BASIN HYDROLOGY AND AVAILABLE WATER SUPPLY

CLIMATE

The climate of the St. Joseph River basin, classified as temperate continental, is characterized by warm, occasionally hot summers, cold winters, and considerable daily variations in temperatures.

Northern Indiana frequently encounters cyclonic disturbances generated by the interactions of northeast-moving tropical and south-moving arctic air masses. Locally heavy amounts of rain or snow associated with the eastward passage of low pressure centers are often recorded, although basinwide, precipitation is fairly evenly distributed throughout the year.

Other climatic characteristics of the basin include moderate to high humidities, light to moderate winds (typically from the southwest), and a large proportion of partly cloudy to cloudy days interspersed with clear days. Severe local storms generated by daytime convection or by the passage of cold fronts are most common in spring and early summer. These storms may produce frequent lightning, strong winds, or large hail, as well as sporadic funnel clouds and tornadoes.

The climate of the western part of the basin in both states is influenced by Lake Michigan, particularly from the vicinity of South Bend, Indiana northward to near Hartford and Paw Paw, Michigan (see app. 5).

Although meteorological parameters such as wind, solar radiation, relative humidity and soil temperature also constitute an area's climate, only air temperature and precipitation will be summarized here. Temperature regime defines growing season (the number of days between the last spring and first autumn temperature of 32° F) and largely controls the process of evapotranspiration, which consumes more than 70 percent of the average annual precipitation. Precipitation is the source of all fresh water either on the surface or in the subsurface of the earth. The amount, distribution and mode of occurrence of precipitation will largely define a region's water supply and help determine its hydrologic regime.

Temperature[5]

Annual temperatures within the St. Joseph basin average 49° F (degrees Fahrenheit). Seasonal temperatures average 48° F in spring (March-May), 70° F in summer (June-August), 52° F in autumn (September-November), and 26° F in winter (December-February). January, the coldest month, has a mean monthly temperature of 23° F and a mean daily minimum of 15° F. July is the warmest, and has an average temperature of 72° F and a mean daily maximum of 83° F. Diurnal temperature variations (the difference between normal daily maximums and minimums) typically range from about 15° F in winter to 23° F in summer, although diurnal ranges in South Bend average 1° F to 3° F less. Extreme temperature readings in the basin have ranged from 101° F (Three Rivers, 1971) to -20° F (Goshen and Coldwater, 1963).

Mean growing season ranges from less than 150 days in the more elevated eastern parts of the basin to about 170 days just inland of Lake Michigan. Vegetative cover, soils, impervious surfaces and obstructions to wind are factors which can influence climatic features, particularly growing season. However, these factors typically affect climate only over small areas.

Precipitation

Annual precipitation in the basin averages 35 inches. During extremely dry and wet years, annual totals have ranged from 21 inches to 54 inches. There is a 90 percent probability, however, that annual precipitation will be about 29 inches in the South Bend area, and 27 inches in the rest of the basin.

Monthly precipitation totals have varied from zero to nearly 12 inches, but monthly averages are fairly uniform, as table 3 shows. An average of nearly 20 inches, or 57 percent of the mean annual precipitation, falls from May through October (the crop season). During this time, monthly amounts average 3.3 inches.

Daily precipitation is quite variable due to the

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5 Temperature and precipitation data are taken or derived from data published in several NOAA reports (see references) and unpublished data obtained from the Michigan Department of Agriculture, Climatology Division. Data from South Bend, Goshen, Three Rivers (Michigan) and Coldwater (Michigan) for the period 1951-80 were used to obtain in-basin averages and extremes. The Michigan stations were included due to the lack of published 30-year summaries for Indiana in central and eastern parts of the basin. All other information refers to Indiana unless otherwise indicated.

TABLE 3. Normal Monthly and Annual Precipitation in Inches, 1951-80

Month	South Bend Indiana	Goshen College Indiana	Coldwater Michigan	Three Rivers Michigan
January	2.48	1.78	1.72	1.84
February	1.99	1.58	1.56	1.49
March	3.05	2.60	2.36	2.44
April	4.06	3.59	3.48	3.35
May	2.81	2.97	3.03	3.12
June	3.94	3.61	3.73	3.95
July	3.67	3.61	4.01	3.79
August	3.94	3.66	3.40	3.16
September	3.22	3.03	3.03	3.01
October	3.22	2.73	2.60	2.71
November	2.83	2.32	2.38	2.37
December	2.95	2.23	2.19	2.32
Annual	38.16	33.71	33.49	33.57

periodic passage of frontal systems, and 24-hour amounts have ranged from zero to more than 5 inches. Although precipitation events are generally interspersed among several dry days, daily normals fall between 0.07 inch in February to 0.14 inch in April and June, as interpolated from monthly normals by the use of a statistical function.

