A HYDROLOGIC STUDY OF LAKE GEORGE AND THE UPPER KINNICKINNIC RIVER WATERSHED

by

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Chapter 1

INTRODUCTION AND STATEMENT OF THE PROBLEM

The Kinnickinnic River is a small to medium sized perennial stream approximately 25 miles long that drains a 67,981 acre watershed in parts of Saint Croix and Pierce County, and flows into the Saint Croix River about half way between Hudson and Prescott. (Figure 1. Location of the upper Kinnickinnic River watershed). It is a peaceful river valley that winds its way through hundreds of acres of very productive agricultural land from the beginning to the city of River Falls. From River Falls to the Saint Croix River the Kinnickinnic has cut several feet through limestone and sandstone to form a deep narrow valley with rough and wooded terrain. Being located within one hours commuting distance of Saint Paul - Minneapolis, this area has been under extreme pressure for residential and recreational development. This area is presently being studied under a Federal Tile I Project for the purpose of proper land use planning. Federal, State and local agencies and groups have suggested that this nearly pristine river valley is ideally suited for outdoor recreation, nature study and park development. Therefore, it is extremely important that proper land use planning be implemented to control residential and private recreational development and to encourage public agencies to control, develop and preserve this area for all public use for years to come.

The primary pressure upon the upper part of the river is from agriculture. Several farmsteads are located very close to the river and with expanding cattle numbers several problems with animal wastes getting into the river have been identified. Many fields cultivated for crop production lie adjacent to the river and any soil erosion from

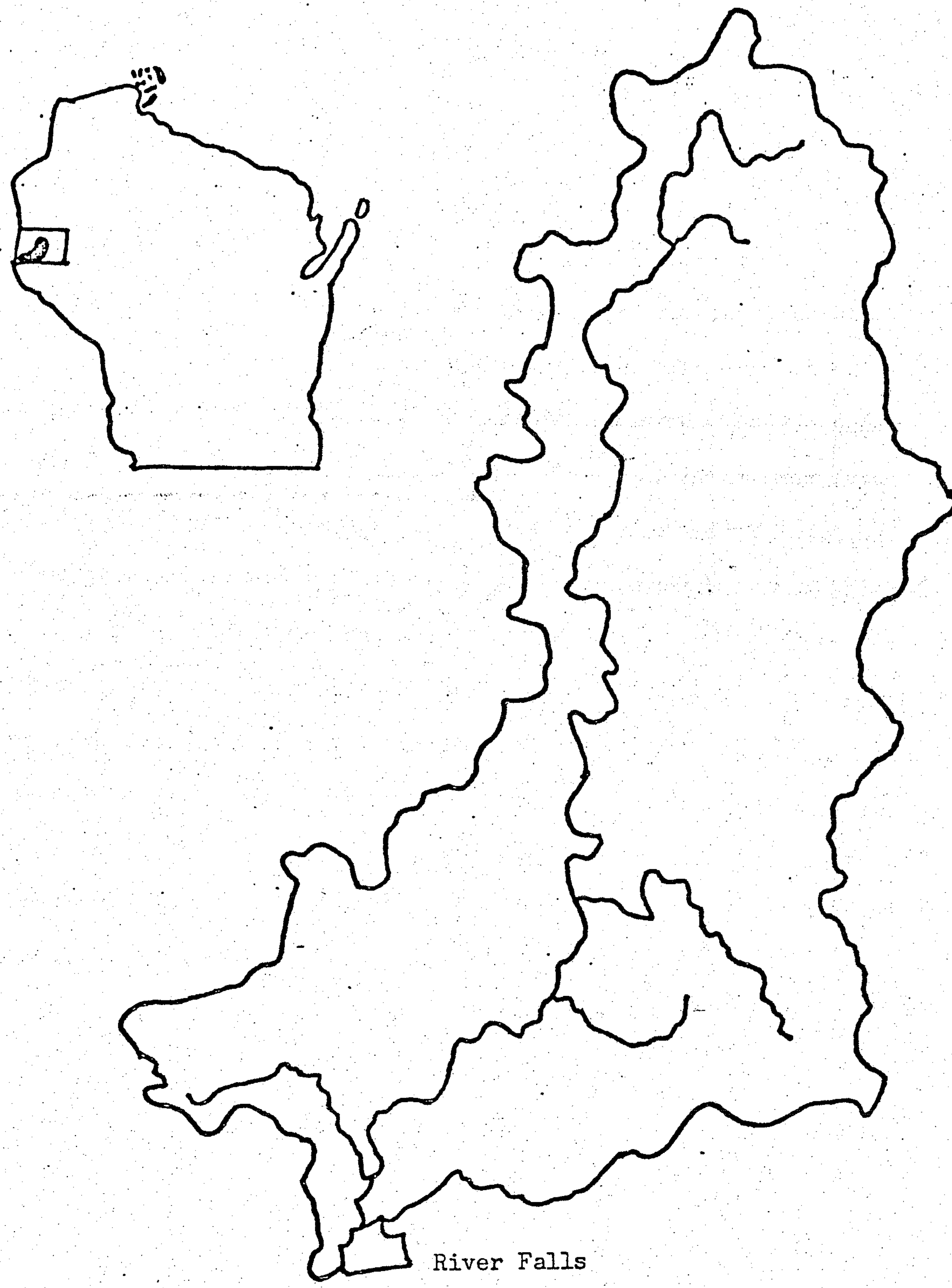

Figure 1: The Upper Kinnickinnic River watershed in St Croix Co. Wisconsin

these fields results in sediment load in the river. Cattle grazing and watering along stream banks destroy the vegetation and accelerate the stream bank erosion process. A number of town, county, state and federal highways run adjacent or cross the river. Erosion from road cuts during or after construction lead to sediment in the river. Fertilizers, herbicides and insecticides spread on adjoining fields can be sources of nutrients and organic materials getting into the river. The Kinnickinnic is also an excellent trout stream and was written up in Field & Stream as one of the best trout streams in the state of Wisconsin. To help protect trout fishing in the upper part of this river the Department of Natural Resources in 1950 established a stream habitat program in coöperation with land owners along the river. In this program 25 feet of easement back from the waters edge is obtained from the landowner and fenced to keep cattle off these river banks. In return a tax free status is obtained for the landowners on this river bank land. Through coöperative programs such as this a desirable stream bank environment is maintained for public use and individual land ownership is maintained.

The Kinnickinnic River flows into Lake George within the city limits of River Falls. The lake is a reservoir formed by a dam across the river originally built in 1867. This first dam was washed out by the flood of 1894 but was replaced in 1904 by the dam that still remains at that site. Lake George located where it is could provide excellent recreational facilities for the city if its characteristics could be improved and maintained. Since the dam was built much of the lake has silted in, greatly limiting the potential use of the lake. Evaluations of these sediments and flow characteristics of the Kinnickinnic River will help determine alternate management plans.

To protect the present environmental quality of the upper Kinnickinnic River Valley and Lake George into which the river flows, it is very important to understand all hydrologic characteristics of the watershed and the lake. Complete evaluation of all hydrologic characteristics will also be necessary if changes are to be made to enhance the recreational use, agricultural use, and urban development of the area.

Figure 2: The Upper Kinnic River watershed

Chapter 2

CLIMATE

The climate of the watershed is of the continental type. Winters are long and snowy, and many of them are extremely cold. The summers are warm and they usually include several short periods in which the weather is excessively hot and humid.

Changes in the weather can be expected every few days from late in fall through spring. All of the climatic features in this watershed area tend toward the extremes, as the area is influenced greatly by the succession of high and low pressure systems that move from west to east across the country.

Temperatures:

Figure 3 on the following page shows the average temperature, plotted along with the average maximum and average minimum temperatures, for each month.

Lowest average air temperatures, on the watershed, occur during the month of January (10 - 15 F), and the highest average air temperatures (68 - 72 F) are reached in July. The temperatures vary about twice as much in winter than they do in the summer. From mid March to late October the temperatures average above freezing. The average growing season is about 120 days, the ground is generally frozen from late November through early April, and maximum depth of frost of 26 inches occurs in early March.

In spring and fall, which are often short, the temperatures and precipitation are composites of the temperatures and precipitation of both summer and winter.

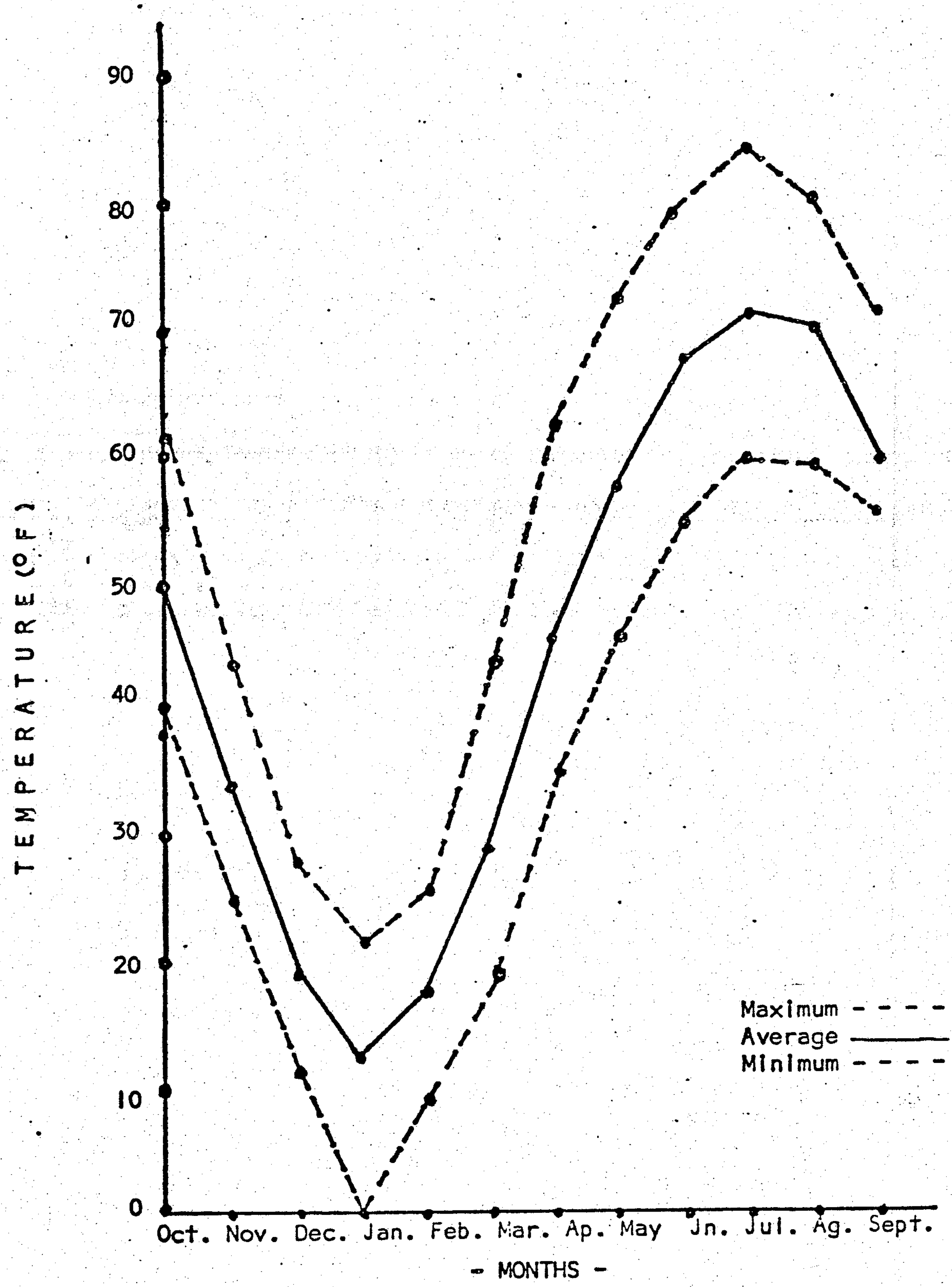

Figure 3-Mean monthly temperature and observed maximum and minimum temperature for the period of record 1918-1973.

Precipitation:

Figure 4 illustrates the average precipitation along with the potential evaporation (PE). The average annual precipitation for River Falls is 29.8 inches with June being the month of greatest precipitation of 4.9 inches and February the least with .8 inches. The extremes in precipitation for River Falls have been from a high of 43.8 inches in 1942 to a low of 17.8 in 1936. About 2/3 of the annual precipitation falls during the growing season. Snowfall comprises about 15% of the annual precipitation. The potential evaporation is highest in July and almost nonexistent from November through March. About once every two years, intensive rainfall occurs on the watershed with rates of 1.4 inches in one hour, 2.1 inches in 6 hours and 2.8 inches in 24 hours. The greatest amount of rainfall measured in 24 hours was 7.25 inches, which fell in River Falls on Memorial Day of 1965.

Potential Evapotranspiration:

Potential evapotranspiration, as computed by the Thornthwaite method, is largely based upon the mean monthly temperature. PE is an index of heat energy available to vaporize water and is an estimate of the amount of evapotranspiration that would occur if plant and soil water were not limiting factors.

The relation of soil moisture to evapotranspiration and precipitation varies throughout the year, as shown in Figure 5. Estimates of monthly "actual" and "potential" evapotranspiration, determined by an empirical method (Thornthwaite and Mather, 1957), illustrate the monthly water balance for River Falls. Winter snow accumulation and spring rainfall maintain a soil-moisture surplus through spring. The monthly surplus decreases as evapotranspiration increases during the spring,

