TABLE 7. Selected Stream-Flow Characteristics[1]

Station Number[2]		Station Name	Maximum Observed Discharge[3]	Minimum Daily Discharge[3]	Average Discharge[3]	7-Day, 10-Year Low Flow[4]
04-097970	OR	Lime Lake Outlet at Panama	46	0	7.7	0
04-098000	D	Fawn River at Orland	205	2.5	-	-
04-099500	D	Pigeon Creek & Hogback Lake nr. Angola	744	3.4	73.	6.0
04-099510		Pigeon Creek near Angola	795	3.4	78.9	5.8
04-099610	D	Pretty Lake Inlet near Stroh	33	0	0.48	0
04-099750		Pigeon River near Scott	2,370	42	361	86.
04-099808		Little Elkhart River at Middlebury	1,690	32	100.4	-
04-099850		Pine Creek near Elkhart	509	3.8	19.9	-
04-100000	D	Christiana Creek at Elkhart	452	40	-	-
04-100220	OR,D	N. Br. Elkhart R. near Cosperville	717	2.2	106	4.5
04-100222	OR	N. Br. Elkhart R. at Cosperville	919	2.4	137	4.0
04-100252	OR	Forker Creek near Burr Oak	338	0.13	17.8	0.2
04-100295		Rimmell Branch near Albion	397	0.14	-	-
04-100465	OR	Turkey Creek at Syracuse	170	0.82	36.8	1.3
04-100500	OR	Elkhart River at Goshen	6,180	7.0	514	81.
04-101000	R	St. Joseph River at Elkhart	18,600	336	3176	818.
Partial-Record Stations						
04-09902050		Ewing Ditch near Angola	-	-	-	0
04-09904050		Berlien Ditch near Angola	-	-	-	0
04-099805		Little Elkhart River near Middlebury	-	-	-	8.0
04-10009550		Dove Creek near Valentine	-	-	-	0
04-100375		Solomon Creek near Syracuse	-	-	-	4.9
04-100490		Turkey Creek near new Paris	-	-	-	14.0
04-100800		Yellow Creek at Dunlap	-	-	-	1.4
04-101300		Judy Creek at Roseland	-	-	-	2.4

[1]All values in cubic feet per second; multiply by 0.646317 to obtain million gallons per day.
[2]D = Discontinued gaging station; OR = occasional regulation; R = regulation.
[3]Active station data from Glatfelter and others (1985) and through water year 1984; discontinued station data given per period of record.
[4]All values from Stewart (1983) and through climatic year 1978, except stations 04-099500 D and 04-100220 D, which are from Rohne (1972) and through climatic year 1967.

The amount of base flow relative to direct runoff is a measure of the degree to which stream flow is sustained by ground-water contribution. Graphical techniques exist to separate base-flow from the stream-flow hydrograph. App. 7 illustrates a hydrograph separation for a one-year period (1984) at the Middlebury gage.

This graphical technique was used to separate annual hydrographs for six gages located on streams having little to no artificial regulation. Separations were made for a normal year (1984) and a wet year (1982) to determine if any significant difference existed in the percent of ground-water contribution. The results are shown in table 8.

Examination of the values of ground-water contribution shows that these six streams can be divided into two distinct groups. Rimmell Branch and Forker Creek have values of ground-water contribution roughly equal to 30 percent. In contrast, Pine Creek and the Pigeon, Little Elkhart, and North Branch Elkhart Rivers have ground-water components of approximately 70 percent (table 8).

In table 9 under the heading of major surficial materials, the six streams are again divided into the same two groups. As the table shows, Rimmell Branch and Forker Creek represent basins which are dominated by till, whereas the other four streams drain areas mainly composed of outwash.

With regard to the six gaged streams presented here, differences in geologic materials appear to be the most significant control of ground-water contribution to stream discharge. The two basins which are dominated by till have low infiltration capacity; therefore, most precipitation is routed to the surface drainage network and subsequently leaves the basin as surface runoff. On the other hand, the four basins dominated by outwash have relatively high infiltration capacities. In these basins, precipitation is readily accepted into the well-drained soils. With downward percolation, the water becomes part of the ground-water system and is ultimately delivered to the local streams as ground-water discharge.

Additional hydrograph separations were completed for four gages located on streams whose low flows may be affected by upstream hydroelectric plants or lake regulation (app. 8). The ground-water component of these streams, whose basins are dominated by outwash, average 70 percent. This percentage equals the average value derived for non-regulated or partially regulated streams draining other outwash-dominated areas (table 8).

Flow Duration

The flow duration curve is a cumulative frequency curve that shows the percent of time that specified discharges are equalled or exceeded during a given

TABLE 8. Hydrograph Separation for Unregulated to Partially Regulated Streams

Station Number	Station Name	Drainage Area (Mi^2)	1982[a] (Wet) RO[b] (in)	DR[c] (in)	GW[d] (in)	DR %	GW %	1984[a] (Normal) RO[b] (in)	DR[c] (in)	GW[d] (in)	DR %	GW %
04099750	Pigeon R. near Scott	361	19.9	5.20	14.70	26.1	73.9	13.31	3.80	9.51	28.5	71.5
04099808	Little Elkhart R. at Middlebury	97.6	16.75	4.05	12.70	24.2	75.8	11.85	2.74	9.11	23.1	76.9
04099850	Pine Ck. near Elkhart	31.0	11.92	3.68	8.24	30.9	69.1	7.25	1.89	5.26	26.1	73.9
04100222	North Branch Elkhart R. at Cosperville (partially)	142	17.82	6.57	11.25	36.9	63.1	12.73	4.85	7.88	38.1	61.9
04100252	Forker Ck. near Burr Oak (partially)	19.2	20.49	15.00	5.49	73.2	26.8	12.73	9.61	3.12	75.5	24.5
04100295	Rimmell Branch near Albion	10.7	17.57	11.99	5.58	68.2	31.8	12.50	8.78	3.72	70.2	29.8

[a]Water Years.
[b]RO = Total runoff.
[c]DR = Direct runoff.
[d]GW = Ground water or base flow.

period of record. For example, daily mean flows of Pigeon River near Scott were at least 97 ft^3/s during 99 percent of the time for water years 1972-84 (as derived from fig. 16). Daily flows for this period exceeded 1400 ft^3/s only 1 percent of the time.