Annual snowfall for Angola (1951-72) and Goshen (1951-80) averages roughly 35 inches, while snowfall at South Bend averages 72 inches (1951-80). Snowfall accounts for nearly 20 percent of the average annual precipitation in the South Bend vicinity, where lake-effect snows are common. Elsewhere in the basin,snowfall accounts for less than 10 percent.

Climatic Data

Climatic data for the St. Joseph River basin are gathered as part of several statewide networks operated by federal and state agencies. The most extensive networks are operated and maintained by the National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA). Official climatic data in the basin are collected at a 24-hour NWS office (South Bend) and at NWS cooperative observer stations operated by water and wastewater utilities, municipalities, universities or private citizens (table 4). Additional precipitation data are gathered by about 10 amateur radio operators as part of a statewide volunteer network (WETNET) which aids the NWS river and flood forecasting program.

The majority of data from NWS stations are published by NOAA in monthly and annual climatic summaries, although WETNET data remain unpublished. Data from selected NWS stations are periodically published in specialized climatic reports.

Other precipitation data are collected at three sites by the Division of Water for hydrologic and hydraulic studies. Data from these stations are unpublished by NOAA, but monthly records remain filed at the division.

Fig. 14 shows the location of active NWS and Division of Water stations. (Amateur radio stations are not included, because the statewide network changes frequently.) Crompton and others (1986) list nine discontinued NWS stations not shown in fig. 14 or in table 4: Albion, Elkhart, Goshen Airport, Howe Military Academy, Kendallville, LaGrange, Notre Dame, Syracuse, and Topeka.

SURFACE-WATER HYDROLOGY

Drainage Characteristics

The surface-water system of the St. Joseph River basin is characterized by more than 200 natural lakes, approximately 27,000 wetlands, and low-gradient streams developed on outwash and till deposits. Part of the St. Lawrence drainage system, the St. Joseph basin drains 1699 mi² (square miles) in Indiana and 2586 mi² in Lower Michigan (fig. 2).

The St. Joseph River heads near Hillsdale, Michigan and flows generally to the southwest. In South Bend, Indiana, the river turns abruptly northward, then flows toward the northwest until it empties into Lake Michigan near Benton Harbor, Michigan.

Approximately 41 miles (about 19 percent) of the St. Joseph River mainstem lie in Indiana. The river enters Indiana in northern Elkhart County and exits in northern St. Joseph County. Average channel slope of this reach is 2.5 feet per mile, which is typical of most major Indiana rivers.

The chief tributary of the St. Joseph River in Indiana is the Elkhart River, which drains 699 mi², mainly in Noble and Elkhart Counties. Pigeon River (basin area: 374 mi²) and Fawn River (basin area: 130 mi²) drain parts of LaGrange and Steuben Counties before entering the St. Joseph River in Michigan. Other streams draining more than 100 mi² include North Branch Elkhart River (277), Turkey Creek (183), Little Elkhart River (129), Christiana Creek (128), and South Branch Elkhart River (114)[6].

Although drainage is not well developed due to the geologically recent deposition of glacial drift, a Horton-Strahler analysis of the basin (based on an examination of stream lengths and orders as described by Horton, 1945 and modified by Strahler, 1957) indicated a "normal" drainage system having a dendritic stream pattern. Drainage in the Indiana part of the basin is generally toward the northwest.

TABLE 4.
Official National Weather Service Stations

Station	Observation[1,2]	Gage[2,3]
Angola	P,T	R,NR
Goshen College	P,T	R,NR
LaGrange Sewage Plant	P,T	R,NR
Ligonier	(P)	(NR)
Kendallville	P	R,(NR)
Prairie Heights	P,T,A	NR
South Bend WSO	P,T,A	NR
Waterford Mills	(P,T,A)	(NR)

[1]Precipitation (P), Temperature (T), Additional parameters (A).

[2]Data not published by NOAA (( )).

[3]Recording precipitation gage (R) -- data automatically recorded at selected intervals; Non-recording precipitation gage (NR) -- data collected manually once daily.

Stream-flow Data

The U.S. Geological Survey (USGS), in cooperation with the State of Indiana, has collected daily stream-flow data since 1931 at a total of 16 gaging stations within the St. Joseph River basin. As of late 1986, 11 continuous-record stream gaging stations remained active (table 5). Stream-flow data are published in reports prepared annually by the USGS.

