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FEASIBILITY OF ARTIFICIAL RECHARGE IN THE PARK FOREST-CHICAGO HEIGHTS AREA

by
Charles K. McDonald and Robert T. Sasman

SPECIAL REPORT

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FEASIBILITY OF ARTIFICIAL RECHARGE IN THE PARK FOREST-CHICAGO HEIGHTS AREA

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INTRODUCTION

The Illinois State Water Survey was requested by officials of the village of Park Forest and the city of Chicago Heights to study the feasibility of artificially recharging the Silurian dolomite aquifer, the source of water supply for the two municipalities. Officials were concerned because of declining water levels in wells due to increased pumpage from the aquifer. The study was initiated in January 1966 when officials of Park Forest and Chicago Heights met with Water Survey hydrologists in Park Forest. The study was planned for completion in the summer of 1966.

It was decided that the scope of the study would be to determine the quantity of water available from Thorn Creek for artificial recharge in the Park Forest-Chicago Heights area, the most favorable method and location for recharge, and the quality of the water available for recharge.

This report presents a description of the area and the ground-water situation as well as the results of the investigations of methods of recharge. Geology, surface water, and water quality applicable to the feasibility of artificial recharge are presented.

Definition of Terms

Acre foot:

A unit for measuring the volume of water. It is equal to the quantity of water required to cover one acre to a depth of one foot.

Aquifer:

A geologic formation or structure that transmits water in sufficient quantity to supply pumping wells or natural springs.

Area of diversion:

The area of one aquifer within which all ground water in that aquifer will flow in the direction of heavy pumpage. The boundary of an area of diversion forms a ground water divide.

Cone of depression:

A dewatering of part of the aquifer around a well or a group of wells due to pumping.

Permeability:

The capacity of a water-bearing material or aquifer to transmit water, measured by the quantity of water passing through a unit cross section in a unit time under 100 percent hydraulic gradient.

Acknowledgments

This report was prepared under the general supervision of William C. Ackermann, Chief of the Illinois State Water Survey, and H. F. Smith, Head of the Hydrology Section. R. J. Schicht, in charge of ground-water research in the Hydrology Section, reviewed, criticized, and assisted with the final manuscript. J. W. Brother prepared the illustrations. J. B. Stall, Water Survey Engineer, prepared the section on surface water hydrology and

R. A. Landon of the State Geological Survey prepared the section on geology.

Special acknowledgment for pumpage and rainfall data is made to the Water Departments of Park Forest and Chicago Heights. Information concerning Sauk Trail Lake was obtained from the Forest Preserve District of Cook County. The Park Forest Water Department also obtained use of a boat and made daily readings of staff gages at various sites.

GEOGRAPHY AND CLIMATE

The area studied (figure 1) is located in southeastern Cook County and northeastern Will County, about 27 miles south of the Chicago loop. This area is located between 87°31' and 87°45' west longitude and between 41°20' and 41°35' north latitude, and covers approximately 70 square miles. A previous ground-water study of the area was completed by the Water Survey in 1962 (Prickett et al., 1964).

Thorn Creek is the only creek common to both Park Forest and Chicago Heights. It flows generally northeast through Park Forest and Chicago Heights (figure 1), and is the closest surface water to the areas of heavy pumpage in both municipalities. Thorn Creek flows entirely through land owned by the Forest Preserve District, except for one small section in Chicago Heights which is a city park.

In the Park Forest area, the land is used primarily for residential and commercial business establishments, while in Chicago Heights, industrial as well as residential and commercial areas constitute most of the land use.

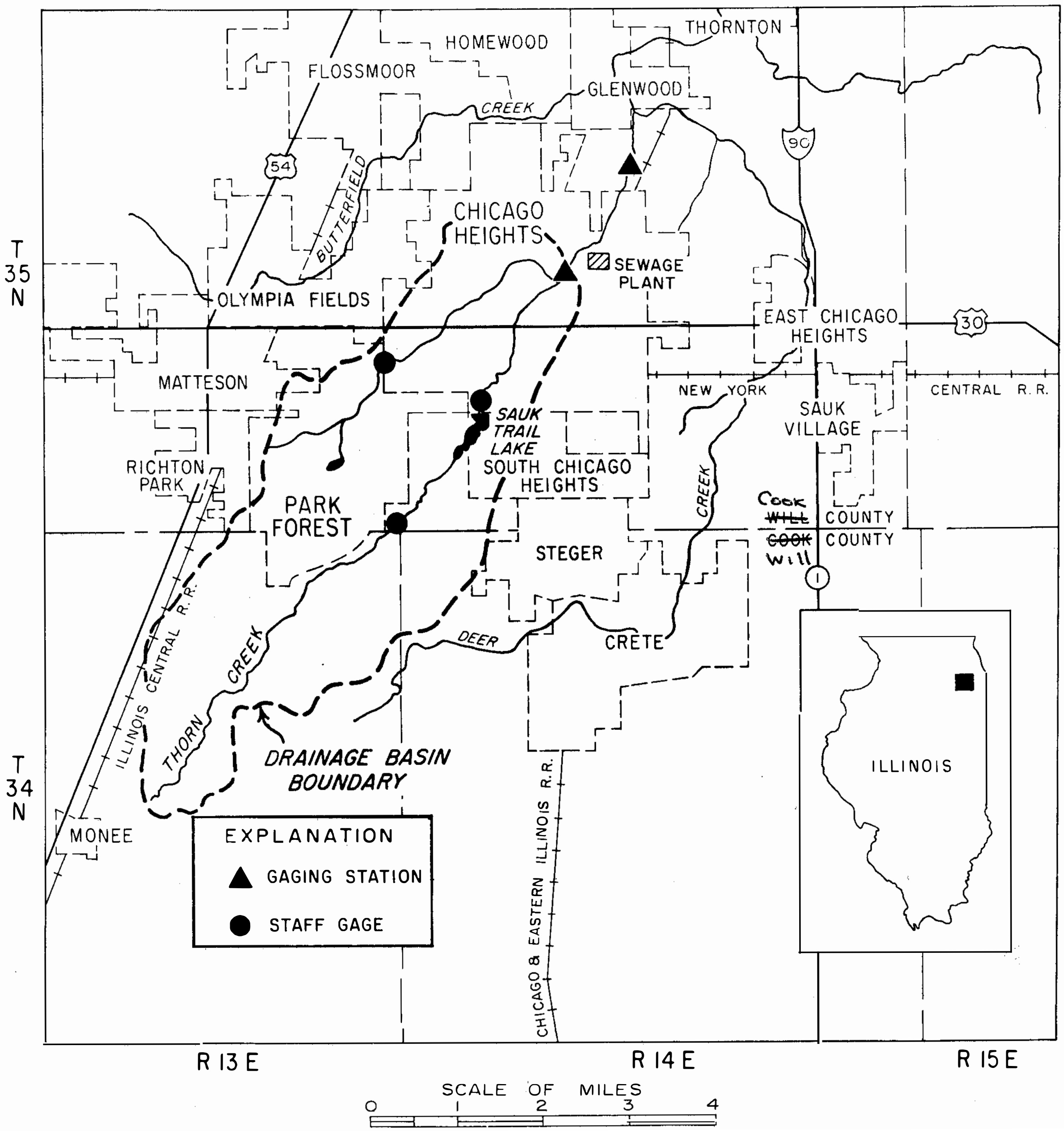

Figure 1. Location of Park Forest-Chicago Heights area

Mean annual precipitation, 33.65 inches, was compiled from precipitation data collected from 1900 to 1961 by the U. S. Army Corps of Engineers at Brandon Road Dam near Joliet, 22 miles west of Chicago Heights. On the average, the months of greatest precipitation are May, June, and September, each having more than 3.5 inches; January, February, and December are the months of least precipitation, each having less than 2 inches. The mean annual snowfall is 30 inches, and the area averages about 42 days with 1 inch or more and 24 days with 3 inches or more of ground snow cover.

The rainfall for Chicago Heights is now measured at the main pumping station; the annual total was 25.83 inches and 37.25 inches for 1964 and 1965, respectively. The raingage for Park Forest is at the water treatment plant, and rainfall for 1953-1964 is tabulated in table 1.

Table 1. Annual Rainfall at Park Forest

Year	Total (inches)	Year	Total (inches)
1953	33.20	1959	37.65 est.
1954	43.43	1960	27.35
1955	35.43 est.	1961	39.03
1956	27.29	1962	24.56 est.
1957	39.83	1963	28.24
1958	32.38 est.	1964	27.27

GROUND WATER

The ground-water portion of this report summarizes ground-water conditions in the Park Forest-Chicago Heights area from 1962 through 1965. A previous report on ground water in the area provided data through 1962 (Prickett et al., 1964). Collection of new data has resulted in reevaluating parts of the earlier report.

Pumpage

According to Prickett et al. (1964), pumpage from the Silurian dolomite aquifer in the Park Forest-Chicago Heights area increased at a uniform rate from 1890, when the first wells were drilled, to 7 mgd in 1940. After 1940 pumpage increased at an accelerating rate. In this study, data on pumpage from the Silurian dolomite aquifer have been limited to the area of diversion. As shown in figure 2, ground-water pumpage in the area of diversion increased from 10.5 mgd in 1960 to a peak of about 13.3 mgd in 1964. Pumpage dropped to 11.9 mgd in 1965. Pumpage has been subdivided into public and industrial use as shown in table 2.

