Kentucky Geological Survey.

Bulletin No. 21
Serial No. 28

THE VALUE OF THE DIX RIVER
AS A
SOURCE OF WATER POWER

1912

Kentucky Geological Survey

CHARLES J. NORWOOD, Director.

BULLETIN No. 21

SERIAL No. 28

Report on

The Value of the Dix River

AS A

SOURCE OF WATER POWER

By AUGUST F. FOERSTE

Field Work Done in 1910-'11

Printed by Interstate Publishing Co.

1912

CONTENTS.

TABLES AND DIAGRAMS.

LETTER OF TRANSMITTAL.

His Excellency, AUGUSTUS E. WILLSON,

Governor of Kentucky.

Sir: I have the honor to transmit for publication a report on the value of Dix river as a source of water power, by Dr. Aug. F. Foerste. The field work for this report was done chiefly in 1910, with visits to the field in the early part of 1911. The report was made ready for publication in 1911.

Very respectfully,

CHARLES J. NORWOOD,

September 30, 1911. *Director, State Geological Survey.*

LETTER OF SUBMITTAL.

PROF. CHARLES J. NORWOOD,

Director, Kentucky Geological Survey.

Sir: I have the honor to submit herewith a report on the availability of the Dix river as a source of high pressure water power. This report represents a part of the work done during the summer of 1910. It necessarily is preliminary in nature, since no effort was made until the summer of 1910 to secure definite data regarding the daily gage height or rate of flow of the Dix river. Early in July of that year I visited Mr. A. H. Horton, District Engineer of the Water Resources Branch of the United States Geological Survey, at his office in Newport, Kentucky, and borrowed from him the Price current meter by means of which the rate of flow of the river was determined. I am under great obligations to Mr. Horton for many valuable suggestions. The first measurements were made in the company of Mr. L. B. Herrington and Mr. Bogart, both of Richmond, Kentucky, and these gentlemen continued the work later. My own attention has been directed chiefly to the problem whether there was any great danger of leakage of the waters, to be held up by a high dam, towards the Kentucky river. No evidence of such danger was discovered. Whether the rainfall is sufficient to supply the reservoir to be held up by the dam with ample water during the dry months is a problem for the engineer to solve. By inaugurating daily records of gage heights of the river, and occasional accurate determinations of stream flow, a beginning of a basis for such a solution has been made. The records of a series of years will be necessary to give absolutely safe results. In the mean time I desire to call attention to the very dry months of July and August in 1911. These months represent very well the dangers from a long continued dry spell. On bringing this matter to the attention of Mr. Arthur Giesler, a competent hydraulic engineer of Dayton, Ohio, I was informed that sufficient water could be impounded during the wet months to tide over the dry ones. It is on my faith in Mr. Giesler's judgement, rather than on my own information, that I found my belief that the Dix river offers one of the best opportunities for developing a high pressure water power within the state of Kentucky.

Very respectfully yours,

AUG. F. FOERSTE,

Assistant Geologist.

INTRODUCTION.

The following observations were begun with a geological investigation of the Dix river area, with a view of determining the influence of the geologic structure of this area upon the feasibility of erecting a high pressure water power plant at Kennedy's mill, about 5 miles east of Burgin, in Mercer county, Kentucky. However, since it soon became evident that an accurate series of observations on the stream flow of the Dix river at the proposed dam site would be of absolute necessity to the answering of many of the questions proposed, it was considered highly advisable not to delay the inauguration of such a systematic investigation of the stream flow of this river, and the assistance of the United States Geological Survey was sought. The Hydrographic division of that Survey, through Mr. A. H. Horton, in charge of the division with headquarters at Newport, Kentucky, promptly offered the loan of a Price Current Meter, which was accepted by Mr. L. B. Herrington, a gentleman who has given a strong impulse to the development of the Dix river dam project.

Mr. Harrington has arranged for the taking of daily gauge readings at the bridge below the mill, and has himself undertaken the securing of the data regarding stream flow, with the use of the Price Current Meter.

The result will be an early substitution of accurate data on stream flow for the usually very inaccurate figures secured by taking a certain percentage of the total rainfall.

Nevertheless, observations on rainfall, if not used to secure data for which they are only moderately well adapted, have some value, and a few of the most readily available statistics are here appended.

CLASSIFICATION OF STRATA WITHIN THE DIX RIVER DRAINAGE AREA.

