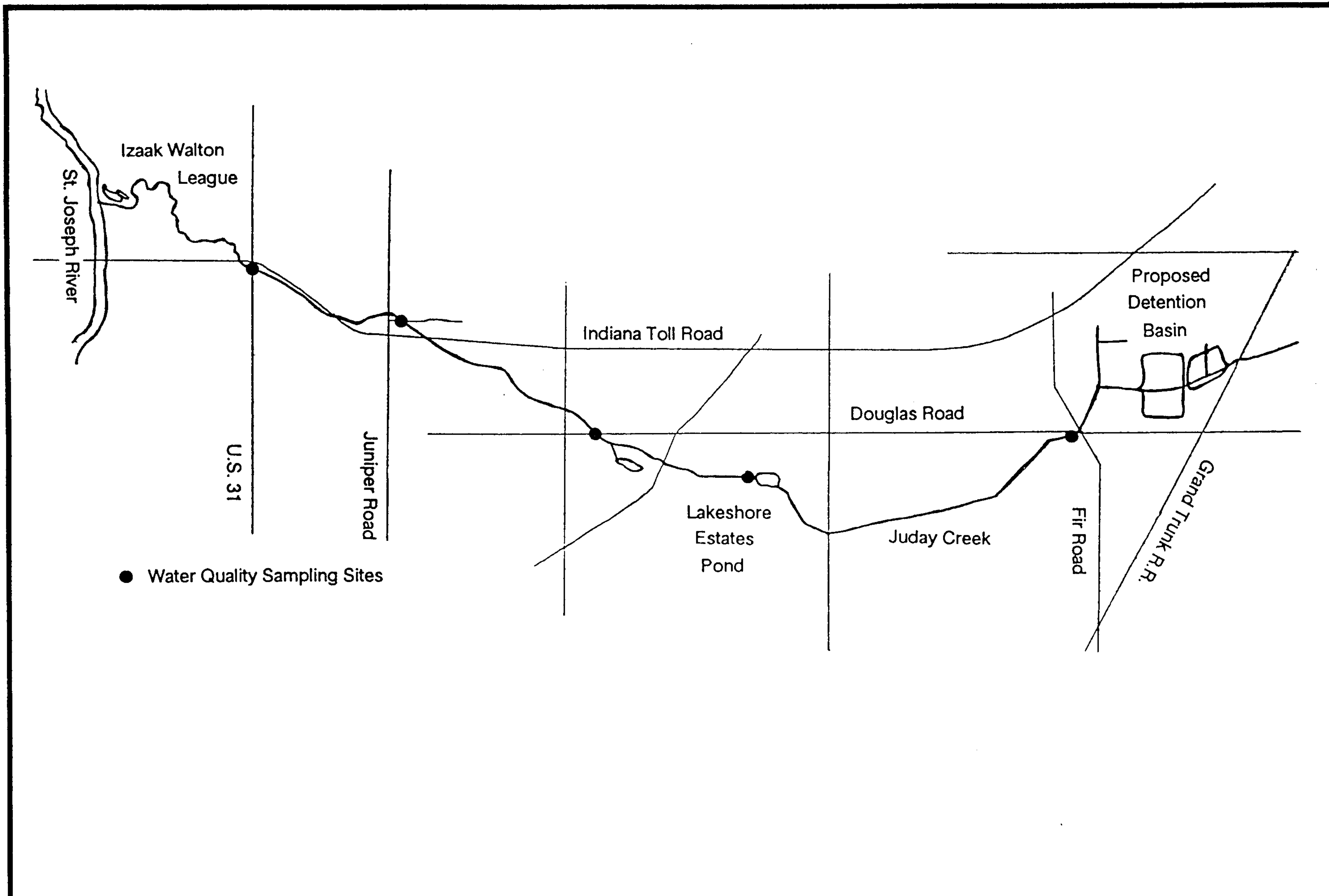
Schwenneker, B.W., 1985. "The Contribution of Allochthonous and Autochthonous Organic Material to Aquatic Insect Secondary Production Rates in a North Temperate Stream," dissertation presented to the University of Notre Dame, South Bend, IN, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Thomann, R.V. and Mueller, J.A., 1987. *Principles of Surface Water Quality Modeling and Control*, Harper & Row, Publishers, Inc., New York, NY, pg 391.

FIGURE 1. JUDAY CREEK STUDY REACH



LTI-Limno-Tech, Inc.

