The potential for agricultural and economic development partially depends on the availability of adequate supplies of surface water and ground water. Surface-water withdrawals are expected to remain high in areas along the lower Kankakee River and its major tributary ditches, where stream flow provides an adequate and dependable supply. Ground-water withdrawals are expected to remain high in the main Kankakee River valley where outwash deposits and carbonate systems can sustain high-capacity pumpage.

As water demands in the basin continue to grow, it will be necessary to develop additional surface-water and ground-water supplies, protect the quantity and quality of existing supplies, and increase the efficiency of water use. Although pumpage-induced drawdown of ground-water levels and heavy withdrawals from tributary ditches may cause recurrences of localized or short-term conflicts among water users, surface-water and ground-water supplies in most of the basin should be adequate to satisfy a variety of water demands in the coming decades.

WATER USE AND PROJECTIONS

The total demand for water in the Kankakee River Basin is expected to increase in future decades as the population and economy continue to grow. Annual water withdrawals for the major water-use categories were *projected* through the 1990s to help identify areas of potential conflict between supply and demand. Projections beyond the year 2000 were not included because of data limitations and the variability of socioeconomic factors.

Withdrawal uses

Withdrawal uses involve the physical removal of water from its surface-water or ground-water source. As discussed in the ***Socioeconomic Setting*** chapter of this report in the section entitled ***Water-Use Overview***, the Division of Water maintains a registry of facilities capable of withdrawing at least 100,000 gallons per day of surface water, ground water, or surface water and ground water combined. The division also maintains reports of annual water use for registered facilities. Reported water use is determined by metering devices, the multiplication of pump capacity and total time of pumpage, or other methods approved by the Division of Water.

It should be emphasized that the term "water use" in this report refers both to the total amount of water withdrawn from available sources and to the intended purpose of the withdrawal. The term "use" does not refer to the amount of water which is consumed, or made unavailable for reuse within a fairly short period of time.

The portion of withdrawn water that is consumed varies with the intended purpose of the withdrawal. Livestock watering and irrigation are estimated to consume from 80 to 100 percent of the withdrawn water. Energy production, public supply and industrial uses generally consume between 3 and 25 percent. Because most of the water withdrawn for these latter three purposes is returned to surface-water or ground-water systems within a short time period, less potential exists for significant impacts on water availability.

It also should be noted that the term "withdrawal capability" represents the amount of water which theoretically could be withdrawn by registered facilities if all pumps were operating at their rated capability 24 hours a day. However, because few facilities in the basin operate in this manner, reported use constitutes only a small percentage of the total withdrawal capability. During 1987, owners of registered facilities in the Kankakee River Basin reported withdrawals totaling only about 5 percent of the total withdrawal capability.

Basin overview

A total of 533 significant water withdrawal facilities representing about 570 wells and 230 surface-water intakes were registered in the Kankakee River Basin in 1987, the base year for this report. These facilities had a combined withdrawal capability of 1366 million gallons a day (mgd), and reported withdrawals of 25.2 billion gallons, or 69 mgd. As figure 52 shows, most of the registered facilities are located in the main valley of the Kankakee River.

During the drought conditions of 1988, 18 new facilities were registered, adding 175 mgd of withdrawal capability and 41 mgd of reported use. Six-

teen of the new facilities were registered in the irrigation category.

Non-registered uses in the Kankakee River Basin include domestic wells, livestock operations, and other facilities capable of withdrawing less than 100,000 gallons of water per day. The total water use for any non-registered facility is fairly small, but the aggregate demand for domestic self-supply and livestock watering purposes is notable.

Nearly equal amounts of water are withdrawn from surface-water and ground-water sources throughout the entire Kankakee River Basin; however, the major water source differs among individual categories. Water withdrawn for energy production primarily is from surface water, whereas most of the water for public and domestic supply is from wells. Water for irrigation is obtained both from surface-water and ground-water sources (figure 53).

About one-third of all water withdrawals in the Kankakee River Basin were for irrigation purposes, and another third were for public and domestic water supply. About one-fourth of the total water withdrawals were related to energy production.

Registered facilities

The reported water use by category and county in 1987 and 1988 is summarized in table 21. As the table shows, total reported water withdrawals are highest in Jasper, St. Joseph and LaPorte Counties.

Appendix 15 summarizes, by county and by water source, the withdrawal capability and reported use by registered facilities in calendar years 1986-88 for all water-use categories combined. Appendices 16-19 present similar information for each water-use category.

Irrigation

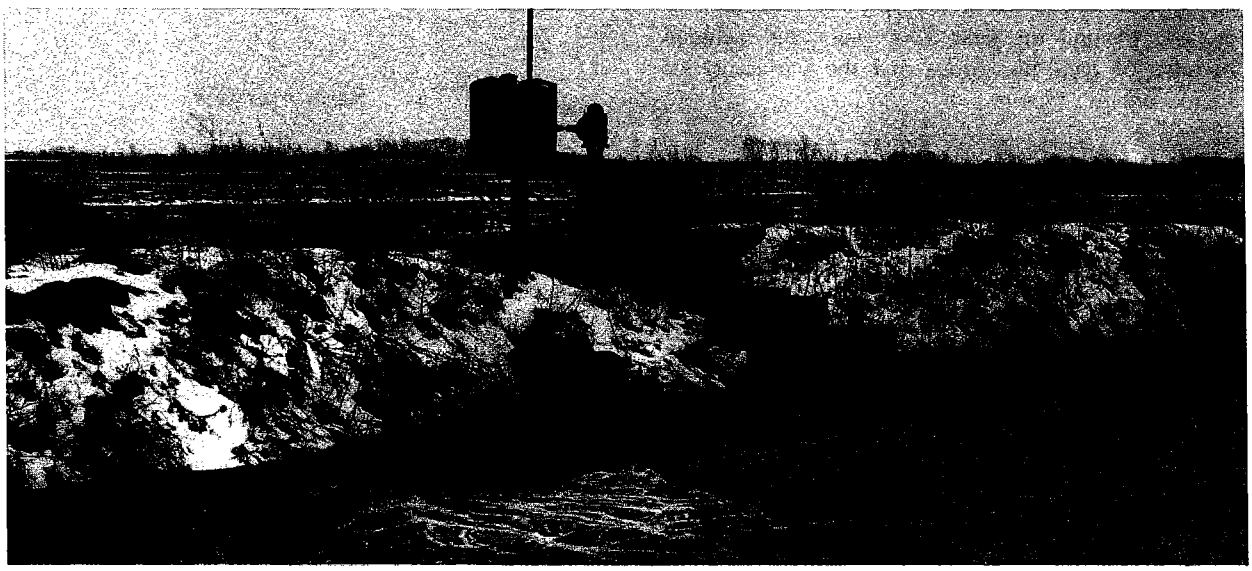
Irrigation water use refers to withdrawals for both agricultural and non-agricultural purposes, such as golf-course irrigation. In the Kankakee River Basin, most irrigation withdrawals are for agricultural purposes.

It should be emphasized that some water-withdrawal facilities categorized by the IDNR Division of Water as agricultural irrigation facilities do not apply water to crops. Instead, excess water is pumped from agricultural land to improve field drainage. The amount of water withdrawn in the Kankakee River Basin for drainage purposes in 1987 constituted about 2 percent of the water withdrawn in the irrigation category.

Irrigation is a seasonal water use that artificially replaces water in the root zone of droughty soils. Because irrigation water primarily is intended to replace water transpired by the irrigated crop, irrigation withdrawals are treated as a totally consumptive use.

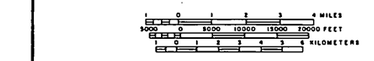
Agricultural irrigation in Indiana is most intensive in northwest and north-central regions, including the Kankakee River Basin. The large amount of irrigation

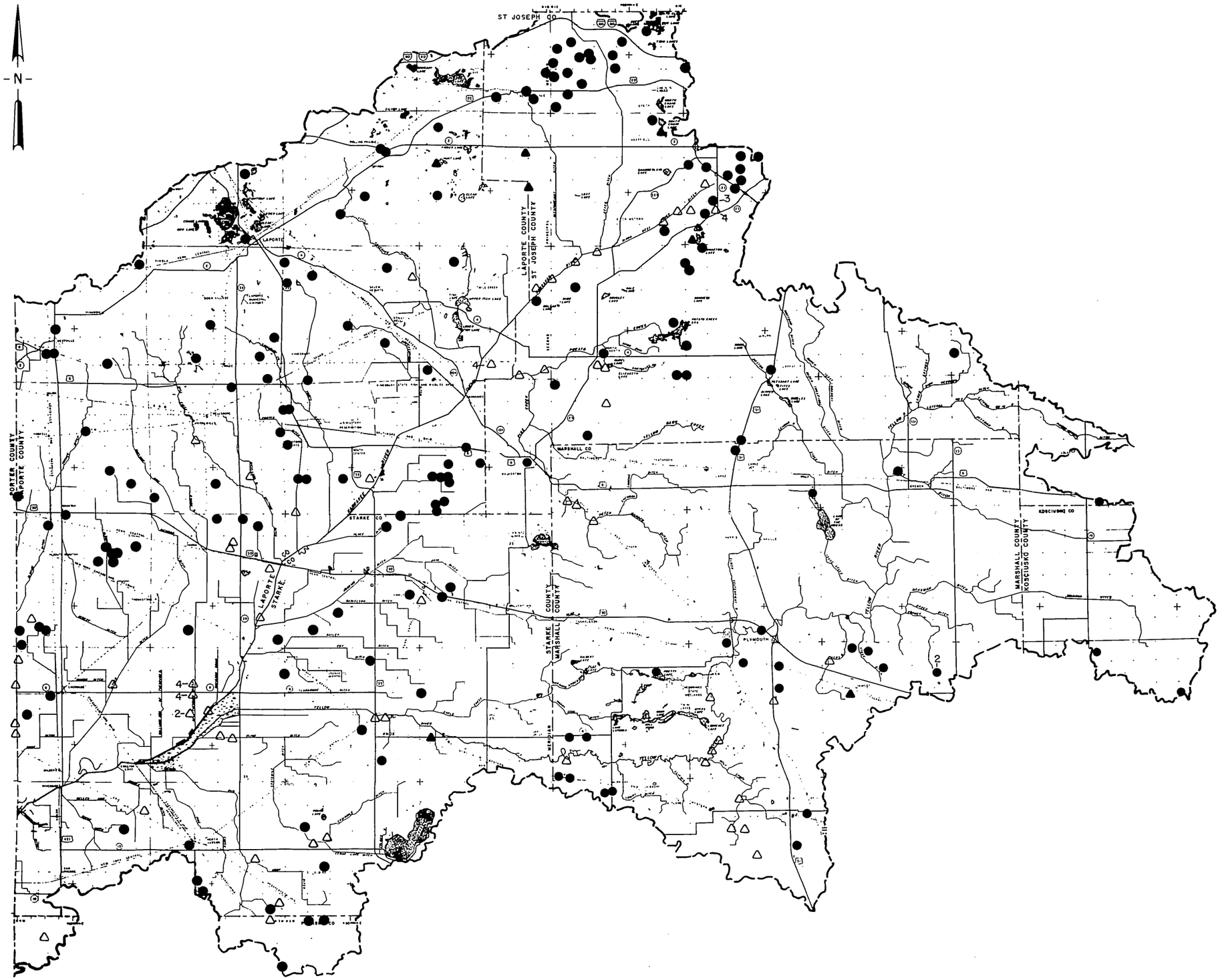
Photo courtesy USDA Soil Conservation Service



STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

UPPER KANKAKEE RIVER BASIN





EXPLANATION

- ● Registered significant ground-water facility
- △ Registered significant surface-water facility
- ▲ Registered significant ground-water and surface-water facility
- 3 Number of facilities at location