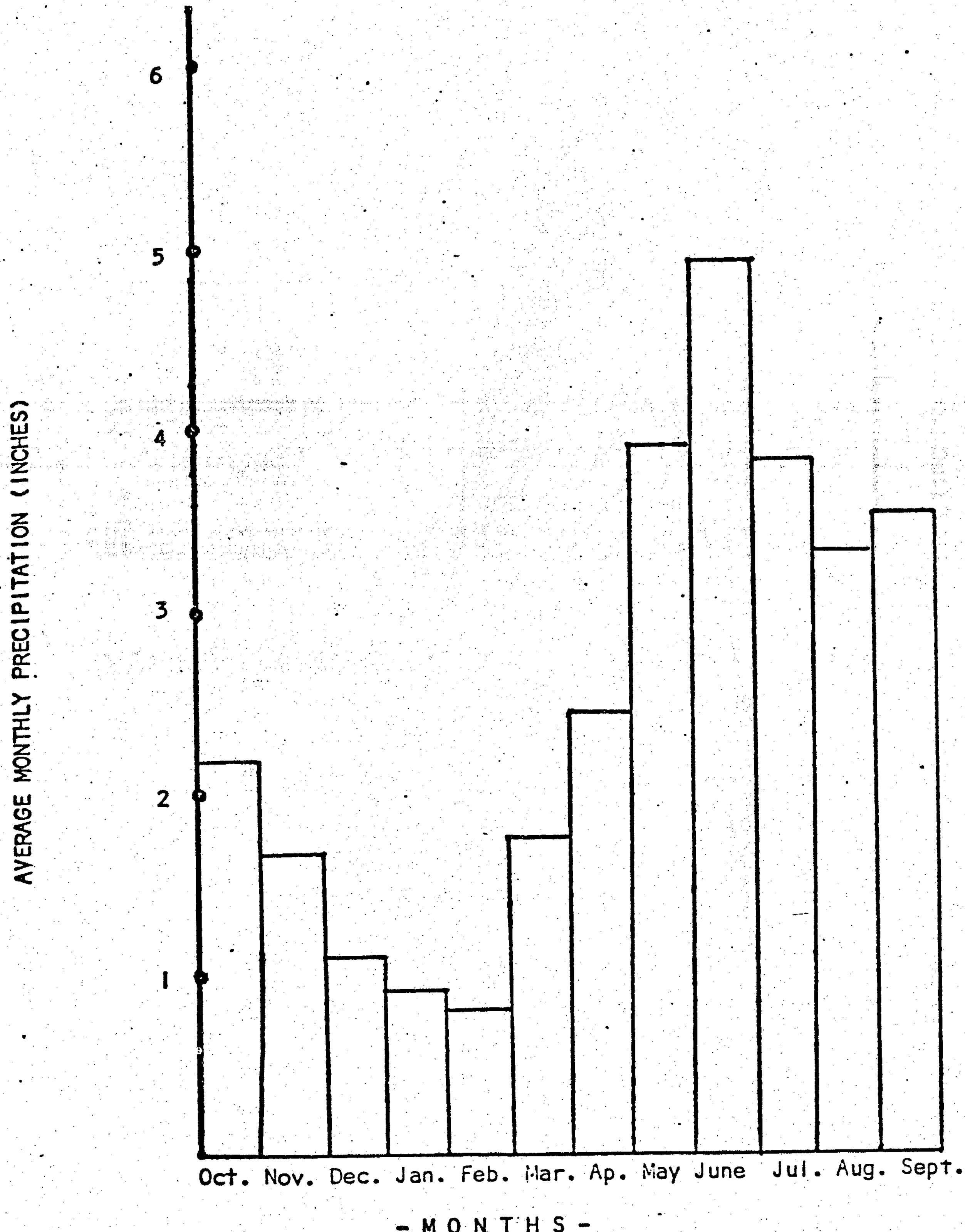

Figure 4: Average monthly percipitation for the period of record 1918-1973

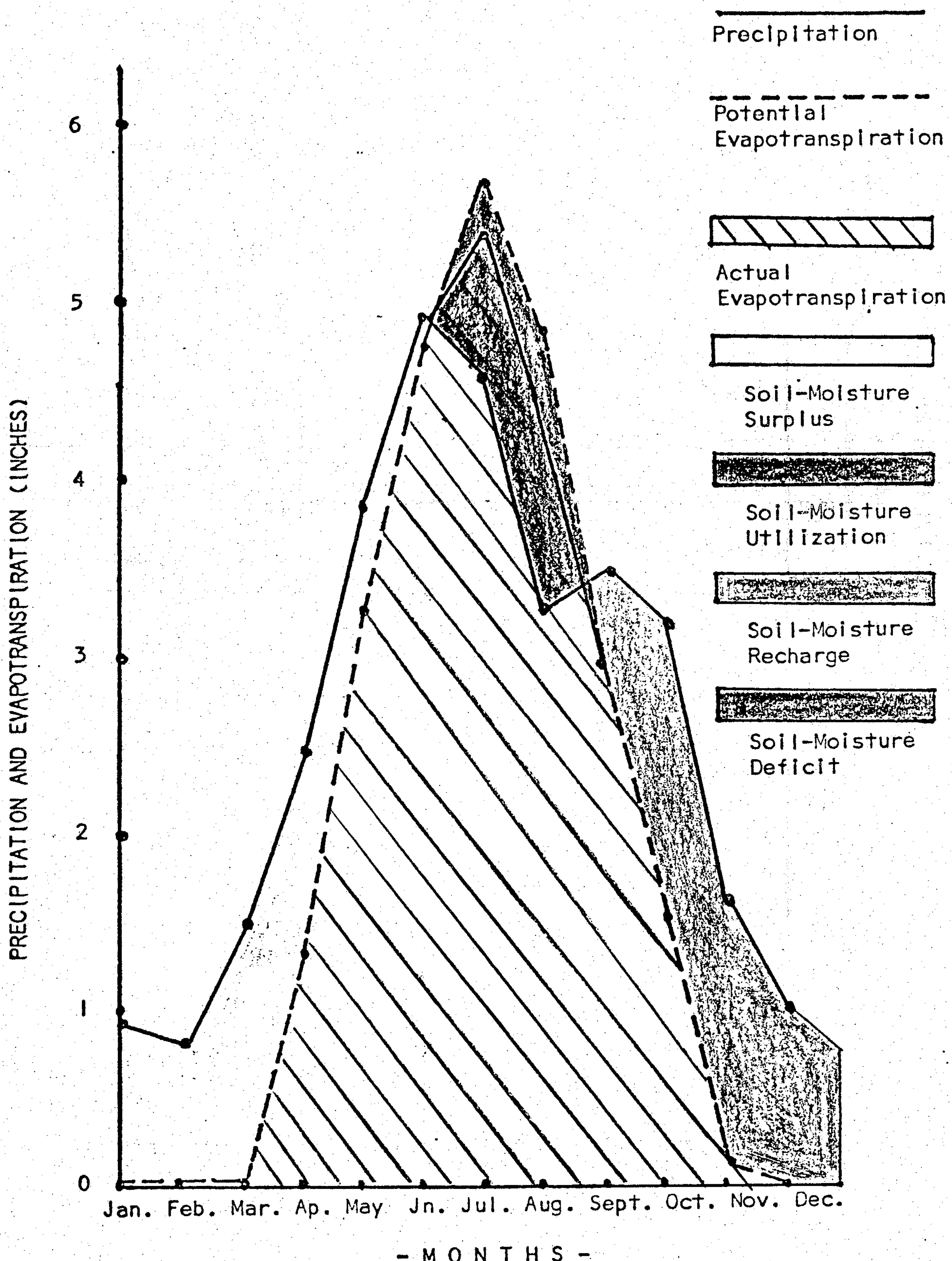

Figure 5-Comparison of mean monthly precipitation and potential evapotranspiration for the period 1918 - 1976.

until evapotranspiration exceeds precipitation in early summer and soil moisture is withdrawn from storage. A moisture deficit exists when soil moisture in storage is depleted and potential evapotranspiration exceeds actual evapotranspiration. In the fall, as air temperature declines and transpiration by vegetation ceases, precipitation recharges soil moisture until the winter phase of surplus moisture resumes. For River Falls the water budget indicates precipitation of 29.8 inches, actual evapotranspiration of 25.0 inches, soil moisture surplus of 4.8 inches, soil moisture utilization of 3.2 inches, and a soil moisture recharge of 3.2 inches.

In summary, precipitation, the source of all water in the basin, falls on the land surface, streams, and lakes and starts the cycle of circulation called the hydrologic cycle. Some water runs rapidly off the land surface to nearby streams and lakes (surface runoff), some water evaporates immediately from the surface soil and plants (evaporation), some water enters the soil but is used by plants (transpiration); and some water seeps down through the soil and eventually reaches the groundwater reservoir (recharge), which contributes base flow to streams and lakes (ground-water runoff).

The cycle is not complete within an area as small as a river basin; usually large parts of continents are involved. Within the Kinnickinnic River basin most precipitation results from storms from the southwest and northwest, and moisture returned to the atmosphere leaves the basin on winds from the same direction.

The hydrologic budget is a simplified equation of the basic components of the hydrologic cycle. Water input to the basin, primarily the precipitation on the basin, equals the algebraic sum of water output and change in storage. Water output includes surface runoff, groundwater underflow, evapotranspiration (sum of evaporation and transpiration), and consumptive use by man. Changes in storage occur in ground and surface water, as well as in soil moisture. The quantities of these budget items fluctuate from year to year, but major fluctuations occur only in precipitation, runoff, and evapotranspiration. Man's effect on these quantities is almost negligible in the Kinnickinnic basin. A very small part of the ground and surface water withdrawn by man is consumed, and part of the water stored on the surface is evaporated.

Therefore, a precipitation of 29.8 inches and evapotranspiration of 25.00 inches leaves 4.8 inches as water for man's use or water to leave the basin as runoff. This would be computed also including changes in storage and underflow. Man's consumptive use of water in the basin is less than .5 percent of evapotranspiration.

Chapter 3

GEOLOGY OF THE KINNICKINNIC RIVER WATERSHED

The geological history of the area, represented by rock formations and glacial and loess depositions, falls into two eras, the Paleozoic and the Cenozoic. The periods or systems within the Paleozoic era are the Ordovician and the Cambrian. The only series or epoch within the Cenozoic is that of the Pleistocene.

The upper series of the Cambrian system, occurring as base rock in northwestern and extreme eastern parts of the watershed, consists of the Trempealeau and Franconia formations.

The lower series of the Ordovician system, consisting of the Prairie du Chien or Lower Magnesian formation, is the dominant bedrock in St. Croix County and occupies most of the area. The middle series of the Ordovician system, made up of St. Peter, Plattville, Decorah and Galena formations, is confined largely to the southwestern and southcentral parts of the county. The upper series of the Ordovician system, consisting of the single Maquoketa formation, is found in a relatively small area in the southwestern part of the watershed.

The Pleistocene series in the area is made up of Wisconsin glaciation and post-glacial depositions. The Wisconsin formation apparently consists of only two members, the Iowan and the Cary age drifts. The only important post glacial deposition to be found in St. Croix County, aside from lesser amounts of alluvium and colluvium, is that of wind-laid materials.

Table 1

Geologic Columnar Section - St. Croix County

Era	System	Series	Formation	Member
Cenozoic		Pleistocene	Post-glacial	Loess
			Wisconsin	Cary Iowan
Paleozoic	Ordovician	Upper	Maquoketa	
		Middle	Galena Decorah Plattville St. Peter	
		Lower	Prairie du Chien*	
	Cambrian**	Upper	Trempealeau Franconia	

* Lower Magnesian Dolomite
** Potsdam Sandstone

The rock formations in the watershed area is composed of Prairie du Chien dolomite, which is of the Lower Ordovician age, and all of the Cambrian sandstones. This includes the Jordan, Trempealeau, Franconia, Dresbach, Eau Claire and Mt. Sinoa sandstone formations. The Cambrian formations are all sandstones with periodic thicknesses of shale or dolomitic siltstone. In most areas the shale and dolomitic siltstone do not go beyond thicknesses of fifteen feet. This formation of rock would be found directly below the Jordan sandstone. The rest of the sandstones range greatly in sorting, size and thicknesses. The Jordan sandstone is probably the best aquifer in this area for tapping of water without going to extreme depths to the lower Cambrian units. It is a beach deposit of Cambrian seas and is well sorted and moderately to well rounded. It ranges in thickness, in this area, from fifty to ninety feet. Its upper contact is intruded by dolomite solution activity and dolomite cement has been introduced. The upper portion also tends to be coarse grained.

The lower sandstone units are probably good aquifers also, but it is not necessary to go to these depths for the water when the Jordan sandstone is found to be in the range of thicknesses as stated earlier. This statement can be improved upon by the fact that the dolomitic siltstone which underlies the Jordan acts as an aquitard, in that it retards water flow because of its fine-grained texture of the dolomite cementing matrix.

There is also another possible aquifer in the watershed, and that is the glacial till that covers the area. In places where moraines and outwash plains are prevalent, the till and drift from the ice action may reach thicknesses of one hundred feet or more. Even though it is extremely poorly sorted, it will still act as a good aquifier.

It must be remembered that this glacial till may be found lying on top of any formation from the Jordan on up. This reasoning comes from the fact that the glacier caused considerable erosion and it was not a complete stripping job, but only eroded the most weathered and weakest rocks.

Chapter 4

GROUND WATER

Large supplies of good quality water are obtained from the ground-water reservoir in the Kinnickinnic River watershed. About 28 billion gallons of water are discharged to streams and from wells each year, which is about 5 million gallons for each person in the basin. Aquifers throughout the basin serve dual functions of providing water supply from wells and springs and of furnishing a perennial base of streamflow and lake stage by seepage and spring discharge.

Ground water is readily available in quantities adequate to meet present and future domestic, agricultural, municipal, and industrial needs in the basin.

At present the greatest use of ground water in the watershed is the city of River Falls with an average daily consumption of 1,400,000 gallons. This water is obtained from three wells each about 400 feet deep with a capacity of 600 to 1,000 gallons per minute. Some large irrigation wells have been installed in the watershed but present use is very small compared to potential irrigation development in the area. In general ground-water development is small and scattered throughout the basin. But detailed ground-water studies may be needed to guide future development.

Ground Water Usage:

About 1 million gallons of water per day were withdrawn for use in the Kinnickinnic River basin in 1968. Of this water, almost 80 percent was from wells, and the rest was diverted from streams, natural lakes, and manmade impoundments. The 1 mgd (million gallons per day) is equivalent to only 1.5 efs, which is about 1 percent of the average runoff from the basin. Most of the water withdrawn was discharged to streams and was available for reuse downstream.

Water for domestic purposes, the largest use, was supplied entirely by ground water and accounted for about 42 percent of the ground water used. Privately supplied water was more than three times the amount publicly supplied, emphasizing the rural character of the basin. Consumption in domestic water use is low, and most of the water withdrawn was discharged into streams through sewage-treatment plants or to the ground through septic tanks.

Industry and commerce also were supplied by ground water and accounted for 28 percent of the ground water used. Much of the water was used for cooling. Consumption of water was very low in industrial and commercial use, and most of the water withdrawn was discharged to streams through storm drains or waste-treatment plants, or to the ground through settling basins.

Stock watering was the third largest withdrawal use, and about 80 percent was ground water. Consumption probably is high in this use.

A very small amount of ground water was used for irrigation. It was largely the 0.2 mgd used for irrigation of row and truck crops from private wells. This use has a very high consumption rate because most water applied is consumed in plant growth or is evaporated from the soil.

Ground Water Aquifers:

Ground water underlies the entire basin and moves constantly from areas of recharge to areas of discharge (streams, lakes, wetlands, and springs). Ground water moves perpendicular to the water-table contours and conforms regionally to the direction of surface runoff. Ground water in the basin generally travels less than 4 miles to discharge areas. A ground water map of the Kinnickinnic River basin is shown in Figure 6. The general direction of flow is southwest west to the Saint Croix River or at shallow depths to the Kinnickinnic River.

The ground-water divide coincides closely with the surface-water divide except in a few areas. The water table in the basin generally is within a few tens of feet of the land surface. It is commonly most shallow near lakes and the Kinnickinnic River. The water table is deepest below hills, especially in the south where topographic relief is great. Maximum water-table depths of 200 to 300 feet occur below hills surrounding the Kinnickinnic River valley.

Most ground water in the basin is obtained from the sand and gravel aquifer or the sandstone aquifer. The sand and gravel aquifer is most important for surface water supplies and shallow wells. The sandstone aquifer is most important for larger and deeper wells for municipal or irrigation use.

1. Sand and Gravel Aquifer. Surficial deposits. - Most deposits of surficial sand and gravel are mainly in extensive outwash plains and alluvial valley fill. These deposits are highly permeable and yield large quantities of water to wells. Most high-capacity wells in surficial sand and gravel are between 40 and 170 feet deep. The range of specific capacities of these wells is generally from 10 to 70 gpm (gallons per minute) per foot of drawdown, and the median is 21. The specific capacity of 25 percent of them is 40 or more. Present withdrawal from these sand and gravel deposits is insignificant compared to their potential for use in the basin. The best potential is in areas where saturated sand and gravel is more than 50 feet thick.

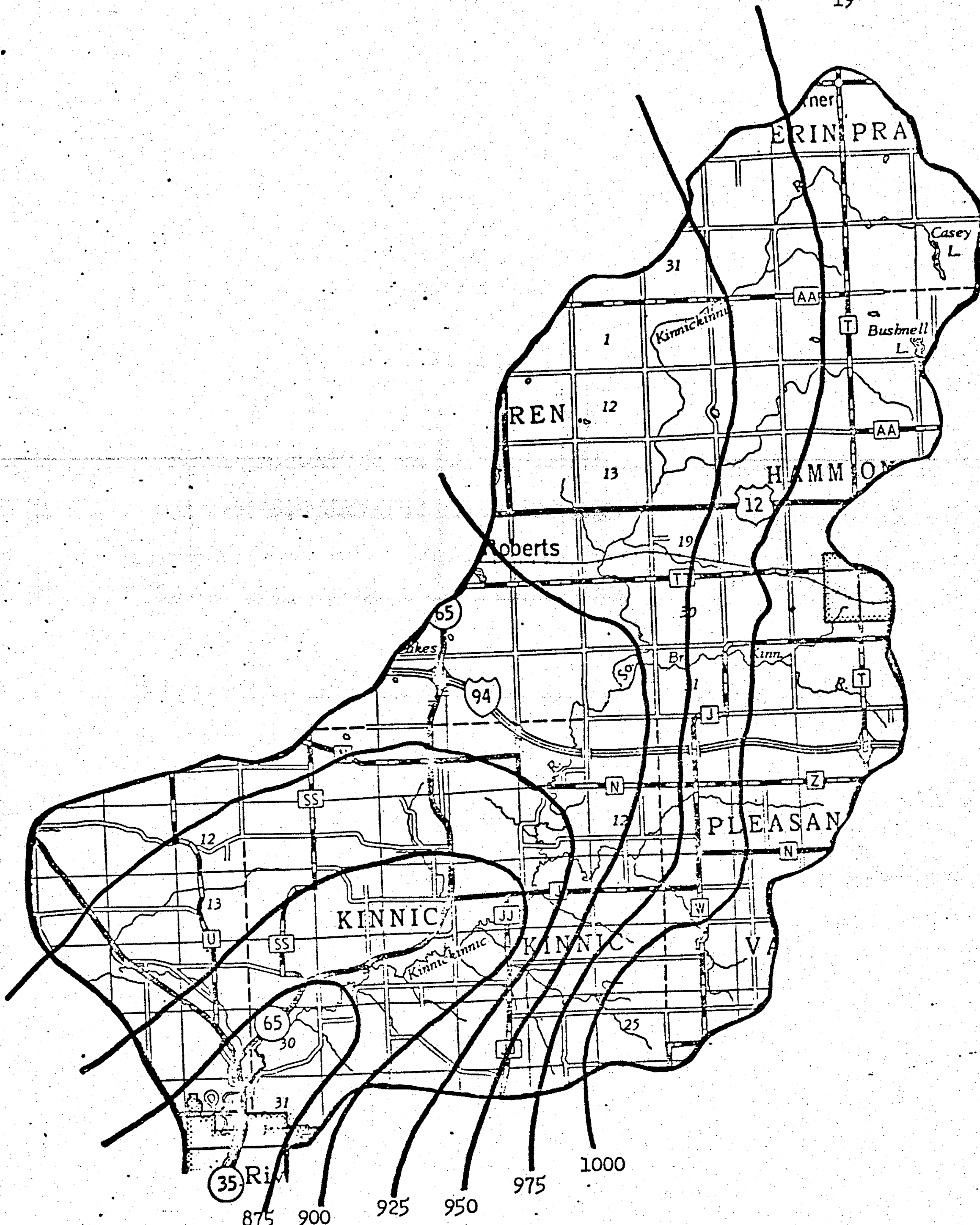

Figure 6: Ground water contour map showing water table elevations in feet above sealevel.