Total Thickness About 2800 Feet.

Systems.	Larger Groups.	Formations.	Members.	Feet.	Lithological Characteristics.
Pennsylvanian.	Pottsville 500 feet.		Lee	500	Sandstone, with large conglomerate lentils thinning westward.
Mississippian 700 feet.	Chester 180 feet. Thinning westward and northward.	Kaskaskia	Leitchfield	40	Upper half, limestone lower half, chiefly clay.
				30	Limestone.
		St. Genevieve.	Maxville	60 50	Limestone. Limestone, chiefly oolitic.
	Meremac. 125 feet.		St. Louis.	90	Limestone, frequently cherty, thinning westward and northward.
			Atherton.	35	Limestone and clay, thinning eastward. Belongs below the typical oolitic Salem limestone but contains the same fauna.
	Waverly. 375 feet.	Keokuk.	Harrodsburg	30	Limestone and clay, thinning eastward.
			Brooks or Knobstone.	330	Argillaceous shales, more indurated and sandy toward the top, softer, and more clayey towards the base, merging into the underlying clays.
		Kinderhook	New Providence.	45	Softer clays.
Devonian, 100 feet.	Bradford and Seneca.		Ohio.	80	Black shale, thinning westward.
	Ulster.		Jeffersonville.	20	Limestone, often cherty.

Classification of Strata Within the Dix River Drainage Area.

(CONTINUED.)

Systems.	Larger Groups.	Formations.	Members.	Feet.	Lithological Characteristics.
Silurian. 170 feet.	Niagaran.	Clinton.	Alger.	140	Chiefly clay.
			IndianFields	15	Limestone and clay.
			Brassfield.	15	Limestone. Corresponds to Clinton of Ohio.
Ordovician. 1350 feet.	Cincinnatian 570 feet.	Richmond 165 feet.	Elkhorn Whitewater Liberty.	70	Clay at top. Chiefly argillaceous limestones. Columnaria horizon at base.
			Waynesville	65	Argillaceous limestone, thinner bedded below, often shaly.
			Arnheim.	30	Rubble limestone, fossiliferous: 5-10 feet. Finegrained limestone: 3-6 feet, disappearing westward. Shaly argillaceous limestone: 7-17 feet, disappearing westward.
		Maysville. 265 feet.	Mount Auburn.	10	Rubble limestone with Platystrophia ponderosa abundant, disappearing westward as distinct horizon.
			Corryville.	80	Upper part, chiefly finegrained limestone: Gilbert limestone. Lower part, about 30 feet thick, unfossiliferous shaly argillaceous limestone: Tate layer.
			Fairmount	75	Fossiliferous limestones often rubbly. Orthorhynchula in upper layers. Strophomena maysvillensis very abundant toward base.

Classification of Strata Within the Dix River Drainage Area.

(CONTINUED.)

Systems.	Larger Groups.	Formations.	Members.	Feet.	Lithological Characteristics.
Ordovician 1350 feet.	Cincinnatian 570 feet	Maysville continued.	Mount Hope	30	Interbedded argillaceous limestones and clays with Strophomena maysvillensis only in moderate numbers. Upper Garrard
			Paint Lick.	70	Sandy argillaceouslimestone, massive, lower Garrard.
		Eden. 120 feet.	Million.	120	Chiefly clay with interbedded limestones thicker and more numerous in upper part.
		Catheys. 20 feet.	....	20	Upper part fossiliferferous limestones. Lower part, less fossiliferous, argillaceous limestones locally.
	Trenton 240 feet.	Lexington. 240 feet.	Perryville	30	Coarsely granular Cornishville limestone, with Strophomena vicina and Dinorthis ulrichi: 5-7 feet. Exceedingly fine grained white limestone: 5-7 feet. Gray or bluish Faulconer limestone, with cherty layers full of gasterpoda locally; 15 feet.
			Paris	75	Coarsely granular limestone, phosphatic near the top.
			Wilmore	120	Granular limestone, similar to the Paris bed, but withan abundance of Prasopora simulatrix and of Dalmanella.
			Logana	15	Fine grained argillaceous limestone, and clay.

Classification of Strata Within the Dix River Drainage Area.

(CONTINUED.)