Figure 52a. Location of registered water withdrawal facilities

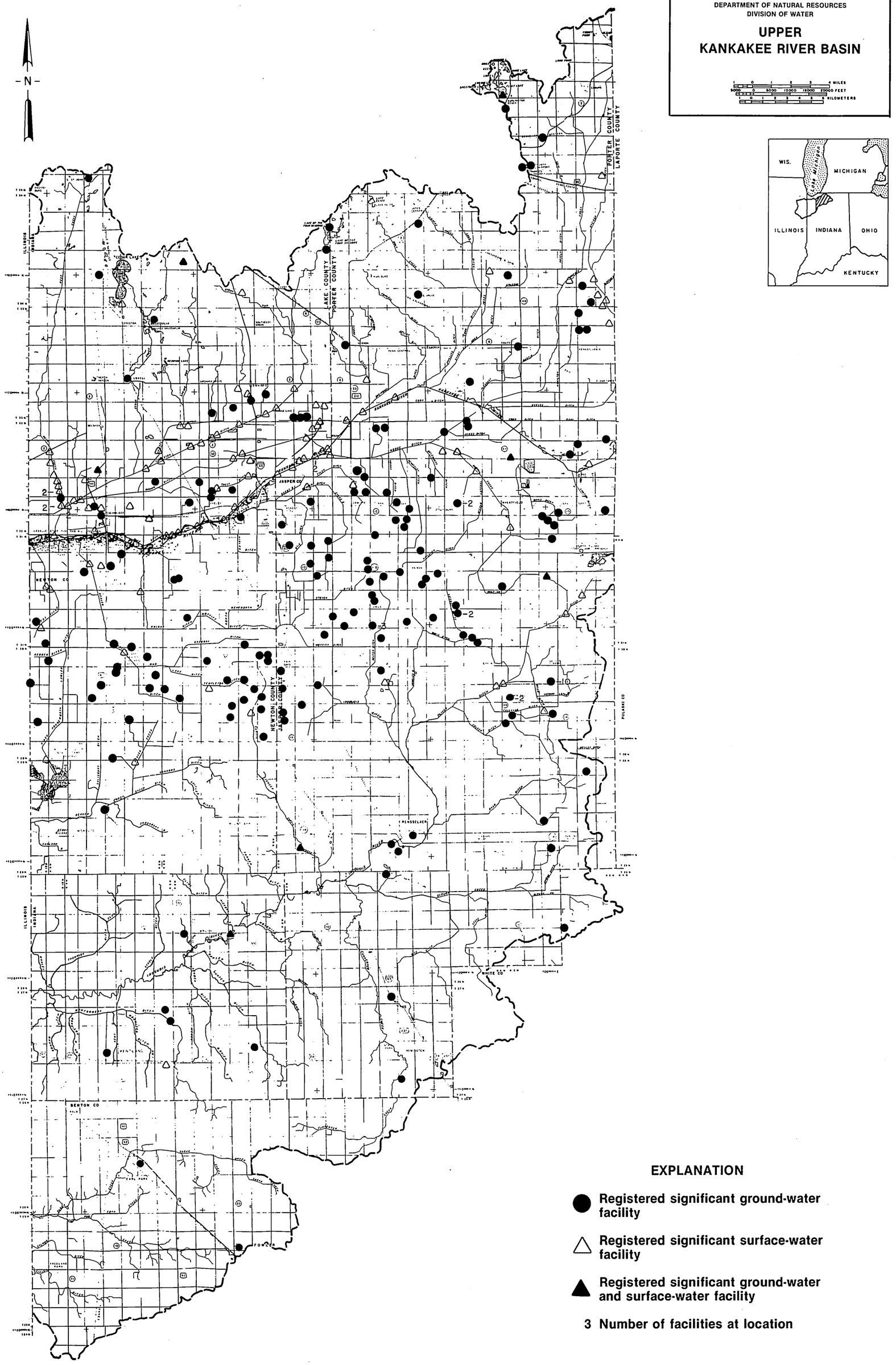


Figure 52b. Location of registered water withdrawal facilities

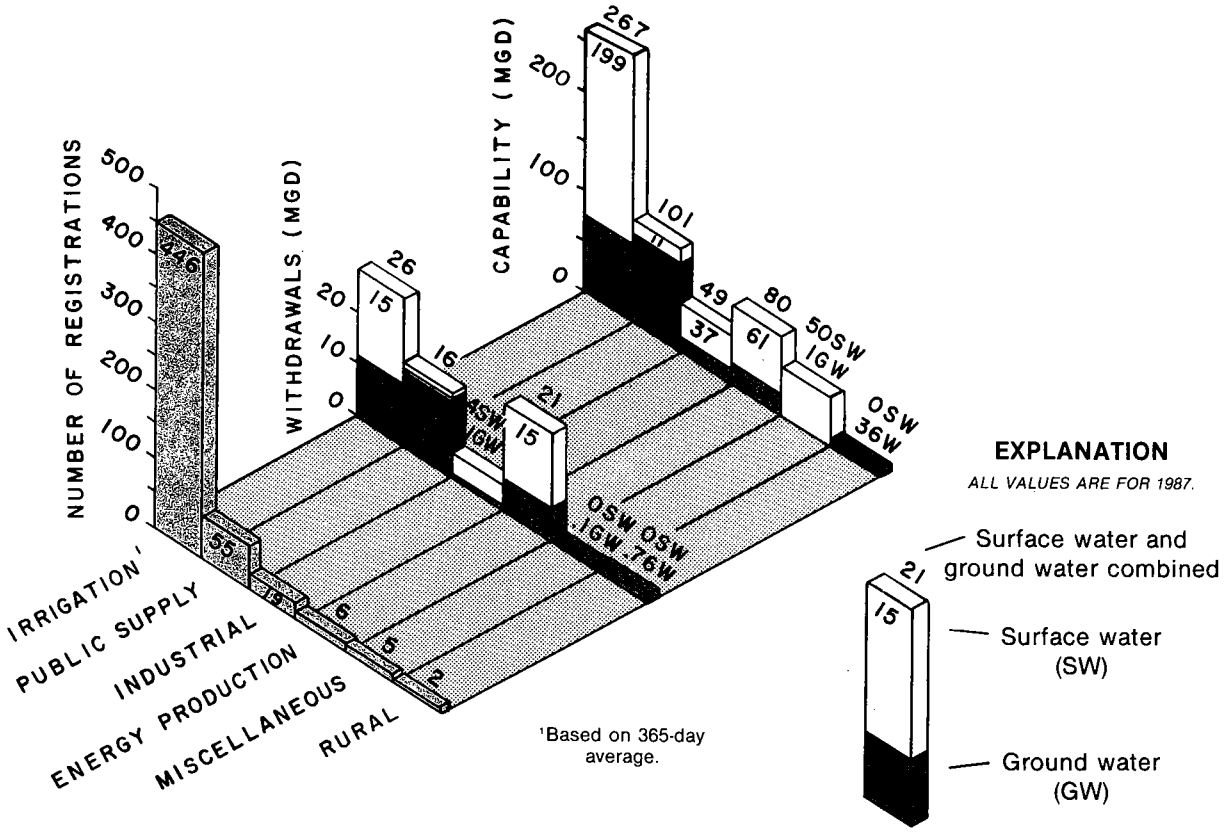


Figure 53. Number of registered water-withdrawal facilities, withdrawal capability, and reported water use

in northern Indiana reflects not only the availability of adequate surface-water and ground-water supplies, but also the suitability of soils, the presence of adequate drainage (either natural or artificial), the large areas having low relief, and the predominance of crops which respond favorably to irrigation.

In 1987, the Kankakee River Basin accounted for about one-third of the total number of Indiana's registered irrigation facilities, about one-third of the state's irrigated land, and 43 percent of the state's reported withdrawals in the irrigation category. In 1988, a drought year, the Kankakee River Basin constituted 47 percent of Indiana's reported irrigation water use.

The large amount of water withdrawn for irrigation in the Kankakee River Basin is used on a relatively small number of farms. In the basin's eight major counties where irrigation is extensive, an average of 7 percent of the 5400 farms utilize irrigation. Moreover, irrigated land in the eight counties represents less than 5 percent of the total cropland area of 1.5 million acres (U.S. Bureau of the Census, 1989).

Even though the number of farms using irrigation and the acreage of irrigated land are small, water withdrawals in the irrigation category during 1987 constituted about one-third of all water withdrawals in the Kankakee River Basin. Moreover, average irrigation withdrawals during the 90-day period of June, July and August exceeded withdrawals for public supply, energy production and industrial uses (figure 54). The 90-day average daily withdrawal for irrigation purposes was 106 mgd, which is approximately four times greater than the 365-day average of 26 mgd.

Appendix 16 summarizes, by water source, the withdrawal capability and reported use by registered irrigation facilities in each county of the Kankakee River Basin in calendar years 1986-88. (Values are presented as 90-day averages.) Table 22 summarizes irrigation data for 1987, but presents data for entire counties rather than in-basin areas.

Table 21. Annual reported water use for registered facilities

{Upper numbers denote average water use in million gallons per day; lower numbers denote number of registered facilities. Rural and miscellaneous water use did not differ significantly from 1987 to 1988.}

County	Irrigation		Energy production		Public supply		Industrial		Rural and miscellaneous	Total[2]	
	1987	1988	1987	1988	1987	1988	1987	1988	1987	1987	1988
Benton	0	0	0	0	0.23	0.26	0	0	0	0.23	0.26
	0	0	0	0	2	2	0	0	0	2	2
Elkhart	0	0	0	0	0	0	0.04	0.04	0	0.04	0.04
	0	0	0	0	0	0	1	1	0	1	1
Jasper	6.83	17.12	15.43	17.93	1.10	1.15	1.35	1.48	0	24.71	37.63
	104	111	1	1	4	4	2	2	1	112	119
Kosciusko	0.06	0.11	0	0	0	0	0	0	0	0.06	0.11
	2	2	0	0	0	0	0	0	0	2	2
Lake	4.38	10.93	0	0	1.75	1.97	0	0	0	6.14	13.62
	75	76	0	0	6	6	0	0	0	81	83
LaPorte	5.29	10.91	0.60	0.56	4.43	4.48	0.15	0.18	0.66	11.13	16.75
	84	87	2	2	10	10	4	4	2	102	105
Marshall	0.59	1.25	0	0	2.42	2.61	0.27	0.24	0	3.28	4.10
	27	28	0	0	5	5	4	4	0	36	37
Newton	3.00	6.65	0	0	0.62	0.74	0.17	0.31	0	3.79	7.68
	49	48	0	0	6	6	1	1	1	57	56
Porter	1.34	3.04	0	0	3.78[1]	4.16[1]	0.01	0.01	0.06	5.19	7.27
	23	26	0	0	5	5	1	1	1	30	33
Pulaski	0.05	0.30	0	0	0	0	0	0	0	0.05	0.30
	4	5	0	0	0	0	0	0	0	4	5
St. Joseph	3.73	8.58	5.13	4.03	0.83	3.19	2.94	3.08	0	12.63	18.86
	52	51	3	3	13	13	4	5	1	73	73
Starke	0.87	2.50	0	0	0.69	0.81	0.01	0.01	0	1.57	3.32
	26	28	0	0	4	4	2	2	0	32	34
White	0	0	0	0	0	0	0	0	0.08	0.08	0.08
	0	0	0	0	0	0	0	0	1	1	1
Total[2]	26.14	61.40	21.15	22.52	15.85	19.37	4.94	5.35	0.81	68.90	110.02
	446	462	6	6	55	55	19	20	7	533	551

[1]Includes withdrawals by the city of Valparaiso, which lies primarily outside of the basin.
[2]Totals may not equal sum of county values because of differences in rounding.

As table 22 shows, Jasper County had the highest number of irrigation facilities and the highest reported irrigation water use in 1987. Reported irrigation withdrawals also were high in LaPorte, Lake, St. Joseph and Newton Counties.

It is interesting to note that Jasper County had the highest irrigation water use in Indiana during 1987. Elkhart County had the second highest irrigation water use, but no irrigation withdrawals occurred in the small portion of the county located within the Kankakee River Basin boundary.