2. Sandstone Aquifer. In the Kinnickinnic basin the sandstone aquifer consists of the saturated parts of the Ordovician formations and Cambrian sandstones. The latter comprise the bulk of the aquifer. The Prairie du Chien Group also forms a substantial part of the aquifer, but the St. Peter Sandstone is only a minor part. The Galena-Platteville unit commonly is not saturated. Throughout its area the sandstone aquifer provides reliable supplies for municipal, industrial, public, domestic, stock, and irrigation uses.

Cambrian sandstones. These rocks are the most widespread part of the aquifer and, therefore, are the most commonly used. They produce large to very large yields, as much as 1,500 gpm, in the southern one-third of the basin. The yields diminish as the sandstone thins to the north. The most productive unit is the Jordan Sandstone. The Eau Claire Sandstone and the St. Lawrence Formation are relatively unproductive.

Because consolidated sandstone is less permeable than unconsolidated sand and gravel, high-capacity wells must penetrate a greater saturated thickness of sandstone than sand and gravel to obtain comparable yields. Depths of high-capacity wells in sandstone range from 196 to 802 feet; however, the median depth is 358 feet. The specific capacities of these wells range generally from 5 to 35 gpm per foot of drawdown, and the median is 15. The specific capacities of 25 percent of them are 27 or more.

Prairie du Chien Group. Rocks of this group, mostly dolomite, furnish water to several domestic and stock wells in the southern one-fourth of the basin. Only four high-capacity wells are known to be finished solely in this unit. Their depths range from 200 to 300 feet, and their yields range from 100 to 837 gpm.

Prairie du Chien Group and Jordan Sandstone. This combined unit, mainly in Pierce and St. Croix Counties, is highly productive, yielding as much as 1,100 gpm to wells. The range of specific capacities of the high-capacity wells generally is from 20 to 60 gpm per foot of drawdown, and the median is 28. These wells range from 246 to 734 feet in depth, but the median depth is 365 feet.

St. Peter Sandstone. This sandstone is topographically high, commonly is unsaturated, and is limited in areal extent. It is an aquifer only locally, mainly where overlain by the Platteville Formation. Adequate yields, 10 to 20 gpm, are obtained for domestic and stock uses from wells generally between 100 and 200 feet in depth.

Ground Water Quality:

Ground water in the Kinnickinnic River basin is generally of very good quality and is usable for most purposes. Regional differences in the quality of ground water are due to the composition, solubility, and surface area of the particles of soil and rock through which the water moves, and to the length of time the water is in contact with these materials. The main chemical constituents in the water are clacium, magnesium, and bicarbonate ions that are derived primarily from dolomite and glacial drift containing fragments of dolomite.

Minor water-use problems are caused by hardness. About 73 percent of the ground water sampled has hardness greater than 120 mg/l, and 47 percent has hardness greater than 180 mg/l; the latter needs softening for many uses.

The overall characteristics of ground-water quality in the basin are fairly similar in all the aquifers. Dissolved-solids content and hardness are greater, successively, in Precambrian rocks, glacial sand

and gravel, Cambrian sandstones, and Ordovician formations. Concentrations of minor constituents are more variable among aquifers, but high concentrations of iron in the sand and gravel aquifer are very common.

The concentration of iron or manganese (often concurrent) generally is unpredictable, and water from wells close together may have large differences in concentrations of these ions. Drinking water standards of the U.S. Public Health Service (1962) recommend maximum allowable concentrations of 0.3 mg/l of iron and 0.05 mg/l of manganese. The standards are based on levels that may produce objectionable taste and stains. The standards are equaled or exceeded by the median concentrations of these constituents in the sand and gravel aquifer and the Cambrian sandstones and by concentrations in several wells in the other units.

The known concentrations of nitrate in ground water of the basin generally are low. Concentrations more than about 10 mg/l probably are not from natural sources but may be from contamination by organic wastes. Ground water in the Ordovician dolomites may be easily contaminated because recharge to these rocks is not filtered as it moves through fractures and solution channels. Likewise, rapid recharge to surficial sand and gravel may carry contaminants. The drinking water standards recommend that nitrate content be less than 45 mg/l because of the association of nitrate with occurrence of methemoglobinemia in infants.

All analyses show low concentrations of sodium, sulfate, and chloride, the maximum concentrations being 36, 126, and 38 mg/l, respectively. This maximum sulfate concentration is in a well in St. Peter Sandstone, which is overlain by the Platteville Formation.

Chapter 5

SOILS

The soils of the 67,981 acre upper Kinnickinnic watershed vary from the level silt covered outwash soils on the stream terrace to the silty glacial till soils on the ridge tops. Most of the soils in the watershed are developed in glacial till or glacial outwash of the Cary age, perhaps 12,500 - 16,000 years ago, but some soils on the ridge tops maybe developed in older glacial till of the Rockian advance 29,000 to 32,000 years ago. The topography of the watershed is very unique with relatively large flat areas in the lower part of the watershed at an elevation of about 900 feet above sea level to the flat top butte type hills with an elevation of about 1100 feet above sea level. The soils in between are developed on very steep slopes in exposed limestone or sandstone bedrock. The butte tops and hill sides were initially covered with a forest vegetation of oak and other hardwoods whereas the outwash soils were developed under a cover of prairie grass. The outwash soils with a thick silt mantle are probably the most productive in the watershed; they are well drained, highly fertile and less subject to erosion. The soils on the uplands and slopes are shallower, more subject to erosion, and therefore somewhat less productive. The soils developed in sandstone residuim or over limestone would be droughty, also limiting crop production. The outwash soils are very permeable with permeabilities of 2.5 to 5.0 inches per hour. The upland soils, because of texture, will have lower permeabilities of .2 to .8 inches per hour. The permeability and slope of the soil will affect runoff and therefore sediment and nutrient transport to the Kinnickinnic River. The soils of the watershed have a tremendous effect on the water quality of the river. A map of the soil associations in the upper Kinnickinnic River watershed is shown in Figure 7.

1. Renova-Vlasaty Association. Moderately deep, silty soils underlain by yellowish-brown, acid till.

This soil association consists of gently rolling to steep upland ridges, very steep bluffs, narrow valleys, sandstone hills, and broad valleys. It occupies about 35 percent of the total land area of the watershed. The soils in most of the association are underlain by a layer of yellowish-brown glacial till that caps the bedrock of limestone or sandstone. The till is most common on the hills and ridgetops, but it also extends into the broad valleys. Most of the soils formed partly in the till and partly in windblown silty material (loess) that forms a mantle over the till. Throughout most of this association are light-colored soils formed under a cover of trees. In the extreme western part, however, some dark-colored soils are intermingled with the light-colored ones. The dark-colored soils have formed in areas, called oak openings, where the cover consisted partly of grass and partly of trees.

A major part of this association is occupied by Renova and Vlasaty soils. Those well drained or moderately well drained soils occur at the highest elevations on the ridgetops in the uplands.

Minor areas of Wykoff soils also occur on the ridgetops. In addition, small, isolated patches of Santiago soils occur there at the highest elevations, and areas of Otterholt and Spencer soils occur where the mantle of silty material is thickest.

Minor acreages of this association are occupied by soils of the Edith-Wykoff complexes; by somewhat poorly drained Sargeant and Almena soils; by areas of Alluvial land; and by Chaseburg, Worthen, Auburndale,

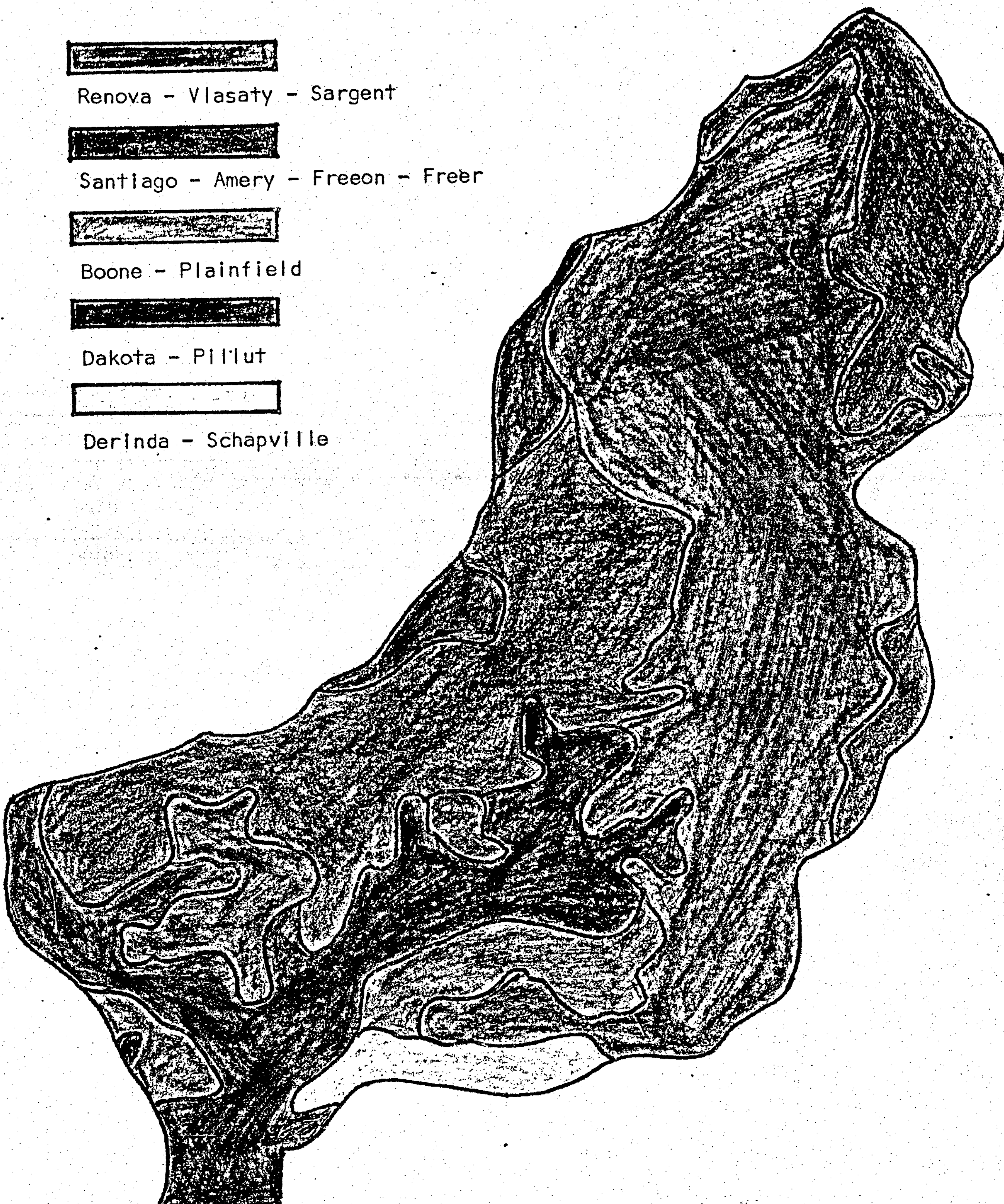

Figure 7: Soil associations in the upper Kinnickinnic River watershed.

and Clyde soils. The association also includes areas of Arland, Boone, Gale, Hixton, Seaton, Whalan, Edith soils mapped separately, and Port Byron, Ostrander, Racine, and Floyd soils, as well as small, isolated patches of Derinda and Schapville soils.

The soils of the Edith-Wykoff complexes are on the steeper hills and gravelly moraines. The Sargeant and Almena soils are lower in the soil pattern, on gentle, mainly concave slopes. The areas of Alluvial land and of Chaseburg, Worthen, Auburndale, and Clyde soils are in the upland drainageways.

The soils of the Arland, Boone, Gale, and Hixton series occupy areas of sandstone hills. The Arland soils occur on the tops of the hills with Renova and Whalan soils; Boone soils are on the side slopes of the hills; and gently rolling Gale and Hixton soils occur with Seaton soils in the gently rolling, broad valleys. All of these soils have formed in material weathered from sandstone bedrock or are underlain by sandstone bedrock. They r ange from well drained and fertile to excessively drained and infertile.

Shallow, gravelly Edith loams are on the hills in the extreme western part of this association. Dark-colored Port Byron, Ostrander, and Racine soils generally occupy the lower side slopes of the hills, and gently rolling areas of those soils occupy the broad valleys. Somewhat poorly drained Floyd soils are in the drainageways.

Cultivated crops are grown on the soils of most of the ridgetops and valleys. The steep side slopes of the ridges and hills are mainly in trees, but some of those steep areas are pastured. The cover of trees is sparse in the western part of the association.

Where the deep, silty soils are properly farmed, yields of crops are generally good. The moderately deep soils are only slightly less productive than the deep soils, but the shallow soils have been more adversely affected by erosion. Droughtiness is not a major problem in this association.

2. Santiago-Whalen-Freeon-Freer Association. Moderately deep to shallow, silty soils underlain by reddish-brown, acid till.

This soil association consists of several small, isolated areas of soils on ridgetops within areas of the Renova-Vlasaty soil association. The physiographic features are similar to those of the Renova-Vlasaty association, but the slopes are more gentle. The areas form a discontinuous pattern at the highest elevation on the landscape. Most of them are centrally located on the broadest ridges. The association occupies about 30 percent of the total land area in the watershed.

Santiago and Whalen soils are dominant in this association. They formed in a mantle of moderately deep, silty or loamy material over reddish-brown sandy loam till. The till overlies yellowish-brown till that is typical in this part of the county. Minor soils of the association that also formed over the reddish-brown till are the moderately well drained Freeon and the somewhat poorly drained Freer. Those soils are on gentle concave slopes of small watersheds.

Other minor soils in the association are the Otterholt soils and Renova and Vlasaty soils, which occur together. The Otterholt soils occur where the mantle of silty material is thick. The Renova and Vlasaty soils generally occur at a slightly lower elevation in the soil pattern than do the other soils.

All of the soils of this association are well suited to general farming and are easily managed. Most of the acreage is used for crops, but some areas are wooded. Where good management is used, yields of corn, oats, and hay are generally good. In cultivated areas the soils are subject to serious erosion, and methods of safely disposing of excess water are needed on the steeper side slopes. Also, the pastures are subject to damage if they are overgrazed. The wooded areas are subject to damage if they are not properly managed.

3. Dakota-Pillot-Anson-Jewett Association. Moderately deep, dark-colored, loamy soils of stream terraces.

This soil association occupies broad stream terraces in the southern end of the watershed. It makes up about 25 percent of the total land area in the watershed.

The principal soils are those of the Dakota and Pillot series. Those soils are moderately deep loams and silt loams underlain by sandy material. For the most part, they are gently sloping. The Dakota, Jewett, Anson and Pillot soils formed under a cover of prairie grasses and scattered oaks, and they are dark colored. The Pillot soils are more silty than the Dakota.

Less extensive in this association are the dark-colored Rockton and Hesch soils. The Rockton soils occur where limestone bedrock is near the surface. The Hesch soils occupy the lower slopes of the sandstone hills that rise above the terraces. They are gently sloping to steep and formed in material weathered from sandstone.

Minor acreages are made up of Renova, Boone, and Hixton soils. They range from moderately steep, where they occur on the river banks, to gently rolling, dunelike, or hummocky on the terraces. Gently sloping to moderately steep Renova soils occupy the tops of the sandstone hills. Boone soils are on the steep side slopes, and gently sloping to steep Hixton soils are on the lower slopes. All of the light-colored soils formed under a cover of trees.

Many of the soils of this association have layers of loamy material within their substratum of loose, sandy material. These loamy layers are common in the substratum of soils in the valley. They are especially prevalent in the soils near hills and ridges capped with limestone.

The Dakota and Pillot soils, and others in this association, are well suited to crops. Yields are generally good if enough rainfall is received, and if the rainfall is well distributed. Many of the soils, however, are somewhat droughty, and some are susceptible to wind erosion.

4. Sparta-Plainfield Association. Deep, sandy soils of stream terraces.

This soil association consists of terraces formed at several different levels by the Kinnickinnic River. It is bordered on the north and west by its alluvial flood plain. The soils of this association are nearly level to gently sloping and are sandy and loamy. They are underlain by loose, sandy and gravelly material. Dark-colored soils are predominant, but light-colored soils are also extensive. The association makes up about 5 percent of the total land area in the watershed.

A major part of this association consists of Sparta and Plainfield soils. The Plainfield soils are less extensive than the Sparta. The Sparta and Plainfield soils are deep, excessively drained, and sandy, and they formed in outwash sand and gravel. They differ from one another in the thickness and color of their surface layers. The Sparta soils have formed under a cover of prairie grasses, and they have a thick, dark-colored surface layer. The Plainfield soils have formed under forest. Their surface layer is lighter colored than that of the Sparta soils.

Minor soils of this association are the Burkhardt, Dakota, and Waukegan. Also, small areas of Onamia, Fayette, Antigo, and Port Byron soils occupy part of the terrace. Terrace escarpments form the steep breaks between the levels of the terrace.

Except for small areas in woodlots, this association has all been cleared, and most of the acreage is used for crops. Some areas of the Plainfield soils have been planted to pines or are idle. Plantings of pines have also been established on some areas of Sparta soils. The Burkhardt, Dakota, and Waukegan soils are better suited to field crops than are the Plainfield and Sparta soils, and they are used mainly for that purpose.

This association is attractive to homebuilders, and several small residential areas have already been established. Attractive homesites, some that overlook the Kinnickinnic River, are available on several levels of the terrace. The sandy and gravelly material that underlies the soils is excellent for the construction of small buildings and for systems for disposing of waste material.