FIGURE 2. JUDAY CREEK TEMPERATURES - APRIL AND MAY 1991

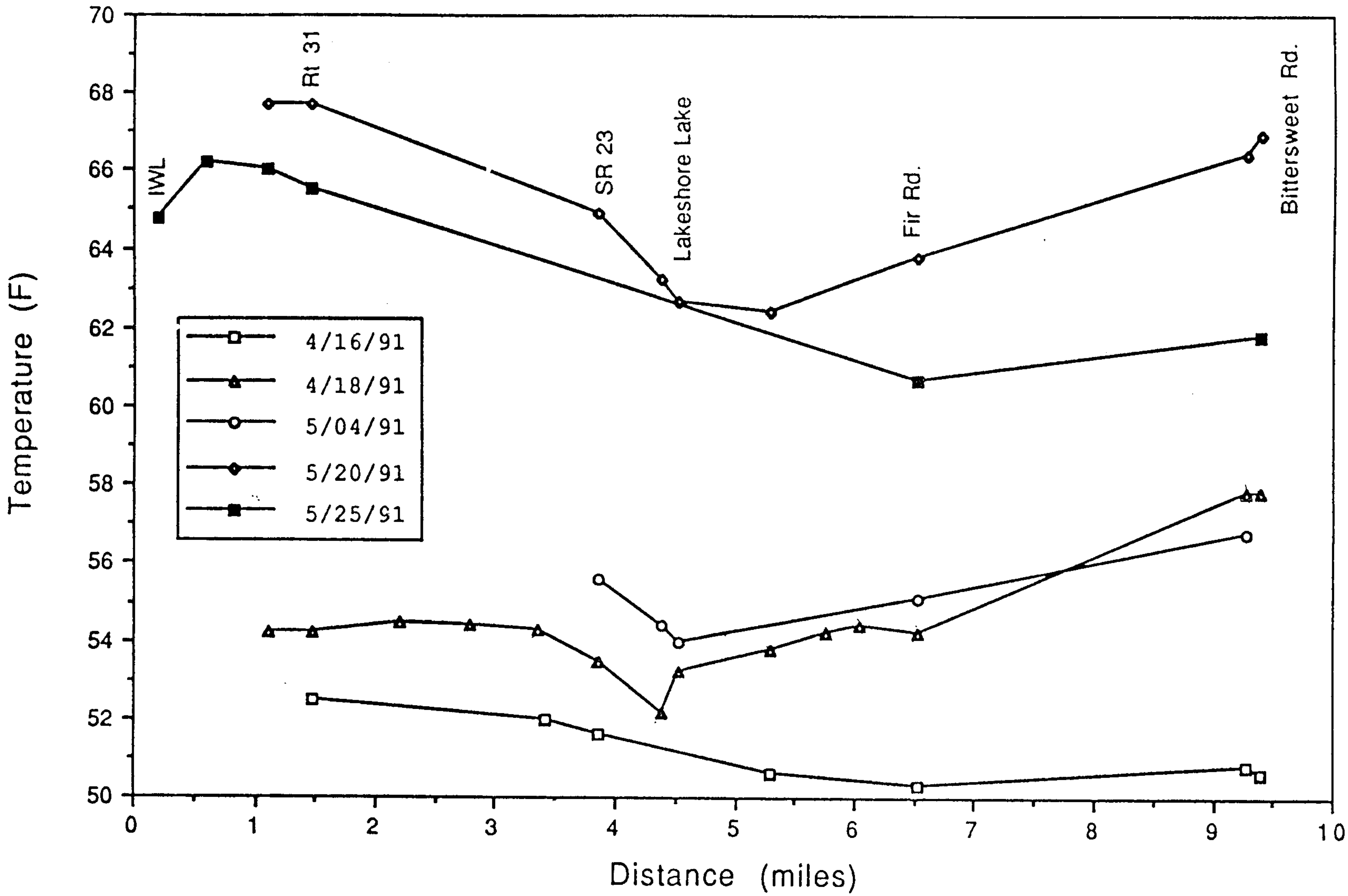


FIGURE 3. JUDAY CREEK TEMPERATURES - JUNE 1991

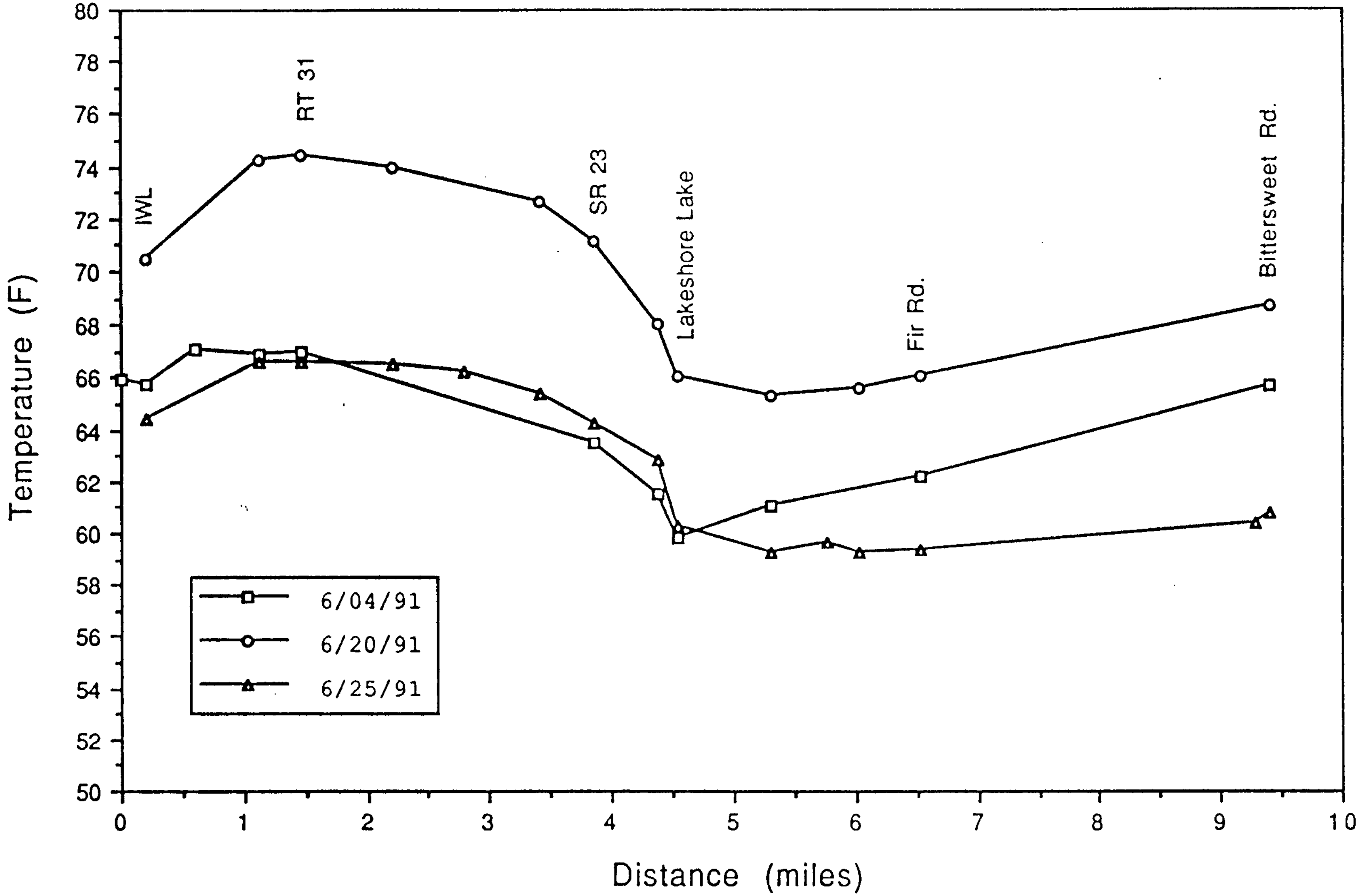


FIGURE 4. JUDAY CREEK TEMPERATURES - JULY 1991

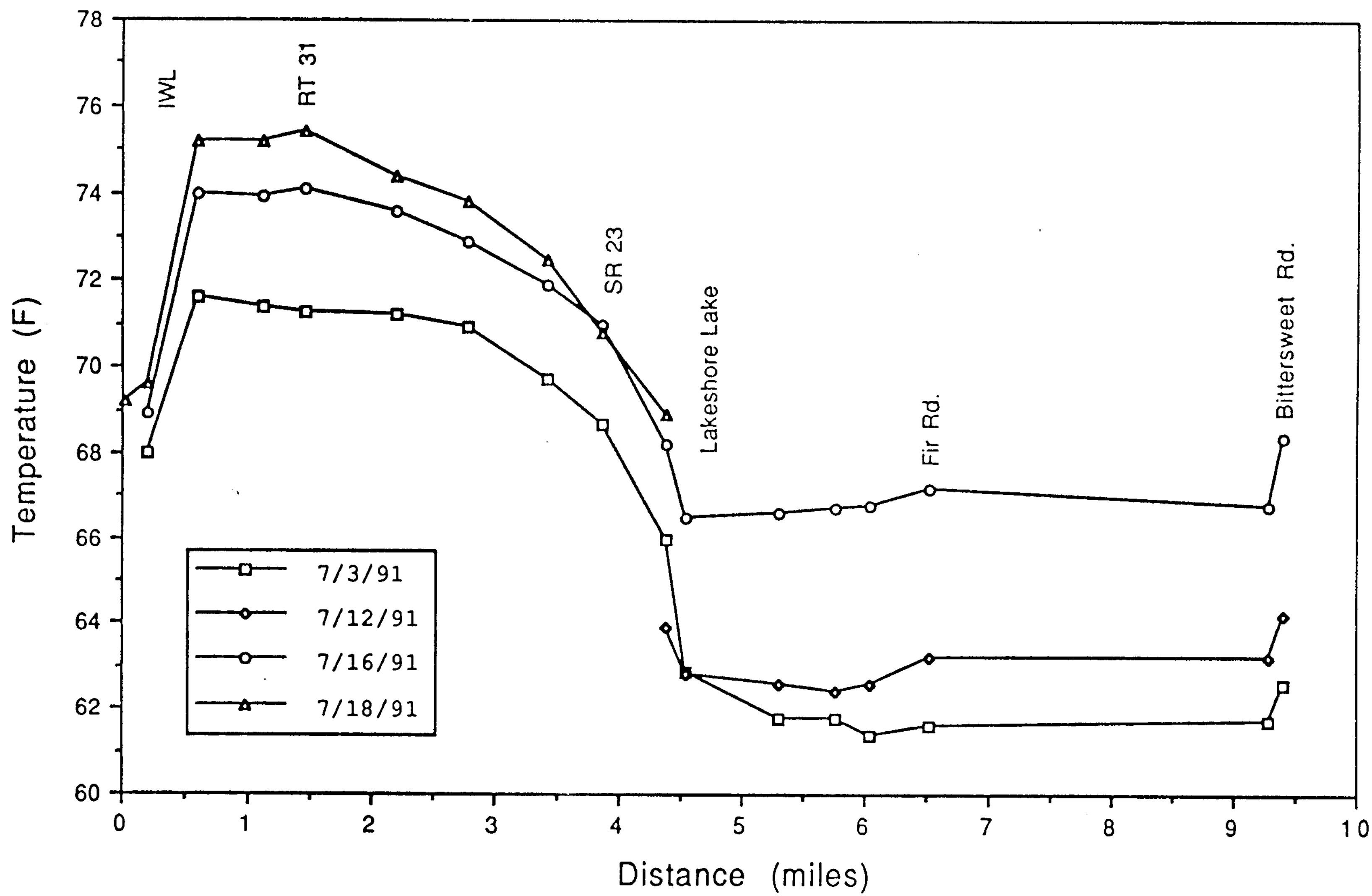
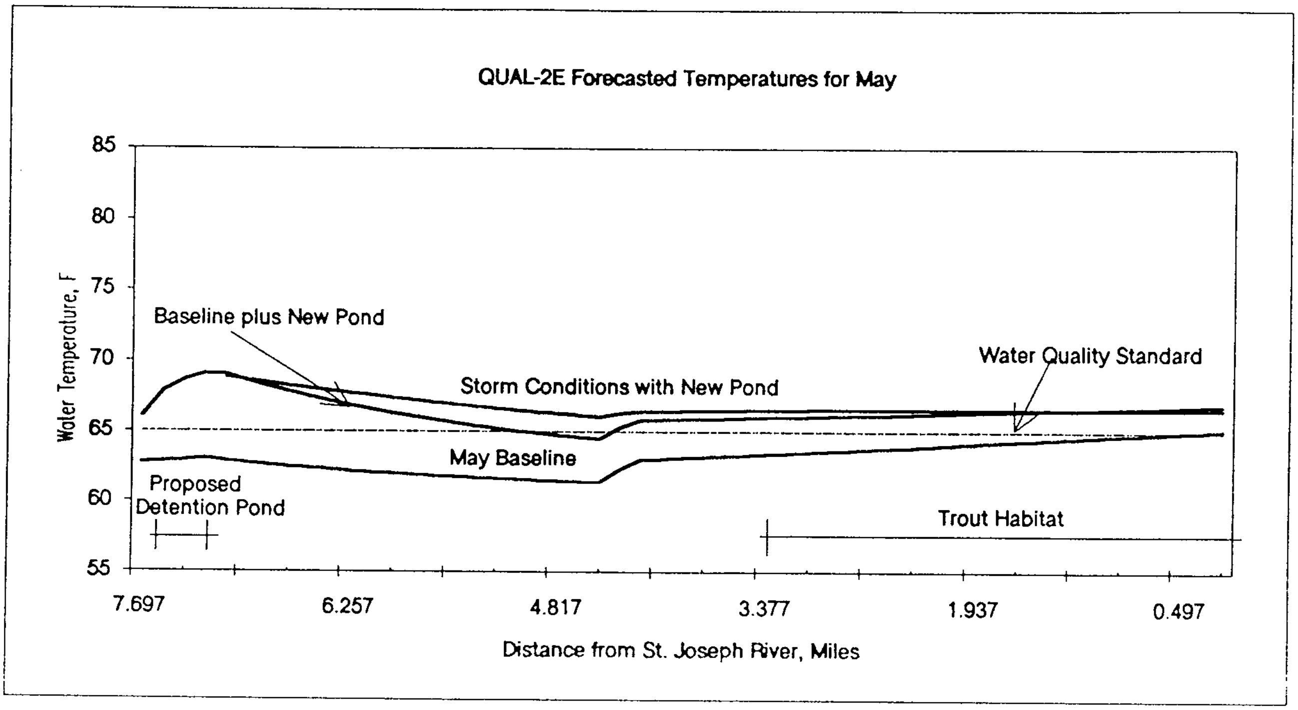
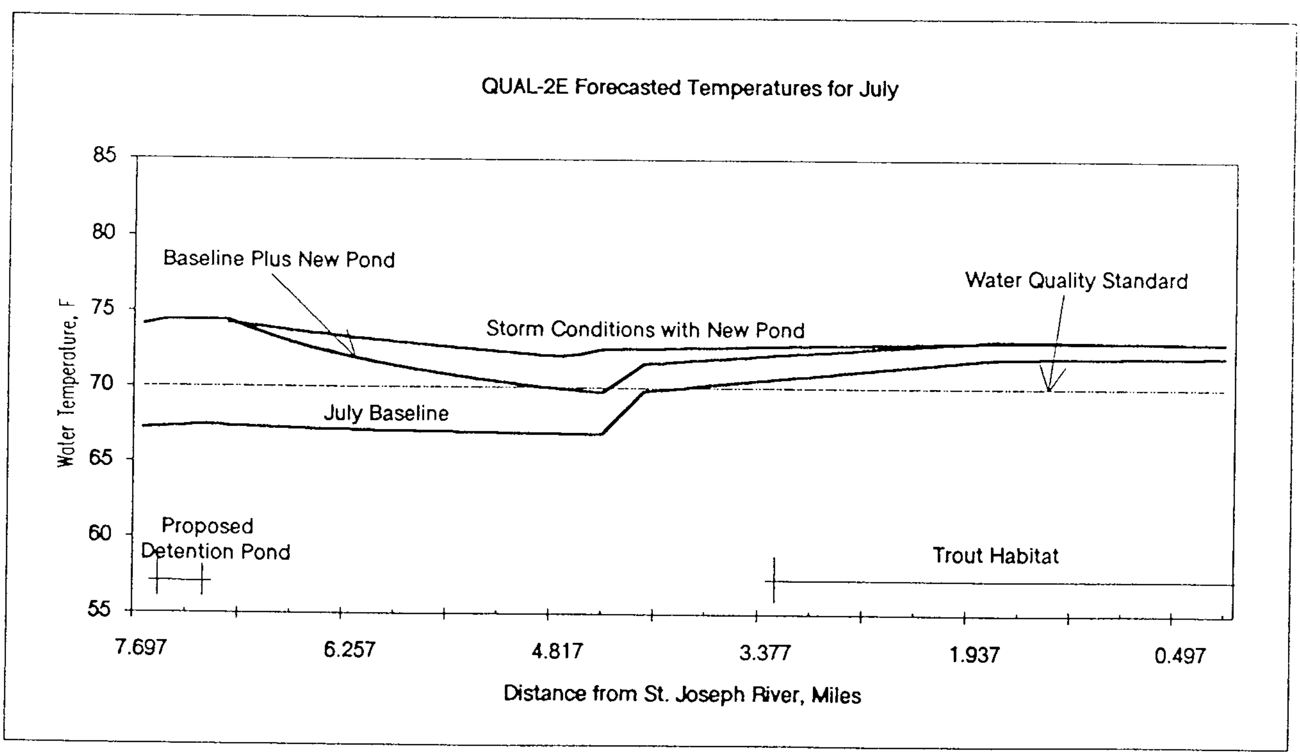


FIGURE 5. MODEL SIMULATION RESULTS





ATTACHMENT A

LIST OF REFERENCES USED FOR DETERMINING CRITICAL TEMPERATURES

TO: Dr. Victor J. Bierman, LTI - Limno-Tech, Inc.

FROM: Dr. Martin E. Berg, University of Notre Dame

RE: References for critical maximum temperatures for trout in Juday Creek

The following is a list of references that were consulted in arriving at the critical maximum temperatures used in the Juday Creek detention basin study.

It should be noted that our decision of critical spring and summer temperatures are based on short-term exposures and not prolonged periods. It also is important to keep in mind that maximum critical temperatures can be affected by the period of acclimation (temperatures prior to reaching a critical maximum) and also, in the case of the steelhead trout, the specific strain present in the stream. since specific environmental requirements for various steelhead trout strains, i.e. rainbow trout, are not readily available, general temperature requirements for rainbow trout are presented.

The temperatures listed below refer to the Critical Maximum Temperature (CMT) as defined by Bonin et al. (1981). Other temperature classifications such as Upper Incipient Lethal Temperature (UILT) (Giattinna and Garton 1982) are not presented in this table although they are generally close to, but slightly lower than, CMT values. CMT is the lethal temperature for fish after gradual acclimation at progressively higher temperatures. UILT is defined as temperatures where 50% of the population can no longer live given an indefinite period of time (Giattinna and Garton 1982). Usually a 7-day week is used as a lethal exposure time (McCauley 1981) with no period of gradual acclimation. All temperatures are presented as both Celsius and Fahrenheit.

TAXA	CRITICAL MAXIMUM TEMPERATURE	REFERENCE
Brown Trout *(Salmo trutta)*	25.6 °C 78.1 °F	Becker 1983
	28.5 °C 83.3 °F	Embody 1922
	27.2 °C 81.0 °F	Needham 1969
	25.0 - 30.0 °C 77.0 - 86.0 °F	Wismer and Christie 1987
Rainbow Trout *(Oncorhynchus mgkiss)*	28.5 °C 83.3 °F	Embody 1984
	26.1 °C 79.0 °F	Jobling 1981
	26.7 °C 80.0 °F	Brown 1974
	29.4 °C 85.0 °F	Lee and Rinne 1980

REFERENCES

Becker, G.C. 1983. Fishes of Wisconsin. The University of Wisconsin Press. Madison, WI. 1052 p.

Bonin, J.D., R.M. Lee and J.N. Rinne. 1981. Measuring thermal limits of fish. Am. Fish. Soc. 110:662-664.

Brown, H.W. 1974. Handbook of the effects of temperature on some North American fishes. Am. Electr. Power Serv. Corp., Canton, OH. 524 p.

Embody, G.C. 1922. Concerning high water temperature and trout. Trans. Am.Fish. Soc. 51:58-61.

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Giattina, J.D. and R.R. Garton. 1982. Graphical model of thermoregulatory behaviour by fishes with a new measure of eurythermality. Can. J. Fish. Aquat. Sci. 39:524-528.

Jobling, M. 1981. Temperature tolerance and the final preferendum - rapid methods for the assessment of optimum growth temperatures. J. Fish. Biol. 19:439-455.

Lee, R.M. and J.N. Rine. 1980. Critical thermal maxima of five trout species in the southwestern United States. Trans. Am. Fish. Soc. 109:632-635.

McCauley, R.W. 1981. Laboratory studies on directive and acute lethal effects of temperature of alewife (Alosa pseudoharengus) and rainbow smelt (Osmerus mordax) collected at Pickering GS pp H1 - h27. In A.E. Christie (ed.). Biological investigations to improve once-through cooling system designs for the Great Lakes. Report No. 81481. Environmental Studies and Assessments Dept. Design and Development Division, Ontario Hydro December 1981. Toronto, Ontario.

Needham, P.R. 1969. Trout streams. Holden-Day, San Francisco, 241 p.

Wismer, D.A. and A.E. Christie. 1987. Temperature relationships of Great Lakes fishes: a data compilation. Spec. Publ. No. 87-3. Great Lakes Fishery Commission.

ATTACHMENT B

LONGITUDINAL TEMPERATURE AND FLOW SURVEYS

PROGRESS REPORT ON

RESEARCH EFFORTS ASSOCIATED WITH THE

JUDAY CREEK STUDY

AND RELATED RESEARCH PERFORMED BY

THE DEPARTMENT OF CIVIL ENGINEERING AND GEOLOGICAL SCIENCES

AT THE UNIVERSITY OF NOTRE DAME

DATE OF REPORT: AUGUST 2, 1991

REPORT SUBMITTED TO:
DR. VICTOR BIERMAN
LIMNO-TECH, INC.

REPORT PREPARED BY:
DR. STEPHEN SILLIMAN
DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF NOTRE DAME

Executive Summary

During the period of April, 1991, through July, 1991, Dr. Stephen Silliman has directed research related to characterizing Juday Creek in terms of water inflows/outflows and in terms of a temperature distribution in the water column and shallow sediments. This work was partially supported through a consulting firm Limno-Tech, Inc. Additional support was provided through the Department of Civil Engineering and Geological Sciences.