Table 2. Pumpage from Silurian Dolomite Aquifer in Park Forest-Chicago Heights Area of Diversion

	Pumpage (mgd)					
	1960	1961	1962	1963	1964	1965
Public	8.4	8.2	8.9	9.5	11.0	10.1
Industrial	2.1	2.0	2.6	2.4	2.3	1.8
Total	10.5	10.2	11.5	11.9	13.3	11.9

Public pumpage increased from 8.4 mgd in 1960 to 11 mgd in 1964, declining to 10.1 mgd in 1965. Industrial pumpage increased from 2.1 mgd in 1960 to 2.4 mgd in 1964 and was 1.8 mgd in 1965. Private or domestic pumpage in the area is negligible and was not considered in pumpage totals.

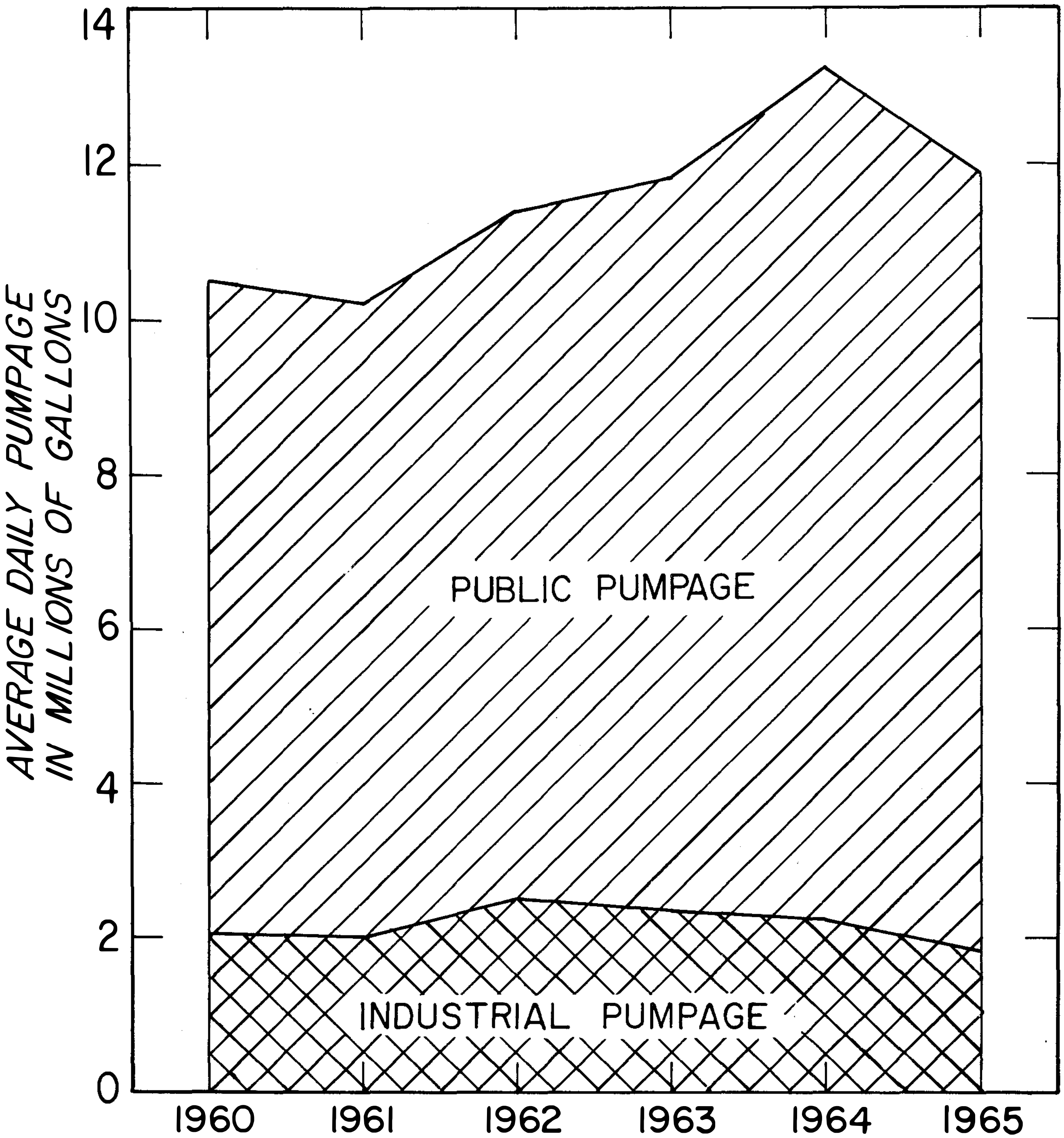

Figure 2. Ground Water pumpage from Silurian Dolomite Aquifer in the Park Forest-Chicago Heights Area, 1960-1965

Pumpage was projected to the year 2000. It was estimated that at that time total withdrawals in the area would amount to about 30 mgd.

Fluctuations of Water Levels

Figures 3 and 4 illustrate the ready response of water levels in the dolomite to fluctuations in precipitation. Figure 3 compares the monthly total rainfall for Park Forest with water levels in Park Forest Well No. 3 (COK 35N13E-25.3f) during 1964; figure 4 compares the monthly total rainfall for Chicago Heights with water levels in the State Water Survey's observation well at the Chicago Heights Industrial Terminal (COK 35N14E-29.6e2) during 1965. Water levels in both of these wells respond fairly rapidly to precipitation changes which indicates rapid infiltration through the glacial drift to the dolomite.

Configuration of Piezometric Surface

A contour map of the piezometric surface was drawn (figure 5) to determine any change in pumping centers. The areas of recharge and discharge and the direction of ground-water movement were also determined by the piezometric surface map, which represents the elevation to which water will rise in wells completed in the Silurian dolomite aquifer.

Ground water in the Park Forest-Chicago Heights area moves in all directions from topographic uplands toward streams and well fields. Heavy concentration of pumpage from wells has produced two major cones of depression in the area. The first is centered in southeastern Chicago Heights and is the deepest one. Water levels in this cone have declined 170 feet below the top of the bedrock

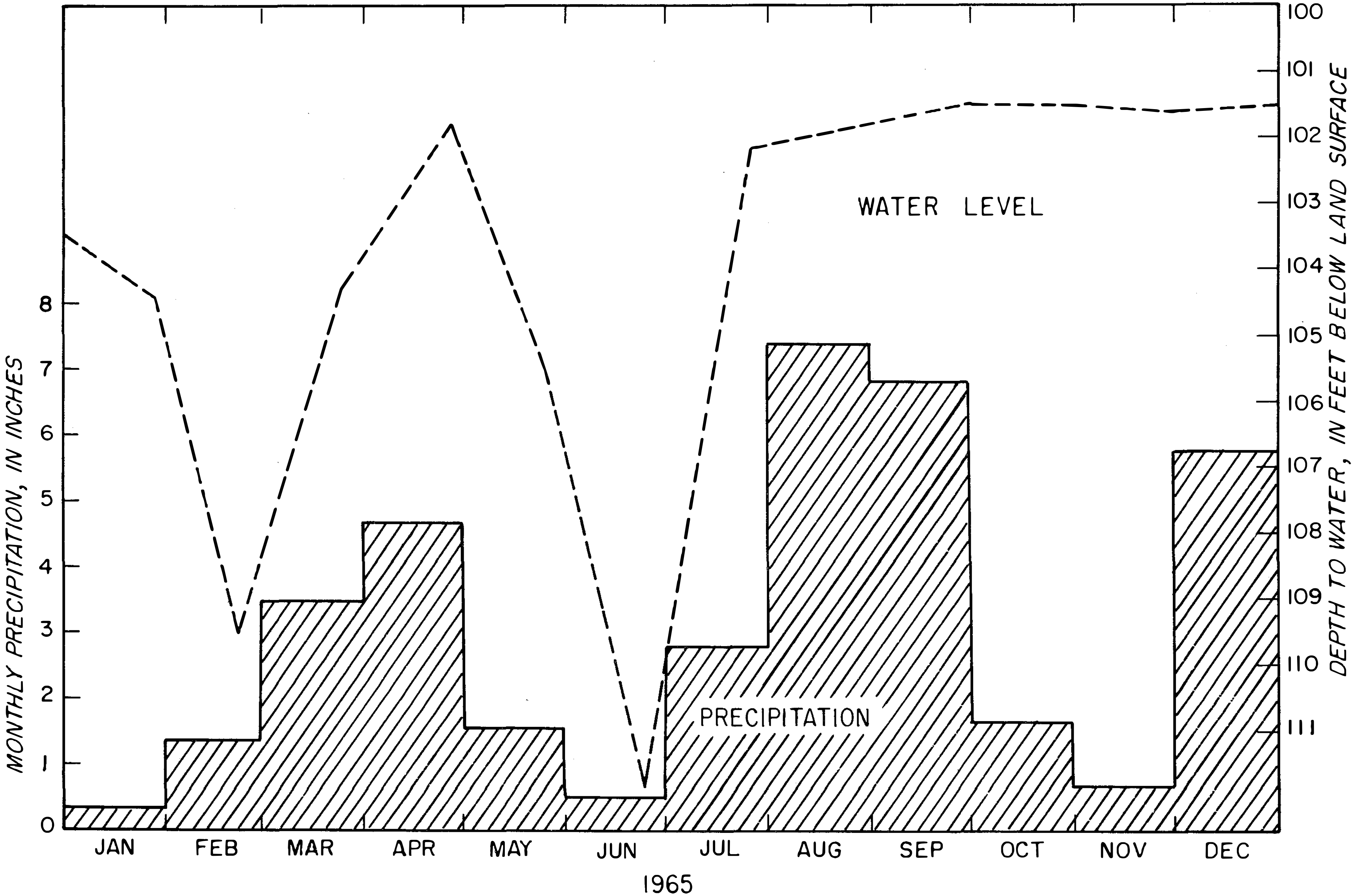

Figure 3. Water levels in well COK 35N 13E-25.3f compared with monthly precipitation at Park Forest