Management is difficult in this association because the soils are droughty and low in fertility. Also, the soils along the terrace escarpments are subject to gullying and to erosion by wind and water.

5. Derinda-Schapville Association. Moderately shallow, silty soils underlain by neutral to calcareous shale.

This association is characterized by gently sloping to steep ridgetops - some broad, some narrow - and by narrow, steep-walled valleys. All of the ridgetops are capped with shale. The shale, in turn, is covered by a layer of glacial till and by windblown silty material (loess). It occupies about 5 percent of the watershed.

A major part of this association consists of Derinda, Schapville, Renova, and Vlasaty soils. In many places Derinda soils and their dark-colored associates, the Schapville soils, occur toward the outer edges of the ridgetops. In those areas the layer of glacial till is thin or absent and the mantle of silty material directly overlies the shale. Wet subsoil variants of the Schapville series occur in the less sloping parts of the association, where the cover of windblown material is thin and a perched water table is near the surface.

In the wet subsoil variants of the Schapville series, percolating water collects above the layer of slowly permeable shale or clay that underlies the blanket of silty material. The water moves laterally along the top of the slowly permeable layer until it reaches an outlet along the marginal breaks. Here, along the fringe of the perched water table, moisture passes upward by capillary action into the overburden of soil material. The additional moisture favors more luxuriant growth of plants, which, in turn, contribute more organic matter to the soils.

The Renova are well-drained soils on the central and highest parts of ridges, generally on the steeper convex slopes. The Vlasaty soils are in areas marginal to those occupied by the Renova soils, at a slightly lower elevation, and mainly on gentle, concave slopes.

Minor acreages in this association are occupied by the Seaton, Wykoff, and Sargeant soils. The Seaton soils are in positions similar to those occupied by the Renova soils, and are well drained. Wykoff soils are on the steeper hilltops. The Sargeant soils are in the lower parts of this association and are somewhat poorly drained. They formed in a mantle of windblown silt that overlies glacial till. The Sargeant soils receive both runoff and seepage waters.

In this association the Seaton, Renova, and Vlasaty soils are the best for farming. They are suited to all the crops commonly grown in the area. The Wykoff soils are slightly less suitable for crops because they are generally steeper and are slightly more droughty than the Seaton, Renova, and Vlasaty soils. The Derinda and Schapville soils have limited depth, and as a result, are not well suited to deep-rooted crops. The Sargeant soils and the wet subsoil variants of the Schapville series generally have slopes that are more gentle than those of the other soils. Excess water is a hazard in the less sloping areas of those soils.

Most of the soils of this association are used for crops. Where the soils are too steep for cultivation, however, they are used mainly for meadow, permanent pasture, or trees, and a small acreage is idle. The native forest in the wooded areas consists of upland hardwoods.

Chapter 6

LAND USE

Because of differing topography, geology and soils the land in the Kinnickinnic River watershed is used in a number of different ways. The land is used primarily for agricultural production but urbanization or rural homesite development has increased dramatically the last few years. Dairy farming has been and still is the major agricultural enterprise but because of prices and potential production cash cropping of corn and soybeans is becoming more predominant. The most significant types of land use in the watershed are for cropland, pasture, and woodland. Figure 8 shows the districution of these types of land use in the watershed area. Based on the total acreage in the watershed it is estimated that 60% of the land area is in cropland, 35% in pasture and 5% in woodland.

Aerial photographs provided much of the information from which the data is drawn. Cropland was determined as a cultivated or contoured developed area. Pasture land was counted as rough and more sloping areas. Also sparsely populated woodland was also set up as pasture. Woodland on an aerial photograph showed dense trees populations and was determined in the photos by its uniform dark color.

According to the map, all cropland is in red, pasture in green, and woodland is in purple. As one can see on the map, a very high percentage of cropland is present in the central part of the watershed around Hammond as compared with the mouth of the watersehd in the vicinity of River Falls. This characteristic will tend to even runoff rates during heavy rains. Also the length of the watershed will have a great deal to do with stretching the runoff over a longer period of time.

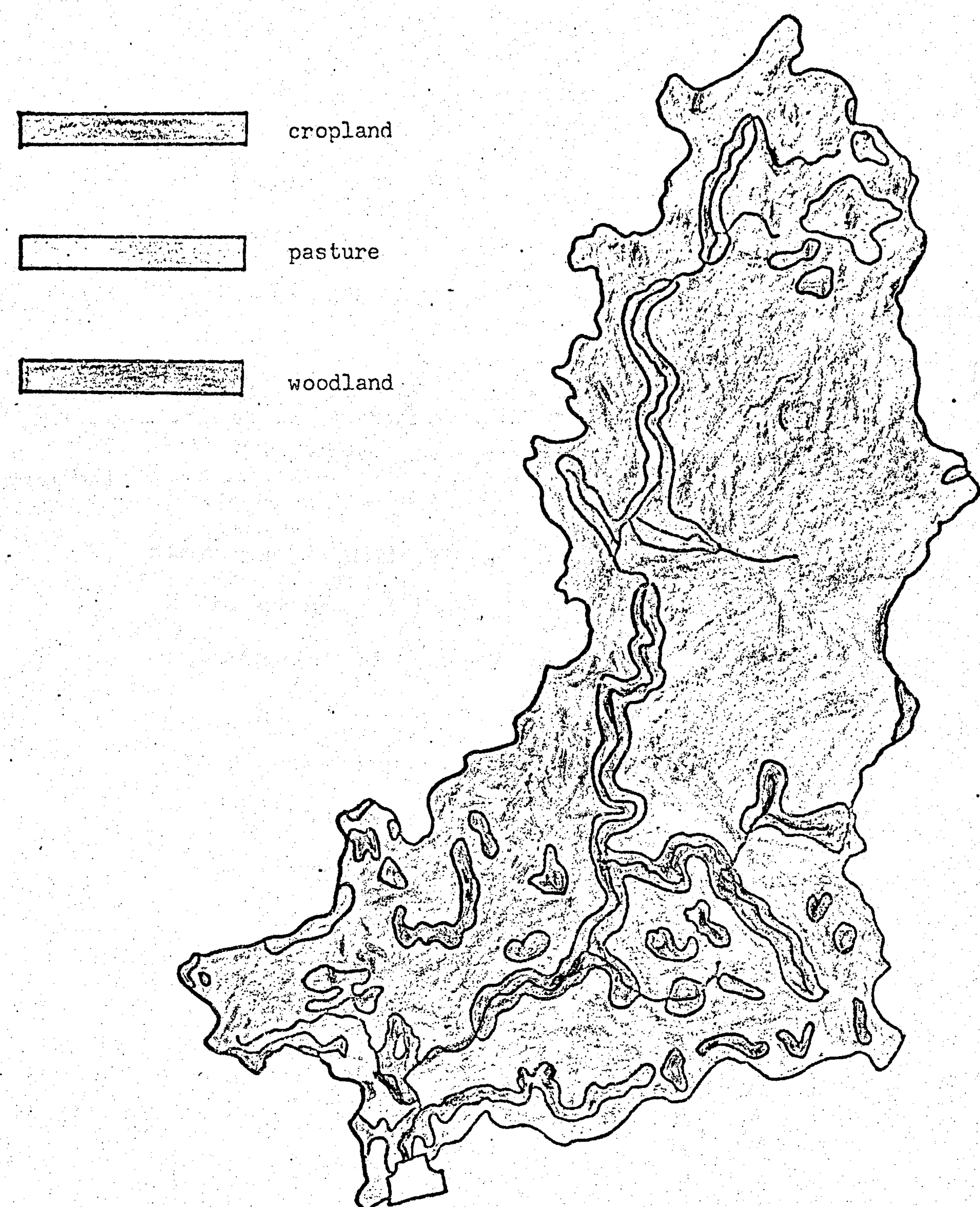

Figure 8: Land use, crop and vegetation in the upper Kinnickinnic River watershed.

The reason for more pasture land in the River Falls area, is the topography. There are many flat topped bluffs in this area making more of the area unfarmable, compared to the area around Roberts and Hammond.

Chapter 7

LAND USE CAPABILITY

Capability classification is the grouping of soils to show, in a general way, their suitability for most kinds of land use. It is a practical classification based on limitations of the soils, the risk of damage when they are used, and the way they respond to treatment. The soils are classified according to degree and kind of permanent limitation, but without consideration of major and generally expensive land-forming that would change the slope, depth, or other characteristics of the soils; and without consideration of possible but unlikely major reclamation projects.

In the capability system, all kinds of soils are grouped into capability classes depending on limitations for crop production. Capability Classes, the broadest grouping, are designated by Roman numerals I through VIII. The numerals indicate progressively greater limitations and narrower choices for practical use. Classes are defined as follows:

Class I. Soils have few limitations that restrict their use.

Class II. Soils have some limitations that reduce the choice of plants or require moderate conservation practices.

Class III. Soils have severe limitations that reduce the choice of plants, or require special conservation practices, or both.

Class IV. Soils have very severe limitations that restrict the choice of plants, require very careful management, or both.

Class V. Soils subject to little or no erosion but have other limitations, impractical to remove, that limit their use largely to pasture, range, woodland, or wildlife food and cover.

Class VI. Soils have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland, or wildlife food and cover.

Class VII. Soils have very severe limitations that make them unsuited to cultivation and that restrict their use largely to grazing, woodland, or wildlife.

Class VIII. Soils and landforms have limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife, water supply, or esthetic purposes.

Conservation practices are usually found on the lower classed crop land. Class I and much of Class II has very little need for conservation practices beyond contour tillage. Some type of conservation is needed for most of the Class III land. Conservation practices may range from contour strip cropping and terracing to the use of grass waterways in runoff collecting areas.

In the Kinnickinnic River watershed, 60 to 70% of its class III land has some type of soil conservation practice, while only 25 to 30% has adequate measures for a susceptible soil loss factor. Susceptible soil loss meaning the minimum amount of topsoil is lost each year, and that this amount will not affect plant growth. The soil lost is balanced with the addition of soil nutrients from plant decomposition.

Class III land is so classified, because of its greater slopes over Class II land, and as a result shows greater effects from soil erosion. B horizons are much closer to the surface because more of the topsoil has been washed away.

Class IV land is considered the last class for field cropping purposes, because this land type merges into the wet organic soils or into the highly sloped areas which are highly eroded. Variations toward very rocky or very sandy conditions may also be noted in this class category. Because of the minimum of row cropping in a rotation or class IV land less erosion will occur during years of small grain or meadow. Only 50 to 60% of the class IV land has some type of conservation practice at present in the watershed, mainly because this class of land is of slightly less value than class III.

Class V land is either too wet or too sandy or rocky to grow crops on. There is not at this time any Class V land in the county being used in a cropping system. There is a possibility of draining or building this land up to support a rotation but then would be classified as III or IV. Conservation practices on this land would consist of tree planting, and also lately our water pollution problem has caused diversion terraces to be built below these highly sloped areas to catch runoff from washing accross barnyards.

Class VI land is found in water covered swamps or on rocky uplands where practically no topsoil is present. Little conservation is contributed to these land areas.

Class VII land consists of rock covered land with many rocky outcrops also present. No conservation practices are utilized. Figure 9 shows the distribution of land capability classes in the upper Kinnickinnic river watershed. As one can see, a large percentage of the area is class I, II, or III which would be prime agricultural land. The following table gives the approximate square miles and percent of each land capability class in the watershed.

Table 2

Land capability classes, approximate square miles and percent of watershed area.

Land Capability Class	Approx. sq. miles	Percent
Class I	5 sq. miles	4 - 5%
Class II	18 sq. miles	15 - 18%
Class III	44 sq. miles	40 - 45%
Class IV	13 sq. miles	12 - 13%
Class V	10 sq. miles	8 - 10%
Class VI	7 sq. miles	6 - 7%
Class VII	3 sq. miles	2 - 3%

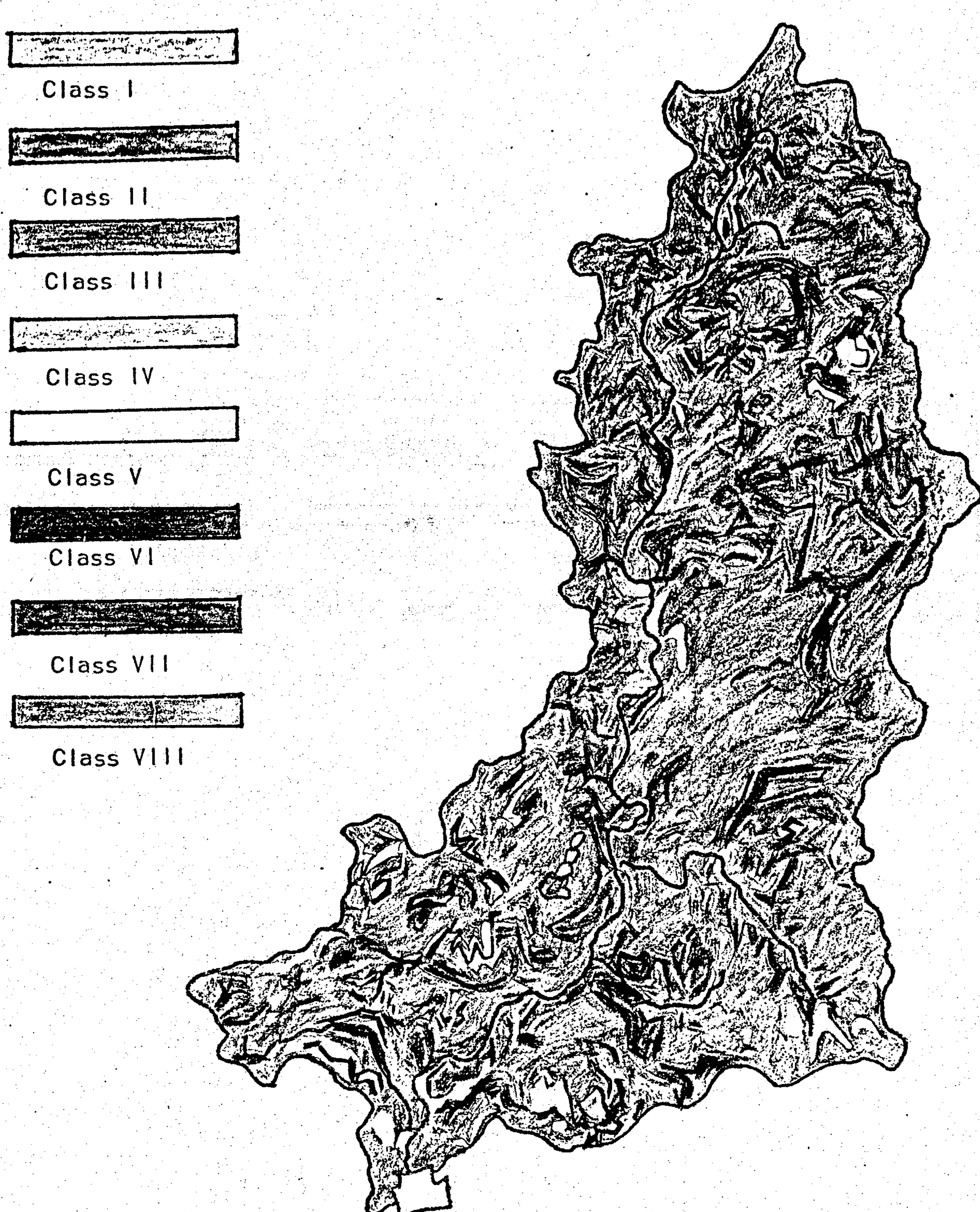

Figure 9: Land use capability in the upper Kinnickinnic River watershed

Chapter 8

SURFACE WATER QUALITY

Several indicators of water quality were monitored in the watershed. It has been shown that soil types, geology, and land use affect runoff in the watershed and also the quality of runoff water reaching the Kinnickinnic River. To monitor water quality water samples were collected weekly during the spring and summer of 1972. The sampling stations were at Highway J in the central part of the watershed, at Highway 35 at the lower end of the watershed and at the outlet of Lake George by the power plant. To assess the water quality the samples were analyzed for temperature, pH, nitrate-nitrogen, dissolved oxygen, coliform bacteria, soluble salts and sediment load.

Temperature:

Water temperatures have been recorded weekly at three stations along the route of the river during the spring and summer of 1972. See Figure 10. Water temperatures fluctuated between 11° and 13°C on the upper reaches of the watershed and 15° to 19°C in Lake George itself. Temperatures were generally higher in the lower portion of the watershed and seemed to respond dramatically to periods of wet and abnormally cold weather. Water temperatures fluctuated greatly in the early part of summer and showed a steady increase in the latter part of the summer. The temperature of the Kinnickinnic River is very consistent throughout the year because the flow is very constant and spring fed. The river is considered by most almost too cold for swimming in the summer but then again rarely ever freezes over in the winter.