Records of stream discharge during periods of low flow and high flow have been collected at partial-record sites where daily discharge data were not available. Additional measurements of discharge have been obtained at miscellaneous sites. Data from partial-record and miscellaneous sites are primarily used in regional hydrology studies to estimate flow characteristics at both gaged and ungaged locations.

Table 5 lists Indiana's continuous-record gaging stations (both active and discontinued), as well as partial-record stations for which discharge-frequency data have been published (Stewart, 1983 and Glatfelter, 1984). Gaging locations are shown in fig. 14.

6 Drainage areas from Hoggatt (1975); may include drainage in Michigan.

TABLE 5. Stream-Flow Gaging Stations

Station Number[1,2]		Station Name	County	Total Drainage Area (mi²)	Period of Record[3]	Remarks[4]
04-097970		Lime Lake Outlet at Panama	Steuben	17.5	1969-	NC,OR
04-098000	D	Fawn River at Orland	Steuben	86.4	1943-47	Staff
04-09902050	L	Ewing Ditch near Angola	Steuben	4.0	1973-74	
04-09904050	L	Berlien Ditch near Angola	Steuben	3.2	1973	
04-099060	C	Pigeon Creek Trib. near Ellis	Steuben	1.22	1972-82	
04-099500	D	Pigeon Creek & Hogback L. near Angola	Steuben	103.	1945-74	NC; moved to 04-099510
04-099510		Pigeon Creek near Angola	Steuben	106.	1945-	NC
04-099610	D	Pretty Lake Inlet near Stroh	LaGrange	1.96	1963-80	NC
04-099750		Pigeon River near Scott	LaGrange	361.	1968-	NC
04-099805	L	Little Elkhart River near Middlebury	Elkhart	60.6	1971-79	
04-099808		Little Elkhart River at Middlebury	Elkhart	97.6	1979-	NC
04-099850		Pine Creek near Elkhart	Elkhart	31.0	1979-	NC
04-100000	D	Christiana Creek at Elkhart	Elkhart	127.	1947-52	Staff gage
04-10009550	L	Dove Creek near Valentine	LaGrange	2.20	1973-74	
04-100165	C	Wible Lake Inlet near Kendallville	Noble	2.47	1973-82	
04-100220	D	N. Br. Elkhart River near Cosperville	Noble	134.	1950-71	OR; wire-weight
04-100222		N. Br. Elkhart River at Cosperville	Noble	142.	1971-	OR
04-100252		Forker Creek near Burr Oak	Noble	19.2	1969-	OR
04-100295		Rimmell Branch near Albion	Noble	10.7	1979-	
04-100375	L	Solomon Creek near Syracuse	Elkhart	33.9	1973-79	
04-100465		Turkey Creek at Syracuse	Kosciusko	43.8	1969-	OR
04-100490	L	Turkey Creek near New Paris	Elkhart	169.	1960-69	
04-100500		Elkhart River at Goshen	Elkhart	594.	1931-	OR
04-100800	L,C	Yellow Creek at Dunlap	Elkhart	32.4	1971-	
04-101000		St. Joseph River at Elkhart	Elkhart	3370.	1947-	R
04-101300	L	Judy Creek at Roseland	St. Joseph	37.3	1973-79	

[1]Numbers are U.S. Geological Survey downstream order identification numbers.
[2]D = discontinued gaging station; L = lowflow partial-record station; C = crest-stage partial-record station.
[3]Refers to calendar year or portion thereof.
[4]NC = non-contributing: portion of drainage basin does not contribute directly to surface runoff; OR = occasional regulation of flow by lake control structure; R = flow regulated by power plant(s) above station.