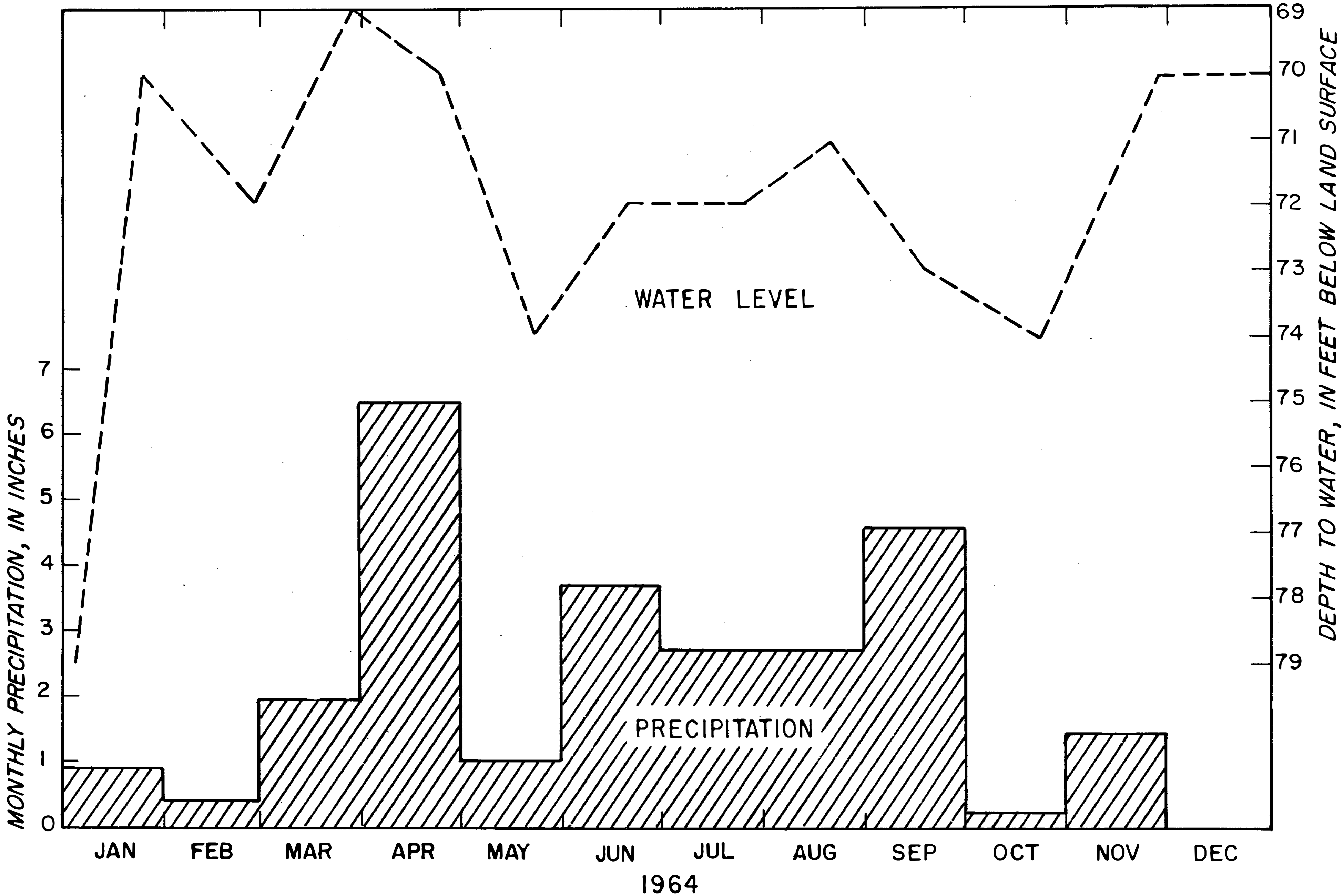

Figure 4. Water levels in well COK 35N 14E-29.6e2 compared with monthly precipitation at Chicago Heights

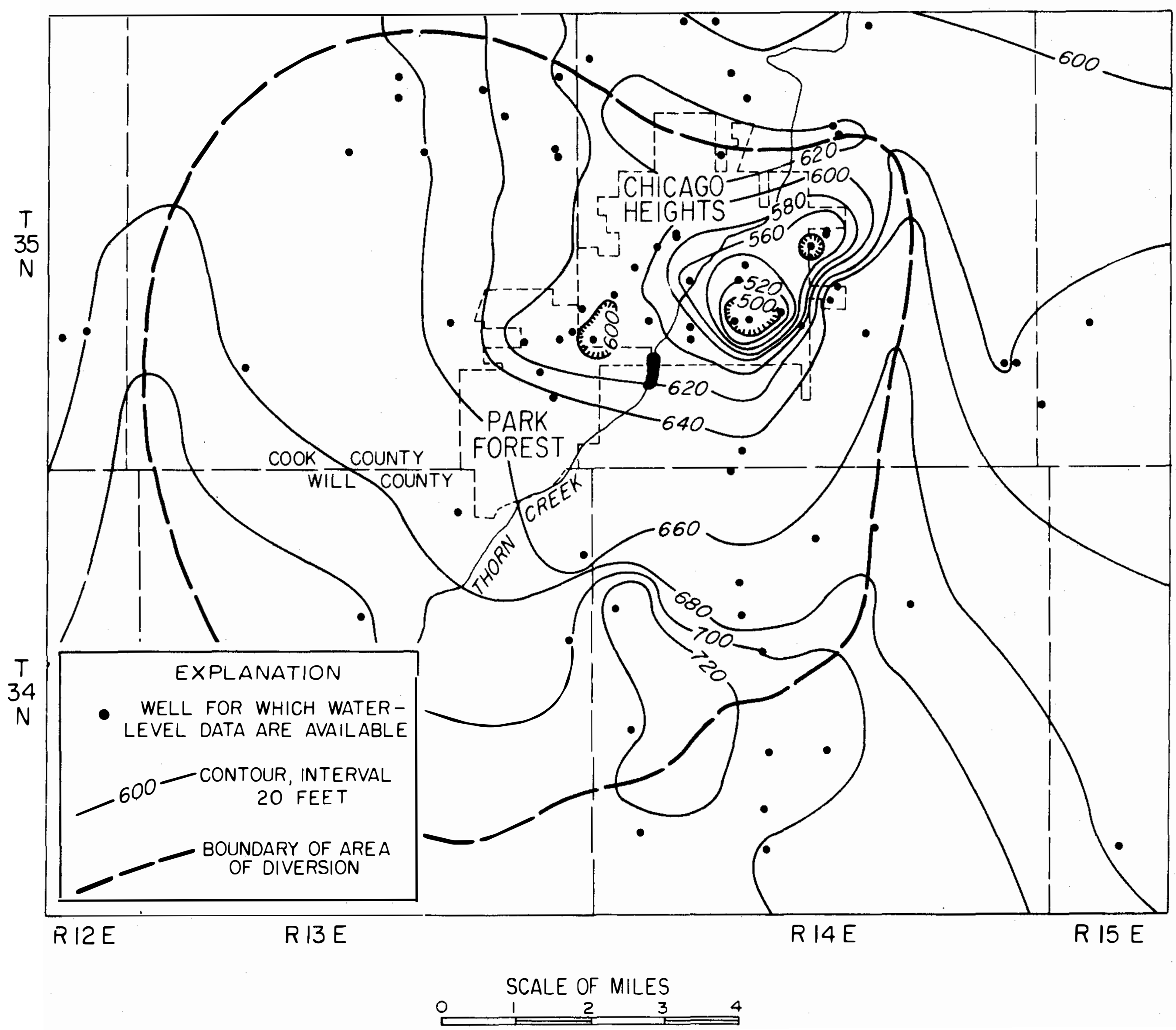

Figure 5. Piezometric surface map of the Silurian Dolomite Aquifer in the Park Forest-Chicago Heights area for 1966.

surface, almost one-half the thickness of the Silurian dolomite. The center of the cone of depression has not deepened appreciably during the past 5 years, but instead has started to spread out as was predicted by Prickett et al. (1964).

The second cone of depression is centered at Park Forest. This has developed into a recognizable cone since 1962. At the present time, water levels in this area are about at the top of the bedrock surface. In 1961 water levels were 20 feet above the bedrock surface.

Flow lines were drawn at right angles to the piezometric surface contours to define the area of diversion. The area has increased in the past 5 years, from about 60 square miles to 70 square miles. It spread principally to the west. The average slope of the piezometric surface (figure 5) between Park Forest and southeastern Chicago Heights is about 100 feet per mile and from northeastern Chicago Heights to southeastern Chicago Heights 60 feet per mile.

Natural Recharge to the Aquifer

The rate of recharge to the aquifer was estimated using the piezometric surface map and past records of pumpage and water levels. The area of diversion of pumping was outlined as shown in figure 5; the pumpage is given in table 2. Because recharge balances discharge, the average rate of recharge to the aquifer is the quotient of the average pumping rate and the area of diversion. The average pumping rate during the period 1960-65 was 11.5 mgd; the average area of diversion during the period was estimated to be 65 square miles. The average rate of recharge to the Silurian dolomite aquifer during the period was 177,000 gallons per day per square mile (gpd/sq mi).