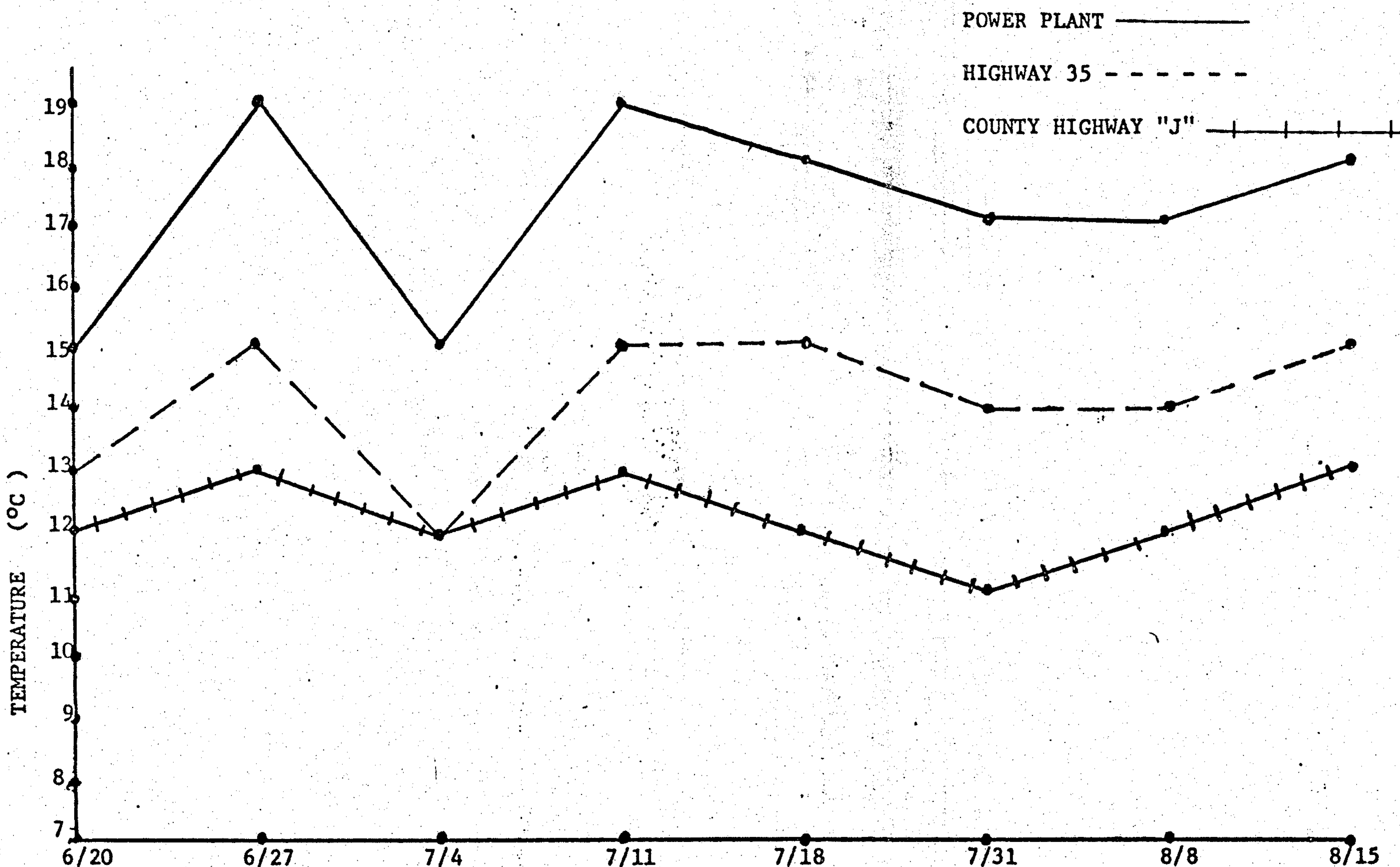

Figure 10: Water temperature in Upper Kinnickinnic River

pH:

The pH values of the stream were usually about 7.5, but these values varied from a high of 8.0 at both the Highway 35 and Highway J sites to a low of 7.0 at the power plant site, as can be seen in Figure 11. Since the ground water flow is through or on top of calcareous cambrian rock formation and glacial materials, considerable carbonates are picked up by the water cuasing higher pH values. During times of snow melt or heavy rainfall causing surface runoff to the river the pH would decrease closer to 7.0. This runoff effect would be greatest at the lower parts of the watershed as is shown by the pH values at the power plant site. At equilibrium in the latter part of the season a pH of 7.5 becomes consistent at all three sites.

Nitrate-Nitrogen:

Nitrate-nitrogen concentrations are shown in Figure 12. Nitrates (NO_3) were generally moderate and like conductivity there appears to be a relationship between high levels and periods of rain or high discharge. Nitrate readings decreased during the summer in Lake George and showed sharp rises with rainfall in the upper reaches of the stream. Since the nitrate concentrations of ground waters in the Kinnickinnic watershed are very low, low values would also be expected in the river. This is shown in Figure 12 where concentrations of .40 - .60 mg/l nitrate-nitrogen were most common during much of the summer season. At times of heavy rainfall and runoff additional nitrogen is carried into the stream from adjoining agricultural fields and barn yards as can be seen in Figure 12 with the highest concentration of .80 mg.l occurring in August. All values measured were well below the Dept. of Health standard for drinking water of 10 mg/l.

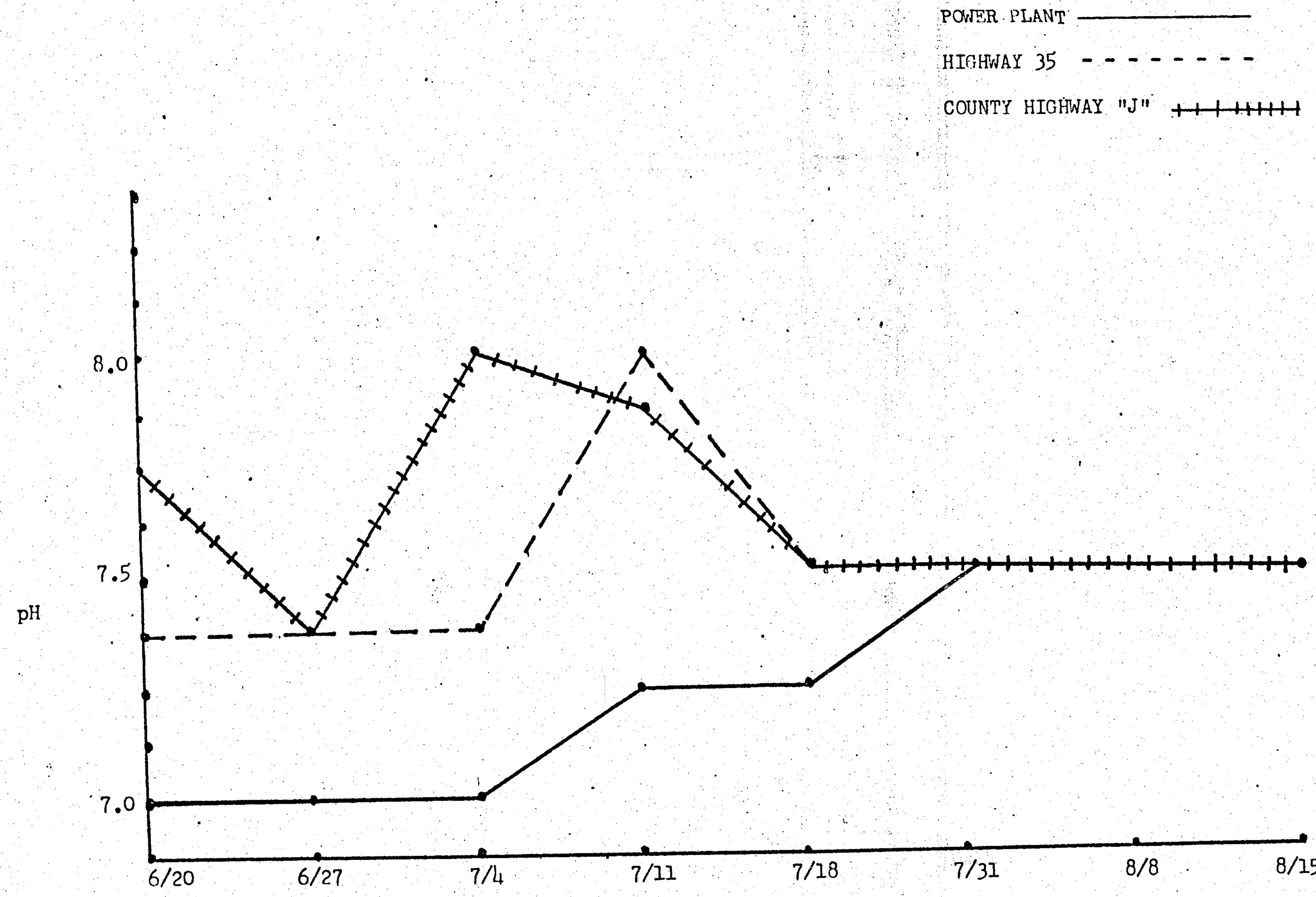

Figure 11: Measured pH of the Kinnickinnic river for 1973

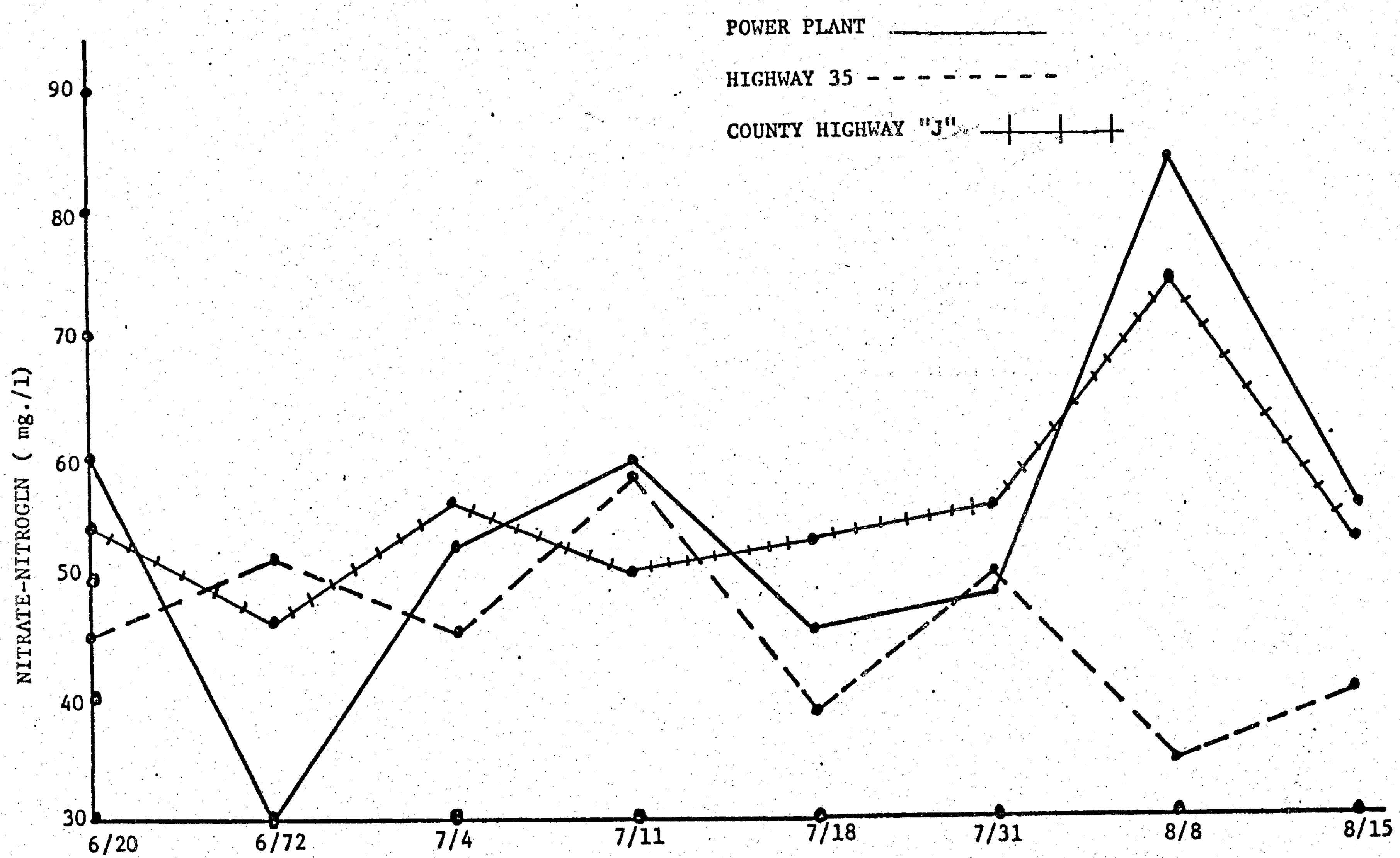

Figure 12: Nitrate-Nitrogen concentrations of the Kinnickinnic river for 1973.

Dissolved Oxygen:

Dissolved oxygen was found to remain at high levels throughout the summer, reaching supersaturation at most points along the river. See Figure 13. Lake George showed the greatest amount of variation during the summer with higher values early and much lower relative values later. Since the amount of dissolved oxygen is a function of water temperature and the amount of organic matter being decomposed, concentrations are higher at the beginning of the summer with lower water temperature and lower at the end of the summer. Again, runoff into the river will carry organic material which will have to be decomposed and also lowering the amount of dissolved oxygen.

Coliform Bacteria:

Bacteriological analysis of samples collected indicated that total coliform bacteria counts were moderate to high, ranging from 100 per 100 ml in the river to 1500 per 100 ml in Lake George. See Figure 14. Samples from Lake George were higher in total coliforms than the other stations. Counts responded to rainfall and surface runoff by increasing significantly during these periods.

The sources of coliform bacteria in a watershed such as the Kinnickinnic are extremely variable and could include such sources as barnyard runoff septic tank effluent as well as many other possible sources. There are a number of farm sites very close to the river where runoff no doubt contributes animal waste and coliform bacteria to the river. The watershed is under heavy urbanization pressure and several homes have been built along the river. In many cases inadequate on-site sewage treatment with septic tanks and filter systems allows for coliform bacteria contributions to the river.