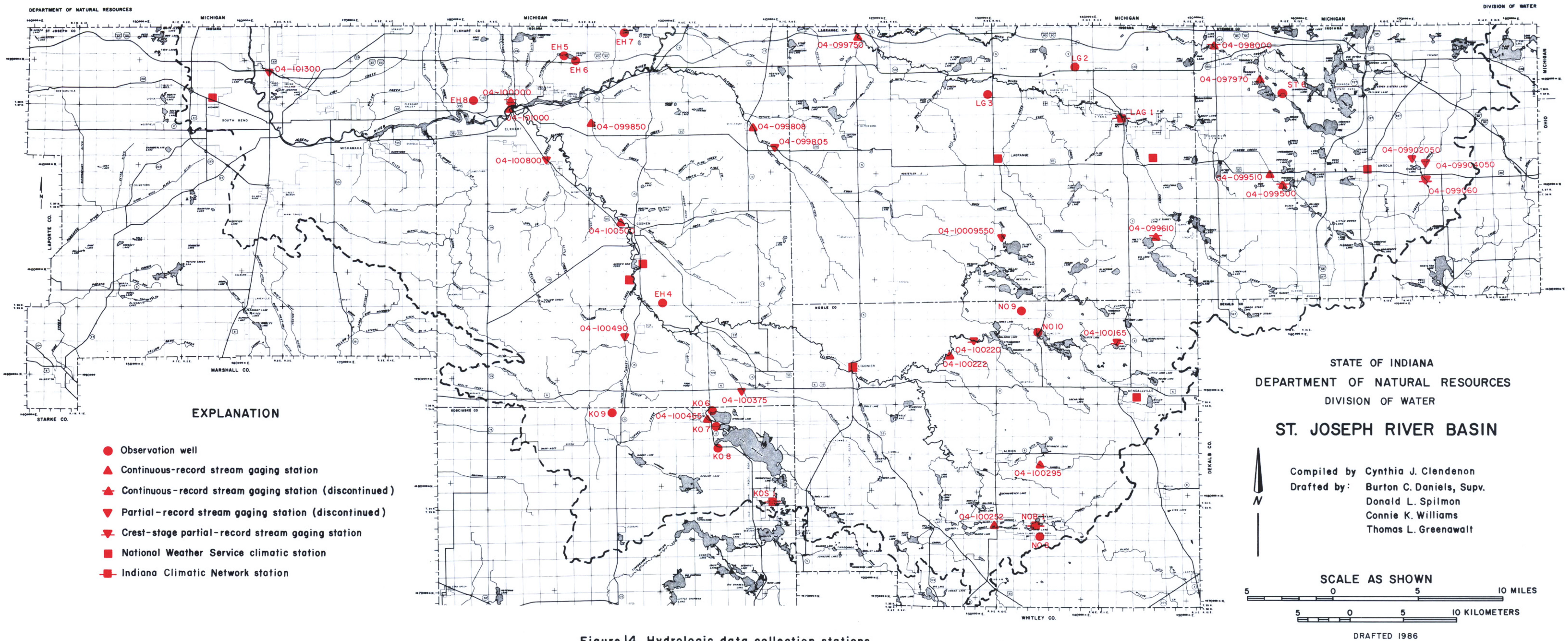

Figure 14. Hydrologic data collection stations

(Miscellaneous station listings and locations are not included. Five low-flow partial-record stations not tabulated or mapped are listed in Crompton and others, 1986.)

Although additions to the basin's stream gaging network currently are not feasible due to funding constraints, future network revisions may be necessary to meet expanding water management needs. In the past, the division primarily used discharge data for flood frequency determinations, hydraulic design studies, clearing and snagging studies, and monitoring of lake outflows. As water management programs develop further, data will also be needed for monitoring potential withdrawal impacts, determining low-flow characteristics, and relating stream-flow characteristics to local and regional hydrogeology. The addition of gages which can provide data useful for several purposes is the most desirable.

For example, a gage installed near the mouth of Christiana Creek could provide data useful in flood-flow calculations. The gage could also have benefits with respect to ground-water and surface-water quality issues, particularly if routine sampling were established. A gage on Solomon Creek, perhaps near the former low-flow partial-record site, could monitor flows in an extensively ditched agricultural area characterized by relatively flat topography and by the presence of both outwash and till deposits.

Partial-record sites may be sufficient for some specific uses. The effects of major ground-water and/or surface-water irrigation withdrawals on stream flow, particularly on smaller streams, could be monitored by two gages operated during the growing season—one upstream of the withdrawal site and one downstream. The interactions of ground water and surface water in undeveloped (and/or protected) wetland areas could best be determined by the installation of a stream gage and a series of observation wells.

Although such additions are not currently scheduled, the discontinuation of three stream gages is recommended: (1) Lime Lake Outlet at Panama; (2) Forker Creek near Burr Oak; and (3) Turkey Creek at Syracuse. Data from these gages, which are located immediately downstream of lake-level control structures, have little value for regional hydrology purposes. Monitoring lake outflows appears to be the major justification for maintaining these gages.

Lakes

Most of Indiana's natural freshwater lakes are found within an area that was covered by the joint terminal moraines of the Michigan, Erie and Saginaw lobes of the Wisconsinan glaciation (fig. 7). Sedimentation, natural erosion associated with drainage basin development, and artificial drainage have destroyed an unknown number of glacial lakes. However, more than 500 lakes formed by the irregular deposition of glacial drift, by the melting of buried isolated blocks of ice, or by erosion and subsequent damming of meltwater stream channels still remain in the interlobate moraines.

The densest zone of glacial lakes extends from eastern Fulton County to Steuben County and thus includes the southeastern half of the St. Joseph basin[7]. About 200 natural lakes of widely varying surface acreages and storage capacities are located within the basin, primarily within LaGrange, Steuben and Noble counties.