Practical Sustained Yield of Existing Well Field

Although water levels are not critical in most of the area, they are at critical stages in the cone of depression in Chicago Heights. According to Prickett et al. (1964) yields of wells in Chicago Heights have decreased an average of about 65 percent as the result of dewatering. The expected increase in ground-water pumpage will further lower water levels at Chicago Heights. Thus, it is estimated that the practical sustained yield with existing well fields is not considerably greater than the 1965 pumping rate, about 12 mgd. The practical sustained yield can be expressed as the average recharge rate (177,000 gpd/sq mi) times the 1965 area of diversion (70 sq mi), or about 12.4 mgd.

The practical sustained yield was exceeded in 1964 when pumpage reached 13.3 mgd. If pumpage increases are concentrated in existing wells away from the center of the Chicago Heights cone of depression, the area of diversion, and therefore the practical sustained yield, can be increased without materially reducing well yields.

Wells and well fields can be developed to the north of Chicago Heights and to the west of Park Forest where water levels are not critical. A practical sustained yield based on additional well fields would be greater because of the resultant increase in the area of diversion. For example, an increase in the area of diversion to 100 sq mi would result in a practical sustained yield of 17.7 mgd. In addition, the shifting of part of the pumpage would stabilize water levels, or even allow water levels to recover, at Chicago Heights.

ARTIFICIAL RECHARGE METHODS

There are several methods of introducing water into the ground to supplement the ground-water supplies already available (Todd, 1959).

Water Spreading Methods

The first method to be considered is water spreading, which is defined as releasing of water over the ground surface in order to increase the quantity of water infiltrating into the ground and percolating to the water table. The spreading method may be classified as flood spreading, basin spreading, ditch or furrow spreading, natural channel, and irrigation spreading. Each is briefly described.

Flood spreading requires relatively flat topography so that water may be diverted to spread evenly over a large area. Generally, canals and earthen distributing gullies are needed to release water over the upper end of the flooding area. It is desirable to form a thin sheet of water over the land, so that the water moves at a minimum velocity to avoid disturbing the soil. Highest infiltration rates occur on areas with undisturbed vegetation and soil covering. Compared with other spreading methods, flood spreading costs least for land preparation. Banks and ditches must surround the area to control the water at all times.

In basin spreading, water may be recharged by releasing it into basins which are formed by excavation or by construction of dikes or small dams. Horizontal dimensions of such basins vary from a few feet to several hundred feet. The most common system consists of individual basins fed by pumped water from nearby surface water sources. These basins require periodic cleaning by scraping of the bottom surface when dry.

In ditch or furrow spreading, water is distributed to a series of ditches or furrows, which are shallow, flat-bottomed, and closely spaced to obtain maximum water contact area. Gradients of major feeder ditches should be sufficient to carry suspended material through the system. A collecting ditch is needed at the lower end of each area to convey excess water back into the main stream channel. The method is adaptable to irregular terrain but seldom provides water contact area equal to that obtainable with basins.

Water spreading in a natural stream channel may use any of the previously mentioned methods. The main purpose is to extend the time and area over which water can recharge from a naturally influent channel. One successful method has been to build small check dams in a wide, flat channel. These dams are usually concrete or rock and wire.

Pit and Deep Well Methods

The second artificial recharge method considered is recharge through pits. Recharge pits differ from land flooding in that the topsoil is removed in the construction of pits. Recharge pits are excavated into the water-bearing porous material and are usually equipped with a layer of filtering material for protection against silt intrusion to the aquifer. Abandoned gravel pits may be used to save excavation costs. Although construction costs per unit area are higher for pits as a rule than for land flooding operations, pits have a higher rate of inflow and occupy a smaller total area than land flooding installations of comparable capacity.

Two recharge pits were previously excavated by the State Water Survey for studies in artificial recharge in Peoria, Illinois.

The first recharge pit at Peoria was installed in 1951. The pit, with bottom dimensions of 40 feet by 62.5 feet and 30 feet in depth, was excavated near the Illinois River. Another pit, with bottom dimensions of 75 feet by 20 feet and 25 feet in depth, was excavated near the river in 1956. The pits were operated only during the cold-water period of the river, in order to keep the ground-water temperatures below 60 F (Suter and Harmeson, 1960).

The third artificial recharge method is by introducing water through drilled wells. This type of recharging is practicable where deep, confined aquifers must be recharged, or where economy of space such as in urban areas is an important consideration. This is an expensive method because of cost of drilling and extensive water treatment. However, abandoned wells adjacent to the surface water source might be used.

Recommended Methods

After these various methods of artificial recharge for the Park Forest-Chicago Heights area were considered, it was decided that the pit method and channel or basin spreading might be feasible methods in the area. In conjunction with other recharge criteria (described later), it was concluded that a recharge pit would be the most feasible method for the area because it requires a minimum amount of land surface and water treatment.

Cost Data

The economics of a recharge operation is very important in planning a ground-water recharge project. Table 3 gives a summary of the cost of artificial recharge at Peoria, Illinois. It was found that the cost of recharging ground water was low enough to be economically feasible at this location.

Table 3. Cost of Artificial Recharge at Peoria

	One Pit		Two Pits	
	1954-55	1955-56	1956-57	1957-58
Recharge during season (million gallons)	365.02	423.63	1,079.86	966.78
Cost per 1,000 gallons recharged	$ 0.027	$ 0.029	$ 0.016	$ 0.016

GEOLOGY

The geologic evaluation for artificial recharge of the Silurian dolomite aquifer in the Park Forest-Chicago Heights area was done by the State Geological Survey at the request of the State Water Survey. The geologic feasibility of recharge operations to the buried dolomite aquifer is based on the thickness of cover material. The Water Survey has designated specific criteria for the following recharge methods: pit - less than 25 feet of cover material; channel - less than 10 feet of cover material; spreading basin - no cover, surface improvement only. Recharge by wells was not considered in this evaluation.

Geologic Description

The Park Forest-Chicago Heights area is underlain by glacial drift that ranges in thickness from less than 1 foot in the east-central part of the area to nearly 100 feet in the southern and western parts. Based on existing mapping and well data, the glacial deposits generally consist of silty clay till (a heterogeneous mixture of clay, silt, sand, and boulders) at the surface and within the upper part of the drift sequence. Locally, lenses of sand and gravel are present within the till. Mapping by Bretz (1955) indicates the presence of lake-bed silts and sands on the flat upland west of South Chicago Heights and east of Thorn Creek. Sand and gravel deposits are present at the base of the drift, which is underlain by dolomite bedrock. A cross section of this sequence of deposits is shown in figure 6 and the line of the cross section is located in figure 7.

The basal sand and gravel deposit is continuous throughout most of the area. It ranges in thickness from less than 1 foot to more than 50 feet and averages approximately 25 feet. An exposure of sand and gravel in the Thorn Creek valley, north of the Sauk Trail Lake spillway, is probably the top of this extensive sand and gravel deposit.

Bedrock beneath the glacial drift consists of dolomites of Silurian age. These rocks, averaging approximately 400 feet thick, are generally highly jointed and fractured in the upper part. The bedrock surface is that of an upland that slopes to the northeast at a rate of about 7 feet per mile. East of Chicago Heights is an ancient reef structure with bedrock either exposed or at shallow depths over an area of approximately 1 square mile. Dips on the bedrock are relatively steep in contrast

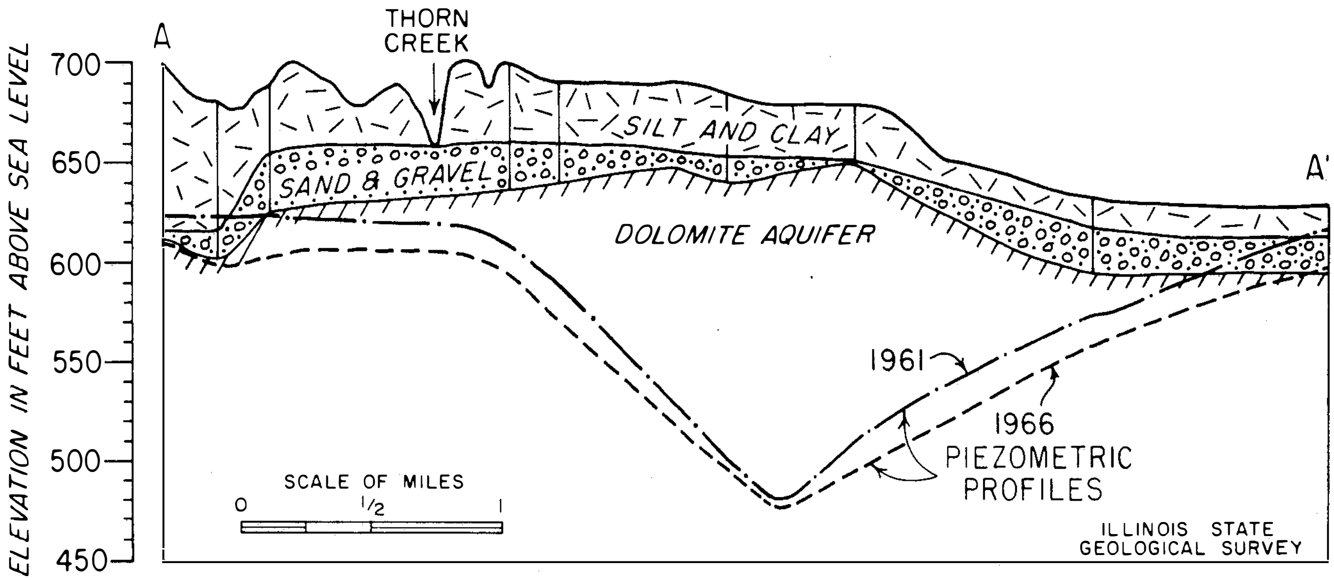

Figure 6. Cross section of cover and aquifer conditions in Park Forest-Chicago Heights Area