Duration data are used in connection with water supply and hydroelectric power studies, industrial and waste treatment plant siting, reservoir design and pollution control. Because a duration curve is derived from all selected discharges for the period of record, the time sequence of flow occurrence is obscured. Hence, a duration curve should only be taken as a probability curve that the flow distribution over several years will be approximately that of prior years, and not as a curve for one or a few years (Rohne, 1972).

The shape of the duration curve is an index of the natural surface-water and ground-water storage within a basin. The more horizontal the curve, the greater is the storage effect, and the greater the potential for high sustained yield from both surface and ground water. By plotting duration curves on a per-square-mile (unit) basis, comparisons can be made among streams having different drainage areas. The unit curves in fig. 16 exemplify three typical flow patterns found throughout the St. Joseph basin.

The flattened duration-curve slope for Pigeon River indicates the moderating effects of natural storage. The presence of a broad floodplain (often bordered by wetlands) and the occurrence of well-drained, loamy soils on permeable valley-train deposits provide large amounts of flood-water storage. These same factors, particularly the presence of transmissive outwash sands and gravels, also facilitate ground-water seepage into the river.[10] The curve for Pigeon River near Scott reflects both the attenuated peak flows (by its relatively flat upper end) and sustained low flows (by its flat lower end). Curves for other rivers developed on outwash deposits would probably exhibit similar overall slopes.

The duration curve for North Branch Elkhart River at Cosperville illustrates the combined effects of natural drainage characteristics and artificial regulation. The high-flow end of the Cosperville curve closely resembles that of the Scott curve, probably due to the similar occurrence of upstream wetlands, vegetation, and large amounts of channel and floodplain storage. Although the presence of loam, silt and muck soils on clayey tills in some parts of the drainage basin may partially account for lower low flows, operation of the Waldron Lake control structure less than 3 miles upstream probably explains the sharp drop in unit flows with exceedence percentages greater than 98 (and particularly greater than 99.5).

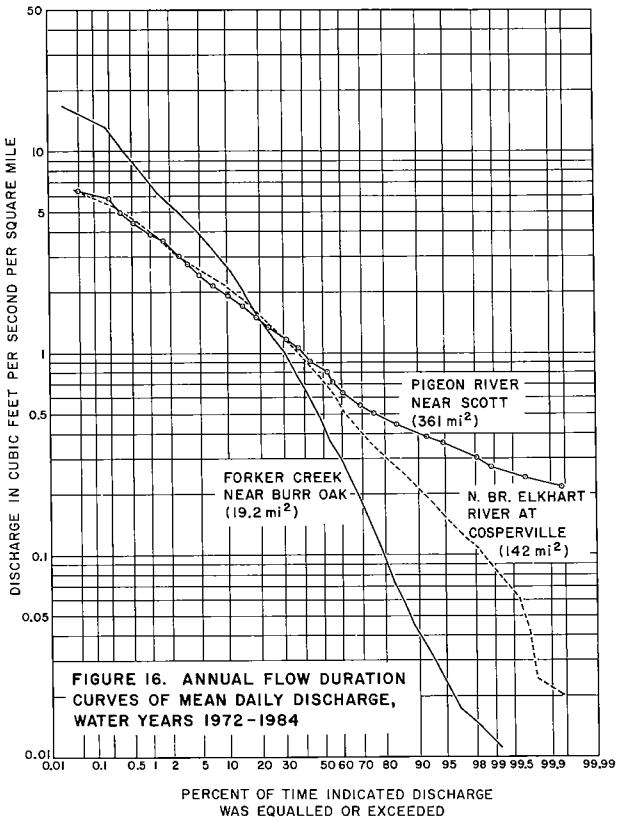

Figure 16. Annual Flow Duration Curves

The wide range of discharges along Forker Creek, as depicted by the steep duration-curve slope, can be attributed primarily to natural factors. The small drainage basin, narrow channel, and clayey soils on glacial till are largely responsible for the poorly sustained stream discharges. However, operation of the Miller Lake control structure about 400 feet upstream of the gage can further reduce stream flows, particularly when the control elevation is increased to maintain upstream lake levels for recreational purposes.

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10 Although direct determinations were not made at the Scott gage, discharge measurements along upstream reaches indicated a uniform rate of ground-water seepage from Mongo to Howe (Bailey and others, 1985). Similar rates are expected further downstream.

Data Selection

Unit flow duration curves (fig. 16), selected stream-flow characteristics (table 7), percentage estimates of ground-water contribution to stream flow (table 8), drainage basin characteristics (table 9), underlying aquifer systems and additional data were used to examine the integrated effects of geology, physiography, topography, soils, vegetative cover, land use and artificial modifications on stream-flow characteristics in the St. Joseph basin. Available data for six continuous-record gages were utilized.

Gaging records for Pigeon River near Scott were considered the most reliable and indicative of natural flow patterns. (The presence of three dams between Mongo and Howe, and surface- and ground-water pumpage from Mongo downstream to the Michigan-Indiana state line should be considered during site-specific analysis, however.)

Flow characteristics of the St. Joseph River at Elkhart and Elkhart River at Goshen were not considered for this discussion because of the presence of upstream hydroelectric power plants on the St. Joseph River, low-head dams from previously operated hydropower facilities on the Elkhart River, and urbanization at both sites. However, because the effect of upstream facilities on duration characteristics has not been quantitatively determined, and because the water supply of these rivers is quite large, unit flow duration curves for a selected base period (1972-84) were included in app. 9.