App. 6 lists 107 natural and manmade lakes having a surface area of at least 50 acres and/or a storage volume of at least 500 acre-feet (163 million gallons). Depth contour maps are available for most of these lakes, as well as 26 smaller lakes. (At least 65 in-basin lakes listed in IDNR files are neither tabulated in app. 6 nor mapped.)

The values most frequently ascribed to in-basin lakes include recreational use, residential development, and fish and wildlife habitat. Lakes also act as areas of ground-water recharge and discharge.

Estimated rates of leakage from and ground-water seepage into basin lakes are not available. However, the similarity of lake and observation well hydrographs for Heaton Lake (in northwest Elkhart County) indicate a hydraulic connection between the lake and surrounding sand and gravel outwash deposits. From an examination of hydrographs (fig. 15), static water levels in the two wells, and a generalized piezometric surface map (Plate 2), it appears that water levels of Heaton Lake reflect regional ground-water flow. The lake probably gains ground water along its northern shore, then loses water on its southern shore as the ground water continues to move downgradient. Ground water similarly seems to flow through Cedar Lake (in northeast LaGrange County). Here, water probably seeps from the lake into the ground-water system along the northwest (outlet) side, where ground-water levels are lower than lake levels (Bailey and others, 1985).

7 The second belt of glacial lakes, lying primarily within the Kankakee River basin, extends from northwest Fulton County to LaPorte County. The rest of Indiana's 1820 lakes, ponds and reservoirs are nearly all manmade and are scattered across the entire state.

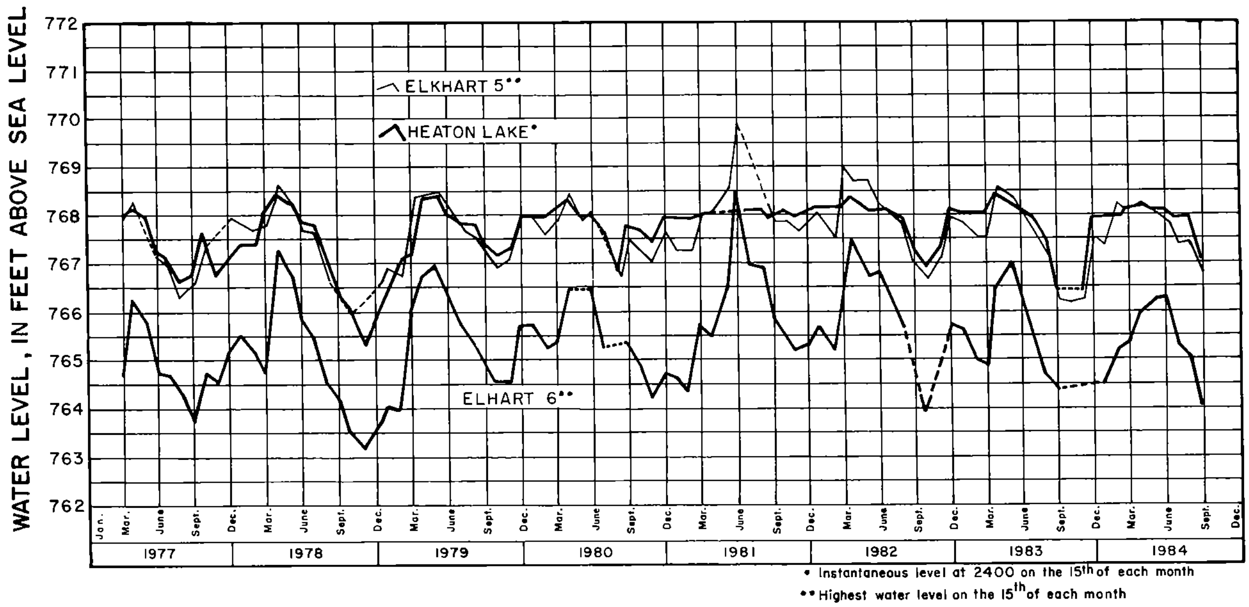

Figure 15. Correlation between Lake Levels and Ground-water Levels at Heaton Lake

Supply Potential of Lakes

Despite the tremendous storage capacities of lakes such as Wawasee and James, Indiana statutes effectively preclude the use of most public freshwater lakes as water supply sources.[8] In accordance with IC 13-2-11.1 and IC 13-2-13, lakes with a legally established average water level are to be maintained at that level. Temporary lowering of the established level requires approval by a local court and the Natural Resources Commission. Such approval is typically granted only for shoreline improvements or lake restoration procedures.