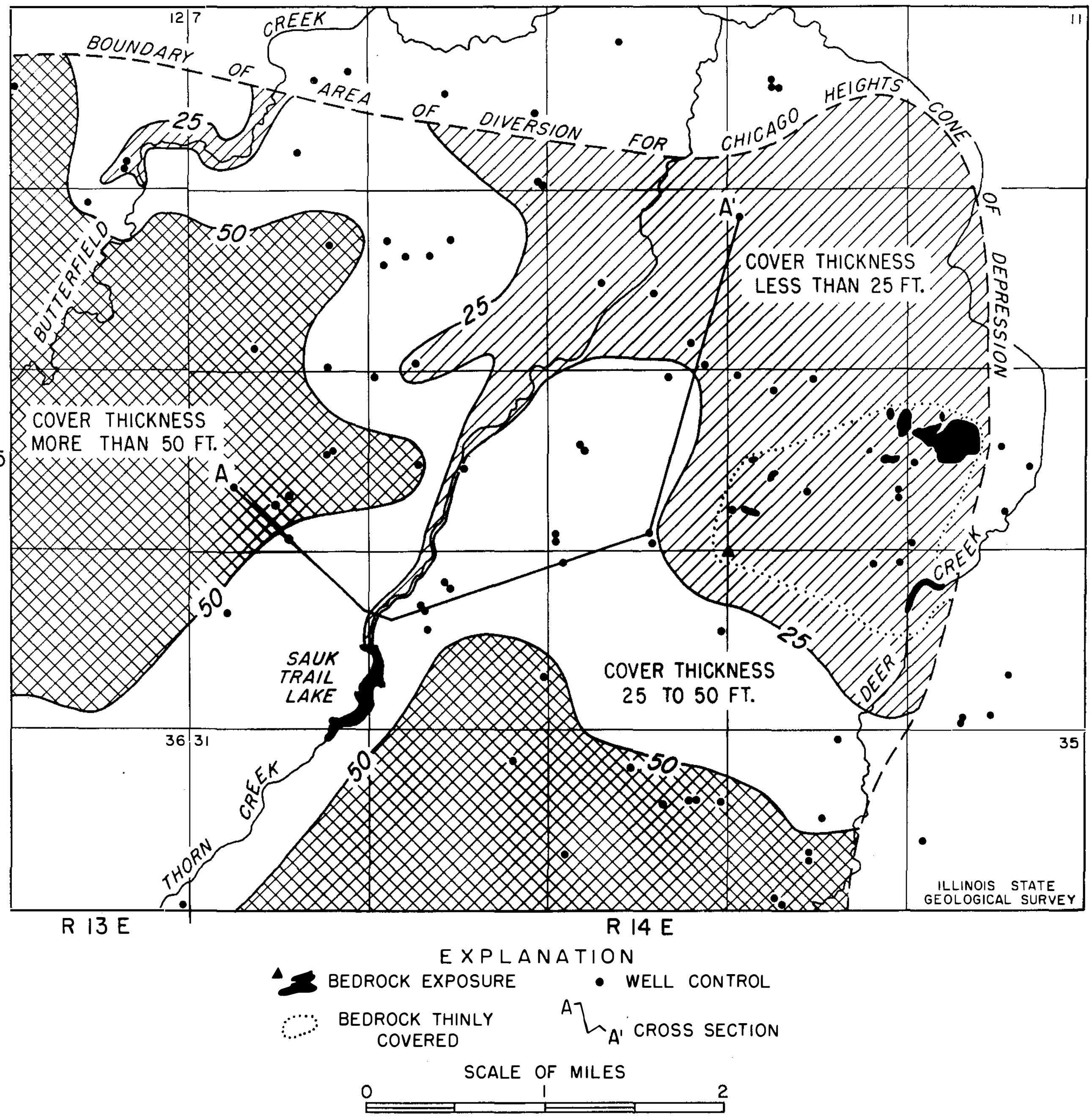

Figure 7. Thickness of cover material over basal gravel or bedrock aquifer.

to the nearly flat lying rock which surrounds this structure. Glacial deposits tend to thicken rather abruptly off the flanks of this bedrock structure.

Well logs were used to contour the thickness of cover material and to outline the bedrock reef structure (figure 7).

Geologic Recommendations

Geologic consideration of those areas suitable for artificial recharge operations has been restricted to the area of ground-water diversion. The dolomite bedrock is the principal aquifer and has a moderate permeability. It is assumed that the basal sands and gravels are in direct hydrologic connection with the underlying bedrock, that is, water is free to move from one deposit to the other. For artificial recharge, the water should be introduced into the sand and gravel aquifer since the cover material (generally till) has a low permeability which would impede recharge. The sand and gravel aquifer would act as a filter deposit for ultimate recharge to the bedrock aquifer.

The criteria stipulated for pit recharge are best met in the Thorn Creek valley north of Sauk Trail Lake, the Butterfield Creek valley, and generally the northeastern part of the area (figure 7). The area where bedrock is exposed and at shallow depth, however, may limit pit excavation.

Recharge by channeling could be considered in the Butterfield Creek valley, in the Thorn Creek valley north of the spillway, and in the area of exposed or near-surface bedrock. In the last location, excavation should again be considered as a limiting factor. Recharge by the spreading basin method is not considered feasible as there are no areas of sizable extent in which sand and gravel is both exposed at land surface and in direct hydrologic connection with the dolomite aquifer.

It is recommended that a drilling program be conducted prior to the final selection of any specific site for artificial recharge operations. Such a program would provide detailed information as to the nature, thickness, and extent of the deposits at the site. Drilling should not terminate where sand and gravel is first encountered but should continue to bedrock to insure that the sand and gravel is continuous to bedrock and not a lens within finer-textured deposits. An example of where such a drilling program is both necessary and applicable is in the Thorn Creek valley north of the Sauk Trail Lake spillway. It would be imperative to determine that the sand and gravel noted at the surface, at that location, is the top of the sand and gravel deposit common to the area at the base of the drift and is continuous to bedrock.

Thorn Creek valley north of Sauk Trail Lake is considered the most feasible site for artificial recharge in the Park Forest-Chicago Heights area because it not only meets geologic criteria but also involves geographically only the two municipalities.

SURFACE WATER

The principal stream in the area is Thorn Creek which flows northeast through Park Forest and Chicago Heights, as shown in figure 1. Also shown in figure 1 is a major tributary to Thorn Creek which flows northeast through Park Forest and into Thorn Creek in Chicago Heights. Thorn Creek proper and its tributary were considered as sources of surface water for artificial recharge. Sauk Trail Lake, a major impoundment on Thorn Creek just south of Chicago

Heights and just east of Park Forest (figure 1), was given careful study to evaluate its effects in contributing to the success of the proposed recharge project.

Stream Gages

Two U. S. Geological Survey recording stream gages (Thorn Creek near Glenwood and Thorn Creek at Chicago Heights) are located on Thorn Creek in the area of interest (figure 1). Table 4 shows the length of records and the size of the drainage areas above the gages. It also gives the average flow at the gage near Glenwood for its 15 years of record (U. S. Geological Survey, 1964). Mean flow for the Chicago Heights gage is not shown because of the short record.

Table 4. Stream Gage Records

Stream gage	Period of record	Drainage area (sq mi)	Mean flow (cfs)	Mean flow (mgd)
Thorn Creek near Glenwood	1949 to present	24.6	31.8	20.6
Thorn Creek at Chicago Heights (Halsted Street)	June 1964 to present	17.1	-	-

Because the gaging station at Glenwood is downstream from the Bloom Township Sanitary District disposal plant, the gage at Chicago Heights was established in 1964 to measure the Thorn Creek flow unaffected by the sewage plant effluent. According to the 1964 streamflow data for the Glenwood station, about 14 cfs (or 9 mgd) of water withdrawn from wells by cities and industries is contained in the sewage plant effluent which is discharged into the stream.

As a part of the present investigation, temporary staff gages were installed at three locations on Thorn Creek (figure 1). The depth of the flow at these points was recorded from daily readings of the staff gages during February, March, April, and May of 1966. On three particular dates, the actual flows at these locations were also measured.

Flow Volume and Duration

To determine the flow volumes at the various locations in the area, the flows were associated by means of curves-of-relation as outlined by Stall (1964). A curve-of-relation between the flow in Thorn Creek at Glenwood and Thorn Creek at Chicago Heights is shown in figure 8. The plotted points are the concurrent daily discharges for the 15-month period July 1964 to September 1965.

Figure 9 shows curves-of-relation between the flows at the sites of the three staff gages. These are based on three concurrent measurements of flow taken at these locations in February and March 1966.

Flow-duration curves for three locations within the Thorn Creek basin are shown in figure 10. Since these curves were derived from daily discharge data, the horizontal scale can be interpreted as showing the percent of all days that the discharge will be equal to that shown on the vertical scale.