Two gages (North Branch Elkhart River at Cosperville and Forker Creek near Burr Oak) are located downstream of two lake chains with artificially controlled water levels. Data from these gages were primarily summarized to illustrate the effects of man-made regulation. Gaging records for Lime Lake Outlet at Panama, Pigeon Creek near Angola, and Turkey Creek at Syracuse were not considered because of lake regulation and the data's lack of utility in defining regional hydrology.

Stream flows at three gages (Little Elkhart River at Middlebury, Pine Creek near Elkhart, Rimmell Branch near Albion) are unaffected by man-made regulation. However, available data are of limited use because of the short periods of published discharge record (water years 1979-84). Although records are not concurrent, data from partial-record stations on Little Elkhart River, Turkey Creek, and Solomon Creek were used to supplement low-flow information and to represent unregulated flow conditions.

Supply Potential of Streams

Based on available hydrologic, geologic, and geomorphic data, it is evident that base flows on non-regulated streams are well sustained in the following river valleys: Fawn and Pigeon Rivers in LaGrange County; Little Elkhart River in LaGrange and Elkhart Counties; and Solomon and Turkey Creeks, primarily in Elkhart County. Geologic and topographic factors largely account for the sustained flows.

In general, these drainage basins have developed on outwash deposits (primarily valley trains) which roughly coincide in areal extent with the Howe Aquifer System and tributary valley portions of the St. Joseph Aquifer System (Plate 1). The drainage basins are characterized by relatively low topographic relief and medium- to coarse-grained, loamy soils. Major soils, generally of the Oshtemo-Fox association (well drained) and Sebewa-Gilford-Homer association (poorly drained) are classified by the Soil Conservation Service as Group B soils having above-average infiltration. Agriculture constitutes the major land use in these major river basins, but forested areas and wetlands occur along some reaches of the Pigeon, Fawn and Little Elkhart Rivers and Turkey Creek.

On a unit basis, published 7-day, 10-year low flows for unregulated, gaged sites are highest for Pigeon River near Scott, Solomon Creek near Syracuse, Little Elkhart River near Middlebury, and Turkey Creek near New Paris. Hydrograph separation for the Pigeon and Little Elkhart rivers shows a 75-percent ground-water contribution to stream flow. Unit flow duration curves for the two gages closely correspond (except for high flows on Little Elkhart having exceedence percentages less than one, which more closely resemble those of the Forker Creek curve).

Although no attempt was made to estimate natural flow characteristics for the St. Joseph and Elkhart Rivers, sustained base flows are expected because of the presence of transmissive valley-train and outwash-plain deposits and sandy (St. Joseph) or loamy (Elkhart) soils in downstream portions of these two large basins (which correspond to the main St. Joseph Aquifer System). Unit flow duration curves for the regulated St. Joseph and Elkhart Rivers (app. 9) resemble the Pigeon Creek curve (fig. 16), and average ground-water contribution to stream flow (70 percent) is only slightly less than average estimates for the Pigeon River and Little Elkhart River gages.

Although data is sparse, base flows of selected tributaries of the St. Joseph River in northwest Elkhart County appear to be moderately to well sustained by

TABLE 9. Selected Basin Characteristics

Gage & County	Drainage Area[1] (mi^2)	Drainage (Density)	Max. Basin Relief[2] (ft)	Relief Ratio[2]	Ruggedness Number	Basin Shape[2]	Major Surficial Materials[3]	Major Soil Associations[4]
Rimmell Branch near Albion (Noble)	10.7	2.16	60	10.0	130	.30	Till (some outwash, muck near gage)	Morley-Blount-Pewamo
Forker Creek near Burr Oak (Noble)	19.2	5.0*	100	10.4	500	.20	Till (some outwash)	Morley-Blount-Pewamo
Pine Creek near Elkhart (Elkhart)	31.0	5.7	170	15.7	969	.27	Outwash Ice-contact(kame) Till	Oshtemo-Fox, Miami-Crosier Brookston-Riddles
Little Elkhart R. at Middlebury (Elkhart)	97.6	3.0	125	8.9	375	.60	Outwash (valley train)	Oshtemo-Fox (Elk.), Sebewa-Gilford-Homer (Lag.)
North Branch Elkhart River at at Cosperville (Noble)	142	3.5*	150	4.2	525	.68	Outwash Till (some ice-contact)	Oshtemo-Fox, Miami-Crosier-Brookston-Riddles
Pigeon River at Scott (LaGrande)	361	1.6	295	8.4	472	.29	Outwash (valley train)	Oshtemo-Fox, (3 other associations)

*Values estimated from limited data set

[1]Glatfelter and others (1985).
[2]Maximum basin relief - the difference of the elevations of the highest and lowerst points in the basin; relief ratio - maximum basin relief divided by basin length; ruggedness number - maximum basin relief times drainage density; basin shape - basin area divided by basin length squared; basin length - the straight line distance, measured parallel to the channel, between the basin mouth and the drainage divide.
[3]Johnson & Keller (1972).
[4]Soil Conservation Service (1982).
[5]Max. basin relief - the difference, in feet, of all elevations of the highest and lowest points in the basin; basin length (L) - the straight line distance, measured parallel to the channel, between the basin mouth and the drainage divide.

ground-water contribution. Discharge measurements along lower reaches of the Elkhart River and Christiana, Baugo and Pine Creeks showed that stream segments not affected by heavy ground-water pumpage were gaining segments (Imbrigiotta and Martin, 1981). Hydrograph separation for Pine Creek near Elkhart (table 8) showed about a 71-percent ground-water contribution to stream flow, approximately equal to average percentages obtained for the Elkhart River at Goshen and the St. Joseph River at Elkhart, Indiana and Niles, Michigan (app. 8).