Even if state laws were amended to allow lowering of lake levels for supply purposes, treatment costs would limit non-drought uses to irrigation or livestock watering. In addition, pumpage-induced lowering of lake levels, even during non-drought periods, could not only affect water quality, fisheries habitat, and surrounding wetlands, but would be opposed by lakeside property owners.

The addition of lake storage (again assuming amendments to current lake laws) could similarly affect water quality and fish and wildlife habitat. Moreover, not only would the proximity of most homes to the lakeshore limit the amount of additional storage, but few lake-level control structures are designed to store water at elevations above the legal level. Increasing storage would therefore require the modification of existing structures.

Hence, given the current statutory and economic constraints and the abundance of ground-water and riverine supplies, the use of lakes as a water supply source in the St. Joseph basin is not a viable or a necessary alternative.

Lake Data

Historical records regarding lakes and drainage in Indiana date back to the early 1800s, but systematic records of lake levels have only been maintained for the past few decades. In 1943, the IDNR (formerly the Indiana Department of Conservation) entered into a cooperative agreement with the U.S. Geological Survey for the collection of water-surface elevations of selected Indiana lakes.

Lake data were primarily intended for use in the establishment of normal lake levels as defined by Indiana law (IC 13-2-13). Although legal levels are still occasionally established, stage data are presently

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8 According to IDNR data files, significant water withdrawals only occur on three in-basin lakes: Wawasee, Syracuse, and Sylvan. These withdrawals (for golf course irrigation) have no observable effect on water-level hydrographs.

utilized for other regulatory and management purposes, such as monitoring maximum and minimum levels, determining the location of shoreline for lakeshore construction and engineering projects, defining a lake's recreation potential, or investigating water quality problems.

The U.S. Geological Survey currently monitors daily water levels of about 50 lakes in the St. Joseph basin. Historical water-level data are available for about 40 additional lakes. Nearly 80 lakes in the basin have legal levels (app. 6).

Wetlands

In general terms, inland wetlands occur where the water table is usually at or near ground surface. Because wetland soils are periodically or permanently covered by water, these areas support plants and animals specifically adapted for life in the water or in saturated soil.

Wetlands can be classified by dominant plants, soils, and frequency of flooding. The U.S. Fish and Wildlife Service (USFWS) utilizes a hierarchical classification that progresses from systems and subsystems to classes, subclasses, and dominance types (characteristic plants and animals)[9]. To more fully describe wetlands, users of the system can apply modifying terms to classes and subclasses (for water regime, water chemistry and soil type, for example).

Based on the USFWS classification scheme, wetland systems in the St. Joseph River basin are defined as lacustrine, riverine and palustrine. In general, the wetlands and deep-water habitats classified as lacustrine and riverine consist of lakes and reservoirs (within the normal pool contour), and stream channels (ranging from intermittent tributaries to major rivers). Palustrine areas include not only vegetated wetlands traditionally termed marshes, swamps, bogs, sloughs and prairies, but also isolated catchments, small ponds, islands in lakes or rivers, and parts of river floodplains. Palustrine wetlands may also include farmland, because land so designated would support hydrophytes (wetland plants) if it were not tilled, planted to crops, or partially drained.

Lacustrine and riverine systems often share common boundaries, and are generally bounded by palustrine systems on either side. However, some wetlands may occur as isolated systems, bounded on all sides by non-wetland areas.

Despite the historical draining, clearing and filling of wetlands to facilitate agricultural or other development, the St. Joseph basin contains an estimated 27,000 wetlands that cover approximately 200 mi^2 (table 6). As the table shows, palustrine wetlands constitute 98 percent of in-basin wetlands and 75 percent of total wetland acreage. The densest zone of lakes and wetlands occurs in the morainal areas of Steuben, Noble, and LaGrange counties.

Major functions of wetlands include fish and wildlife habitat, water quality improvement, flood-water storage, aquatic food chain support, sediment entrapment, shoreline stabilization, recreation, and ground-water recharge and discharge.

Although direct data are not available, riverine wetlands, and to a lesser extent, lacustrine and palustrine wetlands in the St. Joseph basin are expected to be areas of ground-water discharge, particularly along major river systems where ground-water flow patterns have been well established. Locally, water may seep from wetlands to ground-water, either as a general rule (refer to discussion in the ''Lakes'' section) or at certain times of the year. However, regional ground-water levels within the basin are probably maintained by rainfall-derived recharge.

Wetland Conservation

Six areas representing palustrine, lacustrine and/or riverine wetland systems are at least partially protected from harmful development under IDNR's wetland conservation program: Eagle Lake and Mallard Roost (Noble County); Jimmerson Lake, Marsh Lake, and Ropchan (Steuben County); and Lake Wawasee (Kosciusko County).