The work performed to date has included regular measurement of temperature profiles in the water column within Juday Creek, two surveys of water quality in the lake bordering on Lake Shore Estates, measurement of sediment temperatures, measurement of groundwater elevation and temperature along property owned by Notre Dame, and measurement of chloride concentration along the creek. Due to an unfriendly response from the manager of Lake Shore Estates, it has been concluded that it would be unsafe to deploy the Hydrolab in this lake. Based on these data, the following observations have been noted:

(1) Juday Creek apparently gains significant flow from groundwater along the reach from Bittersweet Road (north of Cleveland) through the inflow to the lake at Lake Shore Estates,

(2) The creek is apparently neutral and/or loses water to the groundwater from the outflow of this lake through the bridge on the Izaak Walton League property (located off of Darden Road),

(3) The creek gains substantial groundwater via springs along the lower reach of the Izaak Walton League property,

(4) Sediment temperatures provide an excellent indicator of whether the creek is gaining or losing,

(5) Water quality in terms of Chloride is relatively constant throughout the creek with a slight increase between Bittersweet and Fir roads,

(6) The lake at Lake Shore Estates has provided consistent warming of the creek water (approximately 2 degrees Fahrenheit) throughout June and July, and

(7) The lakes on the Izaak Walton League property have become extremely warm with outflow temperature from the lower lake of 77 degrees on June 4 and 82.5 degrees on June 20.

Introduction and Scope of Efforts

Dr. Stephen E. Silliman and the Department of Civil Engineering and Geological Sciences have undertaken a study of flow and thermal conditions along Juday Creek. The study was initiated through concerns by Cole Associates, Inc., that a storm water retention pond designed by their firm would lead to substantial warming along Juday Creek and, thereby, would negatively impact the trout population within the creek. Through several discussions, the scope of the work was defined by Limno-Tech Incorporated with Dr. Silliman as a subcontractor. The scope of the work defined under the verbal agreement between Dr. Silliman and Limno-Tech Incorporated involved regular monitoring by Dr. Silliman of the inflow and outflow temperatures on the lake at Lake Shore Estates, regular monitoring of lake temperatures at selected locations, monitoring creek temperature at six hour intervals at a single location, one longitudinal profile of water temperature along the creek, two to three surveys of water quality in the lake during August utilizing the Hydrolab Scout and a two week period of monitoring of lake water quality at six hour increments and a single location utilizing the Hydrolab DataSonde. The deployment of the DataSonde has now been put on hold for a variety of reasons. The most pressing reason, however, is the negative interaction which has occurred between the manager of Lake Shore Estates and personnel from Notre Dame, Cole Associates and the county. At the present time, Dr. Silliman considers deployment of the DataSonde to be an unacceptable risk to University property (the DataSonde costs approximately $13,000).

Since the inception of this work, the Department of Civil Engineering and Geological Sciences has substantially increased its role in research on Juday Creek. Additional efforts include regular longitudinal surveys of temperature along the creek, surveys of sediment temperature along the creek bed, surveys of lake sediment temperature and lake bottom temperatures in the lake at Lake Shore Estates, installation of a pressure-transducer gauging station on the creek, monitoring of groundwater levels and temperatures at one location along the creek, monitoring outflow temperatures of two lakes on the Izaak Walton League property, and monitoring of chloride concentrations along the creek. Hence, interest in the creek has extended beyond just the consideration of the retention pond project.

Presentation of Data Collected

The attached table presents the data collected during the longitudinal surveys on the creek. Distance is in miles from the confluence of the St. Joseph River and Juday Creek as estimated from topological maps for the area. These distances may be improved through a meeting on Monday, August 5, 1991, between Dr. Silliman and Mr. Joe Pietrozak. Mr. Pietrozak is with the County Surveyor's Office and is working with a series of surveying monuments along Juday Creek. Use of these monuments and the Notre Dame surveying station may allow precise definitions of sampling locations relative to the regional survey base map.

All temperatures reported are in degrees Fahrenheit and were collected using a submersible thermistor probe and attached digital meter. The meter provides a reading to the nearest 0.1 degrees Fahrenheit and in random tests has been shown to provide reproducible readings to this precision.

In terms of location names utilized, Bittersweet Road represents the crossing of Juday Creek and Bittersweet north of Cleveland Road. Bittersweet South is a second flowing channel which crosses Bittersweet south of Cleveland Road. This channel apparently joins Juday Creek east of the railroad tracks. Cleveland Road is the crossing of Juday Creek and Cleveland Road west of Bittersweet Road. Fir Road is the intersection of Fir and Douglas Roads. Merrifield represents the crossing of Juday Creek and Merrifield Road in the Winding Brook subdivision. Winding Brook represents the crossing of Juday Creek and Winding Brook Road in the Winding Brook subdivision. Edison Lakes (new road) represents the crossing of the creek and Edison Lakes Road. This crossing was only recently completed (approximately March, 1991). Lake Inflow represents the creek temperature approximately 30 feet east of the inflow to the lake at Lake Shore Estates. Lake-End Road represents the lake temperature approximately 25 feet from shore at a depth of approximately 1 foot. The location of this measurement is at the intersection of a dirt road and the lake along the south shore approximately 200 feet west of the inflow. Lake-Rods represents the lake temperature approximately 25 feet from shore at a depth of approximately 1 foot in a shallow portion of the lake approximately 150 feet east of the outflow. The location is identified physically by the presence of two green rods extending from the lake approximately five feet from shore. Lake Outflow represents the creek temperature collected from the bridge approximately 20 feet west of the point of outflow from the lake. Rt. 23, Douglas, Ironwood, Juniper, Rt. 31 and Kennilworth represent, respectively, the creek crossings with each of these roads. ND Property represents a location at which the creek crosses Notre Dame property north of Douglas Road and approximately 0.5 miles east of Juniper Road. IWL-bridge represents the creek crossing at the bridge on the road into the Izaak Walton League property (off of Darden Road). IWL-lakes represents a point on the creek which is accessed by walking between the two lakes on the League property and then following a small trail down to the water. Juday at St. Joe represents the confluence of the creek and the St. Joseph River. Top Pond Out is the temperature of the overflow of the upper lake on the Izaak Walton League property. Bottom Pond Out is the temperature of the overflow from the lower lake on the property. Neither of these ponds are along the creek, but the upper is fed through diverted creek water. Spring represents the temperature of a small spring entering the creek along the lower stretch of the Izaak Walton League property. The spring is located immediately upstream from the IWL-lakes sampling location.

In terms of separating project efforts from additional research efforts, the project outline was based on a single longitudinal survey and regular surveys of lake inflow and outflow. The data set was extended through addition of the other longitudinal points on the regular lake measurements.

These profile data are represented in Figures 1-3. In addition to these data, sediment temperatures and flows along the creek have also been measured (again, outside of the original scope of effort). Although several partial sediment profiles have been collected, the only complete record was collected on July 16, 1991. This record, along with the associated water temperature, is shown in Figure 4. Due to the time requirements to complete flow measurements, no complete flow profile has been collected. Partial profiles have been collected both above and below the lake at Lake Shore Estates. Sample profiles are shown in Figure 5.

Chloride data were collected from the different sampling locations along the stream (additional to the original scope of work). These data did not provide any obvious structure and varied between 60 and 80 ppm. Finally, the Scout has been utilized on the lake at the Lake Shore Estates on two occasions (as included in the original scope of work). The first was in mid-May and the sampling program was performed on a windy day. As expected, all parameters, including oxygen concentrations, were relatively uniform and the oxygen was very close to saturation. The only variation observed was a local cool water zone at approximately 5 feet depth along the northwest corner of the lake.

Observations Regarding the Data -- Consideration of the Entire Creek

The data collected to date has provided several observations regarding flow and thermal response along Juday Creek. Foremost among these is the fact that the creek apparently gains water along the stretch from Bittersweet to the inflow to the lake at Lake Shore Estates and is either neutral or loses water below this lake (except for the gaining stretch in the last half mile). This observation is derived from analysis of the water temperature plots, the sediment temperature plots, and the flow measurements.

The water temperature plots (Figures 1-3) show a lack of warming and, in many cases, consistent cooling throughout the stretch of creek above the lake. This is particularly obvious in the temperature profiles collected in June and July. Cooling along this stretch is interpreted as an indication of cool water inflow as the water temperature is significantly below ambient air temperature and there has been substantial solar radiation during this entire period. It is interesting to note that the cooling is not uniform throughout the stretch. During July, in fact, a substantial portion of the cooling occurred within the quarter mile stretch between the creek crossing at Bittersweet and the crossing at Cleveland (Figure 3), implying substantial inflow along this stretch. It is anticipated that there may be some addition of warmer surface waters in this stretch as the flow is substantially higher at Fir yet the temperature is not substantially reduced (discussed below). Finally, it was noted in the July plots that the water in the creek did not show significant cooling between Fir and the lake inflow. Two interpretations of this result are presented. First, this may be indicative of a reduced groundwater inflow during this monitoring period, thus reducing the volume of cool water being mixed into the system. Second, the extreme heat observed during this period may be adding enough solar energy to the creek that the groundwater inflow is simply maintaining the energy per unit volume of water at equilibrium. It is anticipated that this observation is a combination of these two interpretations.

Below the lake but above the Izaak Walton League springs, we observe consistent warming of water temperatures. From these data, we conclude that the creek is either losing or neutral between the lake and the bridge on the League property. As discussed below, this conclusion is firmly supported by the sediment temperatures. It is interesting to note that each profile shows a decreasing rate of warming as we move towards the St. Joseph River. At the present time, we do not believe that this is due to groundwater inflows. Hence, we conclude that it is either a natural result of the thermal energy balance or is a result of cool surface inflows. As there are several constructed ponds which interact with the creek along this stretch, it is difficult to determine the surface water hydrology along this reach of the creek.

The water temperature data provided evidence of gaining and losing portions of the stream. However, it is desirable to support these observations with more direct measurements. At the Notre Dame property, this was possible through monitoring of water levels in groundwater wells near the creek. Throughout the period of study, two wells located within 100 feet of the creek maintained water levels more than two feet below the water level in the creek, thus providing direct hydrologic evidence of a losing creek along this stretch (approximately mile 2.8).

Sediment temperatures were collected along the length of the creek in the hopes that they would provide evidence of gaining or losing stretches at other locations. The results, shown in Figure 4, were astounding. Along the entire stretch above the lake, the temperature of the sediment at two inches depth was in the temperature range of 55-60 degrees Fahrenheit. This was substantially below the creek temperature and is quite consistent with shallow, local groundwater temperatures for this time of year. Thus strong evidence was provided that there was active advective flow from the groundwater into the creek. For the stretch between the lake outflow and the Izaak Walton League bridge, the sediment temperatures followed very closely the temperature of the creek water, thus implying active advective movement of water from the creek into the groundwater. At the lower stretch of the Izaak Walton League property, the trend supports a gaining creek as the sediment temperature is again below 60 degrees Fahrenheit.

Figure 5 shows preliminary flow measurements collected using a propeller type velocity meter. The measurements shown are subject to significant error as only three velocities were collected per cross section and the cross sectional area was itself crudely estimated during these initial surveys. Despite the crude nature of the measurements, however, these profiles show a distinct increase in flow above the lake and in the area of the Izaak Walton League. Further, steady or slightly decreasing flow was noted below the lake. A more precise set of measurements are to be collected in conjunction with water and sediment temperatures next week.

Observations Regarding the Creek -- The Reach between Fir and Bittersweet

Due to the difficulty of accessing the stretch of the creek between Fir and Bittersweet Roads, we have not produced multiple surveys of this portion of the creek. However, based on analysis of Figures 2 and 3, we determined that additional data in this portion of the creek may be useful in examining the hydrologic conditions in the area of the proposed pond. Hence, two stretches of this portion of the creek were sampled on July 31. The results of this survey are presented in Figure 6.

Figure 6 indicates that this stretch of the creek is quite complex hydrologically and does not represent uniform inflow over the length of this portion of the creek. As noted earlier, substantial cooling is observed between Bittersweet and Cleveland. As noted in Figure 6, this is consistent with the cool sediment temperatures in this section of the creek. One of the confusing portions from Figures 2 and 3 was the increased flow at Fir Road without an associated decrease in temperature. The data in Figure 6 provides an explanation for this observation. Several portions of the creek between Cleveland and Fir are apparently not strongly gaining groundwater (and, indeed, may be losing water). Examples can be found near the railroad tracks and between Cleveland Road and the farm road where sediment temperatures increase substantially. The lack of inflow leads to local warming of the creek water. In addition, a side stream entered Juday Creek at the Juday Creek Golf Course. This stream was warmer than the creek (71 degrees on 7/31) and caused an increase in both flow and temperature in the creek.

It is concluded, therefore, that this stretch of the creek (which surrounds the proposed location for the retention pond) has variable rates of groundwater inflow. It is not clear whether the creek may be losing water at any point in this stretch, but it is clear that there is not a consistent, strong inflow of groundwater. Further, surface inflows are adding thermal energy to the creek in this stretch.

Observations Regarding the Lake at Lake Shore Estates

The analyses performed to date on the lake have included both thermal monitoring and two sets of data collected on the Scout. The Scout data indicate that, in general, there is little variation of water chemistry within the lake. Additional data sets will be collected with the Scout during the coming, late summer, weeks.

Temperature monitoring of the inflow and outflow from the lake have provided evidence that the lake is warming the water. Referring to Figures 2 and 3 and the table of data, it is observed that during June and July, the outflow was approximately 2 degrees (Fahrenheit) warmer than the inflow. Hence, we conclude that the exposure resulting from the increased surface area on the lake is leading to solar warming of the lake water.