Drainage basins from Steuben County southwestward to the southern St. Joseph basin boundary in Noble County generally are characterized by variable relief and clayey soils on till deposits which roughly coincide in areal extent with the Kendallville Aquifer System (Plate 1). Although natural flow data are lacking, base flows appear to be moderately to poorly sustained, depending on local geologic, geomorphic and manmade conditions. The relatively small ground-water component of stream flow (30 percent) and the presence of Group C soils (below-average infiltration) on till are reflected in the steep duration-curve slopes for Forker Creek (fig. 16) and Rimmell Branch (not shown, but very similar). Stream-flow characteristics for the North Branch Elkhart River and Pigeon Creek near Angola include a moderate amount of ground-water contribution (62 to 68 percent), but moderately to poorly sustained unit low flows, possibly due to upstream lake effects.

Surface-Water Quality[11]

The water quality of rivers, lakes and streams in the St. Joseph River basin is protected under Indiana Water Pollution Control Board Regulations 330 IAC 1-1 and 330 IAC 2-4. These state regulations designate surface-water use for aquatic life, public supply, industry, agriculture, recreation, limited use and exceptional use. App. 10 summarizes recommended water quality standards from the U.S. Environmental Protection Agency (USEPA), Indiana Environmental Management Board, and the Indiana Water Pollution Control Board for aquatic life, public supply, irrigation and stock.[12] (Standards for industries are not listed, because the water quality required varies widely depending on the manufacturing process and because industrial standards generally are less stringent than for other uses.)

Standards for recreation include regulations that maintain the aesthetics of a body of water and that protect the public from possible health risks. Concentrations of fecal coliform bacteria are used to monitor the suitability of surface water for body-contact recreation. More stringent limits for fecal coliform have been established for whole-body contact recreation (swimming) than for partial-body contact (wading). All lakes and reservoirs and a few streams in Indiana (including the St. Joseph River) are designated for whole-body contact recreation from April through October, and for partial-body contact recreation during the cool season. The remainder of the streams in Indiana are designated for partial-body contact recreation year-round.

Regulations to protect warm- and cold-water fish communities include limits on pH, temperature, and concentration of dissolved oxygen and toxic substances. More stringent regulations (330 IAC 2-4) apply to natural spawning, rearing and imprinting areas and migration routes for salmonid fishes (app. 11). Portions of the St. Joseph River, as well as other stream reaches in extreme northwest Indiana must meet these higher standards.

Waters designated as "limited use" have naturally poor chemical quality, naturally poor physical conditions (including lack of sufficient flow), irreversible man-induced conditions, or any combination of these factors. Such streams are incapable of supporting diverse communities of fish and other aquatic life for much of the year. Two waterways in the St. Joseph basin, both in southwestern Elkhart County, have been designated for limited use: (1) Berlin Court Ditch from the Nappanee sewage treatment plant to two miles downstream and (2) an unnamed tributary and Werntz Ditch from the Wakarusa sewage plant to the confluence of Werntz Ditch and Baugo Creek.

Exceptional-use streams are high-quality waters which provide exceptional aquatic habitat, support unique assemblages of aquatic organisms, or are integral features of protected or particularly scenic areas. However, no exceptional-use streams have been designated in the basin.

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11 Data in this section were taken primarily from publications of the Indiana Department of Environmental Management, Indiana Stream Pollution Control Board, Indiana State Board of Health, Michiana Area Council of Governments, U.S. Environmental Protection Agency (see references), and personal communication with Steve Boswell and Dennis Clark, IDEM.

12 State water quality rules are presently being recodified by the Indiana Department of Environmental Management.

River Quality Data

The Indiana Department of Environmental Management (IDEM) routinely monitors water quality at four stations in the St. Joseph River basin: St. Joseph River at Bristol, Mishawaka, and South Bend; and Elkhart River at Elkhart (fig. 17). A temporary station is located on Pigeon River at Mongo for IDNR fisheries purposes. These stations are part of a statewide surface-water quality monitoring network established in 1957 by the Indiana State Board of Health (now operated and maintained by IDEM). Physical, chemical and bacteriological data are used to detect water quality trends, support pollution abatement activities and enforcement actions, locate potential pollution sources, and obtain background data for surface-water users.

Since 1979, periodic sampling has been conducted at selected stations throughout Indiana (including Bristol and South Bend) to monitor the composition of fish and aquatic invertebrate communities and to detect toxic materials in fish flesh. Additional stream monitoring activities in the basin (and statewide) have included primary productivity studies, sediment sampling, and habitat evaluations, as well as bioassays of wastewater effluents.

Comprehensive water quality data are available from two IDEM surveys (1985-86) of at least 40 sites along the St. Joseph River. Data from these surveys are needed primarily for water quality modeling and wasteload allocations as they relate to the 1985 salmonid designation. In 1977, the Michiana Area Council of Governments collected data on the St. Joseph and Elkhart rivers and their major tributaries to provide background information used in developing a waste-treatment management plan (MACOG, 1978).

Rivers and Streams

All available data indicate that water quality in the St. Joseph and Elkhart rivers is generally good. For the most part, standards for public drinking water and aquatic life have not been exceeded at the South Bend and Bristol monitoring stations during the period 1975-84. For the same period, ammonia and BOD (biochemical oxygen demand) data from the South Bend and Bristol stations were studied by the IDEM in an effort to statistically describe water quality trends. Results show that ammonia concentrations remained well below the recommended criteria and BOD levels decreased. In general, low BOD levels indicate a low amount of oxygen-consuming wastes in a river, which allows for greater availability of oxygen for aquatic life.