Based on 1987 water-use data from the Division of Water and land-use data from the U.S. Bureau of the Census (1989), Lake and Jasper Counties had the highest per-acre water use in the irrigation category (more than 10 inches). LaPorte and St. Joseph Counties had the greatest number of irrigated acres, and a per-acre water use of 5 inches. Possible causes for the

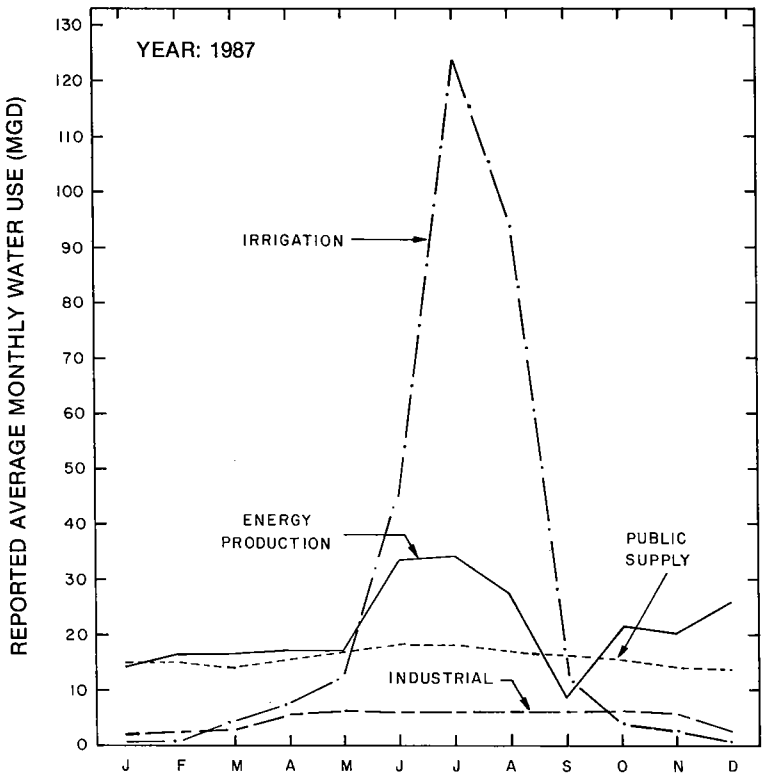


Figure 54. Variation of monthly water use

significant difference in per-acre water use among these counties include not only differences in irrigation practices, but also differences in compliance for water-use reporting and methods for estimating water use. It is also possible that some reported withdrawals were for agricultural drainage purposes rather than for irrigation.

In some counties, a relatively small number of registered irrigation facilities accounts for the majority of irrigation water withdrawals. For example, 12 registered facilities in Lake County that withdraw water from either Singleton Ditch or the Kankakee River accounted for nearly two-thirds of the county's reported irrigation withdrawals in 1987. In Jasper County, 24 facilities (registered by 10 owners) accounted for nearly three-fourths of the county's irrigation withdrawals.

As figure 53 illustrates, about 15 mgd (56 percent) of water withdrawn in 1987 for irrigation within the Kankakee River Basin was derived from surface-water sources, and about 11 mgd (44 percent) was from ground-water sources. The largest number of surface-water withdrawals occur along the Kankakee River, especially in its lower reaches, and along Singleton Ditch and other tributary ditches in Lake County (figure 52). Ground-water withdrawals occur throughout the river valley, but are slightly more common in the extreme upper and lower portions.

Although registered withdrawal capability in Jasper and LaPorte Counties are considerably greater for surface-water sources than for ground-water sources, the reported use in 1987 was fairly evenly distributed between surface water and ground water. In Lake and Porter Counties, both the capability and use predominantly were from surface-water sources. In Newton County, ground water provided more than three-fourths of the irrigation water.

The most common methods for large-scale agricultural irrigation in the Kankakee River are center-pivot sprinkler irrigation and subsurface irrigation. In a center-pivot system, water is applied to crops from sprinkler or spray heads on a pipeline supported on mobile towers. The pipeline is fixed at one end (the pivot), where it is connected to the water supply. Automated controls on the towers regulate their mo-

Table 22. Irrigated land and irrigation water use

{Values are for 1987 and are for entire counties to allow comparisons of data from different agencies.}

Irrigated farms, irrigated land: Data are from U.S. Bureau of the Census (1989).

Registered irrigation facilities, number of registered withdrawal points, irrigation water use: Data are from unpublished files of the IDNR, Division of Water. County values may differ from in-basin values shown in table 21 and appendix 16. One irrigated farm may comprise several registered facilities; one facility may encompass several withdrawal points.

Irrigation water use: Values are expressed in million gallons (mg), 90-day average in million gallons per day (mgd), inches per acre of irrigated cropland, and percent withdrawn from ground water.

County	Irrigated farms		Irrigated land		Registered irrigation facilities	Number of registered withdrawal points		Irrigation water use		
	Number	% of total farms	Acres	% of total cropland		Ground water	Surface water	mg (mgd)	inches	% GW
Jasper	49	6	9,138	3	106	132	31	2516 28.0	10	50
Lake	34	6	5,524	4	83	34	77	1766 19.6	12	13
LaPorte	78	9	15,607	7	84	72	31	1932 21.5	5	48
Marshall	44	4	4,086	2	34	25	19	316 3.5	3	74
Newton	16	3	9,874	5	49	44	13	1094 12.2	4	73
Porter	33	6	3,618	3	28	26	15	553 6.1	6	21
St. Joseph	71	8	10,632	7	70	63	28	1560 17.3	5	50
Starke	44	10	8,650	7	42	40	17	416 4.6	2	65

tion to move the pipeline slowly in an arc about the pivot.

Center-pivot towers typically are from 1000 to 2500 feet long and irrigate 1/4- to 1-square-mile plots. Large end-guns often are used to partially irrigate each corner of the field.

Subsurface irrigation continues to be a major irrigation method in Jasper, Newton and southern Lake Counties. In most cases, water-control structures in drainage ditches are closed off to retain water and consequently raise the water level. The water subsequently travels through tile lines and/or seeps through the soil layers to supply water to the root zone of crops. In some instances, ground water from wells or surface water from nearby streams or ditches is used to supplement the water supply in the ditch.

It should be noted that subsurface irrigators who do not withdraw water via pumps or intakes are not required to register with the Division of Water; hence, reported water withdrawals by registered irrigation facilities may not include all the water applied to crops for irrigation purposes.

Crops commonly irrigated by sprinkler and subsurface methods include corn, soybeans, hay and forage crops, potatoes, and mint.

Irrigation projections

In the past three decades, Indiana farmers have shown increasing interest in the irrigation of field crops. Between 1967 and 1977, the number of irrigated acres in Indiana more than doubled, from about 30,000 acres to nearly 65,000 acres (see Indiana Department of Natural Resources, 1969; Governor's Water Resources Study Commission, 1980). Between 1978

and 1987, irrigated acreage again doubled, from about 75,000 to nearly 170,000 acres (U.S. Bureau of the Census, 1984a, 1989).

Irrigation increases in major counties of the Kankakee River Basin are shown in figure 55. Average annual increases in irrigated land between 1967 and 1987 have been greatest in LaPorte County, St. Joseph County, Starke County, Newton County, and Jasper County.

Improving crop yields and protecting against crop failure during drought periods are the major incentives for utilizing large-scale irrigation systems. Other factors also have fostered interest in irrigation, including: 1) improvements in irrigation equipment; 2) rising land values; and 3) escalating costs of fertilizer, herbicides, machinery, and other crop inputs which will lose efficiency if crop yields are poor.

The demand for irrigation water, the desirability of irrigating, and the choice of an appropriate irrigation system are related to a variety of physical, economic and legal factors, including: 1) the nature of local soils and topography; 2) the specific moisture requirements of the crop under cultivation; 3) the economic costs of system operation and production; 4) the nature of the agricultural management strategy; and 5) the existence of jurisdictional or legal limitations on water use (Bedell and Van Til, 1979).

The irrigation potential of a soil, or its adaptability to irrigation, is determined by many soil properties, particularly soil texture, structure, and depth. These properties determine a soil's water-holding capacity, water intake (*infiltration*), and internal drainage (*permeability*).

In general, irrigation potential is highest on shallow, droughty, coarse-textured soils having high intake rates and good drainage. However, on soils which hold more than 4 inches of water in the root zone, the gains in crop production may not be favorable enough to economically justify irrigation (Robbins and others, 1977). Moreover, if the land is not naturally well drained, artificial drainage must be established before or at the same time the irrigation system is installed.

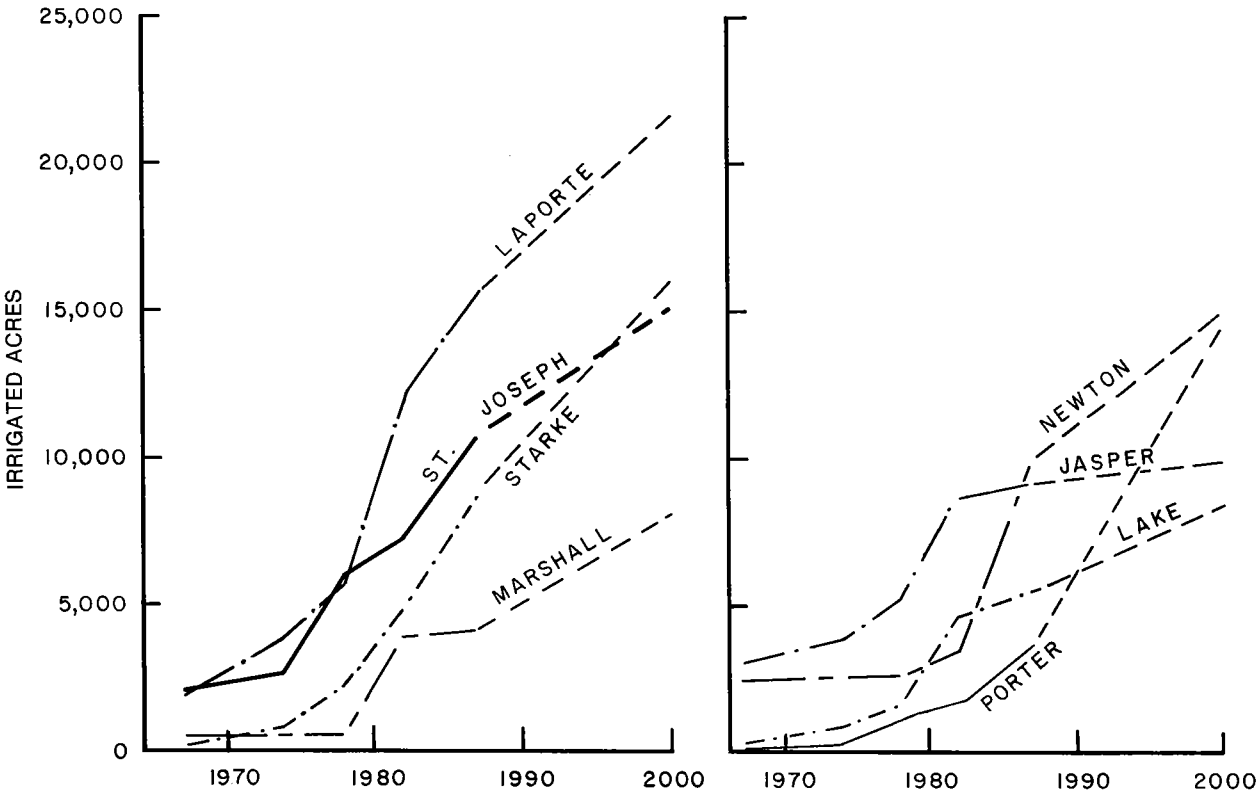


Figure 55. Historic and projected acreage of irrigated land for major basin counties

Soils in the Kankakee River Basin were evaluated for irrigation potential on the basis of major soil associations, which were described in the ***Physical Environment*** chapter of this report in the section entitled ***Soils***. Descriptions of general soil associations in the basin are found in appendix 3.

Each soil association can be assigned to one of four categories that describe the soil's response to irrigation. These categories were developed on the assumption that crop yields in sandier soils would significantly increase with irrigation, whereas yields in deep loam, silt loam, and fine-textured soils would not increase sufficiently to make irrigation profitable for grain crops at historic average corn price-to-cost ratios.

Soil associations in Group 1 and Group 2 are poorly adapated to irrigation, whereas soils in Group 3 and Group 4 are moderately to well adapted to irrigation. In this analysis, soil associations categorized into Group 1 and Group 2 are not considered further because it is assumed that a profitable response to irrigation in less than 2 years out of 5 is economically undesirable.

About 60 percent (987,000 acres) of the land area in the Kankakee River Basin falls into Groups 3 and 4 (table 23). As appendix 3 shows, these soils lie primarily in the main Kankakee River valley and in the lower Yellow River Basin.