The upper curve is for the gage on Thorn Creek at Glenwood for the 15-year period 1950-1964. The middle curve, for Thorn Creek at Chicago Heights, was derived from the upper curve by using the curve-of-relation in figure 8. The Chicago Heights curve in figure 10 is much lower than the Glenwood curve, which means generally that

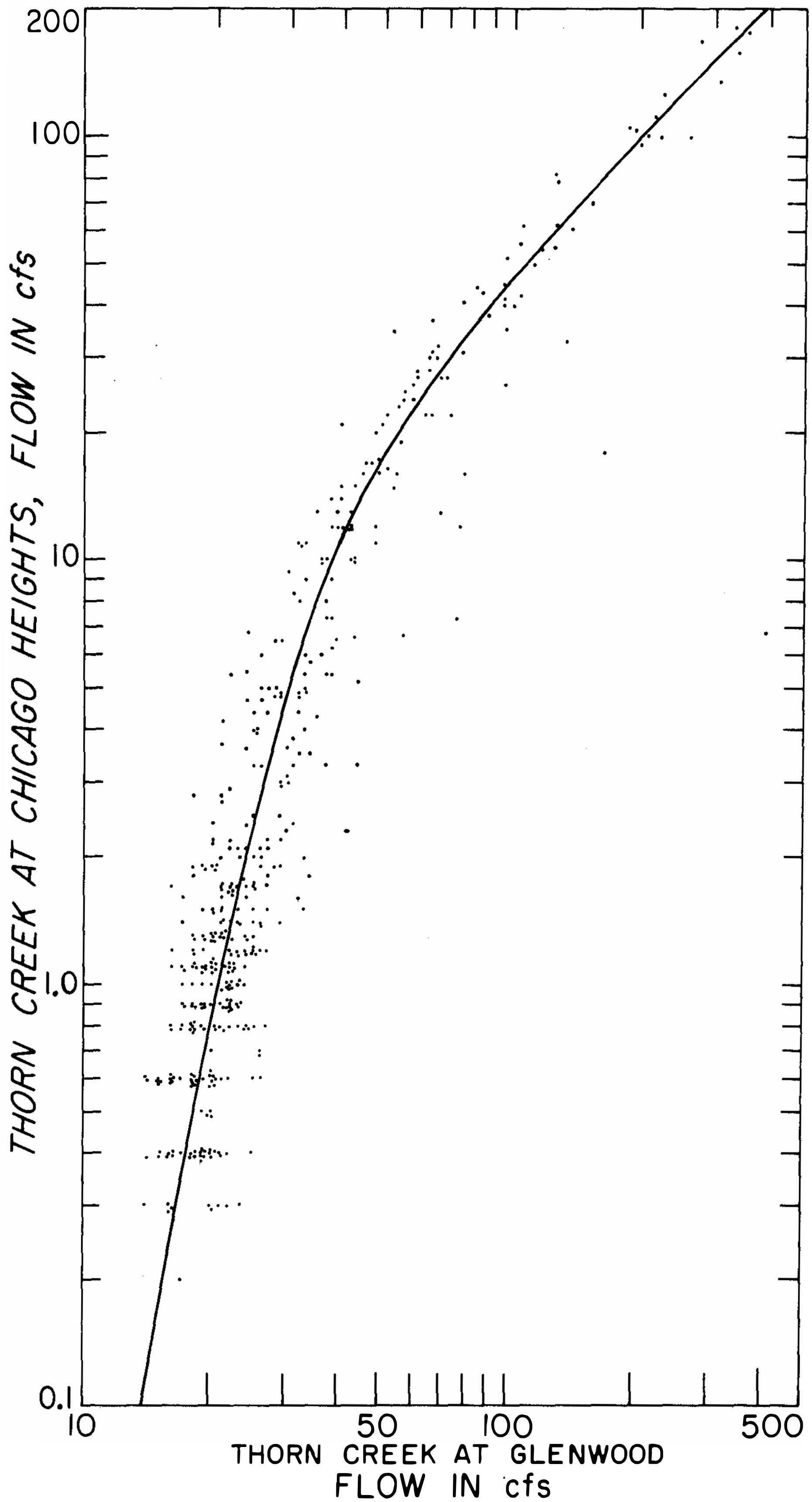

Figure 8. Curve-of-relation of flows at Glenwood and Chicago Heights for the 15-month period July 1964 to September 1965.

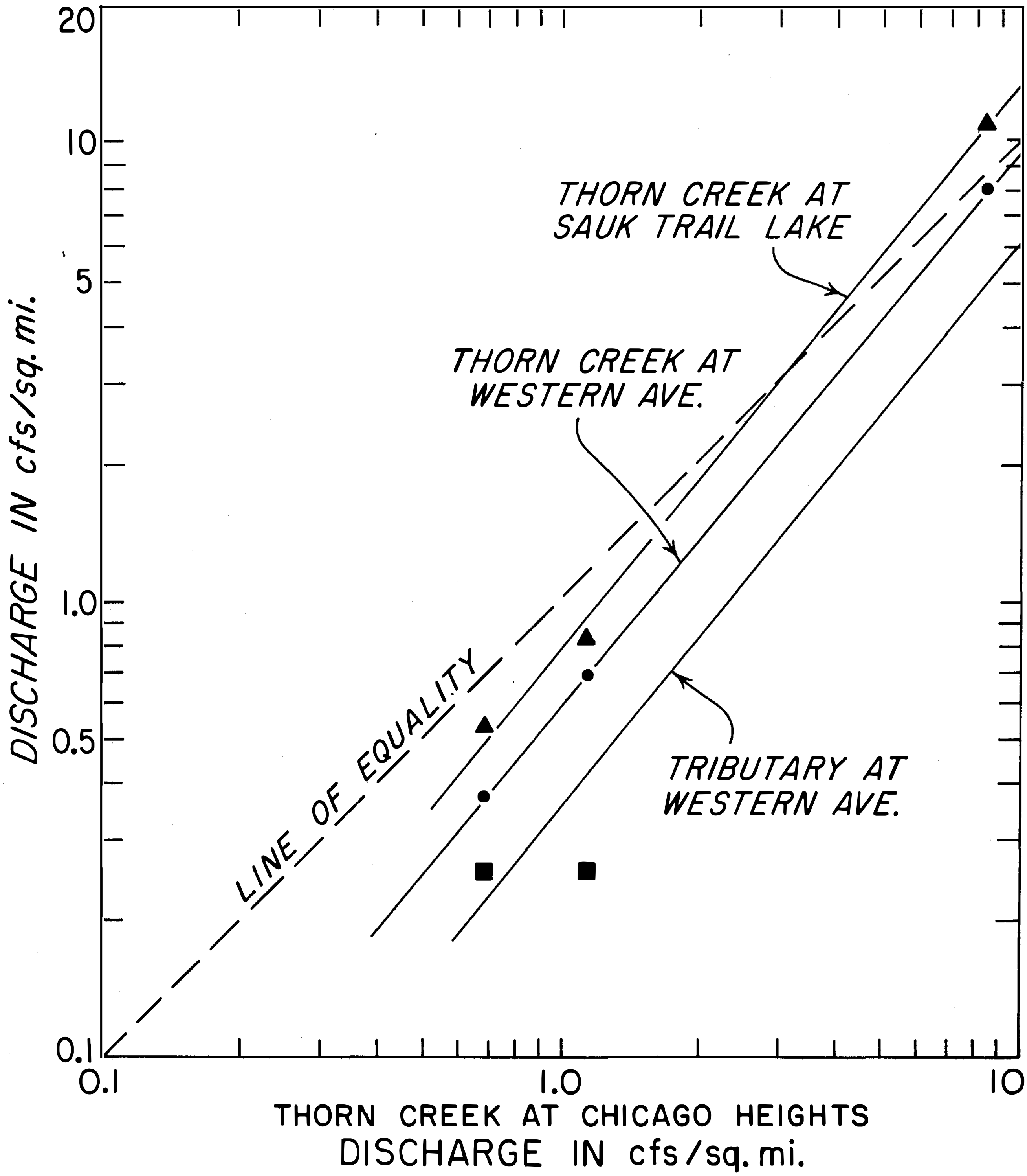

Figure 9. Curves-of-relation of flows at various locations on Thorn Creek.