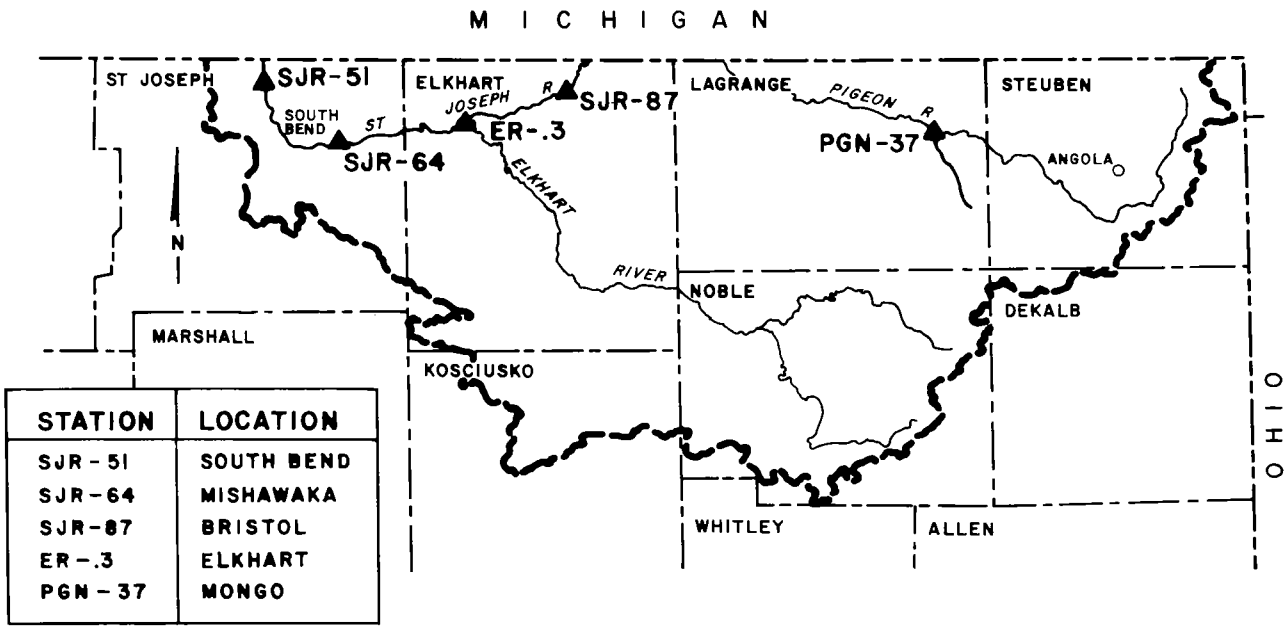

Figure 17. Location Map of IDEM Surface — Water Quality Monitoring Stations

Since monthly sampling of dissolved oxygen by IDEM comprises a single measurement, diurnal variations are not detected. However, seasonal variations, due primarily to the inverse relation between oxygen concentrations and water temperature, can be generalized. As fig. 18 shows, monthly dissolved oxygen concentrations averaged over the period 1975-84 for monitoring stations on the St. Joseph and Elkhart Rivers have remained above the 5.0 milligrams per liter limit, a critical amount for most fish life, and 6.0 milligrams per liter for salmonid fish (see app. 11). The summer 1985 IDEM survey of the St. Joseph River revealed dissolved oxygen concentrations well above recommended limits at all sites sampled during 24-hour periods.

Biological studies by the IDEM have indicated diverse benthic invertebrate and fish communities at the Bristol and South Bend stations. IDNR surveys show that quality fisheries for many of Indiana's sport fish (bass, muskie, pike, and walleye, for example) are found throughout the basin. Put-and-take trout fisheries are maintained by the IDNR in numerous lakes and streams. According to reports of local fishermen, small isolated populations of trout are reproducing naturally in some tributaries of the St. Joseph and Elkhart Rivers (Thomas Lauer, IDNR Division of Fish and Wildlife, personal communication, 1986).

Michigan and Indiana are cooperatively working to establish and maintain a salmonid fishery in the St. Joseph River. A cold-water hatchery (Twin Branch) has been constructed near Mishawaka, and fish ladders are being built over hydroelectric dams at Mishawaka and South Bend, as well as in Michigan. In 1985, the St. Joseph River below the Twin Branch dam and downstream to the state line was upgraded to a migration route for salmonid fish (app. 11). Consequently, a more stringent water quality regulation (330 IAC 2-4) now applies to this reach.

Regulations for whole-body contact recreation have been met at the Bristol station in the St. Joseph River since at least 1975. However, fecal coliform concentrations in the river show a marked increase in water samples analyzed from Elkhart downstream to the Indiana-Michigan state line. Despite significant improvement in fecal coliform counts at the South Bend station, violations for whole-body contact continue to occur. Violations for partial-body contact recreation on the Elkhart River have occurred less frequently since 1982. Continued improvements are anticipated along both rivers as combined sewer overflows are controlled and sewage treatment facilities are upgraded.

For the most part, concentrations of metals such as cadmium, lead and mercury have been below established limits at the Bristol and South Bend stations for the past 10 years, as well as during the 1985 survey. Concentrations of metals, pesticides and polychlorinated biphenyls (PCBs) were below detection limits during the 1985 survey in sediment of the mainstem St. Joseph River near Elkhart, Mishawaka and South Bend; however, low levels of PCBs were detected in sediment samples near the mouths of five major tributaries.