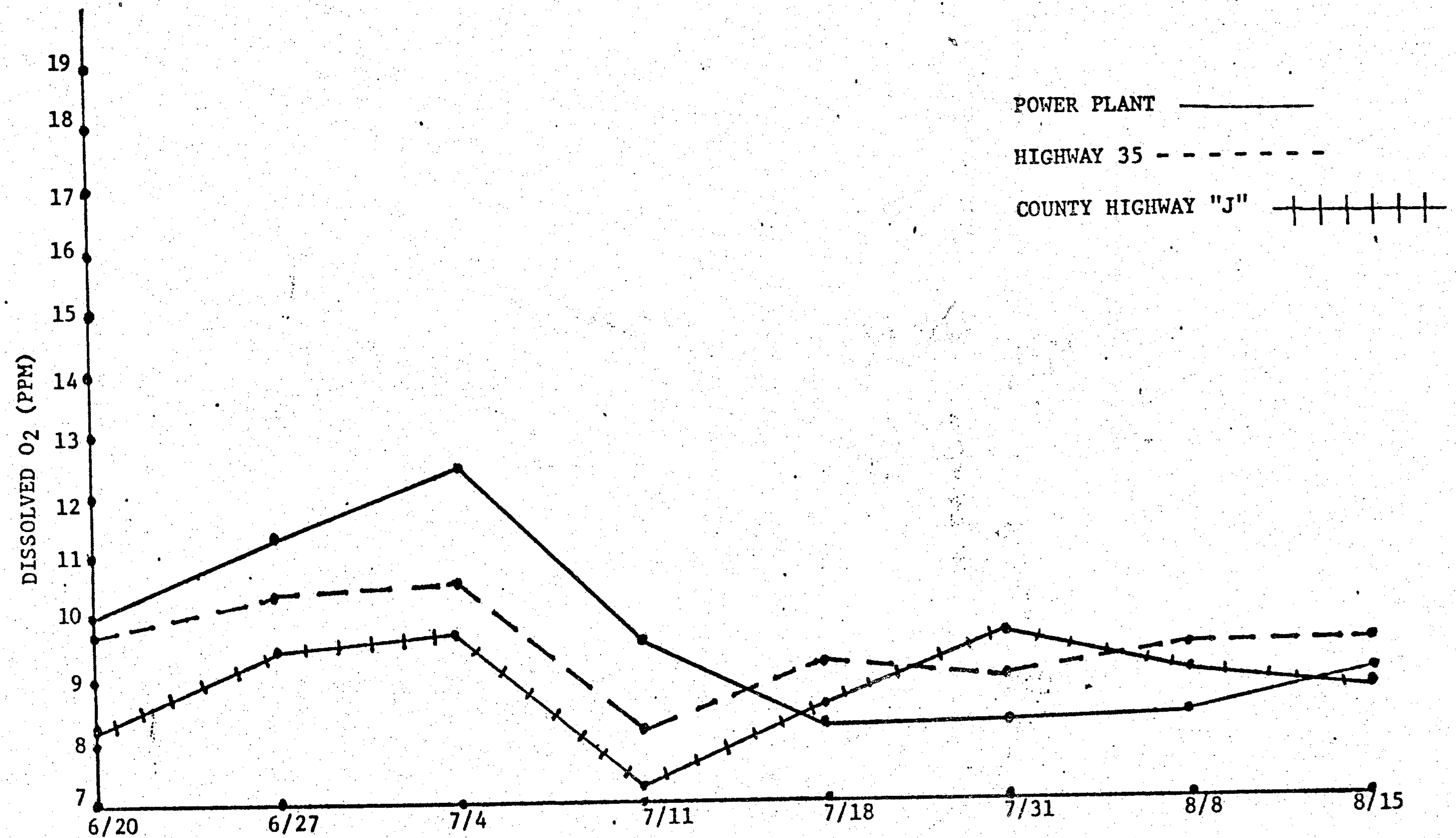

Figure 13: Dissolved oxygen concentrations of the Kinnickinnic river for 1973

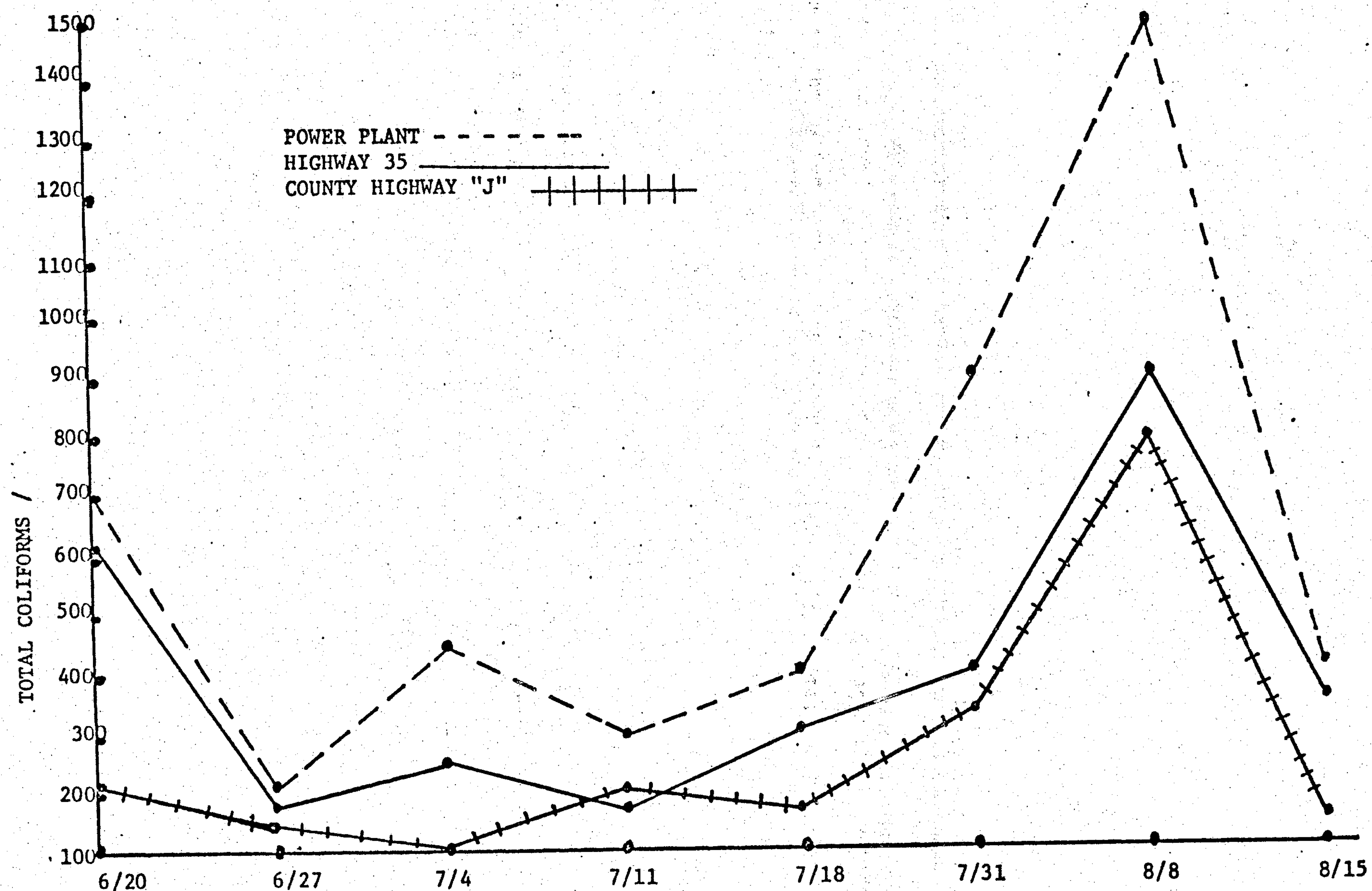

Figure 14: Total coliform bacteria concentrations of the Kinnickinnic river for 1973

Soluble Salts:

Soluble salts in water samples are most commonly determined by a measurement of specific electrical conductance and empirically relating soluble salt concentrations to this conductance. Specific conductance values of 160 to 440 micromhos at 25°C which equal soluble salt concentrations of 100 to 300 mg/liter were recorded during the sampling period. As can be seen in Figure 15, soluble salt concentrations generally increase in going from the upper part of the watershed to the lower part. Concentrations vary depending upon whether stream flow is coming from ground water or surface runoff. Since soluble salt concentrations are generally high in the ground water of the Kinnickinnic watershed comparable concentrations are found in the stream at low flow and lower concentrations at high flow. The specific ions making up the soluble salts would be Ca^{++}, Mg^{++}, Na^{+}, K^{+}, HCO_3^{-}, $SO_4^{=}$ and Cl^{-}. In general Ca^{++}, Mg^{++} and HCO_3^{-} are quite high, with Na^{+}, K^{+}, Cl^{-} and $SO_4^{=}$ present in much lower concentrations.

Suspended Sediment Measurement:

Suspended sediment were measured with a partial flow sampler which allows partial flow of water and sediment into sampler over a long period of time. To get a depth profile of suspended sediments four samplers were attached to a support so samples were taken at the surface one fourth of the distance down, three fourths of the distance down and at the bottom. A 1 liter volume sample of water with suspended sediment was collected at each depth over a 4 hour sampling period. The samples were then evaporated down and contained sediments determined gravimetrically. Dissolved solids determined by conductivity measurements were subtracted to yield just suspended sediments results obtained from sampling during March, April and May, presented in Table

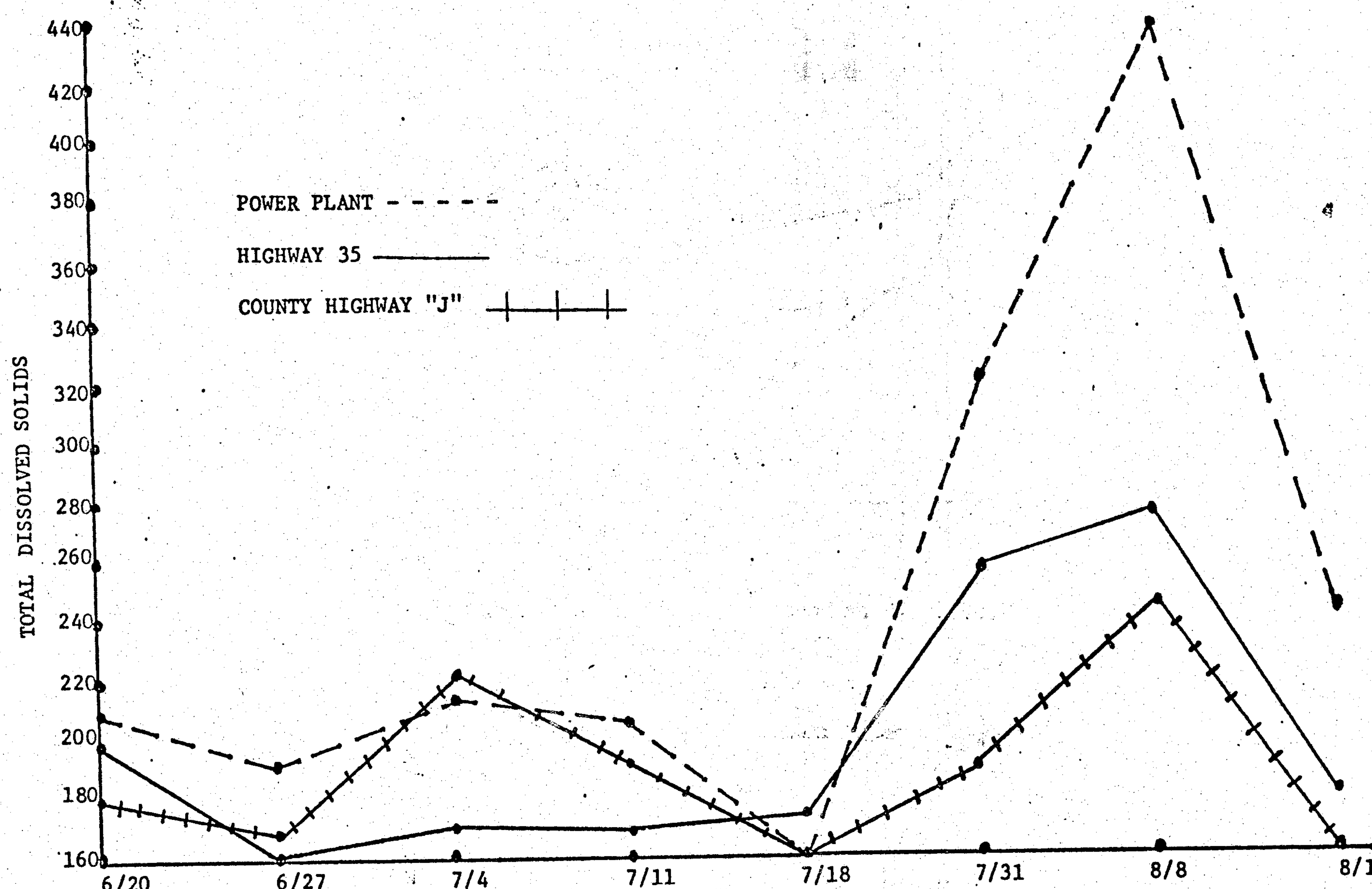

Figure 15: Total soluble salt concentrations of the Kinnickinnic river for 1973

Table 3. Suspended sediment concentrations determined from water samples taken from the Kinnickinnic River at Co. Rd. MM.

	Suspended sediment (gms/liter)			
Date	Surface	1/4 down	3/4 down	bottom
Mar. 21, 1972	.1857	.1858	.1883	.1992
Apr. 5, 1972	.1287	.1373	.1210	.1340
Apr. 7, 1972	.2186	.2011	.2194	.2110
Apr. 11, 1972	.2125	.2316	.2142	.2212
Apr. 13, 1972	.2129	.2058	.2062	.2009
Apr. 15, 1972	.2149	.2210	.2316	.2331
Apr. 17, 1972	.2297	.2360	.2430	.2408
Apr. 19, 1972	.1954	.1970	.2318	.2400
Apr. 22, 1972	.1974	.2163	.2027	.2068
Apr. 25, 1972	.2474	.2453	.2562	.2592
May 2, 1972	.2286	.2058	.1864	.1986
May 4, 1972	.2170	.2624	.2581	.2680

Suspended sediment load was determined to average .2 grams per liter during peak flow rates. Normal spring runoff produced about .1 gram per liter and summer or low flow rates yielded .002 gram per liter in suspended load. It was determined that the river experienced no more than 10 days a year at peak flow, 20 days at normal runoff and an assumed 335 days at low flow rates. This gives an average annual yield of 905 tons entering into the lake. Sediments were found to consist of a mixture of sand and silt in the upper layers grading sharply to coarse sand in the lower layers. Sediment depths averaged between 4 and 5 feet with only occasional areas exceeding 6 feet in depth.

Lake George was found to have an area of about 11.3 acres and a volume of about 30 acre feet. Inflow of sediments had an average rate of about 533 cubic yards per year. This combined with a lake volume of 435,600 cubic yards results in a projected fill in time of 817 years. This estimate, however, does not take into account bed load and vastly heavier amounts carried by 100 year interval floods. It would still seem reasonable to expect a reservoir life of about 300 to 400 years.

Chapter 9

STREAMFLOW

The Kinnickinnic River is a peaceful rural stream running about 18 miles from its beginning to where it flows into Lake George. The upper Kinnickinnic River, starting at an elevation of 960 feet above sea level, has a gradual gradient of about 6 feet per mile in contrast to the lower part of the river which has a gradient of 20 feet per mile. The upper river channel lies on top of Prairie du Chien limestone preventing downward cutting and keeping the gradual gradient about 10 miles in distance. From Lake George at an elevation of 880 feet above sea level to the Saint Croix River the Kinnickinnic River has cut through the Prairie du Chien limestone and into the Cambrian sandstone before dropping into the Saint Croix River at an elevation of about 675 feet above sea level. The Kinnickinnic River is a perennial stream with very consistant discharge. The flow is maintained by ground water drainage from fifteen intermittent tributaries and several springs along its channel. Even though its discharge is very constant during the year, it does respond rapidly to snow melt and rainfall because of very little surface storage in the watershed. Other similar rivers in the area such as the Apple and the Willow have far more wetlands and ponds for surface storage and do not respond as dramatically to rainfall. Because of this rapid response to rainfall and snowmelt a number of significant floods have occurred along the Kinnickinnic River. The average discharge of the Kinnickinnic River flowing into Lake George is about 75 cfs with a peak discharge of about 500 cfs occurring about March 15th because of snowmelt. Additional peaks in the discharge may occur in April through October depending on rainstorms. The hydrograph for the

Kinnickinnic River discharge into Lake George for the water year 1972 is shown in Figure 16. Even though the Kinnickinnic River is a quiet peaceful river several serious floods with considerable damage have occurred in the last several years. The floods of 1894, 1934 and 1965 are probably the best recorded and remembered. The flood of 1894 is probably the greatest one recorded and occurred because of a rainfall in excess of 8.0 inches in 24 hours. The rainfall frequency for 100 years in the River Falls area is only 6 inches in 24 hours. The rainstorm that occurred in 1894 must have had a recurrence interval in excess of 200 years. The flood of 1894 washed out the Maple Street bridge as well as the Prairie Mill Dam, the Green Wood Dam and the Junction Dam, all located in River Falls. Floods occurred twice in 1934, first in April with a rapid rise in temperature and melting of snow plus 3.00 inches of precipitation, and again in September when over 4.00 inches of rain fell in 48 hours in River Falls with considerably more up in the watershed. On June 1st, 1965, 7.37 inches of rain fell in River Falls with heavier amounts north and northeast causing considerable flooding and damage along the Kinnickinnic River. It is known and recorded that these floods have occurred and will occur again. The problem is that people forget rather quickly and continue to build and develop in these flood plains. It is absolutely essential that flood plain zoning laws are passed to control developing in the flood plain, therefore protecting the people and saving tax payers money. To establish what flood levels could exist in the Kinnickinnic River watershed stream flow data and watershed data have been analyzed and projected flood elevations and flood plain areas for 10, 25, 100 and 500 year floods have been established. Since actual stream flow data

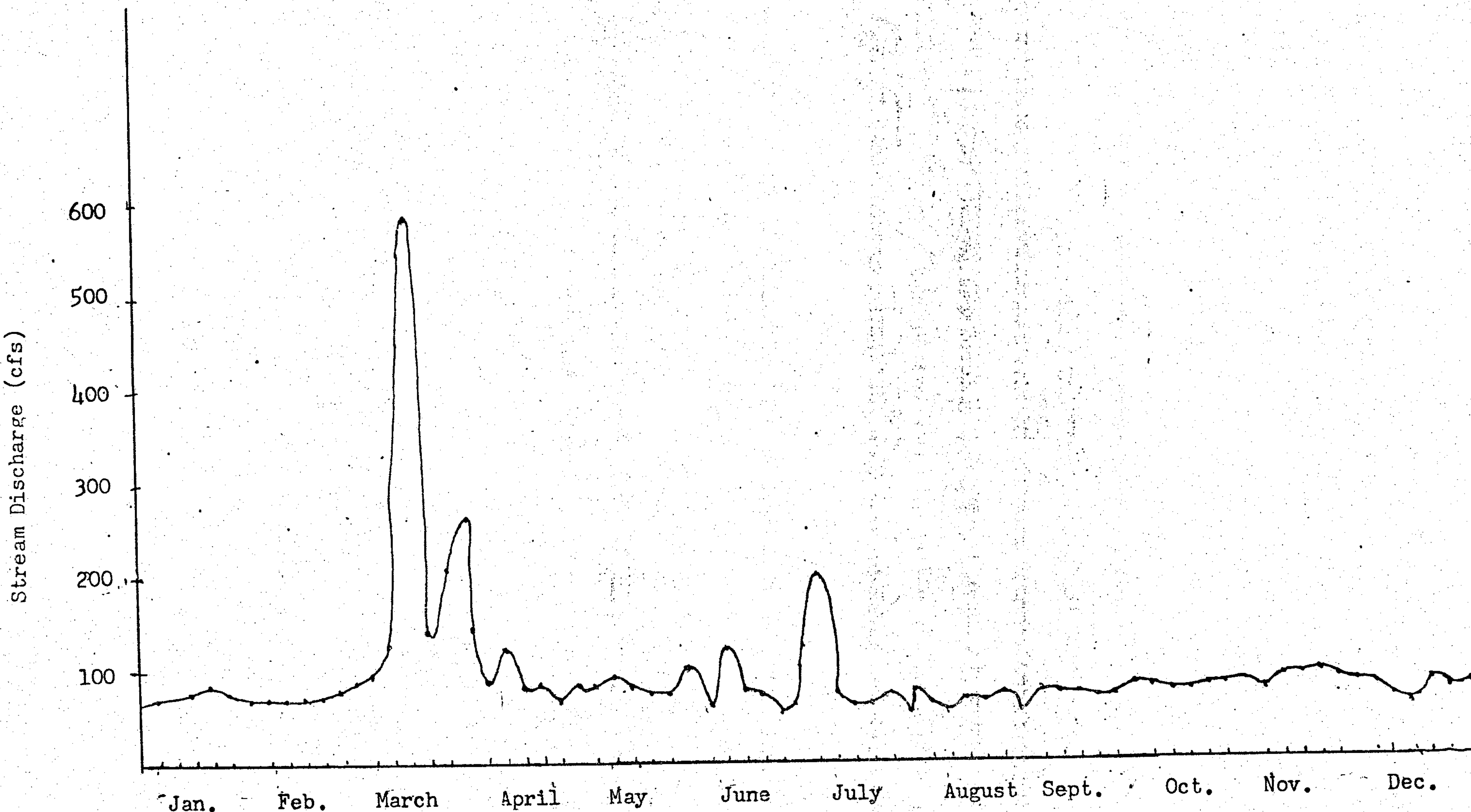

Figure 16: Hydrograph of Kinnickinnic River Discharge at inlet to Lake George for water year 1972

is quite limited values determined are estimated using the methods of the Soil Conservation Service and U.S. Dept. of Interior. The data arrived at by these procedures for the Kinnickinnic River at the County Rd. MM bridge are shown in rating curve Figure 17 and Table 2.