The interaction of the lake water with the groundwater is not fully understood at this point. As indicated by the comparison of sediment and creek temperatures (Figure 4), the lake is apparently at the contact between the primary gaining and losing portions of the creek. Mr. Doug Petroff, an undergraduate who studied the lake over the summer, measured lake sediment temperature and lake water temperature approximately 2 feet above the sediment. He noted that the lake water was consistently approximately two degrees warmer than the sediment. He concluded from this analysis that there was a slight outflow of groundwater. In the opinion of Dr. Silliman, this status is questionable at the present time and it is suspected that the direction of water movement is strongly dependent on the storm history (and, hence, the relative levels of the lake and water table) such that it varies with time.

As an aside to this discussion, Dr. Silliman wonders at the coincidence that the change from a gaining to a losing stream occurs at this artificial lake. Of concern here is whether installation of the lake altered the natural flow patterns in the region. If this is the case and a similar phenomenon occurs around the retention pond after construction, the gaining portion of the creek between Fir Road and the current lake (and the associated cooling) may be replaced by a losing creek. Under this scenario, the creek would not receive an inflow of cool groundwater until the Izaak Walton League property. Note that we are stating that this will happen, but wonder whether the strategic location of the current lake is a coincidence or was forced by installation of the lake.

Personnel

Dr. Silliman would like to acknowledge several summer students at Notre Dame who were not supported by the county project but who contributed substantially to the project. Mr. David Booth (University of Utah) and Mr. Douglas Petroff (Indiana University) were actively involved in equipment design, sampling strategy and data analysis. They have both completed their junior years in college and were supported through other funding sources. In addition, three high school students actively contributed to data collection. They were supported through a program for gifted high school students. Finally, Mr. Bruce Haikola, a recent graduate from our Department, contributed significantly to this project through his directed research during the spring semester of 1991.

Summary

Work to date has demonstrated that Juday Creek is not a gaining stream throughout its length. Rather, the creek tends to be gaining in the upper half and losing in the majority of the lower half. In the vicinity of the proposed pond, the creek is mainly gaining with some locations showing evidence of neutral hydraulic conditions or a slight loss to the groundwater. Additional efforts will include continued monitoring of stream and sediment temperatures, completion of detailed flow measurements along the stream, sampling of basic water quality along the stream, and two sets of spatial monitoring of water quality within the lake at Lake Shore Estates utilizing the Scout. Groundwater elevations and temperatures will continue to be monitored (approximately monthly) along the Notre Dame property as will pressure and temperature at the stream gauging station (6 hour intervals).

Location	Distance	4/16/91	4/18/91	5/04/91	5/20/91	5/25/91	6/04/91	6/20/91	6/25/91	7/03/91	7/12/91	7/16/91
Bittersweet Rd.	9.40	50.6	57.8		66.9	61.8	65.7	68.7	60.8	62.6	64.2	68.4
Bittersweet - South			57.6		65.6							
Cleveland Rd.	9.27	50.8	57.8	56.8	66.4				60.4	61.7	63.2	66.8
Fir Rd.	6.52	50.3	54.2	55.1	63.8	60.7	62.2	66.0	59.3	61.6	63.2	67.2
Merrifield	6.03		54.4					65.6	59.2	61.4	62.6	66.8
Winding Brook	5.76		54.2						59.6	61.8	62.4	66.7
Edison Lakes (new road)	5.30	50.6	53.8		62.4		61.0	65.3	59.2	61.8	62.6	66.6
Lake Inflow	4.53		53.2	54.0	62.7		59.8	66.0	60.3	62.9	62.8	66.5
Lake- End Road			52.1	53.5	61.6		61.8					
Lake - Rods			52.2	54.5	63.5		64.6					
Lake Outflow	4.39		52.2	54.4	63.2		61.5	68.0	62.8	66.0	63.9	68.2
Rt. 23	3.86	51.6	53.5	55.6	64.9		63.5	71.1	64.2	68.7		71.0
Douglas	3.42	52.0						72.6	65.4	69.7		71.9
Ironwood	3.35		54.3									
ND Property	2.79		54.4						66.2	70.9		72.9
Juniper Rd.	2.21		54.5					74.0	66.5	71.2		73.6
Rt. 31	1.47	52.5	54.2		67.7	65.5	67.0	74.4	66.6	71.3		74.1
Kennilworth	1.12		54.2		67.7	66.0	66.9	74.2	66.6	71.4		73.9
IWL-bridge	0.60					66.2	67.1			71.6		74.0
IWL-lakes	0.20					64.8	65.8	70.5	64.4	68.0		68.9
Juday at St Joe	0.01						65.9					
Top Pond Out							70.4	74.0	69.4			
Bottom Pond Out							77.0	82.5	77.0			
Spring								62.4	62.4	63.0		