No detectable levels of dioxin (TCDD) were found in fish from the St. Joseph River during a 1982 IDEM-USEPA study. However, analyses of fish for toxic substances have shown violations of Food and Drug Administration action levels for PCBs (1983-85) and the pesticide chlordane (1979-84) downstream of South Bend. A fish consumption advisory was issued in 1985 for carp, smallmouth bass and redhorse suckers taken

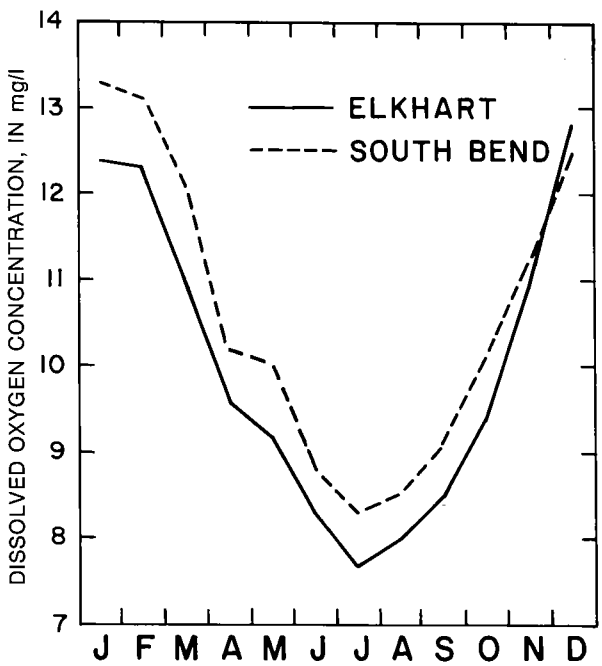

Figure 18. Average Monthly Concentrations of Dissolved Oxygen for St. Joseph and Elkhart River Water Quality Monitoring Stations Based on IDEM Monthly Sampling 1975-1984

from the St. Joseph River downstream of South Bend. Further research is being conducted to trace the sources of PCBs so that corrective action can be taken.

Lakes

Since 1970, most public freshwater lakes in Indiana have been sampled periodically by the Indiana State Board of Health (now by IDEM) for physical, chemical and biological parameters. Data obtained were used to develop a trophic classification system[13], as mandated by Section 314(a) of the 1977 amendment to the Federal Clean Water Act (PL 92-500). The IDEM further identified seven lake management groups based on a lake's trophic state, acreage and mean depth. Intensive surveys by the IDEM and U.S. Environmental Protection Agency (USEPA) further characterized the trophic state of selected lakes, particularly those exhibiting advanced eutrophy, and outlined restoration measures for problem lakes.

Lakes in the St. Joseph River basin have been classified into all trophic classes and assigned to all management groups (app. 6), thus indicating a wide range of trophic characteristics and lake morphometry. Seventy-nine percent of the in-basin lakes of at least 50 acres or 500 acre-feet have been designated as Class I or Class II (app. 12). These lakes rarely have water quality problems or impairment of designated uses. About 17 percent of in-basin lakes may support periodic algal blooms or excessive weed growths, but seldom have impairment of designated uses (Class III). Four lakes considered as Class IV only partially support designated uses due to excessive weed or algal growth.

Curbing nutrient input is the most common IDEM recommendation for long-term lake management (app. 12). Successful nutrient control schemes (primarily directed at nitrogen and phosphorus) can often be accomplished by improving wastewater treatment and land-use practices. In some cases, however, in-lake restoration measures may be required to limit the availability of nutrients already present in the lake.

Special limnological investigations of 14 lakes in the St. Joseph River basin have been conducted either by the IDEM (as part of the Indiana Lakes Program), the USEPA (as part of the National Eutrophication Survey), or both agencies (see "Selected References"). These lakes, primarily found in Steuben and LaGrange counties, include the following: Crooked, Dallas, James, Long, Marsh, Martin, Olin, Oliver, Pigeon, Sylvan, Wabee, Wawasee, Westler and Witmer. Additional studies have been conducted on these and other basin lakes, generally in association with universities.

Sylvan Lake in Noble County is the most widely studied lake in the St. Joseph basin. Unnatural acceleration of nutrient loading led to algal blooms and dense growths of aquatic weeds in the early 1900s. Decades later, this shallow, manmade lake was described as "one of the most productive lakes in the temperate regions of the world" (Wetzel, 1966). The historical degradation of water quality was accompanied by an explosion of carp and sucker populations and a decline in game fish, particularly during the 1960s and 1970s.

Temporary water quality improvements were made following the upgrading of Kendallville's sewage treatment facility, the construction of Rome City's sewer system, and periodic algacide treatments and lake-level drawdowns. However, both water quality and game fishing have improved dramatically following an IDNR fish eradication and selective restocking project in 1984. Continued control of nutrient inputs and carp populations should maintain the lake in its present condition.

Since sparse information is available on toxic substances in Indiana lakes, recent studies by IDEM included sampling of sediment and fish tissue for toxic substances in addition to collection of limnological data. Twenty-eight lakes and reservoirs in Indiana with a potential for contamination and/or high recreational use were selected as 1985-86 monitoring stations. Crooked Lake in Steuben County, the only in-basin lake selected, was sampled during summer 1986. Although data are not yet available, sediment and fish samples will be analyzed for metals, PCBs and pesticides.

GROUND-WATER HYDROLOGY

Ground-water resources in the St. Joseph River basin are probably the most abundant in Indiana. Wells yielding 200 to 500 gpm (gallons per minute) are common throughout the basin. Yields of 500 to 1500 gpm are common in areas where sand and gravel deposits are thick. In contrast, the presence of thick localized clay deposits can make a sufficient domestic supply (10 gpm) difficult to obtain.

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13 Indiana Lake Classification System and Management Plan (1980; currently under revision).

Significant ground-water supplies are confined to unconsolidated glacial sand and gravel deposits. Underlying bedrock, which consists primarily of shale (and a small area of limestone in Kosciusko County), is not considered an important ground-water source.

Ground-Water Data

Ground-water data for the St. Joseph River basin come from several sources: water-well records, the observation well network, lithologic logs, seismic information and localized project data (for example, pump tests and other analytical and mathematical models).