Other protected wetlands, some of which are dedicated nature preserves, occur in or near the Pigeon River State Fish and Wildlife Area and Pokagon State Park. Four additional nature preserves containing wetlands are located near Olin, High and Little Whitford lakes and along the South Branch Elkhart River. In Steuben County, two other preserves are located northeast of Orland and northeast of Angola.

Some wetlands associated with rivers and public freshwater lakes are protected under various state and federal laws dealing with dredging, filling, alterations

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9 Cowardin and others (1979) present details of the classification system, which for most purposes replaces the wetland classification described in Shaw and Fredine (1956).

TABLE 6. Estimated Number and Acreage of Wetlands[1]

Wetland classification	Frequency in sample	Estimated frequency	% of total	Acreage in sample	Estimated acreage	% of total acreage
Lacustrine, limnetic, open water	11	396	1.44	868.30	31,258.80	24.66
Lacustrine, littoral, open water	1	36	0.13	2.10	75.60	0.06
Palustrine, aquatic bed	2	72	0.26	2.00	72.00	0.06
Palustrine, emergent	408	14,688	53.47	885.75	31,887.11	25.15
Palustrine, forested	181	6,516	23.72	1,103.66	39,731.76	31.34
Palustrine, open water	88	3,168	11.53	123.20	4,435.27	3.50
Palustrine, scrub shrub	61	2,196	7.99	518.36	18,660.92	14.72
Palustrine, unconsolid. bottom	2	72	0.26	0.30	10.80	0.01
Palustrine, unconsolid. shore	2	72	0.26	1.10	39.60	0.03
Palustrine, lower perennial, open water	7	252	0.92	16.50	593.85	0.47
Total	763	27,468	100.00	3,521.27	126,765.71	100.00

[1]Division of Fish and Wildlife estimates, based on maps and aerial photographs obtained from U.S. Fish and Wildlife Service, National Wetlands Inventory. Estimates were derived from a 3% random sample of each of 49 legal townships encompassing the St. Joseph basin.

of water level, changes to shoreline or lake-bed, and other modifications that are detrimental to fish, wildlife and botanical resources.

Most wetlands in the basin, however, are not protected under state or federal laws. For example, less than 3 percent of total wetland acreage is protected under IDNR's wetland conservation and nature preserve programs. In non-protected areas, wetland acreage continues to be drained or filled each year, primarily for agricultural development (J.F. New, IDNR Division of Fish and Wildlife, personal communication, 1986). In addition, ponds dug in wetland areas (as mapped on USGS 7.5-minute topographic quadrangles) are used as sources of irrigation water, particularly in northern LaGrange and northern Steuben Counties. High-capacity wells (mainly for irrigation, rural, or public supply uses) are also located in wetland areas as based upon IDNR water use information and USGS topographic maps.

Stream-flow Characteristics

Net precipitation is the limiting factor of stream flow. However, factors that affect the spatial and temporal distribution of flow (and hence largely determine the water supply potential of given stream reaches) include the following: climate (evapotranspiration, storm events); soils and land cover (vegetation, lakes and wetlands, impervious surfaces); topography and physiography (including drainage area, drainage density, channel morphometry); geology (surficial and bedrock); ground-water movement; and manmade modifications to surface- and ground-water systems (stream channelization, instream dams, diversions, and pumpage).

Geographic variations of these factors account for the diversity of stream-flow characteristics within and among basins. Quantitative interpretations of flow regimes require intensive studies of sites on both gaged and ungaged streams. Although some site-specific data have been collected in parts of the St. Joseph River basin, the complex combination of factors controlling stream discharge precludes regionalized extrapolations from such data. However, selected hydrologic parameters derived from discharge records provide a framework for characterizing the basin's surface-water system.

Average Flows

Of all hydrologic parameters, average (mean) discharge is the most easily recognized and one of the most widely used. The combined effects of the factors listed above are reflected in this parameter, which can be defined as follows: if it were possible to store, in a single hypothetical reservoir, all the water that flows from a watershed during a specified period and then release it at a uniform rate over the same period, that rate would be the average flow. This flow represents the theoretical upper limit of the long-term yield which can be developed from a stream, even with regulation.

Long-term (period of record) average daily discharge is given in table 7 for continuous-record gaging stations. Average discharge, the arithmetic mean of all daily flows, is greater than the median flow (the discharge equalled or exceeded 50 percent of the time). Based on data from Stewart (1983), average discharges at continuous-record stations in the St. Joseph basin are equalled or exceeded 30 to 40 percent of the time.