Figure 1
Juday Creek Temperatures - April and May 1991

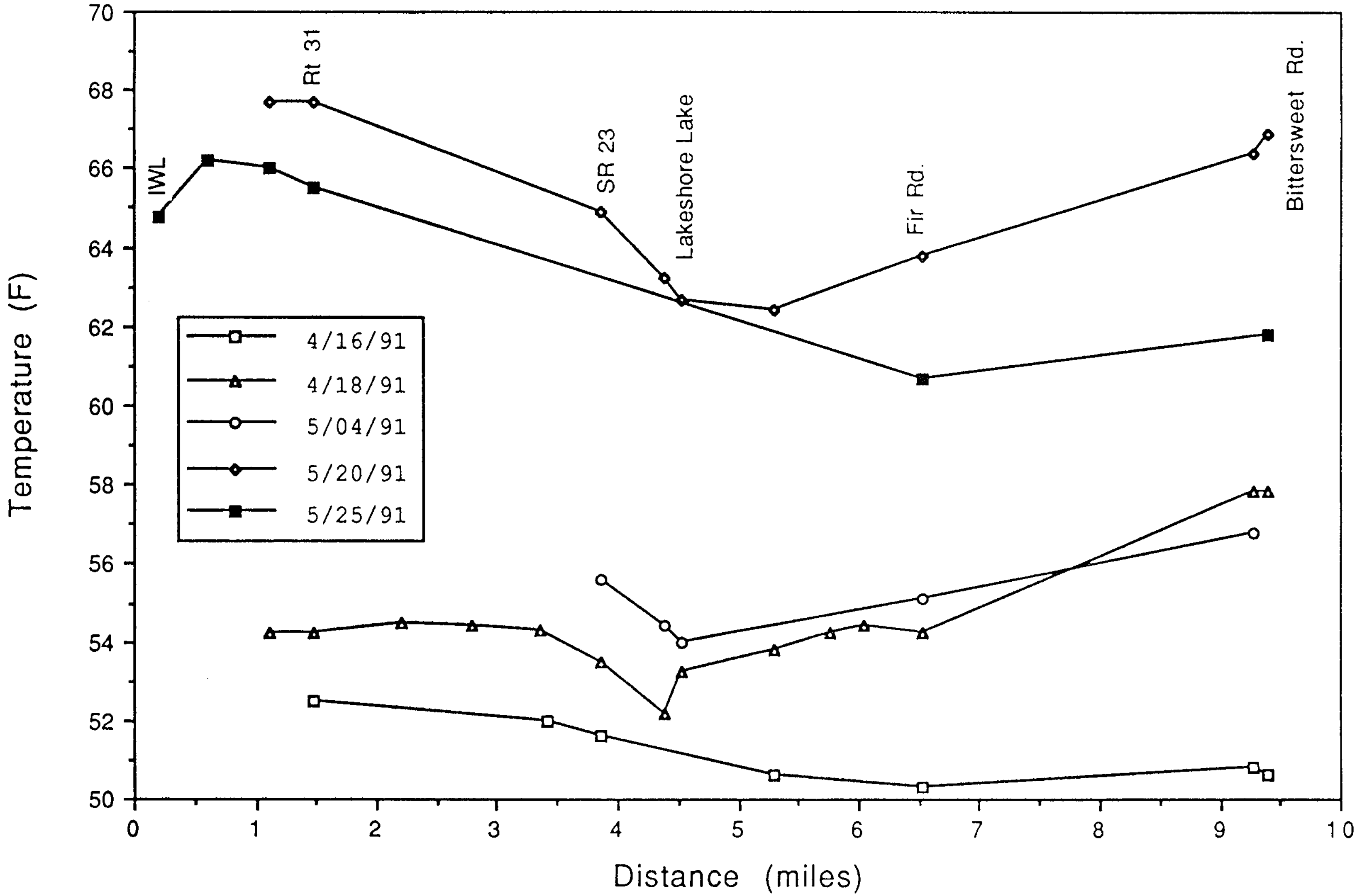


Figure 2
Juday Creek Temperatures - June 1991

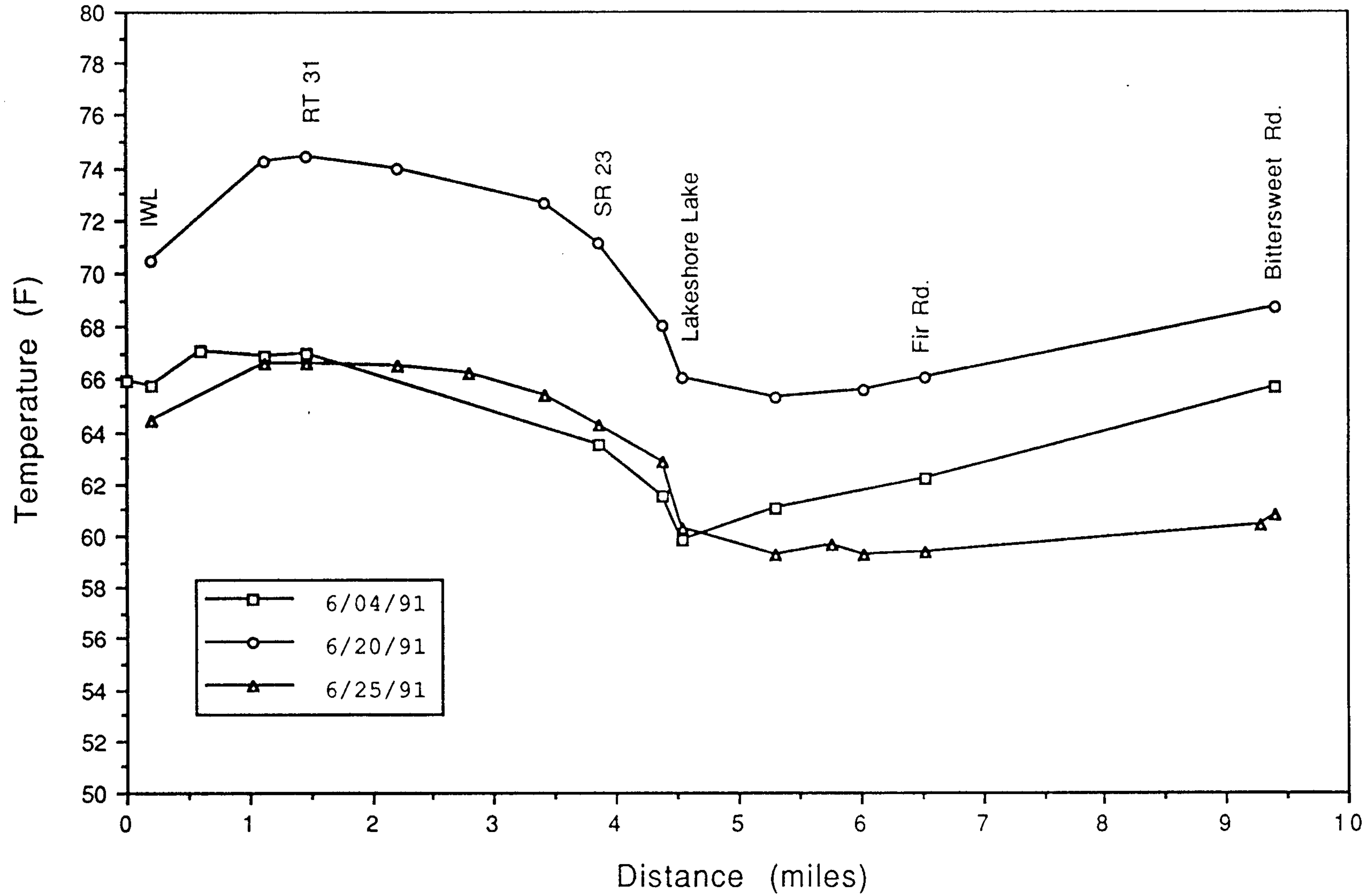


Figure 3
Juday Creek Temperatures - July 1991

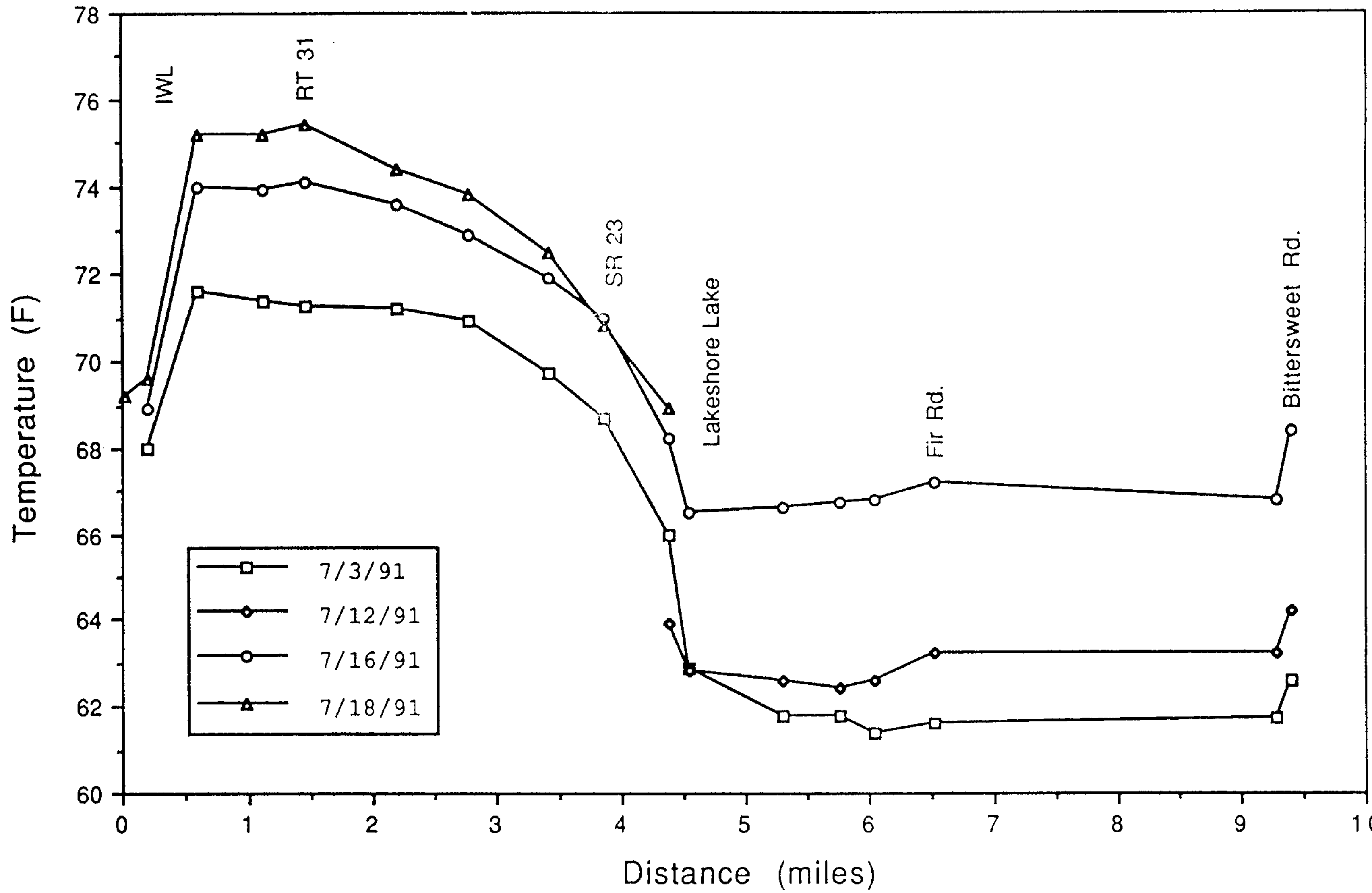


Figure 4
Juday Creek Sediment and Water Temperatures

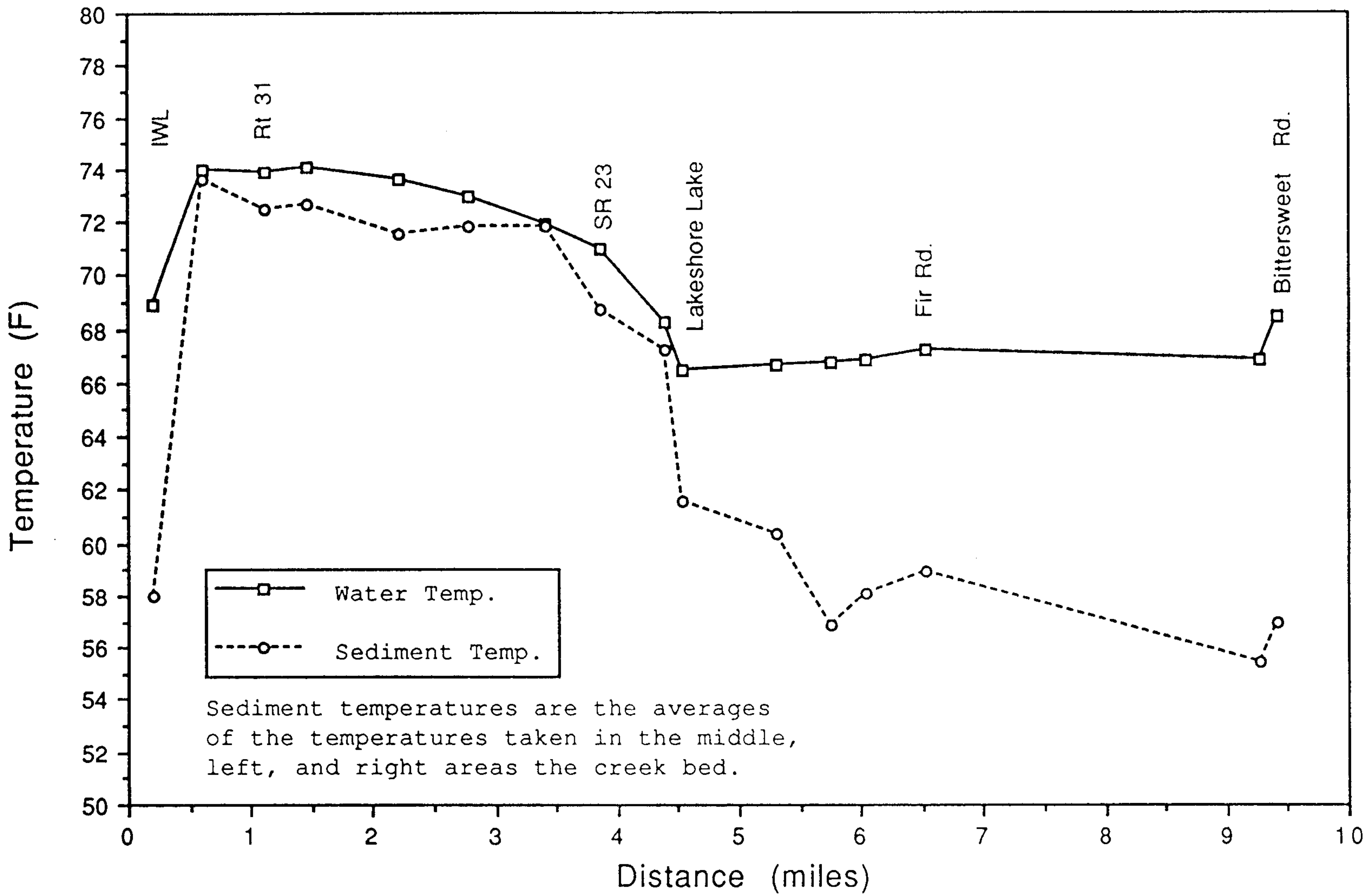


Figure 5
Juday Creek Flows

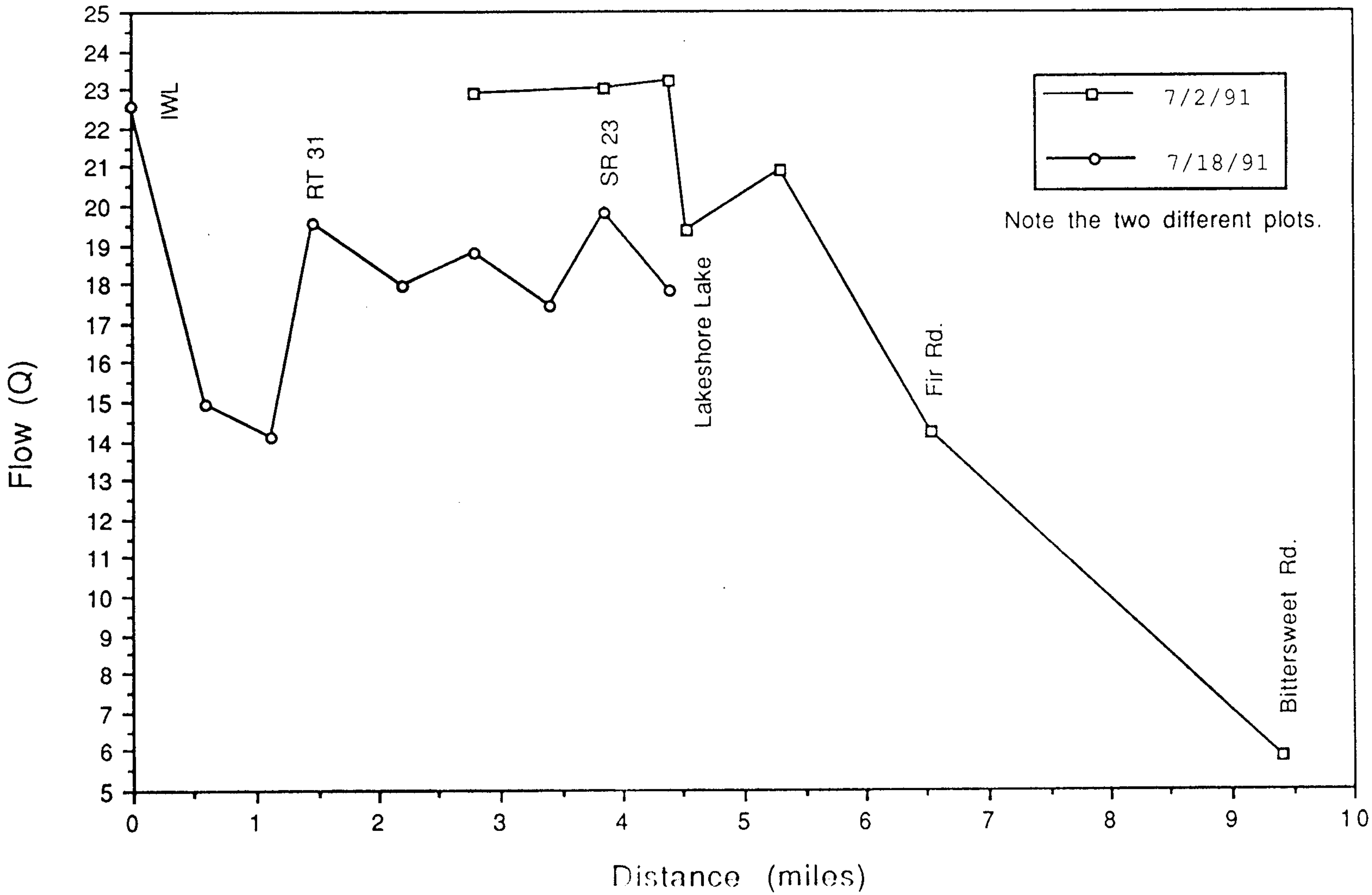
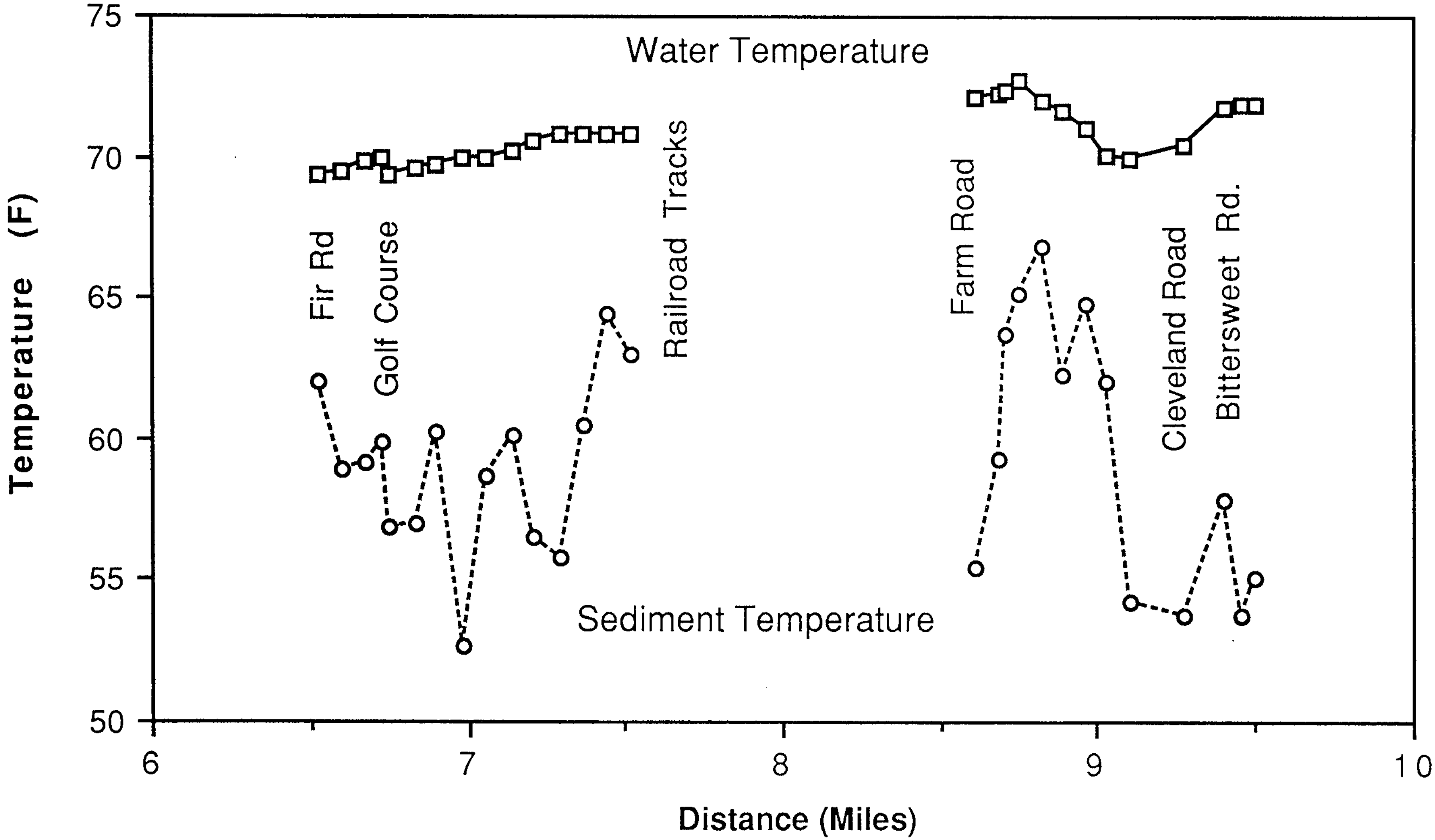


Figure 6
Juday Creek Temperatures - Upper Reach - 7/31/91



ATTACHMENT C
SPRING AND SUMMER SURVEYS

To: Dr. Vic Bierman, LTI - Limno-Tech, Inc.
From: Dr. Martin B. Berg, University of Notre Dame
Re: Summary Report of Juday Creek Spring Survey

June 15, 1991

Juday Creek Project (JDYCR) Spring Survey

INTRODUCTION

A survey of Juday Creek was conducted on 14 May 1991 by Dr. Martin B. Berg (Department of Biological Sciences, University of Notre Dame) and Mr. Tim Feist (LTI - Limno-Tech, Inc.). This survey represents Phase I of a two phase approach to monitoring the physical and chemical characteristics of Juday Creek. Phase II, designed to monitor the stream during low flow conditions, will be conducted in late July 1991 and will examine the same parameters as Phase I. The results of these surveys will be used to model and predict the impact(s), if any, of a proposed detention basin upstream of the Fir Road - Douglas Road intersection.