It is estimated that at least one-fourth of the soils in Groups 3 and 4 within the Kankakee River Basin are not irrigable because of unsuitable physical characteristics, including topography. For example, irrigation is not recommended on lands having slopes greater than 6 percent.

Lands covered by lakes, rivers, and urban or built-up areas are considered as unavailable for agriculture, and consequently unavailable for irrigation. Other lands that are considered unavailable for agriculture and irrigation include public properties such as parks, wildlife refuges and nature preserves.

The percent of irrigable land actually utilized for irrigation depends on economic, farm management, and climatic factors. For example, an increase in energy prices, a decrease in corn prices, or a period of unusually wet years would probably cause a decrease in irrigation. Conversely, water use in a dry year is expected to exceed water use in a wet or average year. From 1987 (a year of average to above-average precipitation) to the drought year of 1988, irrigation water use doubled in the eight-county basin region (table 21).

Because the interactions of these and other variables cannot be predicted, recent trends in irrigation were considered too volatile to use as a basis for projecting irrigated acreage and irrigation water use. Increases in irrigated acreage provided by local county extension agents are considered to be more realistic than projections derived either from a detailed analysis of the soil maps in appendix 3 or from statistical methods.

Projections of irrigated land in the year 2000 are shown in table 24 and illustrated in figure 55 for major basin counties. Projections of irrigation water use also are given in the table. Values were computed for years of average and below-average precipitation to approximate a range in potential withdrawals. In this application, the term "dry year" does not refer to an extreme drought but to a year in which there is a sizeable deficiency in rainfall.

Table 24 also shows water-use projections derived from a ratio of irrigated cropland to reported water use for 1987. A comparison of these values with values for an average and dry year shows considerable variation among counties.

As table 24 shows, irrigation water use in the Kankakee River Basin is expected to remain high in Jasper County, even though increases in irrigated land are expected to be minor relative to other county increases. Irrigation water use also is expected to remain high in LaPorte County, which has the largest acreage of potentially irrigable soils but a high degree of urbanization and government-owned lands. The projected increase in water use for Porter County may be conservatively high, but the potential for significant irriga-

Table 23. Irrigation potential by soil associations

Category	Area
1- Little or no profitable response (none)	729,990 acres
2- Response 1-2 years in 5 years (slight)	24,800 acres
3- Response 3-4 years in 5 years (moderate)	776,100 acres
4- Response expected yearly (high)	210,600 acres

tion expansion in southern Porter County must be considered. Irrigation water use in other basin counties also is expected to increase, but the degree of increase is difficult to determine.

Energy production

Energy production, the second highest water use in the Kankakee River Basin, includes any self-supplied water withdrawal related to the energy production process,such as coal preparation, oil recovery, cooling water, mineral extraction, and power generation. Of the six facilities in the Kankakee River Basin registered under the Division of Water's energy production category (appendix 17), only one uses water directly for power generation.

The R.M. Schahfer electric generating station, owned by the Northern Indiana Public Service Company, uses a closed-cycle cooling system for its coal-fired steam turbines. The plant withdraws water from the Kankakee River for recycling between the cooling towers and the power station. Additional water withdrawn from ground-water sources is primarily used for drinking water and sanitary purposes.

The other five registered energy production facilities in the Kankakee River Basin use ground water primarily for drinking water, sanitary purposes, fire protection, process water, and cooling water. These facilities include a liquified natural gas storage facility near New Carlisle, a correctional center near Westville, an ethanol plant in South Bend, and electric-service substations in southwestern St. Joseph County.

In 1987, about 21 mgd of water was withdrawn by these six registered energy production facilities. As figure 53 illustrates, about 15 mgd (71 percent) of the water withdrawn was derived from surface water (the Kankakee River). The remainder was from ground water.

As figure 54 shows, the peak water use by energy production facilities occurs in June and July, when energy needs are high for air conditioning and other purposes. A secondary peak occurs in December when heating demands are high.

Water withdrawals for energy production are expected to increase slightly during the 1990s as the population within the basin continues to grow. Demands for energy also are expected to increase during a drought, such as the one experienced in 1988, when withdrawals in the energy production category showed a 6 percent increase over 1987 values.

Table 24. Water use projections for irrigation category

{Values, for the year 2000, are for entire counties, including non-basin areas.}

Irrigated cropland: Projections are from county extension agents.

Irrigation water use: Values for average year are based on application rate of 9 inches; values for dry year are based on application rate of 10 inches.

County	Irrigated cropland (acres)	Projected irrigation water use			
		At 1987 rate		Avg. year (mgd)	Dry year (mgd)
		mg	mgd		
Jasper	10,000	2753	30.6	27.0	30.2
Lake	8,500	2717	30.2	23.0	25.6
LaPorte	21,600	2673	29.8	58.7	65.2
Marshall	8,000	618	6.9	21.7	24.1
Newton	15,000	1662	18.5	40.7	45.3
Porter	14,500	2214	24.5	39.4	43.7
St. Joseph	15,000	2200	24.4	40.7	45.3
Starke	16,000	769	8.5	43.4	48.3

Public supply

The public supply category includes the water that is withdrawn by public and private water suppliers and delivered to users who do not provide their own water. Water suppliers provide water for a variety of uses such as residential, commercial, and industrial use. As presently defined by the Division of Water, public supply also refers to subdivisions, mobile home parks, schools, healthcare facilities, hotels and motels, conservancy districts, and other facilities that have their own water supplies (usually wells) and that use water primarily for drinking water, washing, cooking and sanitary purposes. This categorization system differs from systems used by some states and organizations, in which most of the latter water-use types generally are considered as either domestic self-supplied or commercial uses.

Of the 55 registered water withdrawal facilities classified under the Division of Water's public supply category (table 25), 32 are municipal utilities, 13 are schools, three are subdivisions, and three are parks. The remaining four include a motel, a mobile home park, an industrial park, and a nursing home.

In 1987, these public supply facilities withdrew a total of nearly 16 mgd (table 21), or about 19 percent of the total water use in the basin. Appendix 18 summarizes, by water source, the withdrawal capability and reported use by registered public supply facilities during 1986-88 for each county within the basin.

It is important to note that the public supply water-use values in table 21 and appendix 18 include withdrawals by three municipalities whose corporate limits are located partly or entirely outside of the Kankakee River Basin but whose well fields are located inside the basin boundary. Valparaiso in Porter County, St. John in Lake County, and Fowler in Benton County all withdraw water from inside the Kankakee River Basin but supply some or all of the water to residents in adjoining river basins.

Most of the water withdrawn in the Kankakee River Basin in 1987 for public supply purposes was derived from ground-water sources. The only surface-water withdrawals occurred on Flint Lake near Valparaiso and on a small pond in a St. Joseph County park near New Carlisle.

As figure 54 shows, withdrawals for public supply remain fairly constant throughout a year of normal precipitation. In the drought year of 1988, however, public-supply use was unusually high in the summer months, probably as a result of increases in lawn and garden watering.

According to a Division of Water analysis, total and per capita water use increases with increasing municipal population. Per capita use may be higher for municipalities with many industries than for municipalities of comparable size with a small industrial base.

One method of estimating mean water use for a given population is by using the following equation, which was developed using data for the years 1960, 1970, 1980, and 1986-87:

$$mgd = 3.735 \times 10^{-5} \times p^{1.125}$$

where mgd is water use in million gallons per day, and p is population served. Mean water use also can be estimated by multiplying the median water-use value by a correction factor of 1.06. The relationship between median water use and population is illustrated in graphical form in figure 56.

During the 1990s, water withdrawals by public supply facilities are expected to increase slightly in most basin counties, roughly paralleling the anticipated increases in population (figure 5, appendix 1). The only exception is LaPorte County, whose population and public-supply water use are expected to decline slightly during the 1990s. Water-use projections for public supply are shown in table 26.

Industrial self-supplied

Industrial self-supplied water use refers to process water, waste assimilation, dewatering, sand and gravel operations, and some cooling and mineral extraction uses. Under the Division of Water's categorization system, industrial water use includes only the withdrawals that a company develops for itself. If an industry also purchases water from a public-supply utility, the amount of water purchased is included in the public supply category.

In 1987, industrial self-supplied water withdrawals totaled about 5 mgd (table 21), or 6 percent of total registered and non-registered withdrawals. Of the total amount of water withdrawn, 76 percent was derived from surface water and 24 percent from ground water.

About 86 percent of industrial water withdrawals in 1987 occurred in Jasper and St. Joseph Counties (ap-

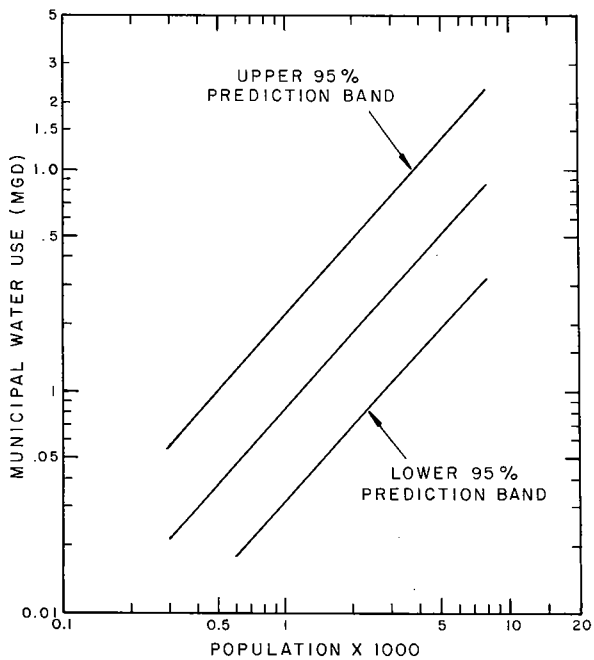


Figure 56. Relation of median water use to municipal population

Table 25. Public water supply facilities and type of water use

Facility name	Type
BENTON COUNTY	
Earl Park	Municipality
Fowler	Municipality
JASPER COUNTY	
Best Western-Remington	Motel
Remington	Municipality
Rensselaer	Municipality
St. Joseph College	School
LAKE COUNTY	
Dalecarlia Utilities	Subdivision
Lowell	Municipality
St. John[1]	Municipality
Schneider	Municipality
Utilities Inc. — Utopia	Subdivision
Utilities Inc. — Lake of the Four Seasons	Subdivision
LAPORTE COUNTY	
Kingsbury Utilities	Industrial park
Kingsford Heights	Municipality
LaCrosse	Municipality
LaPorte[2]	Municipality
New Durham Estates	Mobile home
New Prairie School Corp.[3]	School
Wanatah	Municipality
Westville	Municipality
MARSHALL COUNTY	
Argos	Municipality
Bremen	Municipality
Marshall Co. Comm.	Nursing Home
Plymouth	Municipality
Union United School Corp.	School
NEWTON COUNTY	
Brook	Municipality
Goodland	Municipality
Kentland	Municipality
Morocco	Municipality
North Newton School	School
South Newton School	School
PORTER COUNTY	
Hebron	Municipality
Kouts	Municipality
Porter Twp. School	School
Valparaiso[1,2]	Municipality
ST. JOSEPH COUNTY	
Lakeville	Municipality
New Carlisle	Municipality
North Liberty	Municipality
Penn-Harris-Madison School	School
Potato Creek State Park[2]	Park
St. Joseph Co. Parks	Park
South Bend Comm. School[2]	School
South Bend	Municipality
Union North United School	School
Walkerton	Municipality
STARKE COUNTY	
Hamlet	Municipality
Knox	Municipality
North Judson	Municipality
Oregon Davis Jr.-Sr. High School	School

[1]Corporate limit lies partly outside of the basin boundary
[2]Two facilities
[3]Three facilities

pendix 17). Most of the water was withdrawn from stone quarries and gravel pits for sand and gravel production.

Withdrawals for industrial purposes remain fairly constant throughout the year (figure 54).

The methodology used to make industrial water-use projections is explained in a report by the Governor's Water Resource Study Commission (1980). As the projections show (table 26), only slight increases in industrial water use are anticipated during the 1990s.