Since 1959, water-well drilling contractors have been required to submit to the state (IDNR) a complete record of every water well that is drilled (IC 25-39-1). More than 18,000 water-well records are maintained in the IDNR, Division of Water files for the St. Joseph River basin and were reviewed and screened for the ground-water resource assessment of this study. Most of the records are for relatively shallow wells (less than 150 feet).

Water-level data in the St. Joseph River basin have been collected from observation wells by the U.S. Geological Survey in cooperation with the IDNR (formerly the Department of Conservation) since 1935. Seven wells monitored water levels from that time until the period 1944-47, when 21 wells were added to the basin network. Seventeen of the 21 wells were added in St. Joseph County and were used to monitor changes in water levels near South Bend. By the mid-1950s, many of the wells were discontinued because of the close similarity of water-level patterns (Crompton and others, 1986).

Currently, water-level data are collected from 13 observation wells in Elkhart, Kosciusko, LaGrange, Noble and Steuben Counties (table 10). Four of these wells monitor water-level fluctuations in aquifers near natural lakes and six monitor water levels in areas of extensive high-capacity ground-water pumpage. The other three wells, two in Noble County and one in Steuben County, monitor long-term changes in water levels in areas not affected by extensive pumpage.

Water-level data from six observation wells and the three adjacent lakes were collected for approximately 10 years to establish general relationships between ground water and selected natural lakes within the St. Joseph River basin. (Two of these wells were discontinued in 1986.) Water-level correlation between Heaton Lake and the surrounding outwash aquifer was previously discussed in the first "Lakes" section. Ground-water and lake levels for the other two lakes either show graphical correlations (Sylvan Lake) or are inconclusive (Syracuse Lake).

Six observation wells are located in areas of extensive ground-water pumpage. Five of the six are located in areas of agricultural irrigation (Elkhart 4 and 7, LaGrange 2 and 3, Kosciusko 9) and one is located in an urban area near industrial and public supply wells (Elkhart 8). No apparent impact on water levels has yet been observed in these wells. The hydrograph for Elkhart 4 (fig. 19) typifies water-level fluctuations in observation wells located in areas of intensive irriga-

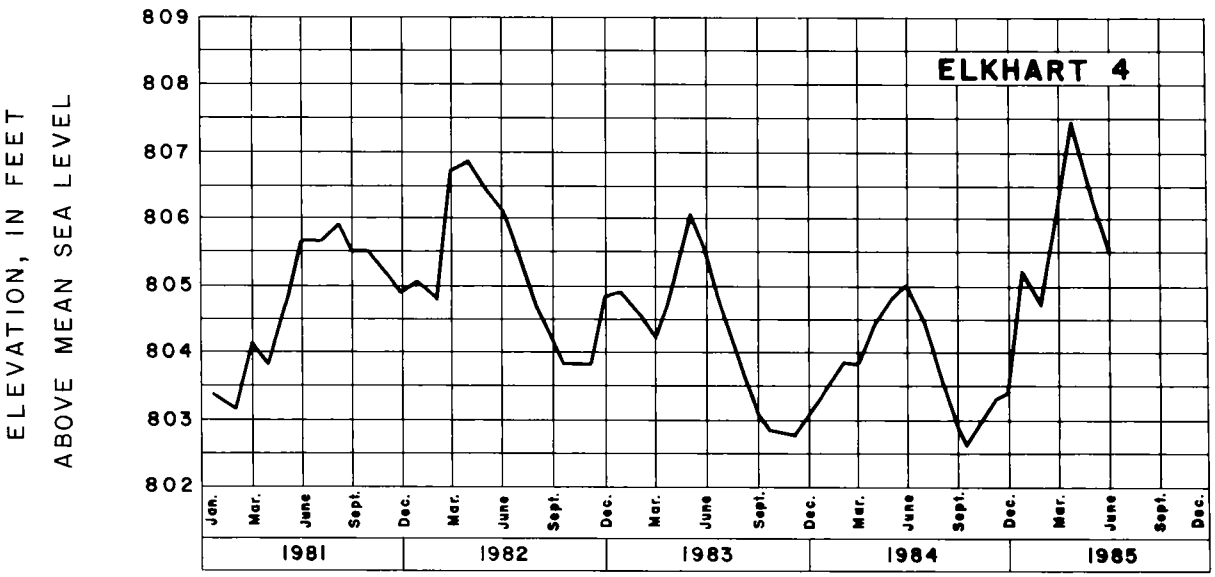

Figure 19. Water-level Fluctuations in Observation Well Near Irrigation Pumpage

TABLE 10. Observation Wells[1]

County Code[2]	County and Well Number[2]		Period of Record[3]	Aquifer System[4]	Aquifer Type[5,6]	Well Dia. (in.)[6]	Screened Depth (feet)[6]	Aquifer Class[7]	Remarks
EH	Elkhart	4	1966-	Elkhart Trib.	S & G	6	60	A	
		5	1976-	St. Joseph	S & G	1.5	13	SP	Lake-Ground Water Connection
		6	1976-	St. Joseph	S & G	1.5	22	SP	Lake-Ground Water Connection
		7	1981-	St. Joseph	Sand	6	61	A	
		8	1983-	St. Joseph	S & G	5	80	A-SP	
KO	Kosciusko	6	1978-	Turkey C. Trib.	Sand	2	23	SP	Lake-Ground Water Connection
		7	1978-	Lakes & Moraines	Sand	2	24	SP	Lake-Ground Water Connection
		9	1982-	Turkey C. Trib.	S & G	4	102	A	
LG	LaGrange	2	1980-	Howe	S & G	5	86	A	
		3	1981-	Howe	S & G	6	40	A	
NO	Noble	8	1966-	Kendallville	S & G	6	148	UA	No record 1971-74
		9	1976-	Lakes & Moraines	Sand	6	42	UA	
	Steuben	6	1986-	Lakes & Moraines	S & G	6	76	UA	
Discontinued Wells[8]									
Elkhart		3	1950-71		S & G	-	-	A	
Kosciusko		2	1937-67		S & G	-	-	SP	Flowing Well
		5	1976-82		Sand	1.5	13	UA	
		8	1978-86		Sand	2	27	SP	Lake-Ground Water Connection
Noble		6	1946-66		S & G	-	-	A	
		10	1978-86		S & G	2	24	SP	Lake-Ground Water Connection
Steuben		3	1955-71		S & G	-	-	UA	
		5	1979-82		S & G	5	103	UA	Destroyed