METHODS

Physical and Chemical Parameters

This report presents results for the following parameters: water temperature, dissolved oxygen (D.O.), discharge and sestonic chlorophyll *a*. In addition, water samples for soluble reactive phosphorus and total phosphorus also were collected and delivered to EIS, Inc. of South Bend, Indiana for analysis. Results of these latter two parameters will be provided directly to Dr. Vic Bierman of LTI - Limno-Tech, Inc.

Dissolved oxygen and water temperature were measured using a Yellow Springs Instruments (YSI) Model 54B dissolved oxygen meter and probe. Current velocity for discharge calculations was measured using a Montedoro-Whitney Model PVM-2A portable current velocity meter. Discharge at each site was calculated using the equation of continuity. Results for chlorophyll *a* concentrations were determined fluorometrically using a Turner Model 450 fluorometer with methanol as an extraction solvent.

Sampling Sites

Five sampling locations were established along Juday Creek in accordance with the agreement reached at the 10 April 1991 meeting. Samples were collected from: Business Route 31 in Roseland adjacent to the Phillips 66 station (Site 1), upstream from Juniper Road at the bridge (Site 2), Douglas Road (Site 3), the outflow of the Lakeshore Estates Pond (Site 4) and Fir road (Site 5). Site 1 was the most downstream location whereas Site 5 was the most upstream site.

RESULTS AND DISCUSSION

All results from the Phase I portion of this study are presented in Table 1. Water temperatures exhibited a general trend of higher values at downstream sites compared to upstream locations. The sole exception was the slightly lower water temperature at Site 4 (16°C). The observation of cooler temperatures at Site 4, compared to upstream areas, is consistent with the findings of Dr. Steve Silliman (Department of Civil Engineering, University of Notre Dame) in his initial monitoring of the Lakeshore Estates impoundment. On four of five monitoring dates, he found the outflow to have a lower temperature than the inflow.

Dissolved oxygen concentrations exhibited little change along Juday Creek. Although slightly higher D.O. concentrations were observed at Site 3 (12.4 mg/l) compared to Site 2 (12.2 mg/l) and Sites 1, 3 and 4 (12.0 mg/l), these differences are probably not significant and are likely due to dense growths of algae present at Site 3. The photosynthetic activity of these algae could likely account for the higher D.O levels observed. The overall trend in D.O. is expected because most streams the size of Juday Creek usually exhibit high D.O. (near or above saturation) due to the turbulent nature of the flow.

Discharge values at the five sites were considerably more variable than those for water temperature and dissolved oxygen. Discharge ranged from 0.7 m^3/s at Sites 1 and 5 to 1.2 m^3/s at Site 3. The lack of a well-defined trend in discharge supports initial observations by Dr. Steve Silliman that certain areas of Juday Creek may be hydraulically "de-coupled" from other areas due to groundwater gains and losses.

Sestonic chlorophyll a concentrations exhibited a trend similar to water temperature in that values were higher at downstream sites. As with water temperature, Site 4 deviated from the general pattern. Chlorophyll a levels at this site were slightly higher than Site 3, the next downstream location, although still lower than sites farther downstream. Again, this is not unexpected because high phytoplankton production in the impoundment likely contributes to the higher chlorophyll value at Site 4. Chlorophyll a values are expected to increase at downstream locations in Juday Creek because these sites experience a cumulative effect from all upstream areas.

In summary, the results from this initial Phase I study are consistent with our understanding of stream ecosystems. Only two deviations were observed with respect to the expected patterns of variation in water temperature, dissolved oxygen and chlorophyll a along Juday Creek. Both of these departures occurred at Site 4 and can be directly attributable to the effect of the impoundment at Lakeshore Estates. In addition, deviations from a generalized pattern of increasing discharge along Juday Creek further supports the view that areas of the stream differ with respect to the extent of their interaction with groundwater.

Table 1. Data collected from the Juday Creek Project Spring Survey (14-V-91).

	SITE 1 BUS. ROUTE 31	SITE 2 JUNIPER ROAD	SITE 3 DOUGLAS ROAD	SITE 4 LAKESHORE ESTATES	SITE 5 FIR ROAD
WATER TEMPERATURE °C (°F)	18.0 (64.4)	18.0 (64.4)	17.5 (63.5)	16.0 (60.8)	17.0 (62.6)
DISSOLVED OXYGEN (mg/l)	12.0	12.2	12.4	12.0	12.0
DISCHARGE m^3/s (cfs)	0.7 (24.7)	0.8 (28.2)	1.2 (42.3)	0.9 (31.8)	0.7 (24.7)
CHLOROPHYLL a (μg/l)	5.53	4.16	3.59	3.98	2.56

ANALYTICAL REPORT NON-ORGANIC PARAMETERS

REPORT TO: Victor Bierman Jr., Ph.D., LTI-Limno-Tech, Inc.
20780 Gatehouse Dr., South Bend, IN 46637

BILL TO: LTI-Limno-Tech. Inc.

EIS LAB NUMBER: 17699-17703

EIS PROJECT NO:

CLIENT P.O. NO:

DATE SAMPLED: 5-14-91

DATE RECEIVED: 5-14-91

REPORT FORWARDED: 7-5-91

SAMPLE IDENTIFICATION:

Project: JDVCR

Surface Water

collected by: T.J.F.

Sample Description	Total Phosphrous (mg/l)	Soluble Ortho. Phosphate (mg/l)
US 31	<0.08	<0.08
Juniper	<0.08	<0.08
Douglas	<0.08	<0.08
Lakeshore Pond	<0.08	<0.08
Fir	<0.08	<0.08
Quality Assurance Data		
Precision (%RSD)	0	0
Accuracy (%R)	--	100

Chain-of-Custody is enclosed.

LABORATORY DIRECTOR

2001
Rev (12-03-90)

To: Dr. Victor J. Bierman, LTI - Limno-Tech, Inc.
From: Dr. Martin B. Berg, University of Notre Dame
Re: Summary Report of Juday Creek Summer Survey

August 24, 1991

Juday Creek Project (JDYCR) Summer Survey

INTRODUCTION

A survey of Juday Creek was conducted on 30 July 1991 by Dr. Martin B. Berg (Department of Biological Sciences, University of Notre Dame). This survey represents the final phase, Phase II, of monitoring the physical and chemical characteristics of Juday Creek. Phase II initially was designed to monitor the stream during low flow conditions, and given the paucity of precipitation during the summer of 1991, I believe we have met our intentions.

METHODS

Physical and Chemical Parameters

This report presents results for the following parameters: water temperature, dissolved oxygen (D.O.), discharge and sestonic chlorophyll a. In addition, water samples for soluble reactive phosphorus and total phosphorus also were collected and delivered to EIS, Inc. of South Bend, Indiana for analysis. Methods and sample site descriptions were presented in the Phase I report and will not be reiterated here. The only differences between Phase I and Phase II analyses were the levels of sensitivity for phosphorus samples. Soluble reactive phosphorus and total phosphorus analyses performed by EIS, Inc. in Phase I were conducted at too high a level of detection (80 μg/l) for most freshwater systems. A request was made to EIS, Inc., by both Dr. Victor J. Bierman of LTI - Limno-Tech, Inc. and myself, to analyze both forms of phosphorus at levels of detection of approximately 10 μg/l. We both were informed that procedures would be modified to achieve levels of detection in the requested range. As with the results from Phase I, results of phosphorus analyses from Phase II were to be provided directly to Dr. Bierman.

RESULTS AND DISCUSSION

All results from the Phase II portion of this study are presented in Table 1. As in Phase I, water temperatures exhibited a "general" trend of higher values at downstream sites compared to upstream locations. The apparently cooler temperatures at Site 1 likely are due to the stream flowing through more heavily canopied areas upstream, resulting in a slight decrease in water temperature due to shading and reduced irradiance reaching the stream.

Dissolved oxygen concentrations along the length of the stream varied to a much greater extent than observed during the spring sampling period. The increase in dissolved oxygen at Site 4 is probably a result of high primary production in the Lakeshore Estates pond. This explanation is supported by results from the chlorophyll a analysis. Increases in chlorophyll a at Site 4 is another indication of the high levels of primary production within the Lakeshore Estates pond (see below for discussion of chlorophyll a results). High densities of algae and aquatic macrophytes adjacent to, and immediately upstream from, Douglas Road account for the further increase in dissolved oxygen exhibited at Site 3 compared to Site 4.

Discharge values during summer low flow were 43 - 50% lower than values at the same sites in May. The intersite trends observed during the July sampling period were, however, consistent with those from the spring sampling. As during spring, discharge was highest at Site 3 followed by Sites 4, 2, 1 and 5, respectively. Discharge ranged from 0.3 m^3/s at Site 5 to 0.6 m^3/s at Site 3. The range of discharge values was much greater during spring (0.5 m^3/s) than during summer low flow (0.3 m^3/s). The decrease in intersite differences during summer compared to spring may be due to streamflow approaching some baseline minimum.

Patterns in the level of chlorophyll a in July were similar to those observed in May, except for those sites immediately influenced by the Lakeshore Estates pond. Levels of chlorophyll a at Sites 4 and 3 reflect the high algal production occuring in the pond. Chlorophyll values were fifteen times higher at Site 4 in July compared to the same site in May. Similarly, the next site downstream, Site 3, had chlorophyll values eight-fold higher than in May. These two observations are not surprising because high phytoplankton production in the impoundment would translate directly to high sestonic chlorophyll a at sites downstream. It is interesting to note that the high level of chlorophyll a associated with the Lakeshore Estates pond is reduced 50% by Site 3 and is no longer evident by the time streamwater reaches Site 2. July values at Sites 1, 2 and 5 were comparable to those observed in May.

In summary, I believe that the results from Phase II are an accurate indication of stream conditions during periods of summer low flow. Any substantial differences with respect to the patterns observed in July compared to May, can be directly attributed to the Lakeshore Estates pond.

Table 1. Data collected from the Juday Creek Project Summer Survey (30-VII-91).

	SITE 1 BUS. ROUTE 31	SITE 2 JUNIPER ROAD	SITE 3 DOUGLAS ROAD	SITE 4 LAKESHORE ESTATES	SITE 5 FIR ROAD
WATER TEMPERATURE °C (°F)	21.0 (69.8)	22.0 (71.6)	21.0 (69.8)	19.5 (67.1)	19.5 (67.3)
DISSOLVED OXYGEN (mg/l)	10.9	10.2	11.6	10.4	8.5
DISCHARGE m^3/s (cfs)	0.4 (14.1)	0.4 (14.1)	0.6 (21.2)	0.5 (17.6)	0.3 (10.6)
CHLOROPHYLL a (µg/l)	4.81	4.50	28.64	62.81	1.21

eis

ANALYTICAL REPORT NON-ORGANIC PARAMETERS

REPORT TO: Mr. Victor Bierman, Limno-Tech Inc.
20780 Gatehouse Dr,. South Bend, IN 46637

BILL TO: Limno-Tech, Inc.

EIS LAB NUMBER: 19847-19852

EIS PROJECT NO:

CLIENT P.O. NO:

DATE SAMPLED: 7-30-91

DATE RECEIVED: 7-30-91

REPORT FORWARDED: 8-13-91

SAMPLE IDENTIFICATION:

Juday Creek

Midwater Flowers

Sample Description	Total Phosphorus (mg/l)	Soluble Ortho Phosphate (mg/l)
Trip Blank	<0.05	--
Phillips 66	0.13	<0.032
Juniper Road	0.11	<0.032
Douglas Road	0.10	<0.032
Lakeshore Estates	0.08	<0.032
Fir Road	0.08	0.04

Quality Assurance Data

	Total Phosphorus	Soluble Ortho Phosphate
Precision (%RSD)	0	0
Accuracy (%R)	--	90

Chain-of-Custody is enclosed.