Rural and miscellaneous

Water withdrawals by rural and miscellaneous facilities in the Kankakee River Basin constitute only about 1 percent of water use in the basin. Of the total 0.8 mgd withdrawn under these two categories in 1987, 0.7 mgd was for rural uses, including the Mixsawbah State Fish Hatchery in LaPorte County and a large poultry operation in White County (appendix 19). Nonregistered, self-supplied domestic withdrawals are not categorized as rural uses, unlike an earlier classifica-

Table 26. Water use projections for public supply and industry categories for the year 2000

{Values are in million gallons per day.}

	Public supply	Industry
Benton	0.20	—
Elkhart	—	0.05
Jasper	1.15	1.84
Lake	1.97	—
LaPorte	4.30	0.17
Marshall	2.66	0.34
Newton	0.62	0.15
Porter	0.70	0.01
Valparaiso	3.99	—
St. Joseph	1.02	3.33
Starke	0.74	0.01
Total	17.35	5.90

tion used by the Governor's Water Resources Study Commission (1980).

The remaining 0.1 mgd withdrawn in 1987 was used for miscellaneous purposes, which may include activities such as fire protection, flood control, drainage control, water slides, snow-making and lake-level maintenance. Of these potential uses, however, the only reported withdrawal in 1987 was for maintaining the water level of a shallow lake for recreational purposes.

Because water withdrawals for rural and miscellaneous uses constitute only about one percent of all withdrawals, projections were not calculated for this report.

Non-registered use categories

Domestic self-supplied

Domestic self-supplied water use refers to residential water users who obtain water from private water wells rather than from public supply systems. It is estimated that about 146,000 basin residents, or 63 percent of the basin population, have domestic wells. As mentioned previously, the Division of Water categorizes withdrawals by commercial or institutional organizations as public supply uses rather than as domestic self-supplied or commercial uses.

Estimated withdrawals by domestic self-supplied facilities in 1987 (11 mgd) constituted approximately 13 percent of the total water use in the basin. Table 27 lists the estimated withdrawals by county. The estimated values were obtained by multiplying the approximated self-supplied population within the basin portion of each county by an estimated per capita usage of 76.46 gallons per day (Indiana Department of Natural Resources, 1982a).

Projected domestic self-supplied water uses for the year 2000 are shown in table 27. Withdrawals are expected to increase slightly or remain fairly stable in most basin counties over the next 10 years. Decreases are anticipated only in LaPorte, Newton and Starke Counties, primarily because of projected decreases in population.

Livestock

Livestock water use (table 28) was determined by multiplying the estimated population of a particular livestock category by an estimate of the amount of water consumed daily per animal (Indiana Department of Natural Resources, 1982a). According to these calculations, withdrawals for livestock watering purposes totaled 3.2 mgd in 1987. About 75 percent of the water withdrawn was used for beef cattle and hogs. In a few cases, water withdrawals tabulated as livestock

Table 27. Estimated and projected annual water use for domestic self-supplied category

County	Self-supplied population	Water use (mgd)	
		1987	2000
Benton	2,486	0.19	0.19
Elkhart	5,361	0.41	0.44
Jasper	19,191	1.47	1.51
Kosciusko	3,649	0.28	0.30
Lake	24,022	1.84	2.03
LaPorte	10,568	0.81	0.78
Marshall	17,897	1.37	1.46
Newton	9,162	0.70	0.67
Porter	18,506	1.41	1.67
Pulaski	635	0.05	0.05
St. Joseph	20,444	1.56	1.57
Starke	13,046	1.00	0.97
White	914	0.07	0.07
Total	145,881	11.15	11.71

Table 28. Estimated annual water use for livestock category

{Data derived or adapted from Indiana Department of Natural Resources, 1982a; U.S. Department of Agriculture, 1987b, 1988c; U.S. Bureau of Census, 1989.}

Livestock class	Estimated number (1,000 head)	Average daily water use (gal/hd/day)	Average annual water use (mgd)
Beef cattle	101.0	11.5	1.16
Dairy cattle	22.1	22.5	0.50
Hogs	313.8	4	1.26
Sheep	6.9	1.5	0.01
Chickens	2,382.0	0.1	0.24
Turkeys	150.0	0.2	0.03
		Total	3.20

Table 29. Estimated recreation participation and occasions for the basin region

{Data from Indiana Department of Natural Resources, 1988d.}

Activity	Number of participants	Number of occasions
Fishing	500,427	12,655,804
Swimming	538,338	12,182,597
Motorboating	288,125	3,555,459
Sailing	98,569	2,062,063
Waterskiing	144,062	1,979,417
Canoeing	128,898	1,205,196
Ice skating	83,405	1,046,727
Other activities	11,092,804	322,745,975
Total		357,433,238

water use also may have been included either in the irrigation or rural categories of registered significant water withdrawal facilities.

Livestock water use is expected to increase only slightly during the 1990s. Increases will depend largely on the farm economy and climatic factors.

Instream uses

Instream uses are defined as non-withdrawal uses taking place within a stream, lake or reservoir. Instream uses in the Kankakee River Basin primarily include recreation activities, fish and wildlife habitat, and waste assimilation. The generation of hydroelectric power is a common instream use in some areas of Indiana; however, no sites are suitable in the Kankakee River Basin for the development of a hydropower facility.

Water-related recreation needs in the 1990s will depend on user demand, the availability of facilities, and a variety of demographic and socioeconomic factors. Estimates of potential recreational use were calculated for a 14-county service area that includes the 13 counties of the Kankakee River Basin and also Fulton County (Indiana Department of Natural Resources, 1989). It was assumed that residents of the 14-county area would participate in water-based or water-enhanced recreation activities at the same rate as all persons living in the northern planning region, for which information was obtained in an outdoor recreation issues study (Indiana University, 1987).

The values shown in table 29 represent the number of recreationists and amount of participation for the 14-county service area. It does not imply that all participants use waters of the Kankakee River Basin exclusively as the location of their activity. Moreover, the values do not account for the number of visits from non-service area residents, nor the number of times persons from within the service area go outside the area for recreation.

It should be recognized that future recreation needs may differ from present needs. The change in the age distribution of the basin's population will significantly affect the demand for recreation opportunities. Other concerns include: 1) the need for more water-based recreation facilities; 2) increasing need for access to the state's waters; 3) particularly high demand for greenways; and 4) a significant need for more public land. These factors are discussed in more detail in a 5-year recreation plan (Indiana Department of Natural Resources, 1988a).

Summaries of basin fisheries and wastewater treatment were provided in the ***Surface-Water Hydrology*** chapter of this report under the subheading ***Surface-Water Quality***. The future quality of basin fisheries will depend largely on the water quality and presence of suitable habitat, the availability of sufficient stream flow, stocking activities by the IDNR, and fishing pressure. Factors that will help maintain or improve surface-water quality in future years include control

of nonpoint-source pollution, upgrading of wastewater-treatment facilities, improved treatment-plant operations, and improved compliance with discharge limits. Detailed information on wastewater-management plans is available from the Indiana Department of Environmental Management.

The conservation of wetland wildlife habitat was discussed in the ***Surface-Water Hydrology*** chapter of this report under the subheading ***Wetland Protection Programs***. Compliance with existing regulations, implementation of existing programs, and establishment of additional programs will help ensure the future conservation of wetland and riparian habitats.

SURFACE-WATER DEVELOPMENT

Most surface-water withdrawals in the Kankakee River Basin occur along the Kankakee River and its major tributary ditches, particularly in Lake, Porter, Jasper and Newton Counties. As future demands increase on streams and ditches, additional steps may be needed toward the establishment of protected minimum flows.

Some withdrawals occur along lakes and wetlands, but these systems are not considered as probable water supply sources because of their limited storage capacity, water quality considerations, and regulatory, economic and environmental constraints.

Wetlands and lakes

Although some palustrine wetlands in the Kankakee River Basin may store considerable amounts of water at certain times, their shallow depths and the temporary nature of ponding does not make these wetlands suitable as water supply sources. Moreover, regulatory and non-regulatory programs administered by state and federal agencies (appendix 4) discourage the detrimental exploitation of wetlands, including certain land uses which would adversely impact nearby wetlands. The values of wetlands and the need for continued conservation of these areas was discussed earlier in this report.

Despite the large storage capacity of some public freshwater lakes in the Kankakee River Basin, few lakes are used as water supply sources. Some water is withdrawn from Flint Lake by the Valparaiso Waterworks; however, water from the lake is primarily intended to supplement the municipal supply derived primarily from ground water.

Existing state laws effectively preclude significant pumpage from natural lakes. In accordance with Indiana law, lakes with a legally established average level are to be maintained at that level. Temporary lowering of the lake requires approval by a local court and the Natural Resources Commission. Approval typically is granted only for shoreline improvements or lake restoration.

Even if state laws were amended to allow lowering of lake levels for supply purposes, treatment costs would probably limit uses to irrigation, livestock watering, or fire protection. Pumpage-induced lowering of water levels could detrimentally affect existing water quality, fisheries habitat, and adjacent wetlands. Moreover, significant lowering of lake levels would be objectionable to most lakeside property owners.

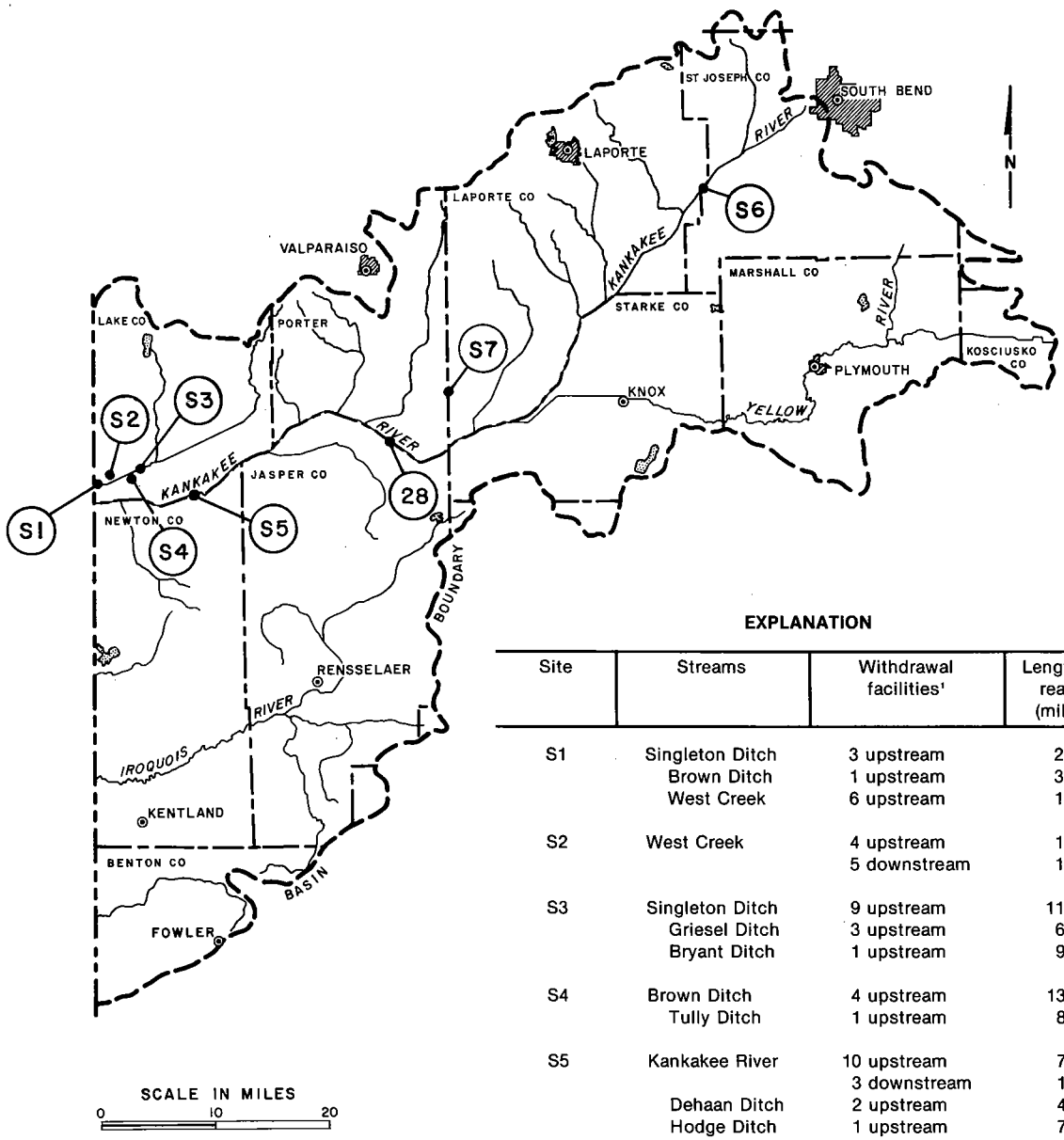
Adding lake storage for supply purposes also has considerable drawbacks. Amendments to current lake laws or approval for temporary lake-level increases would be required. Moreover, existing control structures at potential supply sites would have to be modified, because few lake-level control structures are designed to store water at elevations above the legal level. Furthermore, the inundation of lakefront property would be objectionable to lakeside property owners.