[1]Locations shown in fig. 14.
[2]U.S. Geological Survey county code and local well number.
[3]Calendar year or portion thereof.
[4]Division of Water designation; Tributary Valley (Trib.); discussed in text.
[5]Sand and Gravel (S & G).
[6]From Glatfelter, Stewart, and Nell (1985).
[7]Division of Water classification: affected by ground-water pumpage (A), unaffected (UA), special purpose (SP).
[8]Wells included in Division of Water data files; additional wells are listed in Crompton and others (1986).

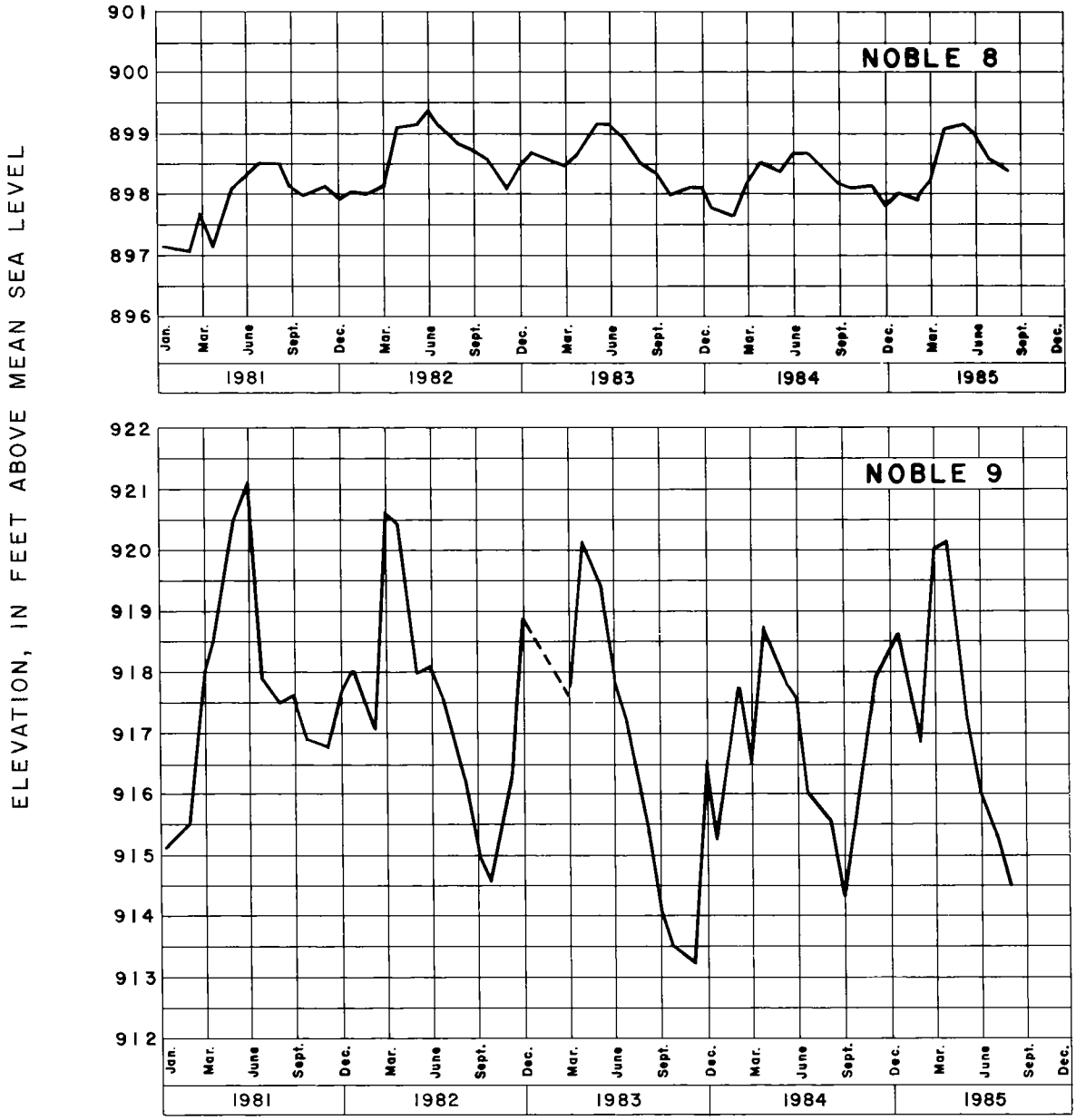

Figure 20. Water-level Fluctuations in Selected Observation Wells

tion. Hydrographs for the other five wells are shown in app. 13.

Noble 8 and 9 and Steuben 6 (recently drilled) were installed to monitor natural water-level fluctuations. Although neither Noble 8 nor 9 is affected by nearby pumpage, the fluctuations in Noble 8 are considerably less than those in Noble 9 (fig. 20). Crompton and others (1986) suggest that the larger water-level fluctuations in Noble 9 could be a result of the well's position on a ground-water divide (although a distinct divide is not apparent from IDNR data). The smaller water-level fluctuations in Noble 8 probably reflect changes in a deep regional flow system with lesser variability in recharge and discharge.

Modifications to the St. Joseph River basin observation well network are scheduled as a result of an IDNR evaluation of Indiana's hydrologic data collection programs. Steuben 6 has recently been added to