Table 4 Flood Discharge - Frequency Data for the Kinnickinnic River

Discharge (efs)	Recurrence Interval (years)	Frequency (%)	Elevation of Flood Water above sea level
4,200	10	10	883.4
5,900	25	4	885.6
7,200	50	2	887.0
8,600	100	1	888.3
9,900	500	.2	890.0

Based on the calculated data more extreme flooding than has been experienced in the last 50 years could be expected in the Kinnickinnic watershed. According to these data the flood of June 1, 1965 had a recurrence interval of less than 50 years and the one of 1934 equal to about a 100 year flood. The importance of this information lies in what will be done in flood plain zoning to protect the people in the watershed and maintain environmental quality. For the purpose of showing administrators, planners, and engineers concerned with future land development what areas are in the flood plain the U.S. Geological Survey has prepared flood prone area maps. The flood prone area map for the upper Kinnickinnic River is shown in Figure 18. The flood prone area is the land area that has a 1 in 100 chance on the average of being inundated with water or one can say is within the 100 year flood plain area. Zoning ordinances need to be adopted to prevent improper development in this flood plain area. Certain types of land

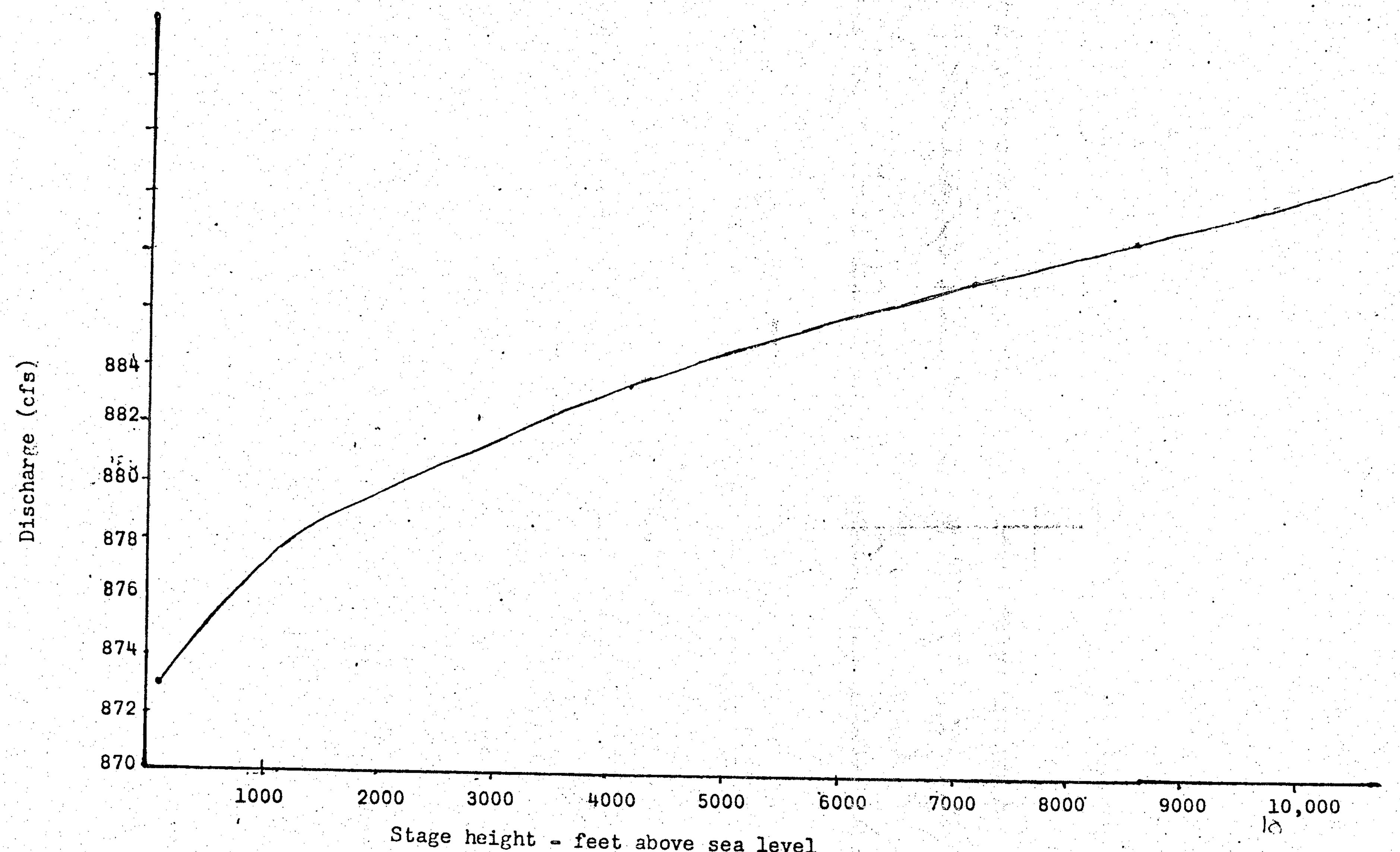

Figure 17: Rating Curve for Kinnickinnic river at Count Road MM bridge.

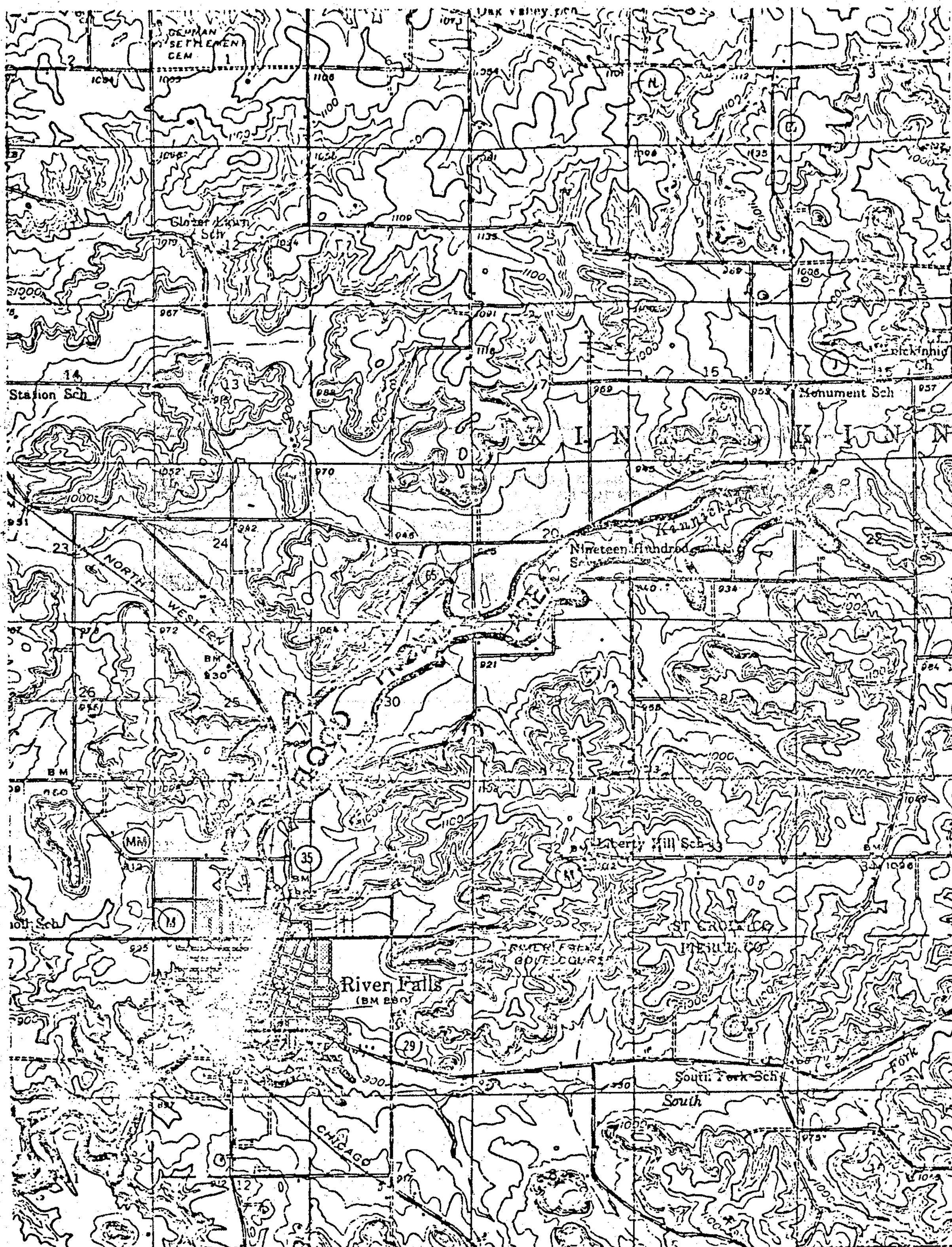

Figure 18: Flood prone area along Kinnickinnic river from River Falls north to County Road J.

use such as parks, agricultural and recreational would be acceptable but no permanent housing should be allowed. A good example of an improperly designed subdivision is Danate Park located along the Kinnickinnic River just north of the city of River Falls. Danate Park is a planned and approved subdivision of 30 lots with 14 of the 30 lots falling entirely within the 100 year flood plain area. In addition to the 14 there are also 5 lots that also partially fall within the 100 year flood plain area. This subdivision, when plotted and submitted in 1961, was approved by the city of River Falls, the town of Troy, the county of Saint Croix and the state of Wisconsin Department of Resource Development. See Figure 19 showing the Danata Park subdivision, lots and area which would be inundated with a 100 year flood. The predicted elevation of the 100 year flood would be about 888 feet above sea level; see Table 2. The average elevation of Riverside Drive and lots 4, 5, 21,22,23 and 24 is about 881 feet, putting them 7 feet under water in the 100 year flood. In 1965 a flood of about a 50 year recurrence interval, water level 887 feet above sea level, occurred on the Kinnickinnic River. Lots 4 through 12 and 21 through 24 with an average elevation at that time of 881 were covered with water. Recorded markings on trees and other observation points have checked out with the predicted elevation of 887 feet above sea level. The developer seeing the problem of flooding on several of the proposed lots had several yards of fill hauled in to raise the elevation of lots 6, 7, 8, 9, 10, 11, 12, 21, 23 and 24 to 886 feet above sea level, hopefully in his mind high enough to be usable lots. No one has yet built on the lots in the flood but a number of people have tried. They have been turned down on a sanitary permit basis, not on a flood plain basis.

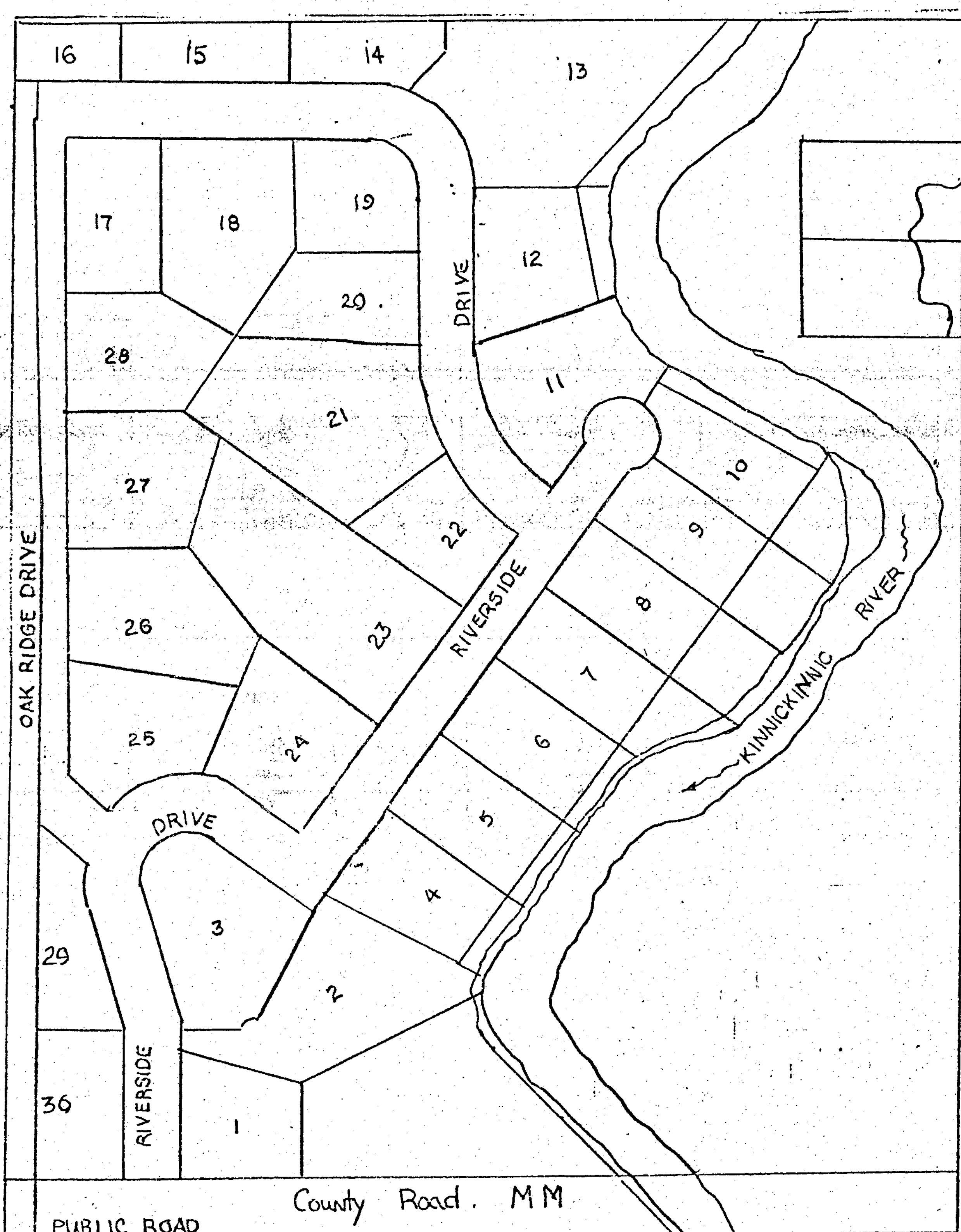

Figure 19: Danate Park Subdivision along Kinnickinnic River at north edge of River Falls city limits.

Indications of the county zoning administrator were that if the area was annexed by the city and city sewer became available these lots raised to 886 feet above sea level could be built upon. It would be unfortunate if any homes are built in this flood plain, one does not change a flood area by just raising the elevation and in this case the elevation is still well below the 100 year flood. This is just one example of several similar cases along the Kinnickinnic River where tremendous pressure is being placed for rural homesites along the peaceful Kinnickinnic River. People too soon forget the problems and costs of flooding of homes and therefore strict flood plain zoning must be developed to protect the environmental quality of the Kinnickinnic River and its watershed as well as the people living in the watershed.

Chapter 10

DAMS BUILT ON THE KINNICKINNIC RIVER

During the history of the city of River Falls and the Kinnickinnic River several dams have been built on the river for one purpose or another. These dams during the years have held back water and collected sediment changing the environment of the river. When the dams were washed out large amounts of sediment were washed downstream also influencing the river channel. The characteristics of Lake George, a reservoir formed by a dam, have been affected over the years by the other dams built on the river. Figure 20 shows the various dams that were built on the river and their approximate location.

The first dam was built in 1854 by C.B. Cox a few hundred feet south of where Division Street would have crossed the Kinnickinnic. The remains of the dam can still be found to this date. The dam was built to provide power for a grist mill. The dam had a height of around 18 feet. This dam was owned by several people and probably can best be identified by the name of the Prairie Mill Dam. This dam was used for about 40 years until it was washed out in 1894 by a cloud burst. This dam was never rebuilt.

The next dam moving south downstream was built in 1858 by George Fortune. It was known as the Fortune Dam and later it was purchased by a Green Wood and was known as the Green Wood Dam. The dam site was located a few hundred feet south of the Maple street bridge behind the present site of the Hotel Walvern. This dam was the smallest dam and only had a height of around five feet. This dam also washed out in 1894 when the Prairie Mill Dam burst. This dam was never rebuilt. When the Junction Dam was built in 1867, the Green Wood dam was covered up by the Junction dams back waters.