Because of these and other limitations, lakes are not considered as potential water supply sources in the Kankakee River Basin. Instead, the primary source of surface water in the basin should continue to be streams and ditches.

Streams

Streams are a major surface-water resource in the Kankakee River Basin and support a variety of withdrawal and non-withdrawal (instream) uses. As demand for water continues to increase, there will be a greater need to protect the quantity and quality of water in streams.

Although many streams in the Kankakee River Basin exhibit well-sustained flows as a result of the high degree of interconnection between surface-water and ground-water systems, the seasonal, monthly, and daily variability of stream flows coupled with increasing withdrawal uses are expected to produce localized or short-term conflicts between water supply and demand.



EXPLANATION

Site	Streams	Withdrawal facilities[1]	Length of reach (miles)
S1	Singleton Ditch	3 upstream	2.7
	Brown Ditch	1 upstream	3.1
	West Creek	6 upstream	1.9
S2	West Creek	4 upstream	1.9
		5 downstream	1.1
S3	Singleton Ditch	9 upstream	11.4
	Griesel Ditch	3 upstream	6.1
	Bryant Ditch	1 upstream	9.7
S4	Brown Ditch	4 upstream	13.6
	Tully Ditch	1 upstream	8.2
S5	Kankakee River	10 upstream	7.6
		3 downstream	1.8
	Dehaan Ditch	2 upstream	4.3
	Hodge Ditch	1 upstream	7.6
S6	Kankakee River	14 upstream	10.1
S7	Reeves Ditch	2 downstream	1.9
	Grieger Ditch	7 upstream	3.9
28	Kankakee River	NIPSCO	—

[1]Some withdrawal facilities are common to sites S1, S2 and S3 because of the proximity of withdrawal facilities

Figure 57. Location of significant stream sites

Table 30. Monthly stream-flow characteristics and water withdrawals at significant stream sites

{Values are in million gallons per day.}

Site number: Significant site locations are shown in figures 57 and 29.

7Q10: The annual lowest mean flow for seven consecutive days that can be expected to occur on the average of once every 10 years.

Lowest stream flow: Lowest daily flow that occurred during specified month and year.

Average withdrawal: Withdrawal averaged over the number of days of operation.

Site no.	7Q10	Year	JULY		AUGUST	
			Lowest streamflow	Average withdrawal	Lowest streamflow	Average withdrawal
S1[1]	8.6	1988	8.6	11.0	9.2	9.7
		1987	38.0	6.1	28.1	3.6
		1986	18.4	14.4	11.1	6.2
S2[2]	3.0	1988	2.1	7.4	2.6	6.1
		1987	9.2	3.7	8.0	0.7
		1986	4.5	9.5	3.1	3.95
S3	4.8	1988	4.5	20.7	4.7	20.7
		1987	20.0	11.7	14.2	7.3
		1986	9.7	11.2	5.6	11.2
S4[3]	0.8	1988	0.8	3.0	0.8	3.0
		1987	3.5	4.7	2.5	2.2
		1986	1.7	3.5	1.0	0.8
S5	273	1988	229	42.6	183	42.6
		1987	418	27.8	419	27.2
		1986	756	38.9	453	31.7
S6	36.4	1988	35.6	38.2	28.4	38.2
		1987	53.0	25.4	44.6	25.6
		1986	70.4	29.3	47.8	28.9
S7[3]	10.2	1988	9.4	8.6	8.7	8.6
		1987	13.2	4.9	11.3	5.1
		1986	16.9	4.6	13.2	4.6

[1]Parameters were calculated or estimated from gages on Singleton Ditch (05520000 Illini, Illinois, 1945-1977 and 05519000 Schneider, Indiana, 1948-present).
[2]Parameters were calculated or estimated from a gage on West Creek (05519500 Schneider, Indiana, 1948-1952 and 1954-1972) and a gage (05519000) on Singleton Ditch.
[3]Flows were estimated (no gage at this site).

Impacts of stream withdrawals

Impacts of stream withdrawals are not confined to the point of withdrawal, but can result in reduced stream-flow availability in downstream segments. A number of withdrawal uses reach their peaks during the seasonal periods of low stream flow. The demands placed upon low flows by withdrawal and instream uses are greatly exacerbated during droughts.

The relationship between withdrawal uses and available water supply in streams was examined at eight sites within the Kankakee River Basin (figure 57). The significant sites were selected in areas where total or cumulative water withdrawals near the site are large relative to low stream flows (figures 29, 52). The largest number of significant sites are in the lower Kankakee River Basin, where large amounts of water are withdrawn from the mainstem Kankakee River and from several tributary ditches.

Agricultural irrigation is the primary water use for seven of the eight significant stream sites (figure 57, sites S1-S7). Irrigation, which is considered to be a totally consumptive use, occurs during periods when stream flows are in seasonal decline. Moreover, irriga-

Table 31. Stream flow and withdrawals at NIPSCO's Schahfer plant

{Values are in million gallons per day. Site locations are shown in figures 57 and 29.}

Year	Historical minimum flow, Dunns Bridge[1]	Historical minimum flow, Kouts[2]	Monthly mean flow, Dunns Bridge	Monthly mean flow, Kouts	Net mean withdrawal
		JULY			
1988	271	266	271	226	20.7
1987	—	—	474	472	14.4
1986	—	—	876	939	15.7
		AUGUST			
1988	240	257	260	257	13.5
1987	—	—	435	412	18.2
1986	—	—	522	505	8.1

[1]The 7Q10 flow is 224 mgd.
[2]The 7Q10 flow is 259 mgd.

tion withdrawals place a relatively high demand on the water resource per unit area within the region of irrigation.

July and August were selected for analysis of potential conflict between water supply and demand because these two months typically are characterized by maximum irrigation withdrawals and low stream flows. Average water withdrawals at facilities along a stream reach upstream of a significant site or along a series of reaches associated with a site were totaled and compared to the following stream-flow parameters: 1) the annual 7-day, 10-year low flow (7Q10); and 2) the lowest daily mean flow of July and August for the years 1986-88. It is interesting to note that during the drought year of 1988, stream flow reached record lows in July and August at many of the sites.

Monthly withdrawals at significant sites S1, S2, S3 and S4 were large in comparison to gaged and estimated stream flows for the three years analyzed (table 30). Site 3 on Singleton Ditch is especially noteworthy because cumulative withdrawals are four to five times greater than the low stream flows, and because base flows are only moderately sustained by ground-water contribution.

The analysis provides a reasonable assessment of potential conflict between water supply and demand, but it may not represent a worst-case condition because water use was averaged over the total number of operating days; hence, higher withdrawals may have occurred for any given day. Moreover, the exact relationship between stream withdrawals and stream flow is not clearly understood, due in part to ground water contribution to stream flow.

Despite these limitations, it is apparent that there is a high potential for water-use conflicts on Singleton Ditch and several of its tributaries in southwestern Lake County during periods of drought. The IDNR Division of Water has no record of existing conflicts on these ditches; however, a county extension agent and several farmers reported that water shortages and water-use conflicts occurred at several locations on Singleton Ditch during the summer of 1988. It is assumed that water-supply problems also occurred on smaller ditches with limited storage capacities and/or minimal ground-water contribution.

Lower reaches of the Kankakee River support a large number of high-capacity withdrawals (figure 52), primarily for irrigation. Although cumulative withdrawals in some reaches are quite high, the river's flow appears to be adequate for large seasonal withdrawals.

At one site on the Kankakee River (figure 57, site 28), water is used by the R.M. Schahfer electric generating station operated by the Northern Indiana Public Service Company. Energy production at this site requires a high degree water-supply dependability, even under adverse conditions.

The power station, which is permitted under Indiana's navigable river statute (I.C. 13-2-4-9), withdraws water from the Kankakee River, uses it primarily for cooling and air-pollution control, and discharges a portion of the withdrawn water to an on-site settling pond. Under the terms of the permit, the plant can withdraw up to 106 cfs (68.5 mgd) from the river, and must return enough water to the river so that the consumptive use, measured as the net reduction in

stream flow (the difference in flow between the plant's intake and discharge points) does not exceed 41 cfs (26.5 mgd). The return flow from the settling pond to the river can be as high as 65 cfs (42 mgd), or can be reduced to as low as 0 cfs, provided that stream flow as measured at the Dunns Bridge station on the Kankakee River is greater than 289 cfs. Special conditions for withdrawals and return flows are applied when stream flows are at or below 289 cfs.

The station's water intake on the Kankakee River is about 0.7 miles upstream of a stream gage near Kouts. Stream flows at this gage were compared to stream flows at the Dunns Bridge gage which is located upstream of the intake and about 4.2 miles upstream of the Kouts gage (see figure 29). Reported net withdrawal at the power plant was analyzed for July and August of 1986-88 (table 31) and compared to mean monthly stream flow at the two stream gages.

Table 31 shows that mean monthly flows were less at the downstream gage than at the upstream gage for August for all three years analyzed and for July in 1987 and 1988. However, it should be emphasized that the differences in mean monthly flows are within the 10-percent margin of error commonly associated with reliable stream-flow measurements. During extreme low flows, the margin of error may be even higher.

A graphical plot of daily stream flows at the two stations against daily net withdrawals for 1985 and 1988 revealed that during periods of low stream flow, sharp increases in net water withdrawals at the plant appeared to produce distinct decreases in stream flow at the Kouts gage relative to the more constant flows at the Dunns Bridge gage. Conversely, abrupt decreases in net withdrawals at the plant appeared to produce distinct increases in flow at the Kouts gage. The degree to which stream flows are modified at the Kouts gage cannot be quantified, however, because of data limitations and because of the complex interactions of surface-water and ground-water systems.

Stream rights

The impacts of withdrawal uses on stream flows must be considered to determine how the potential for water-use conflicts can be minimized, particularly during a drought. Historically, water users have developed the most readily available source of supply without consideration of the effects of such development on other uses, particularly instream uses. Constraints on water use in a particular location may result from its competing value for various instream and withdrawal uses.

Indiana has long recognized the "riparian rights doctrine". Riparian rights are based on ownership of land abutting a watercourse. Indiana has adopted a modified reasonable-use policy in which each riparian landowner's right to use water from the watercourse is limited to uses that are reasonable under the circumstances. The person who asserts the unreasonableness of the use has the burden of proof.

Withdrawal rights are considered as private rights arising out of land ownership. Instream-use rights, unlike withdrawal rights, may exist both for private individuals and public entities; however, public rights are not held to be paramount to every conflicting private riparian right or public activity. Resolution of conflicting interests as well as statutory expansion of public rights, are influenced by the state's economic interests.

Under Indiana law (I.C. 13-2-4-9), a permit is required for any facility planning to withdraw water from a navigable waterway. (In the Kankakee River Basin, the Kankakee and Yellow Rivers have been designated as navigable.) The navigable river program is administered by the IDNR Division of Water.

Under the navigable rivers law, permit applications are evaluated for their impacts on navigability, the environment, and safety of life and property at the withdrawal site. Although the permitting program is directly relevant to water-resource management, it has a number of shortcomings. First, the program is limited in scope because it applies only to navigable rivers and excludes public water-supply utilities. Second, the law is difficult to enforce because no administrative rules have been promulgated. Finally, the program's effectiveness is limited because no defined criteria exist for evaluating the effects of proposed withdrawals.