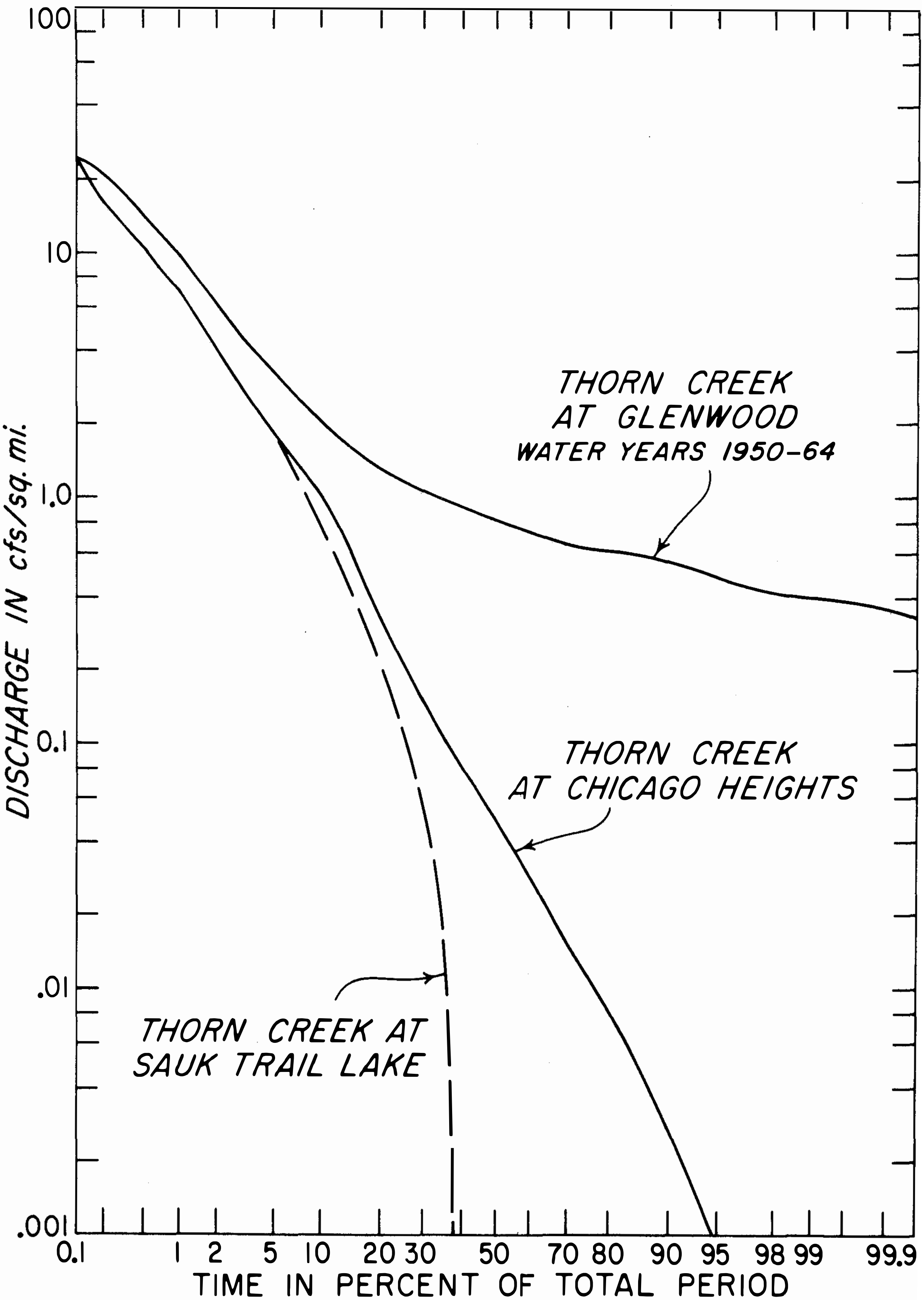

Figure 10. Flow duration curves of daily discharge

smaller flows occur at Chicago Heights. This is due partly to the fact that the sewage plant effluent is contained in the flow at the Glenwood gage and not at the Chicago Heights gage.

The lower dashed curve in figure 10 shows the flow duration to be expected in Thorn Creek at the outlet of Sauk Trail Lake. This is the suggested location for artificial ground-water recharge. This curve was derived from the middle curve for the Chicago Heights gage and the curve-of-relation in figure 9.

Availability of Flows

The lowermost curve in figure 10 represents the duration of daily flows which can be considered available for ground-water recharge at the outlet of Sauk Trail Lake. It relates the discharge available per square mile to the percent of time this discharge would be available. This curve is converted into a more directly useful form in figure 11 (solid upper curve).

Although the number of days per year that a given flow would be available is known from figure 7, these days would not occur in any particular season or sequence. Thus, complete utilization of the flow on all of these days would not be possible in an operational schedule of ground-water recharge. It can be reasonably assumed that two-thirds of these flows might be captured and used effectively for ground-water recharge; the other one-third would be lost. The dashed curve in figure 11 shows the amounts of water practically available. For example, 1 mgd of water would be available for ground-water recharge about 50 days per year, and about 3.5 mgd would be available for 30 days each year.

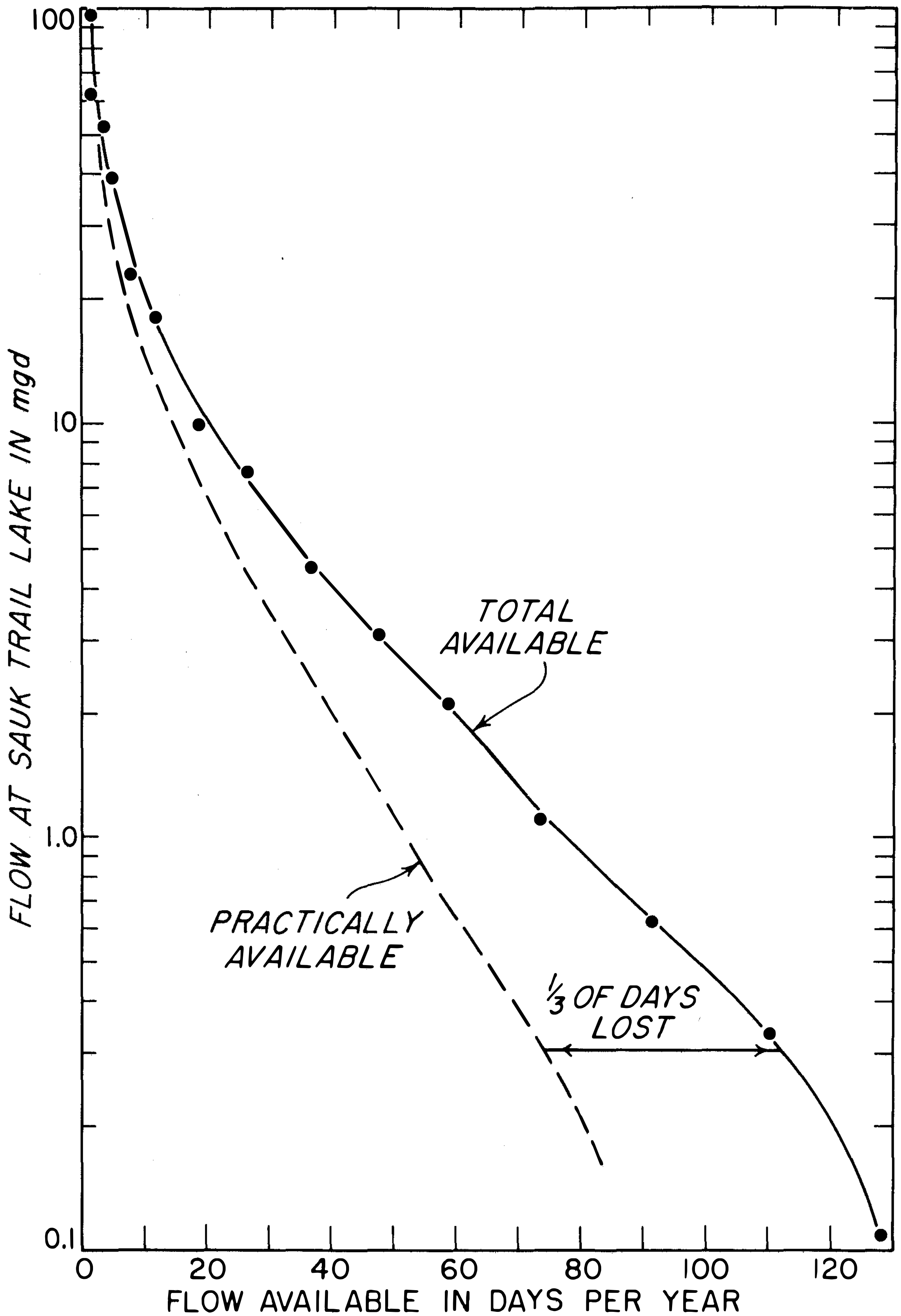

Figure 11. Availability of flows in Thorn Creek at Sauk Trail Lake for artificial recharge.

This curve for water practically available could be changed to increase the days per year of flow available by controlling the outflow of Sauk Trail Lake, or the inflow to the lake, with a series of small detention reservoirs upstream. In other words, the upstream reservoirs could provide a uniform flow of water to Sauk Trail Lake for artificial recharge. Recharge of 1.0 to 2.0 mgd could be maintained for longer periods of time. It may be possible to recharge half the annual runoff or about 1.4 mgd.

A special investigation was made of Sauk Trail Lake and the amounts of water that may be available from it. The average annual runoff of this basin was determined by using long-term flow records on the nearby Deer Creek basin (Stall, 1964, p. 334). The average annual runoff of Thorn Creek above Sauk Trail Lake, a drainage area of 8.70 square miles, is 6.85 inches per year (0.57 inches per month), which is equivalent to 2.8 mgd. If it were possible to capture and use the entire runoff from this basin, this would average 2.8 mgd for the entire year. As shown earlier in figure 11 only part of this can be captured and used.

Water available from an impoundment such as Sauk Trail Lake is also reduced during drought periods, when only a small part of the annual average runoff can be counted on for water supply. The drought flows were characterized and the yield of Sauk Trail Lake was computed by the method described by Stall (1964).

For this determination it was assumed that Sauk Trail Lake could be emptied only half-way for purposes of water supply; the remaining half of the water must always be held in the lake to serve recreational interests. The computations show that during a drought of 5-year recurrence interval the yield would be 0.2 mgd, and during a more severe 20-year recurrence interval drought only 0.1 mgd could be provided.