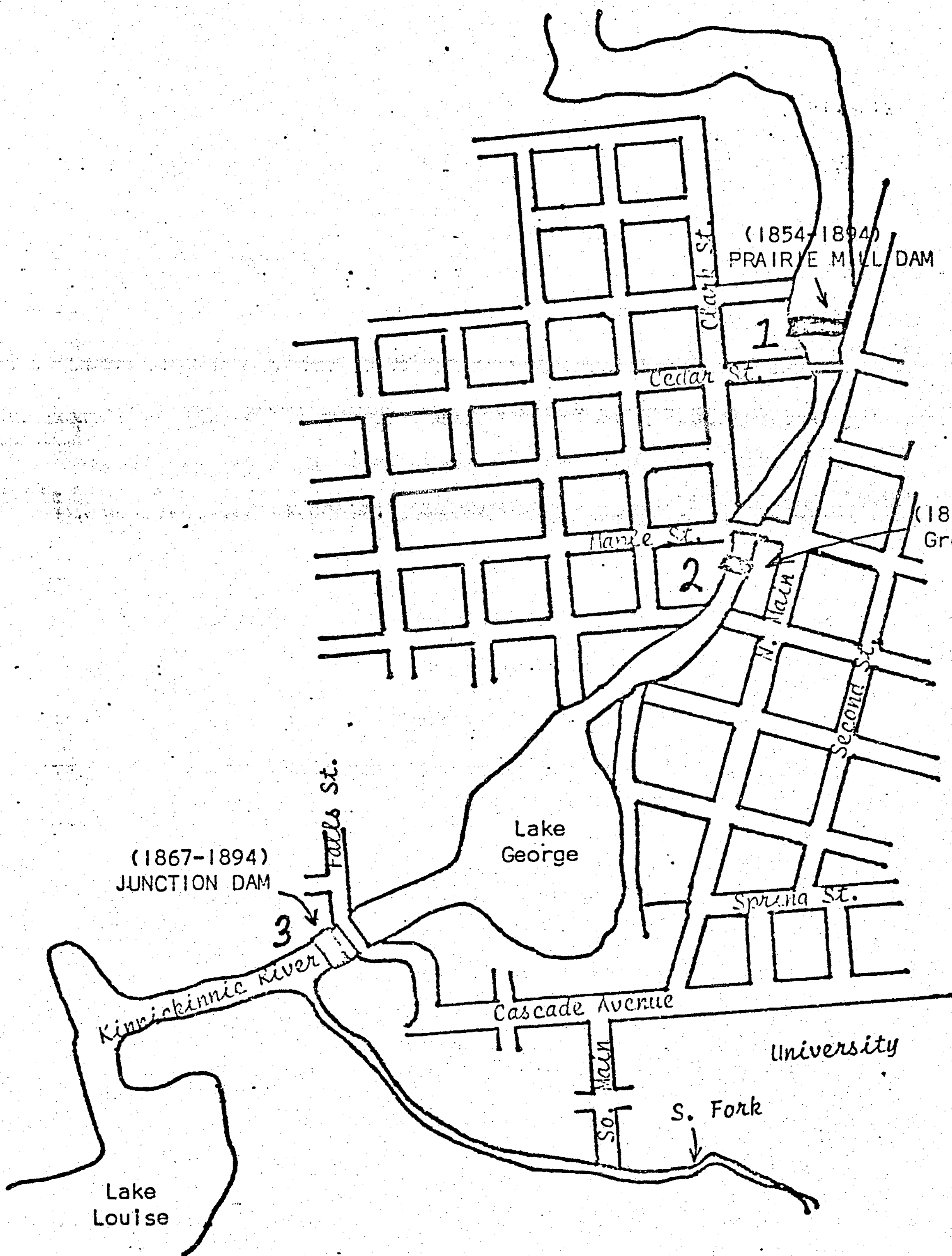

Figure 20: Dams and Reservoirs on the Kinnickinnic River

The next dam which actually formed Lake George was built in 1867 and was known as the Junction Dam, which was located at the present site of where the power plant is today. The Junction Dam had a height of around 15 feet. This dam also washed out in the cloud burst of 1894. This dam, however, was rebuilt, and the dam site is being used by the present River Falls Power Plant.

Lake George also had an island in it and at one time, people lived on the island. The buildings and the island were also swept away in the cloud burst of 1894.

The information about the dams was obtained from back issues of the River Falls Journal, River Falls history pamphlets from the stated historical society, and interviews of three residents, M.A. Shepard, age 91, Burt Symes, age 97 and Bill Kohl, age 91, all from River Falls. The interviews provided ample information not only of the dams in River Falls, but also some history of Clifton Hollow, Dams on the South Fork of the Kinnickinnic, the dam at Martel, and early history of River Falls.

Chapter 11

LAKE GEORGE

Lake George is an acre reservoir formed by the power dam at site number 3 in Figure 20. It is a pleasant little lake and could have great recreational value because of its location in the city of River Falls. This recreational value can only be enjoyed if the shoreline of the lake is improved and lake sediments dredged out to improve lake depth and water quality. Before making these improvements a very complete study of the lake must be made.

Contour Map of Lake Bottom:

To determine a lake bottom contour the work was done in the winter when the work could be done on top of the ice. A grid pattern was first layed out on the ice. This was achieved by using a transict to first establish a baseline between two land marks that would run the length of the lake. The baseline ran in an east-west direction. On the baseline and 200 feet from the east shore, the first north-south line was established. After the north-south baselines were established the grid was completed using a length of string 200 feet long which was marked off in 25 foot lengths. At each crossline a "X" was made on the ice with the use of furnace ashes. With the grid completed, the next step was to determine the lake contour.

A gas powered ice auger was used to drill the many holes through the lake ice. Holes were drilled on an interval of 50 feet as it was determined that the lake bottom was not sloped enough to warrant drilling at intervals of 25 feet. To measure the depth of water, a pole was fabricated from scraps of wood found in the Directors garage. A large base was attached to the pole to prevent inaccuracy due to pole sinkage. The pole was marked off in inches to achieve accurate results. The system to determine where each point was located was as follows; the main baseline which ran east and west was considered as "0". The east-west lines parallel to the main line were numbered in succession. The number one line would be on both sides of the main line and 25 feet from the mainline. The second line would be on both sides of the mainline and 50 feet from the mainline. Lines which ran perpendicular to the mainline or in a north-south direction were numbered in succession, with the first line being closest to the east shore on the mainline. To better illustrate the system an example of 6R10 will be explained. The six means the sixth interval from the east shore on the main baseline, R refers to the right side of the baseline when facing a west direction. 10 refers to 10 intervals to the right or north of the baseline. So 6R10 is 150 feet away from the east shore on the main baseline and 250 feet right or north of the baseline.

At each drilled hole the depth to the lake bottom was measured and recorded in the manner described above. From this information a contour map was made of Lake George. See contour map of lake bottom shown in Figure 2I.

Lake Bottom Sediments:

The next step in the project was to determine the depth of sediment or the thickness of material down to bedrock. The procedure here was to use a long rod, which was found someplace, and ram it into the sediments until a solid barrier was encountered. The length of rod driven into the lake was measured. To determine the amount of silt material, the depth of water at that point was subtracted from the length of rod driven into the lake. From this data a contour of the bedrock can be drawn and also the volume of loose material in the lake can be calculated.

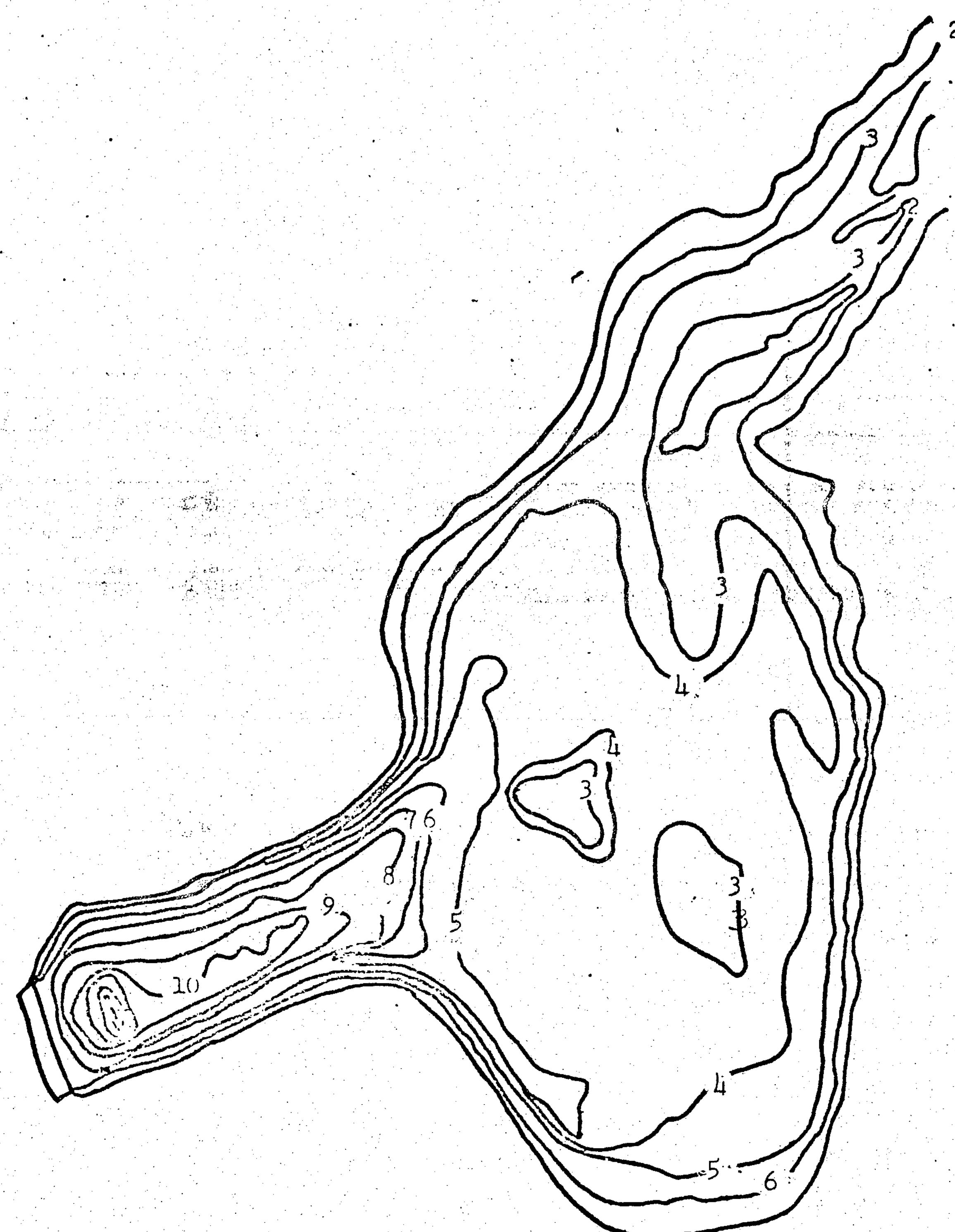

Figure 21: Countour map of Lake George showing the depth below surface in feet.

In this area of the project there were more problems than in the water depth area. I feel it would be of benefit to list and discuss them here. The first one is that the rod used to ram through the sediments was not of heavy enough construction. As a result the rod would bend when driven into compacted material. The rod did not weigh enough and was difficult to ram to the bedrock in many cases. After the rod was too bent to be used it was discarded and replaced by a 20 foot Re Bar. This one-half inch steel rod was an improvement.

The last area of work on the lake was to obtain samples of the sediment down to the bedrock, to be analyzed for percent of sand, silt and clay. The problems with this project were almost unlimited. With the tube equipment from the University, the sediment would either fall out of the tube before it was raised to the surface or if the material stayed in the tube there was no way to get the core out of the tube without drying the material for several days. The tube worked "OK" in places where the material was soft, but where the sand was deposited the tube had to be driven into the sediments which resulted in several sheared bolts and almost losing the tube. This system was not used for further testing.

Because the hole would fill up as the tube was pulled out of the sediments a three foot long tube was of little value in taking samples of sediments which were nearly ten feet deep. A two inch well pipe was then used in hopes of getting intact samples down to the bedrock. But this did not work either. The problem was that the pipe could not be driven into the sediment beyond several feet. The material brought up to the surface inside the tube was nearly impossible to remove. The core sample was much altered when it was finally rammed from the tube.

As a result of these unforeseen problems the amount of data on sediments is very limited. The samples which were taken from the lake were brought to the lab and analyzed for percent sand, silt and clay.

While data about the lake was being collected, the warmer spring winds started to blow from the south. The snow cover on the lake turned to five inches of water and the ice became honeycombed. Then shortly thereafter while taking a core sample the police started to shout from shore which ended all activities on the lake. This data collection took place during the first half of March 1972.

The last part of the project was to determine the amount of material being carried in the river. This data is important because it is used as a rule to estimate the amount of sediment being deposited in the lake each year. From this data the feasibility of using Lake George as a recreational lake can be determined.

An unforeseen drawback with this project was the early spring. The peak runoff was during the middle of March which is about one month ahead of the usual peak period. Because of the early runoff, water sampling did not include the days of highest runoff.

The equipment used to take water samples were pieces found at the Director's home. Fruit jars with covers were used to take the samples. The covers had two holes in them, one hole for the water to enter the jar and the other to allow the air to escape. The holes had to be small so when the jars were lowered into the river they would fill at a slow rate to get an accurate sample. Four jars were used for sample collection, with each sample being taken at a lower depth than the one before it. This was to determine if the river was carrying different amounts of sediment at different depths. The jars were tied to a long pole to allow the samples to be taken at the bottom of the river and also near the swiftest part of the river. A bench from a picnic table was slid into the water which enabled me to walk into the river to collect samples. When the samples were collected they were taken to the lab for analysis. The first step was to determine the volume of the sample. This was done by pouring the sample into a marked 1000 ml cylinder. The sample was then poured into a washed and weighed jar and placed in an oven to evaporate the water leaving the sediment behind. With the water evaporated the jar would be removed from the oven, cooled to room temperature which also allowed the humidity to reach equilibrium. The jars were then weighed to determine the amount of sediment in each sample.

In addition to the water samples the river was recorded in other ways. River velocity was recorded several times and also the river stage was recorded many times. To get volume flow the contour of the river was determined at the point where the water samples were taken.

Enlarged photos were made of the lake from prints from the Soil Survey of Pierce County. These photos will be used to record much of the data gained from the lake study. Data such as the contour map and also the sediment depth contour map.

Some of the problems associated with this project I feel should be recorded in hopes that future projects will be designed with these problems in mind. The first one is that this project required more than one person many times to do the work. The problem was that only work-study students were involved in the project which were very difficult to get organized because of tight schedules.

The equipment used was many times just junk found along the way which didn't work too well. A lot of time was used in making equipment.

Testing equipment was almost always locked up. This required much time to be wasted finding a key or waiting until a key was available. These problems along with others required much time to be wasted just getting to work. In the future I would recommend having funds available so a non work-study student could work on the project when needed. Also the student and the director should have a certain time each day to discuss the progress of the project. Any student employed as a work-study student should have a key so he can get to work on time any day, as many of these projects cannot be stopped for lunch, 4 P.M. closing or weekends when the room is not used for classes. Also much of the work must be done on weekends when students are more available, so keys should be available so the student does not have to store the equipment in his apartment or call and drive around town to find someone with a key to open the doors.

Chapter 12

SUMMARY AND CONCLUSIONS

The first rod used to determine the amount of sediment in the lake was insufficient. It was too thin and of very light construction. When rammed into the silt material the rod would tend to bend under the downward pressure. Therefore the accuracy of the measurements using this rod is a bit limited. However, on line 9 and points 1,3,4, and all points thereafter a different rod was used. A 20 foot Re Bar was purchased from the local lumber yard. This was an improvement but, with limitations. The surface of the rod was very rough and of heavy construction. These limitations made the rod hard to ram into the silt material. Many times while using both rods a solid bottom could not be reached. In these cases the material became too stoney or compacted for the rod to be driven deeper into the sediment.

The measurements obtained can be used as a general rule as to the amount of sediment in the lake bed.

One area which I think should be looked into is the runoff from the city. Runoff from rains and spring melt contain considerable amounts of silt material. This material perhaps would have little effect on silting in the lake but would increase the turbidity of the water.

During the summer I wrote a letter to SCSA in Iowa, asking for information on inland lake problems. I received a reply from John Stall, an engineer for the Illinois State Water Survey. He stated that to prevent rooted aquatic vegetation from growing a depth of over five feet is necessary. He also stated that any lake fairly protected from wind will have algae growing in it.

My conclusion, and based on the information now known, is that the lake could be deepened several feet so that the water depth would be over five feet at all points to prevent rooted aquatic plants from growing. The excavated material could be used for a boat launch ramp and also to make the lake more useful during winter months as ice thickness reaches nearly three feet thick. Winter uses could include snowmobiles and skating in the proper places. Water contact sports should not be allowed until more data on water quality is available. City runoff together with poor farming practices such as those on the farm north of the Highway 35 bridge may produce poor water quality which would prevent the use of the lake for contact sports.