Andie Pozite
LABORATORY DIRECTOR

2001
Rev (12-03-90)

ATTACHMENT D
SEDIMENT OXYGEN DEMAND SURVEY

LTI – Limno-Tech, Inc.
Memorandum

TO:	V. Bierman, J. Marr	**DATE:**	08/05/91
		PROJECT:	JDYCR-2
FROM:	Tim J. Feist		
SUBJECT:	Juday Creek SOD Study		

SUMMARY

Limno-Tech, Inc. (LTI) conducted sediment oxygen demand (SOD) measurements in Lakeshore Estates Pond, a section of Juday Creek near South Bend, Indiana. The purpose of the survey was to provide an indication of the effects on the creek's dissolved oxygen of a proposed detention pond upstream on Juday Creek. The Lakeshore Estates Pond was selected since depositional sediments in the Pond are similar to those expected to be found in the detention basin. Four SOD measurements were made, of which three were considered valid. The mean SOD measured was 4.0 g/m^2/day at 20^o C, with a range of 3.4 to 4.5 g/m^2/day at 20^o C.

INTRODUCTION

Sediment oxygen demand (SOD) can be an important parameter influencing dissolved oxygen concentrations in a water body since it is a persistent, in-place dissolved oxygen sink that is sometimes dominated by non-point contributions. LTI conducted a sediment oxygen demand study of sediments in the Lakeshore Estates Pond to determine the possible impacts on stream D.O. of a proposed detention pond farther upstream on Juday Creek.

In situ SOD was measured using methods successfully used in streams in Alabama, Florida, Ohio, and Michigan. SOD was measured using a hemispherical stainless steel chamber to isolate a volume of water over a specific area of sediment. The change in dissolved oxygen concentrations within the chamber over time was monitored with a calibrated YSI dissolved oxygen/temperature probe fitted into the chamber. Two sets of measurements were made, with two chambers in each set for a total of four SOD measurements. SOD incubations were run for between 1 and 2 hours, depending on the time necessary to obtain an accurate estimate of the rate of D.O. depletion. Over the course of SOD measurements, 6 dark bottles were filled with pond water and incubated in the pond to provide a correction for algal respiration and biochemical oxygen demand within the water column. SOD was determined by subtracting the mean rate of change of dissolved oxygen within the dark bottles from the rate of change in the chamber. The resulting SOD values were adjusted to a standard temperature of 20^o C.

LOCATION

The SOD study was conducted on depositional sediments in the southwest corner of Lakeshore Estates Pond. These sediments are similar to those expected to be found in a proposed detention basin on Juday Creek. The SOD chambers were set in 25 to 35 inch deep water approximately 30 feet offshore. This area was the transitional zone between the firmer, sandier sediments near shore and the soft, silt and fine sand depositional sediments located along the drop off into deeper water. The chambers were located over the softer depositional sediments. For the second set of measurements both chambers were moved approximately 10 feet west of their original locations. Ambient pond temperature was 19 to 20^{0} C during the measurements.

RESULTS

The right chamber developed a large bubble within it during the first run. This resulted in erratic readings, and the measurement was dropped. Of the remaining 3 measurements, SOD averaged 4.0 g/m^{2}/day at 20^{0} C ranged from 3.4 to 4.5 g/m^{2} /day at 20^{0} C (Table 1). Chambers placed in the soft silt sediments exhibited lower SODs than the chamber placed in the more sandy sediment.

TABLE 1. SOD Study of Lakeshore Estates Pond

Location	SOD (g/m^{2}/d @ 20^{0} C)	Observation
Right - 1st run	---	Large bubble caused erratic readings
Right - 2nd run	3.4	8" of soft sandy silt over gravel/sand
Left - 1st run	4.1	Very soft substrate; approximately 24" of silt
Left - 2nd run	4.5	Black silty sand

ATTACHMENT E
QUAL2E MODEL CALIBRATION AND SIMULATIONS

LTI – Limno-Tech, Inc.
Memorandum

TO: John K. Marr, P.E.

DATE: 10/8/91
PROJECT: JDYCR-3

FROM: Sakhr Youness

SUBJECT: Judāy Creek Water Temperature Simulations

SUMMARY:

The modeling of the Juday Creek water temperatures was brought about through concerns that a new storm retention pond upstream of Fir Road would increase the water temperature and negatively impact the trout populations in the downstream reaches of the Creek. Surveys were conducted in May and July of 1991 to support the modeling work. The surveys indicated a complex nature of the flow regime in the Creek because of the obvious interaction with the underlying aquifer. This made it very difficult to do the future projections based on low flows since this interaction is highly sensitive to the stream flow values and no indications of how it would look like under such conditions are available.

Model calibration was conducted based on the surveys. Variations in the values of shading and wind speed are noticed from the upstream reaches to the downstream reach. These variations reflect the difference in the areas the stream passes through where more tree canopy can be found surrounding the Creek in the downstream reach and thus less wind effect. Hydraulic parameters and flows for July and May and climatological parameters for May obtained from the calibrations were used in the projections. Shade and wind speed for July projections were obtained from average July climatological data related to South Bend Indiana obtained from NOAA.

The overall results from the projections indicate that there is very little chance the critical temperatures will be exceeded in May (76^{o}F) or in July (80^{o}F). The temperatures however, rise by more than 2 degrees in May in the critical region in the downstream reaches due to the new pond.

It should be stressed that the nature of Juday Creek, being a shallow stream, makes it very sensitive to the surrounding conditions like weather, flows, and ground water interactions. A better estimate of these parameters will lead to more confidence in the results of the projections.

BACKGROUND:

Juday Creek is a small third order tributary to St. Joseph River. The drainage area of the Creek is 37.3 square miles, part of which is located in Michigan with the majority located in Indiana. The Creek supports a population of trout , especially in the downstream reaches. The critical region for the trout population is thought to be as far upstream as Juniper Road.

The trout populations are sensitive to the water temperature in the Creek. The temperature should not exceed 80°F for any 24 hour period in July and 76°F in May. The study was initiated through concerns that a storm retention pond designed by Cole Associates will lead to substantial warming along Juday Creek and would negatively impact the trout populations within the downstream stretches of the Creek.

Two surveys were conducted at five different locations in the Creek in May and July of 1991 to help a modeling process that would lead to the projection of the water temperatures in the Creek at critical conditions. The surveys included measurements of water temperature, stream width, depth and velocity values at different points across the Creek. An EPA-supported model, QUAL-2E, was chosen to be used in the simulation of the Creek temperatures. The model was calibrated to the data available from the surveys before using it to project the water temperature at the critical conditions.

The baseline condition in the simulations for July was considered to be average conditions taken from the surveys conducted on July 16, 1991 and July 30, 1991. The baseline condition for May was considered to be the conditions during the May 14, 1991 survey. The critical conditions included a case where the baseline conditions were still assumed with the new pond built upstream of Fir Road for both July and May simulations. The other critical condition was assumed to happen with flows corresponding to a 3-year storm in the area with the water temperature upstream reflecting the effect of Fir Pond as resulted from the previous critical condition simulation. The following sections describe the model used and the simulations conducted together with the conclusions from these simulations.

QUAL-2E MODEL DESCRIPTION

QUAL-2E is an EPA-supported model that can simulate many water quality parameters in a one-dimensional branching stream system. The model was chosen because it allowed the simulation of water temperatures based on the significant features of the Juday Creek System. The model can simulate both steady state and dynamic conditions and the effects of different point and non-point sources or sinks on the stream.

Model inputs include data cards that define system features affecting stream temperature. The inputs include data describing the latitude, longitude, and average elevation of the basin. The Julian day is an important input to the model since the model decides many of the steady state heat exchange coefficients based on this parameter and the location parameters. Other inputs include wind speed, shading through cloud cover and tree canopy, barometric pressure, dust attenuation coefficient and others.

The model representation of the stream is done by dividing it into reaches each consisting of equal-size computational elements. Those elements are the key to describing the details of the system, some of them are headwater elements, others are junction or may be point load elements..etc. Incremental inflow into (or outflow from) a reach can be added which allows for distributed load sources or sinks to be simulated. Stream cross sections can be represented by either trapezoidal sections or irregular sections in which the depth and velocity are related to the flow value through certain coefficients. Inflows to the system are represented in the headwater inflow and the incremental inflows along the reaches. The upstream temperature is represented by the headwater inflow temperature. Output from the model is available in both tabular and graphical forms where the value of the simulated parameter is shown along the stream.

The model was suitable for the Juday Creek system and the following sections present the calibration and projections at the critical conditions.

MODEL CALIBRATION:

Surveys were done in July and May of 1991 at five different locations on Juday Creek. The locations extended from Fir Road at river mile 6.52 to Route 31 at river mile 1.54. The survey showed a significant water and heat exchange between the stream and the underlying aquifer. A general trend was noticed for the July and May surveys. The Creek seemed to gain cooler water from the aquifer between Fir Road and Douglas Road, and lose warmer water to it between Douglas Road and Rout 31. Significant cooler ground water inflows added to the flow in the downstream parts near Isaac Walton League just before confluence with St. Joseph River.

The model parameters, like flows, incremental inflows and outflows, and upstream temperatures, were chosen from different project reports and memos. Some parameters, especially those related to climatological conditions, were chosen from the literature. Calibration parameters to July 30, 1991 survey included some climatological inputs like wind speed, and some of the hydraulic parameters that defined the geometry and flow velocity of the stream. The attached tables summarize the different model inputs and their sources for the calibrations and the projections.

Temperature data were available for July 16, 1991. The model was calibrated to these data by only "tuning" some of the meteorological inputs. The difference in temperature between the two data sets was attributed to the different weather conditions on the two days since flow data available on July 18, 1991 showed little difference from those of July 30, 1991 (see progress report prepared in August, 1991 by Dr. S. Silliman).

MODEL PROJECTIONS:

Fir Pond is expected to raise the stream temperature by a certain amount. The rise in temperature is attributed to the long residence time in the pond during which too much heat exchange takes place between the large pond surface and the atmosphere.

The water temperature is very sensitive to the wind speed and the shading of cloud cover and canopy. Values of these parameters varied from one reach to another to reflect the differences in the nature of the areas the stream passes through. The down stream end of the Creek gets more canopy shade than the upstream reaches, which also reduces the wind speed at the water surface. This is represented in the model by giving higher cloud cover for the most downstream reach and less wind speed than the rest of the reaches.

The first projection would be at baseline conditions of July and May with the pond added upstream of Fir Road. Another projection would be to see how temperature will change in the Creek in storm conditions with the pond effect controlling the upstream boundary temperature. A three-year storm was chosen for this purpose, the storm has a total rainfall amount of 2.86 inches falling over 48 hours with a peak one hour intensity of 1.43 inches/hour. With the drainage area approximately 37.3 square miles, the storm would generate an additional stream flow of 36.6 cfs at the upstream end. The design peak outflow from the pond is 53.2 cfs at the 100-year flood conditions. This flow should not be exceeded at the Fir Road Pond outlet in our simulations.

Baseline conditions were chosen based on the survey flows and upstream temperatures as mentioned earlier. The shading and wind speed parameters were taken to be average values of July and May based on climatological data for South Bend, Indiana and taking into account the variation ratios from the upstream reaches to the down stream reach as obtained from the calibrations. The reason why low flow values like 7Q10 or 2Q10 were not chosen is that under such flow conditions we have no idea of the nature of exchange between the aquifer and the overlying stream. The tables and graphs together with the notes on them below describe the inputs and results of the different simulations done.

The graphs show that none of the critical conditions results in violation of the critical temperature whether in May or in July. In May however, it is noticed that the water temperature rises by more than 2°F in the critical region due to the new Fir Road Pond. The pond is supposed to be responsible for raising the water temperature in the upstream end by approximately 7.3 degrees in July and 6.5 degrees in May.

QUAL-2E Input Parameters for Calibration of QUAL-2E

	16-Jul-91	30-Jul-91	14 May, 91	Source
Upstream Temp, F	67.10	67.10	62.60	Survey
Upstream Flow, cfs	10.60	10.60	24.70	Survey
Flow at Lake Shore Pond, cfs	21.20	21.20	49.40	Survey
Shading and Cloud Cover(1)	10-70	58-85	80-95	Calibration
Wind Speed, mph	3.4-5.5	8.40	9.00	Calibration
Depth Range, ft (2)	0.55-5.0	0.55-5.0	0.64-5.0	Survey
Julian Day	197.00	211.00	134.00	Survey

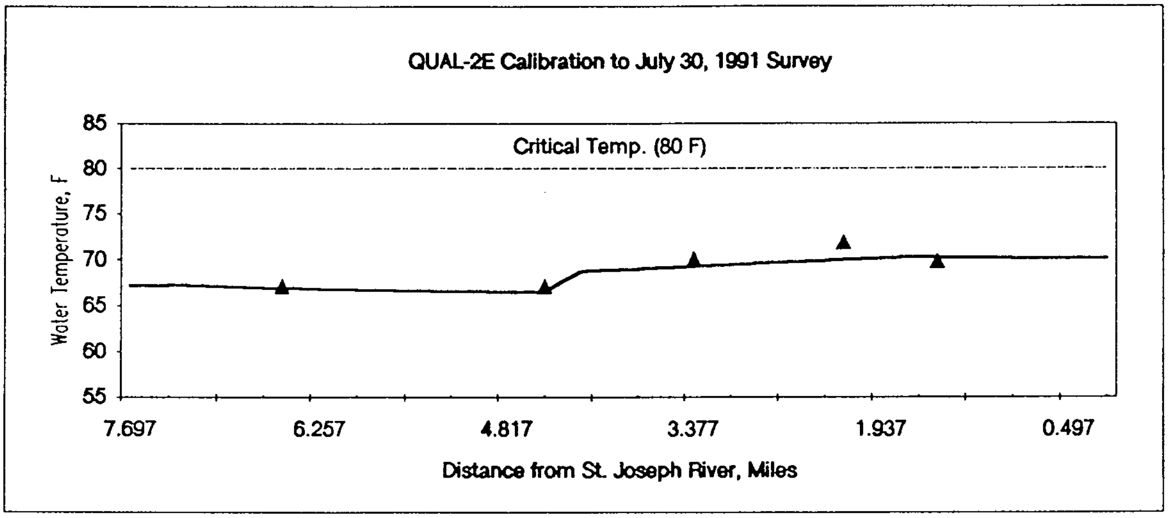
QUAL-2E Input Parameters at Critical Conditions