The existing stream program does not adequately provide certainty of rights to use, mitigation or resolution of conflicts over withdrawal and conveyence of water from its source, impacts of such withdrawals on other uses and interests, or over competing or conflicting uses. At present, there is no procedure, other than through the courts, by which questions of use may be resolved on a timely basis.

Because of such limitations in existing programs, additional steps may be needed to help protect streams in localized areas. The Natural Resources Commission may establish criteria for determination of minimum streamflow (I.C. 13-2-6.1). If established, the

minimum stream-flow criteria may govern the amount of water withdrawn from streams in some areas.

In an ongoing effort to establish a sound framework for administrative and statutory decisions, the Division of Water has contracted researchers to examine technical issues related to surface-water withdrawals. In one study (Delleur and others, 1988), investigators examined the ability of a variety of statistical models to reliably and accurately forecast low flows and assess the severity of a given low flow. The study further explored design flows for waste assimilation.

Another study (Delleur and others, 1990) expanded on the first study by evaluating how much stream flow should be protected from withdrawal in order to provide for instream needs such as fish habitat, waste assimilation, and recreation. This study examined 25 stream gage sites in Indiana, including two sites in the Kankakee River Basin: namely, Cobb Ditch near Kouts and the Kankakee River at Dunns Bridge. The study also suggested a general minimum flow criteria to be applied at a site when a detailed study is not warranted.

A pilot study also is being planned with the Illinois State Water Survey in which an Illinois model for estimating low-flow parameters at ungaged locations would be applied to the Kankakee River Basin in Indiana. Through this effort, division staff would gain the expertise needed to apply the model to streams throughout Indiana.

The Illinois model begins with flow records at gaged locations, then develops regression equations from which low-flow parameters can be estimated for ungaged locations. The model allows these parameters to be estimated for three conditions: namely, flows that would occur if the stream were unaffected by human activities; flows that presently occur; and flows that would occur if the present condition were modified by further withdrawals or discharges.

In other attempts to resolve legal and technical problems associated with stream withdrawals, Division of Water staff are developing administrative rules for the existing navigable rivers permitting program. Staff also are providing technical advice to the Water Resources Study Committee, which has been meeting periodically since 1989 to develop recommendations for the legislature regarding surface and ground water resources in Indiana.

GROUND-WATER DEVELOPMENT

Ground-water resources of the Kankakee River Basin are among the most abundant in Indiana. Because ground-water availability in much of the basin is considered moderate to excellent, a significant potential exists for further ground-water development.

However, localized or short-term conflicts among ground-water users are expected to recur as ground-water demands continue to increase. Provisions found in Indiana laws, particularly I.C. 13-2-2.5, will remain a key factor in developing and protecting ground-water resources in the Kankakee River Basin. Additional regulations, water conservation practices, and improved management may be needed to protect ground water in localized areas.

Impacts of ground-water withdrawals

Ground-water withdrawals for irrigation purposes are responsible for most of the water-supply conflicts

Table 32. Ground-water withdrawals for irrigation in Jasper and Newton Counties

County	Number of registered wells	Registered ground-water withdrawal capability (mgd)[1]	Reported ground-water withdrawals	
			mgd[1]	mg
1985				
Jasper	130	73.06	18.06	1625.4
Newton	44	46.89	13.25	1192.5
Total	174	119.95	31.31	2817.9
1986				
Jasper	130	73.06	14.91	1341.9
Newton	44	46.89	11.89	1070.1
Total	174	119.95	26.80	2412.0
1987				
Jasper	130	73.49	13.81	1242.9
Newton	44	46.89	8.86	797.4
Total	174	120.38	22.67	2040.3
1988				
Jasper	135	77.67	25.59	2303.1
Newton	43	48.35	21.83	1964.7
Total	178	126.02	47.42	4267.8

[1]90-day average

in the Kankakee River Basin. Irrigation has been practiced since the 1950s, but the number of acres irrigated and the amount of water used have increased dramatically since the 1970s, particularly in LaPorte, Jasper, Lake, St. Joseph, and Newton Counties (see figure 55). As discussed in a previous section entitled ***Water Use and Projections***, irrigation is used primarily to improve crop yields on drought-prone sandy soils.

Water withdrawn for irrigation in LaPorte and St. Joseph Counties is pumped from streams, ditches, and outwash deposits, whereas irrigation water in Lake County is supplied largely by streams and ditches. Most irrigation water in Newton County is pumped from a carbonate bedrock aquifer. Ground water from the carbonate aquifer and surface water from streams and ditches provide most of the irrigation water for Jasper County.

Ground-water conflicts caused by irrigation pumpage in the Kankakee River Basin have occurred primarily in Jasper and Newton Counties. Ground-water withdrawals for irrigation in these two counties increased from about 1 billion gallons in 1977 to about 2 billion gallons in 1987, and exceeded 4 billion gallons in the drought year of 1988. As table 32 shows, reported water withdrawals in the irrigation category varied widely from 1985 to 1988, even though the number of registered irrigation wells did not increase significantly. The greatest increase in irrigation withdrawals occurred between 1987 and the drought year of 1988, when reported withdrawals more than doubled.

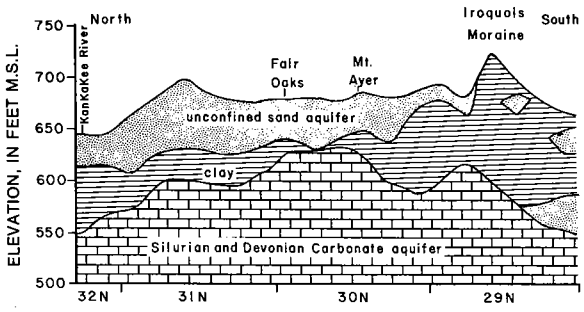


Figure 58. Generalized geologic cross section in irrigation areas near the Jasper-Newton County line

The major irrigation area in Jasper and Newton Counties is located south of the Kankakee River and north of the Iroquois Moraine (see figures 14, 52). Although some domestic, livestock, and irrigation wells in this area are completed in an unconfined sand aquifer known as the Kankakee Aquifer System (plate 2), most wells pump from the underlying carbonate rocks of Silurian and Devonian age (figure 58). A relatively impermeable clay deposit separates the two

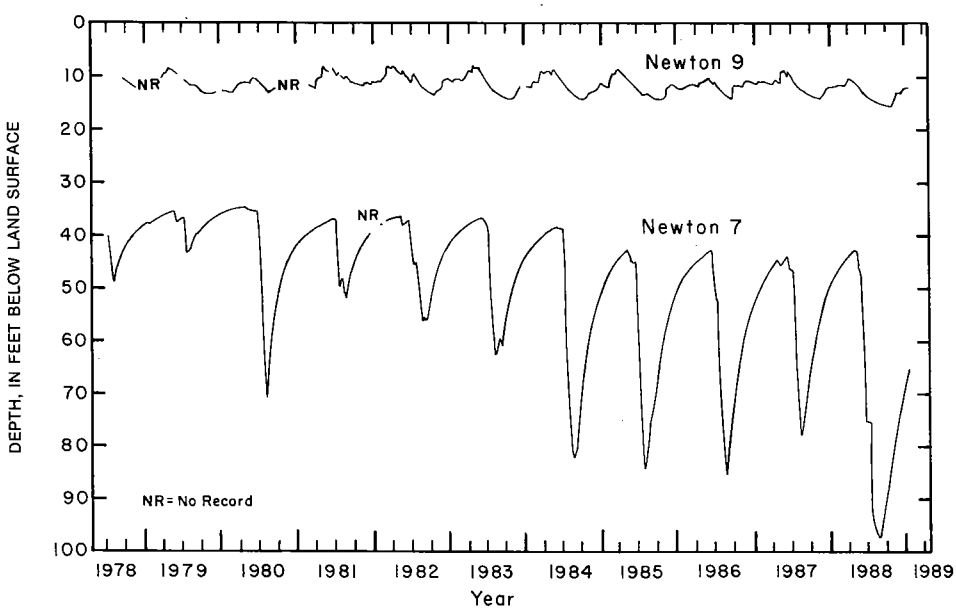


Figure 59. Water-level fluctuations in observation wells completed in the unconfined sand aquifer and Silurian and Devonian carbonate aquifer in west-central Newton County

aquifers in most of the two-county area. Thickness of the clay unit typically is from 20 to 80 feet, but ranges from 0 to 140 feet (Basch and Funkhouser, 1985; Arihood and Basch, in preparation).

In areas where the clay unit is present, water levels in the surficial sand aquifer and the deeper bedrock aquifer appear to fluctuate independently. As the hydrograph for observation well Newton 9 shows (figure 59), water levels in the sand aquifer follow the typical seasonal pattern of springtime highs and autumn lows. In contrast, the hydrograph for Newton 7, a bedrock well, shows a pumpage-induced decline in water level during the summer irrigation season, followed by a winter and spring recovery.

Although the Indiana Department of Natural Resources (formerly the Department of Conservation) first investigated the impacts of irrigation pumpage on water levels in 1954 (Uhl and Kingsbury, 1957), IDNR staff intensified their efforts in 1981, when irrigation pumpage from the carbonate aquifer increased sharply in Jasper and Newton Counties (see Bruns, 1981; Indiana Department of Natural Resources, 1982). In an attempt to better understand the effects of pumping on ground-water levels, the IDNR Division of Water, in cooperation with the U.S. Geological Survey, has conducted ground-water modeling studies (see box on this page).

Historically, under Indiana's "common law" approach to water-rights issues, a ground-water user was not held liable for damages to surrounding landowners if his use of ground water was reasonable and beneficial, and was not done maliciously or gratuitously. Conflicts involving ground-water supply and demand were handled on a case-by-case basis, and often were resolved by court decisions.

In 1982, a new law (I.C. 13-2-2.5) was enacted to provide protection for individuals in Jasper and Newton Counties whose domestic or livestock wells were being adversely affected by declines in ground-water levels caused by nearby high-capacity withdrawals. Under the provisions of this law, the owner of a high-capacity ground-water withdrawal facility (capable of pumping at least 100,000 gallons per day) can be liable for impacts on adjacent domestic wells if high-capacity pumpage has substantially lowered ground-water levels in the area, subsequently causing the domestic wells to fail. In order to have protection under the statute, affected domestic or livestock wells had to meet minimum well-construction standards established by the IDNR. Because ground-water availability conflicts were occurring elsewhere in Indiana, the law was amended on September 1, 1985 to provide protection for small-capacity well owners throughout the state.

Between 1981 and 1989, IDNR staff investigated about 25 complaints of water-supply problems in wells completed in the surficial sand aquifer in northern Jasper and Newton Counties. Investigators determined that losses of water supply in most of these wells were primarily the result of seasonal water-level fluctuations, and not a result of nearby irrigation pumpage from either the surficial sand or the underlying carbonate aquifer. In general, shallow wells that experienced ground-water supply problems either were equipped with inadequate pumps, or were not drilled deep enough to function properly during seasonal water-level declines, particularly during the drought conditions of 1988. Water-supply problems in most of these shallow wells were corrected by deepening the wells or replacing them with more efficient, larger-diameter wells equipped with pumps capable of lifting water from greater depths.

The losses of water supply in wells completed in the carbonate bedrock aquifer frequently resulted from water-level declines induced by high-capacity irriga-

Ground-water modeling

Since 1981, the U.S. Geological Survey in cooperation with the IDNR Division of Water has conducted two studies to assess the effects of irrigation pumpage on the ground-water levels and stream flow in Jasper and Newton Counties. In the first study (Bergeron, 1981), a quasi-three dimensional, two-layered digital model was developed to simulate steady-state flow conditions in the carbonate and unconfined sand aquifers. The model was calibrated to actual water levels and stream discharges measured in June 1978. Once calibrated, the model was used to simulate the effect of withdrawals on ground-water levels in the bedrock and unconfined sand aquifers.

Because of limited data, the model did not accurately simulate pumping impacts on the carbonate aquifer. However, the model did show that two of the most important factors controlling the drawdown or water-level decline in the bedrock are the variation in the thickness and vertical hydraulic conductivity of the semi-confining clay layer overlying bedrock.