To summarize, the surface waters available for artificial recharge from Thorn Creek at the outlet of Sauk Trail Lake can be described as follows:

1) The total annual runoff is 2.8 mgd.
2) The direct flow practically available for recharge (from figure 11) is 1 mgd for 50 days each year, or 3.5 mgd for 30 days each year.
3) The continuous yield available from Sauk Trail Lake during a 5-year recurrence interval drought is 0.2 mgd.
4) Retention reservoirs upstream in addition to Sauk Trail Lake could stabilize (make more uniform) the flow so that flows of 1 to 2 mgd could be obtained for longer periods. It may be possible to recharge half the annual runoff or about 1.4 mgd.

Thus, the amount of surface water available for recharge would be about 12 percent of the present pumpage (11.9 mgd) and 4.7 percent of the 30 mgd projected pumpage for year 2000.

WATER QUALITY

In establishing quality criteria for surface water sources it may be necessary to give consideration to changes in quality which may take place in the interim between recharge and withdrawal from the aquifer, and hence to provide for flexibility of the criteria (Harmeson, 1960). For example, the iron content characteristics in the surface source are subject to appreciable change between the time of recharge and the time of withdrawal. The criteria set forth (Harmeson, 1960) are intended to be interpreted as recommended limits of impurity rather than as standards of quality. The recommendations on quality are as follows:

1) Turbidity:

No limit has been set on raw water turbidity. High turbidities caused by colloidal materials are known to effect greater changes on infiltration rates than do turbidities caused by larger sized particles. For planned recharge installations, additional information should be obtained, prior to construction, on maximum values and frequency durations of turbidities in the surface source to be used.

2) Temperature:

A recommended maximum limit of surface water temperature for use in artificial recharge is 65 F. Normal ground-water temperatures, storage capacity in the aquifer, performance of the aquifer, and intended use of the ground water are factors bearing on the selection of acceptable surface water temperatures. The upper limit of 65 F has been found satisfactory through experience at Peoria. More field work would be necessary to determine the range in water temperature in Thorn Creek during the year, which would partially determine at what time of year recharge can take place.

3) Total Dissolved Minerals:

A maximum of 1000 ppm is recommended. Drinking water standards of the U. S. Public Health Service recommend a concentration of not more than 500 ppm. However, the natural ground water in this area exceeds this value.

4) Hardness (as $CaCO_3$):

A maximum limit of 500 ppm is recommended. In general, Illinois surface waters are softer than ground waters, and recharge may result in some reduction in hardness of ground water by dilution.

5) Iron and Manganese:

No limit is proposed for these constituents, since a substantial part may be removed during infiltration through the recharge interface.

6) Chloride and Sulfate:

A combined maximum limit of 500 ppm is recommended, with anticipation that this level may be diluted by ground water.

7) Nitrate:

A maximum limit of 50 ppm is recommended. This is slightly higher than the proposed drinking water standards of the Public Health Service, but experience at Peoria indicates some reduction can be expected by mixing or dilution in the ground water.

8) Biochemical Oxygen Demand (BOD) and Dissolved Oxygen:

Computation of the dilution requirement based on effluent BOD Population Equivalent is not possible for that part of Thorn Creek from the source to just below Sauk Trail Lake dam, because the strength of sewage effluents produced is not known; however, waters from the sewage plants of the Medical Center on Western Avenue and Remington Arms Company are completely treated. In setting up criteria for dilution requirements, a discharge requirement of 4 cfs per 1000 population served was used for a stream receiving discharges of either untreated sewage or effluents from primary sewage treatment plants. A discharge requirement of 0.6 cfs per 1000 population served was used for a stream receiving the effluents from complete sewage treatment units. Since the population served by these two sewage plants is less than

500 persons, the amount of stream discharge for dilution required for the sewage treatment plant effluents would be 0.3 cfs.

Some mention must be made concerning undesirable water from the storm drain from Remington Arms Company. Chromate has been detected at times in the Remington drainage into Thorn Creek at Western Avenue. This should be eliminated before any attempt is made to recharge the dolomite.

Table 5 shows the mineral analyses of the three sample points. Sample Station 1 is Sauk Trail Lake at Sauk Trail Lake dam; Sample Station 2 is Thorn Creek at Western Avenue; Sample Station 3 is the Thorn Creek tributary at Western Avenue entering south of the railroad; and Sample Station 4 is Thorn Creek tributary entering east of the Western Avenue bridge over Thorn Creek.

Further field studies should be made regarding the slag dump adjacent to Thorn Creek just north of the Sauk Trail Lake dam. Liquid chemical wastes were discharging into the creek during the period of study in the stretch of the stream between the Sauk Trail Lake dam and the railroad bridge north of the dam. These and possibly other similar instances may present water quality problems for artificial recharge. If these problems are eliminated and a recharge pit is used, probably the only treatment necessary would be chlorination of the water to guard against contamination of the aquifer.

CONCLUSIONS

Thorn Creek was the only surface water considered as a source for artificial recharge in this report because it is the only surface water common to both Park Forest and Chicago Heights. All of the land adjacent to Thorn

Table 5. Chemical Analyses of Water from Thorn Creek and its Tributaries near Park Forest

(Chemical constituents in parts per million)

Sample Station No.	Date (1966)	Staff Gage Height (ft)	Temp. (°F)	Lab. No.	Turbidity	Color	Odor	Iron (Fe)	Chloride (Cl)	Alkalinity	Hardness	Total dissolved minerals	Unfiltered residue	Suspended solids (by difference)	Ammonium (NH_4)	Nitrate (NO_3)	Phosphate (PO_4)	ABS	Chromate
1	2/11	0.40	32.5	168285	42	25	0	1.3	26	48	104	150	-	-	0.1	6.6	0.4	0.1	0
	3/2	0.25	33.0	168509	21	40	0	1.0	25	80	156	260	-	-	0.2	9.9	0.5	0.1	0
	3/17	0.10	49.5	168573	96	10	0	4.0	24	132	228	316	-	-	0.2	8.1	0.8	0.0	0
	5/12	-	45.5	168928	353	15	0	13.0	6	60	88	143	537	394	0.1	7.7	0.2	0.0	-
2	2/11	2.05	32.5	168284	132	35	0	3.4	19	68	156	212	-	-	0.1	14.1	0.4	0.1	0
	3/2	1.80	33.0	168510	73	40	0	5.5	38	88	192	325	-	-	0.1	10.1	0.8	0.1	0
	3/17	1.30	49.0	168574	17	5	0	0.8	20	168	320	388	-	-	0.2	9.5	0.2	0.0	0
	5/12	3.90	46.0	168929	423	15	0	15.0	7	76	132	204	696	492	0.1	13.4	0.8	0.0	-
3	2/11	1.25	32.5	168286	41	35	0	2.1	190	108	388	737	-	-	0.1	9.7	2.2	0.1	0
	3/2	1.10	37.5	168511	26	40	0	1.4	210	92	288	658	-	-	0.1	5.6	0.8	0.1	0
	3/17	1.00	49.5	168575	19	5	0	1.2	215	192	630	1022	-	-	0.2	3.8	3.5	0.1	0
	5/12	1.90	48.0	168927	83	10	0	4.0	19	100	232	367	480	113	Tr	10.1	0.7	0.0	-
4	2/3	-	32.5	168283	1	50	0	0.1	63	448	512	739	-	-	3.2	6.1	0.8	0.2	9.2

Creek is owned either by the Forest Preserve District of Cook County or the Chicago Heights Park District.

Ground-water pumpage has been steadily increasing in the area of diversion. The cone of depression has not deepened appreciably since 1961 but is spreading out and lowering water levels further from the center of the cone at Chicago Heights. Continued pumpage increases will take an increased amount of water out of storage, so that water levels will continue to decline. The practical sustained yield will increase as the area of diversion increases. However, since water levels are already at critical stages in Chicago Heights, yields of wells will be further reduced.

Artificial recharge methods given consideration in the study were: 1) water spreading, 2) recharge pits, and 3) recharge wells. Spreading methods were eliminated because of the nature of the geology. The surficial and basal sands and gravels are not connected to any great extent. The recharge well method was eliminated because of the cost involved in treatment of recharge water. The recharge pit is considered the most feasible method for artificial recharge in the Park Forest-Chicago Heights area, because it is geologically sound and requires a minimum amount of land surface and water treatment.

The area which seems best geologically for a recharge pit is in Thorn Creek valley north of the Sauk Trail Lake. Geologic data is lacking in the area and test drilling is necessary to locate a pit site.

Stream flow analysis indicates that the flow over the dam at Sauk Trail Lake averages 2.8 mgd per year. Under the existing stream flow distribution, only 1.0 mgd for 50 days per year or 3.5 mgd for 30 days per year would be available for recharge. By controlling discharge at the dam, either with additional impoundment in Sauk Trail Lake or in upstream reservoirs, a more uniform flow could be provided, and recharge could be obtained over a much longer period of time. It may be possible to recharge half the annual runoff or about 1.4 mgd. This would amount to 12 percent of the present pumpage and 4.7 percent of the projected year 2000 pumpage of 30 mgd.

The quality of water in Sauk Trail Lake seems to be favorable for recharge operations through a pit if the industrial discharge noted is eliminated. The only two sewage plants on Thorn Creek above the dam completely treat the waste water, but the Remington Arms Company has an unfavorable storm water discharging into Thorn Creek. There is enough stream flow to consider sewage only a minor problem.

To summarize, artificial recharge in the area is possible in an amount limited by the surface water available in the Thorn Creek drainage basin. Declining water levels in Chicago Heights which have reduced well yields can be controlled by increasing pumpage in existing wells away from Chicago Heights and by developing new well fields.

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