Low Flows

Low-flow discharge information is essential to the planning, management and regulation of activities associated with surface-water resources. Low-flow data are used in the design and operation of wastewater treatment facilities, power plants, engineering works (such as dams, reservoirs and navigation structures), and water supply facilities. Low-flow information is also used to evaluate water quality and its suitability for various uses. Some low-flow parameters may also be used in the development of regional draft-storage relations, in the forecasting of seasonal low flows, as indicators of the amount of ground-water influx to streams, or as the basis for environmental decisions regarding wetland preservation.

Low-flow characteristics are commonly described by points on low-flow frequency curves prepared from daily discharge records at continuous-record gaging stations. Correlation techniques can be used to estimate curves, or selected points on curves, for stations where short-term records and/or base-flow measurements are available.

Frequency curves are developed from annual minimum flows for selected numbers of consecutive days. In this report, the following points on the 1-day and 7-day curves have been selected as indices of low flow: the minimum daily (1-day average) flow having a 30-year recurrence interval, and the annual minimum 7-day average flow having a 10-year recurrence interval.

The 1-day, 30-year low flow is the annual lowest 1-day mean flow that can be expected to occur once every 30 years, on the average (that is, the annual lowest mean daily flow having a 1-in-30 chance of occurrence in any given year). In this report, the 1-day, 30-year flow indicates the dependable supply of water without storage, and is discussed further in the "Future Water Resource Development" section.

The 7-day, 10-year low flow is the annual lowest mean flow (average discharge) for seven consecutive days that can be expected to occur, through a long period, once every 10 years. There is a 1-in-10 chance that the annual minimum 7-day average discharge in any given year will be less than this value.

In Indiana, the 7-day, 10-year low flow is the legal index for water quality standards. This flow is used for siting, design and operation of wastewater treatment plants, for evaluating wastewater discharge applications and assigning wasteload limits to industrial and municipal dischargers, and as an aid in setting minimum water release requirements below impoundments. As the need for integrated water resource management increases, the 7-day, 10-year low flow or other low-flow parameters may be utilized by the IDNR to establish minimum flows of selected streams.

Table 7 presents annual 7-day, 10-year low flows as reported in Stewart (1983). Stream flows at continuous-record stations are greater than these values an average of 98.6 percent of the time. Estimates of 1-day, 30-year low flows (the lower of the two flows) are given in table 31 later in this report.

Extreme Flows

Table 7 includes extremes for the periods of record at continuous-record gaging stations. Maximum discharge is the instantaneous maximum corresponding to the crest stage obtained by use of a water-stage recorder (Glatfelter and others, 1985). Minimum discharge may either be an instantaneous minimum or a minimum daily mean.

The discharges listed in table 7 may not be representative of extremes under current conditions. For example, the minimum for Elkhart River at Goshen was recorded in 1964 during regulation by three upstream power plants which today are no longer in operation. Extremes for other gages may similarly reflect man-made regulation more closely than natural conditions.

Surface- and Ground-Water Interactions

Hydraulic interactions between surface- and ground-water systems account for much of the diversity of stream-flow characteristics, particularly low flows, within the St. Joseph basin. Hydrograph separation techniques and comparisons of flow duration curves have allowed inferences regarding system interactions at selected continuous-record gaging stations. Recent estimates of ground-water gains or losses to reaches of Pigeon River, Fawn River, Turkey Creek, and their tributaries have provided additional data for areas in LaGrange, Elkhart and Kosciusko Counties where surface- and ground-water pumpage is extensive (Bailey and others, 1985; Lindgren and others, 1985).

Hydrograph Separation

A stream-flow hydrograph is a graphical plot of stream discharge versus time. An example is shown in app. 7 for the Little Elkhart River at Middlebury and a brief explanation of hydrograph components is in app. 8. Through the process of hydrograph separation, an analysis has been made of the stream-flow characteristics at continuous-record gaging stations in the St. Joseph basin. These analyses result in dividing stream discharge into its component parts: surface runoff, interflow, and ground-water flow (base flow). The path, or combination of paths, that water follows during a precipitation event is dependent upon a number of variables, including the intensity of precipitation, soil moisture conditions, soil infiltration capacity, underlying geology, and areal basin characteristics.

Overland flow is the water that flows over the land surface to small channels that eventually reach the main stream channel. The combination of overland flow and precipitation that falls directly upon the stream is defined as surface runoff.

Interflow occurs when rainfall that has infiltrated into the soil moves laterally through the soil to the stream. For convenience, interflow and surface runoff are sometimes combined into one category, direct runoff.

Base flow represents the portion of stream discharge which is contributed from the ground-water system.