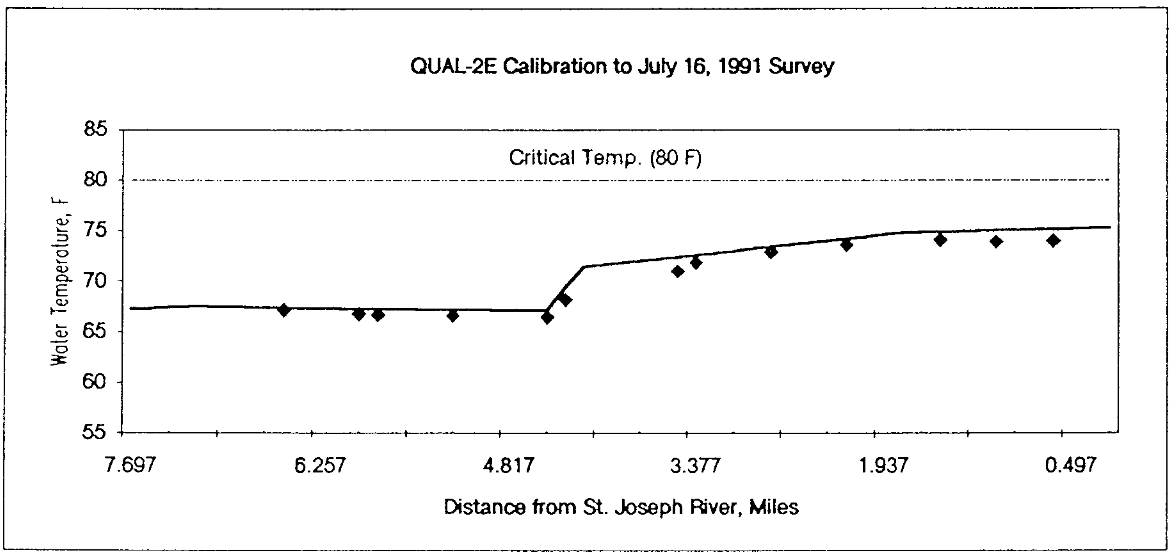
	3- Year Storm		Steady State with Pond	
	July	May	July	May
Upstream Temp, F (3)	74.40	69.10	67.10	62.60
Upstream Flow, cfs (4)	47.20	53.20	10.60	24.70
Flow at Lake Shore Pond, cfs (5)	57.80	70.90	21.20	49.40
Shading and Cloud Cover (6)	58-80	80-95	58-80	80-95
Wind Speed, mph	5.6-7.0	9.00	5.6-7.0	9.00
Depth Range, ft	0.70-5.00	0.73-5.00	0.55-5.00	0.64-5.00
Julian Day	196.00	135.00	196.00	135.00

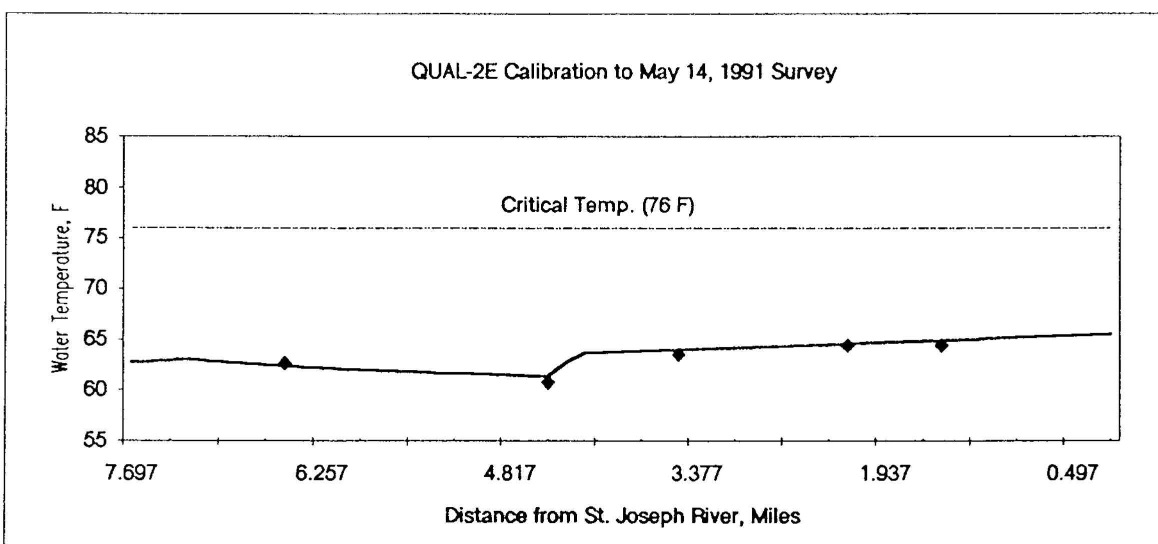
Hydraulic Coefficient Inputs to the Model

Reach (9)	River Miles	Depth Coefficients (7)		Velocity Coefficients (8)	
		A	B	C	D
1	7.121-4.529	0.36000	0.17900	0.16900	0.84900
2 (10)	4.529-4.385	5.00000	0.00000	0.00063	1.00000
3	4.385-2.369	0.48300	0.11100	0.09900	0.88900
4	2.369-0.065	0.30200	0.33000	0.38000	0.45300

Notes:
1- changed from section to another as a calibration parameter reflecting the nature surrounding the Creek in the different reaches
2- varied with the flow values according to the coefficients in table 3 above
3- taken from the baseline simulation with the pond
4- taken from storm 3-year storm conditions
5- accounts for the groundwater inflow taken from the survey
6- average values based on the different surveys in one month and NOAA data
7- assumed relation is Depth = AQ^B, Q being the flow value
8- assumed relation is Velocity= CQ^D, Q being the flow value
9- does not have Fir Road pond
10- Lake Shore Pond


QUAL-2E Calibration to July 30, 1991 Survey
Critical Temp. (80 F)
Water Temperature, F
85
80
75
70
65
60
55
7.697
6.257
4.817
3.377
1.937
0.497
Distance from St. Joseph River, Miles


QUAL-2E Calibration to July 16, 1991 Survey
Critical Temp. (80 F)
Water Temperature, F
85
80
75
70
65
60
55
7.697
6.257
4.817
3.377
1.937
0.497
Distance from St. Joseph River, Miles


QUAL-2E Calibration to May 14, 1991 Survey
Critical Temp. (76 F)
Water Temperature, F
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75
70
65
60
55
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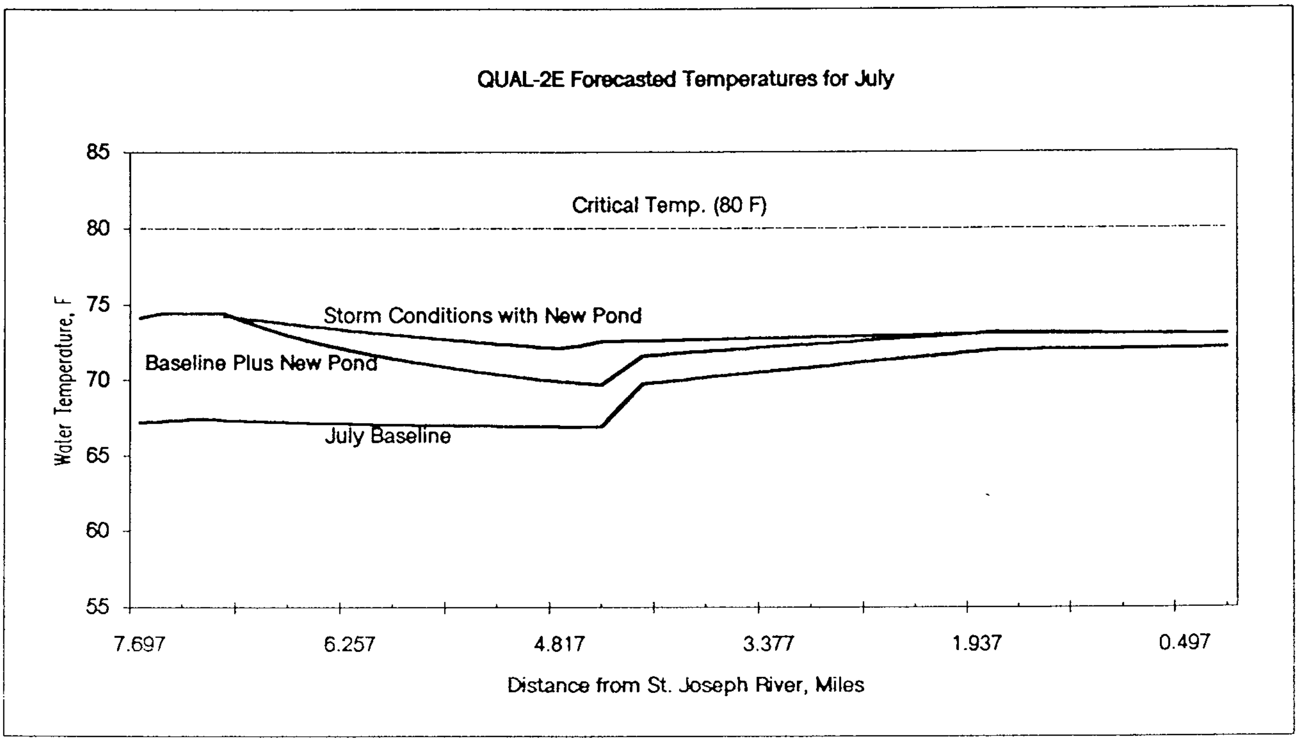
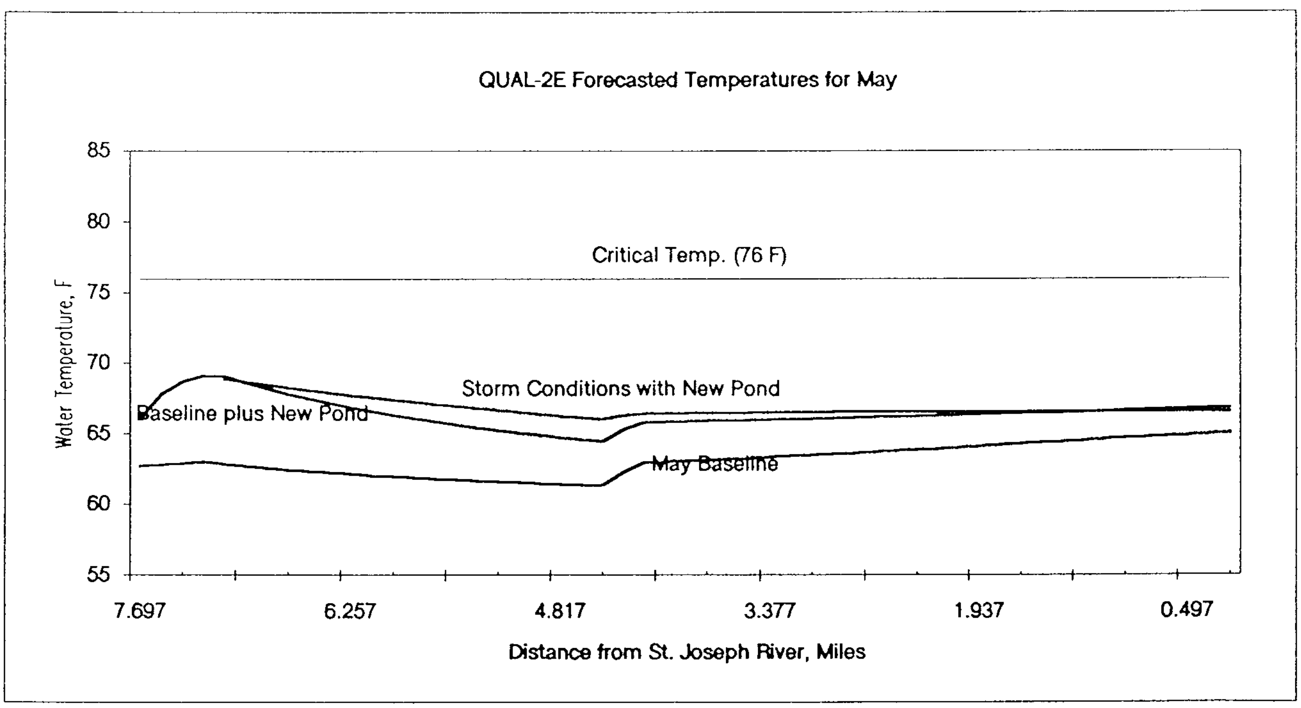
4.817
3.377
1.937
0.497
Distance from St. Joseph River, Miles


QUAL-2E Forecasted Temperatures for July
Critical Temp. (80 F)
Storm Conditions with New Pond
Baseline Plus New Pond
July Baseline
Water Temperature, F
85
80
75
70
65
60
55
7.697
6.257
4.817
3.377
1.937
0.497
Distance from St. Joseph River, Miles


QUAL-2E Forecasted Temperatures for May
Critical Temp. (76 F)
Storm Conditions with New Pond
Baseline plus New Pond
May Baseline
Water Temperature, F
85
80
75
70
65
60
55
7.697
6.257
4.817
3.377
1.937
0.497
Distance from St. Joseph River, Miles

ATTACHMENT F
DRAINAGE AREA RECOMMENDATIONS