In a more recent three-dimensional digital model constructed by the USGS (Arihood and Basch, in preparation), the area of consideration was extended to the Iroquois and Valparaiso Moraines. The new model incorporates nine layers and provides greater variability in the characteristics of the aquifers and confining clay layer. The model was calibrated to 1986 hydrologic data and validated using data from the drought year of 1988. The emphasis of this model is to predict the effect of pumpage from high-capacity irrigation wells and the potential effect of new irrigation wells. The results of this study should be available in 1991.

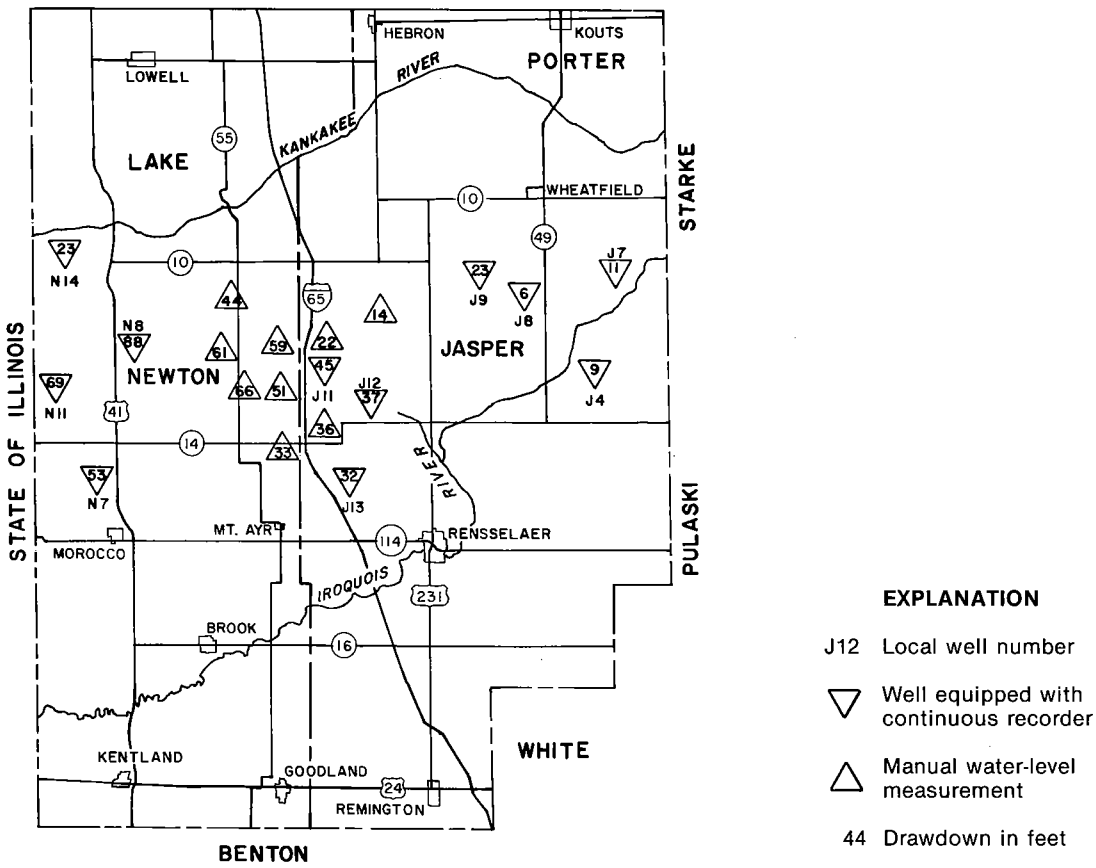


Figure 60. Water-level declines in selected bedrock wells in Jasper and Newton Counties during August 17-19, 1988

tion pumpage. Between 1981 and 1989, more than 200 domestic and livestock wells completed in the bedrock aquifer were reported to be adversely impacted by the reduction in ground-water levels caused by irrigation pumpage.

Many of the domestic and livestock wells in Jasper and Newton Counties that were shown to be affected by high-capacity irrigation pumpage were voluntarily upgraded by area irrigators, and the provisions of I.C. 13-2-2.5 were not invoked. However, about 10 temporary ground-water emergency orders were declared in the two-county area between 1982 and 1989. The primary purpose of the temporary orders was to provide the affected domestic well owner with an immediate temporary supply of potable water. Each matter was subsequently brought before the Natural Resources Commission to determine timely and reasonable compensation as specified in I.C. 13-2-2.5. A few of the groundwater problems resulted in litigation.

It should be emphasized that present irrigation water use in years with normal or near-normal precipitation appears to have minimal effects on the ground-water resource in Jasper County and portions of Newton County. In these areas, ground-water supply problems experienced in past years have been limited to the summer crop-growing season. Aquifer recharge and recovery in fall and winter typically compensates for summer irrigation withdrawals so that on an annual basis, the carbonate aquifer appears to be able to support high-capacity irrigation pumpage without significant long-term depletion. An exception may occur during extended drought when the potential rate of pumpage may exceed the rate of ground-water recharge.

In northwest and west-central Newton County, ground-water levels in the bedrock aquifer are more

strongly impacted by ground-water pumpage than levels in eastern Newton County, primarily because of hydrogeologic differences and the proximity of major pumping centers in both Indiana and Illinois. In western Newton County, ground-water levels in the bedrock recover slowly from seasonal irrigation withdrawals, and in some years may not fully recover before pumping resumes the following season.

During the drought conditions in the summer of 1988, record low ground-water levels were recorded in dozens of observation wells in Indiana, including 19 of the 23 bedrock and unconsolidated observation wells in the Kankakee River Basin. Record low levels resulted from a combination of the following factors: 1) below-normal precipitation in 1987, which produced lower-than-normal water levels in the spring of 1988; 2) hot, dry conditions during the summer of 1988; and 3) increased irrigation pumpage from surface-water and ground-water sources.

To monitor the effects of drought and irrigation pumpage on ground-water levels in Jasper and Newton Counties, IDNR staff frequently measured water levels in selected bedrock and unconsolidated wells. Figure 60 shows the difference in water levels between the springtime highs and the reduced summertime levels measured in bedrock wells during August 17-19, 1988 in Jasper and Newton Counties. The drawdowns measured in most bedrock wells on these dates either equaled or were within 3 feet of the maximum drawdown recorded for the entire year of 1988.

As figure 60 shows, water-level declines in four Jasper County wells exceeded 30 feet, and drawdowns in seven Newton County wells exceeded 50 feet. The greatest water-level declines in Newton County during the summer of 1988 were recorded in observation wells Newton 8 and Newton 11, where maximum drawdowns were 88 and 71 feet, respectively (see Glatfelter and others, 1989). In observation well Newton 8, the minimum water levels during much of July and August were near the top of the carbonate bedrock aquifer. In Newton 11, minimum levels during the two-month period often were approximately 10 feet below the top of the bedrock aquifer. Although dewatering of the carbonate aquifer probably did not occur over a large area, localized dewatering occurred near points of substantial ground-water withdrawals.

The large drawdowns measured in Newton County probably were related not only to the prolonged drought conditions, but also to hydrologeologic conditions and extensive irrigation. Substantial drawdowns near the Indiana-Illinois state line also were influenced by extensive irrigation pumpage from the carbonate aquifer in Kankakee and Iroquois Counties, Illinois (see figure 4). Studies by the Illinois State Water Survey have investigated the impacts of irrigation and drought on the ground-water resources of Illinois, particularly in eastern Kankakee and northern Illinois Counties (Changnon and others, 1982; Bowman and Collins, 1987; Cravens and others, 1989, 1990).

Because the reductions in water level during the summer of 1988 affected several small-capacity wells in Jasper and Newton Counties, and because it was believed that continued irrigation pumpage would exceed the recharge capability of the ground-water resource, provisions of I.C. 13-2-2.5 were invoked to restrict high-capacity pumpage in certain areas of the two counties. The pumpage restrictions were imposed to reduce the rate of water-level decline in the bedrock aquifer and to allow ground-water levels to recover.

Also during the summer of 1988, IDNR staff investigated numerous complaints of water-supply problems in and near the town of Shelby along the lower Kankakee River. The majority of the well failures occurred in shallow wells completed in the surficial sand aquifer. These wells were believed to have failed as the result of ground-water level declines caused by the hot, dry conditions. An emergency supply of potable water was provided to Shelby residents by the Indiana National Guard until seasonal recovery of water levels occurred in the area, allowing the shallow wells to once again function properly.

The town of Lowell in Lake County has experienced high fluoride levels in the public water supply, as discussed in the ***Ground-Water Hydrology*** chapter of this report in the section entitled ***Ground-Water Quality***. In an attempt to meet requirements by the U.S. Environmental Protection Agency (USEPA), the town has examined the possibility of drilling shallow wells in an unconsolidated aquifer, then blending water from the shallow wells with water from four existing bedrock wells in order to achieve compliance with the water-quality standard for fluoride.

However, if the USEPA lowers the standard for fluoride, mixing water from bedrock and unconsolidated wells may be a short-term solution to the water-quality problem. Lowell therefore is attempting to establish an interconnecting supply line, approximately 15 miles long, with the Gary-Hobart Water Corportion. Because the interconnection would require

the transfer of about 1 million gallons per day of water from the Lake Michigan Basin to the Kankakee River Basin, approval must be obtained from the governors of the eight states which border the Great Lakes. The Great Lakes Charter (Section 1109 of Public Law 99-662) requires that a prior notice and consultation process be initiated for interbasin diversions from the Great Lakes. The Governor of Indiana recently has initiated the process on behalf of the town of Lowell.

Suggested approaches to future ground-water development

As demands on ground water increase, the role of the IDNR Division of Water in protecting and managing the ground-water resource will continue to increase. One ground-water management goal in the Kankakee River Basin, and particularly in Jasper and Newton Counties, is to prevent long-term depletion of the ground-water resource while allowing continued ground-water development for both high-capacity and small-capacity uses. Another goal is to balance the need for ground-water development with the right of homeowners to an adequate supply of water.

With these goals in mind, the Division of Water has developed the following water-management alternatives in an attempt to reduce the potential for future conflicts between ground-water supply and ground-water use in these two counties:

1. Additional irrigation wells could be developed in the surficial sand aquifer (Kankakee Aquifer System) to be used as an alternative to, or in conjunction with, wells completed in the carbonate aquifer. Where sufficiently thick, the surficial sand aquifer can produce adequate quantities of water for various uses, including irrigation. However, manifold systems or multiple wells may be required to support high-capacity pumpage for irrigation.

2. Restrictions on drilling new high-capacity bedrock wells may be needed in areas where the greatest seasonal declines in water level are observed. Proposed well sites should be evaluated with regard to not only individual needs but also proper well spacing that would help prevent or minimize interference with nearby wells and reduce impacts to the source aquifer.

3. Irrigators should closely evaluate the benefits of irrigating crops grown on soils that have developed on dune deposits. Moreover, water conservation practices should be implemented on soils composed primarily of sand.

4. Domestic and livestock wells should be installed in a manner that will allow the wells to continue producing an adequate water supply during seasonal water-level declines and during periods of irrigation-induced drawdowns.

5. Continued coordination with the State of Illinois is needed to best manage irrigation development in the bi-state area where the carbonate aquifer is the major source of ground water. A resolution adopted in 1990 by the Indiana General Assembly encouraged the State of Illinois to cooperate with the State of Indiana in developing and conserving shared water resources.

In the coming years, the IDNR Division of Water will continue to closely monitor the ground-water conditions in Jasper and Newton Counties and in other areas of the basin where ground-water conflicts are occurring or are likely to occur. Improved management may be needed in areas where the ground-water resource is being extensively developed.

Minimum ground-water levels may be established by the Natural Resources Commission (I.C. 13-2-6.1). If established, the minimum level criteria may govern the amount of ground water withdrawn in some areas.

The amended water-rights law (I.C. 13-2-2.5) and its associated well-construction requirements will continue to be a key factor in developing and protecting ground water. Additional regulations that also will help ensure the protection of available ground-water supplies include: 1) a 1990 law (I.C. 13-2-2.6) protecting natural freshwater lakes from water-level declines due to nearby ground-water pumpage; 2) amendments to regulations concerning water-well drilling (I.C. 25-39-1.5); and 3) proposed revisions to statewide well-construction guidelines that were first developed in 1985 under the provisions of I.C. 13-2-2.5 (Indiana Department of Natural Resources, 1985).