System	Larger Groups	Formations	Members	Feet.	Lithological Characteristics.
Ordovician 1350 feet.	Black River 120 feet	Lower Lexington of Richmond folio.	Curdsville.	30	Coarsegrained limestone, upper layers cherty and richly fossilliferous locally.
		Upper Highbridge.	Tyrone.	90	Exceedingly fine-grained limestone.
	Stones River, base not exposed 310 feet.	Lower Highbridge about 310 feet.	Oregon, or Ky. River Marble.	25	Fine grained limestone in even bedded layers, dolomitic.
			Campnelson.	285	Exceedingly fine-grained limestone, with a total thickness of about 400 feet of which the lower part is not exposed. Forming massive beds.

Ulrich regards the Tyrone as equivalent to the Lowville of New York, and, therefore, as belonging to the base of the Black River rather than to the top of the Stones River group. Lithologically, however, practically it is identical with the underlying Stones River and could be distinguished only by the expert student of fossils.

THE VALUE OF DIX RIVER AS A SOURCE OF WATER POWER.

Elevations of Water Level Along Dix River Channel.

On the map known as the Harrodsburg sheet or quadrangle, published by the United States Geological Survey in 1905, the elevation of the water level in the Kentucky river at Lock No. 7, at High Bridge, is given as only slightly in excess of 500 feet above sea level.

The Dix river empties into the Kentucky river immediately above High Bridge, and the slack water due to Lock No. 7, in the Kentucky river, extends for about 2 miles up the channel of the Dix river. From this point the river level rises as far as Kennedy's mill, at the crossing of the road from Burgin to Buena Vista. The dam at Kennedy's mill creates slack water for another section also about 2 miles in length, after which the river rises again up stream by a succession of numerous riffles interrupted by limpid pools or by longer stretches of water in which the current is comparatively slow.

Above the dam, at Kennedy's mill, the water level is approximately 550 feet, a rise of 50 feet in the distance of 8 miles measured along the windings of the river from its mouth. The elevation of 600 feet above sea level is reached exactly east of Faulconer, and about a mile south of the point where the boundary line between Mercer and Boyle counties strikes the Dix river. This is equivalent to a rise of 50 feet in a distance of 10 miles measured along the river course, or the same elevation along 8 miles measured from the head of the slack water above Kennedy's mill.

From this point, a mile south of the Mercer-Boyle, boundary line, the river rises much more rapidly. The elevation of 650 feet above sea level is reached at Davistown, a rise of 50 feet in 6 miles. The elevation of 700 feet above sea level is reached directly east of Danville, at the more eastern bend of the river, a mile and a half in a direct line north of Hedgeville. This is equivalent to a rise of 50 feet in six and a half miles.

Effect of Dam 130 Feet High at Kennedy's Mill.

The locality last mentioned lies about 2 miles up stream from the Danville Water Works dam. The river bed immediately below the dam lies approximately at 680 feet above sea level or 130 feet above the level of the water in the area above the dam at Kennedy's mill. From this it is evident that a dam rising to a level 130 feet above the present dam at Kennedy's mill would hold back the water as far as the Danville Water Works, a distance measured along the river course of about 20 miles.

Possibility of Erecting a High Dam at Kennedy's Mill.

The possibility of erecting a dam of these dimensions at Kennedy's mill becomes apparent at once when the elevations of the rocky walls bordering the Dix river gorge in the vicinity of this mill are examined.

Both above and below the bridge at Kennedy's mill, the rocky walls of the Dix river gorge attain a height of 750 feet above sea level on immediately opposite sides of the gorge at several localities where the walls of the gorge are nearly vertical, and where the width of the gorge is comparatively narrow. As a matter of fact, localities can be selected in which the walls on opposite sides of the river spread so little at the top that dams attaining an elevation of 800 feet above sea level could be erected, at comparatively moderate expense when the great height of the dam above river level is considered.

A dam attaining an elevation of 750 feet would hold back the waters as far as the turn of the river one mile north of the road from Danville to Lancaster, by way of Hedgeville.

The data supplied in the preceding lines have been taken from the Harrodsburg sheet, but of course the length of the stream channel between the localities mentioned is subject to slight errors which could be corrected by accurate local surveys. Nevertheless, they are considered as fully within the limits of accuracy necessary for the preliminary survey of a water power project.

Walls of Dix River Gorge at Kennedy's Mill Formed by High Bridge Limestone.

The Dix river gorge is walled in by the lowest rocks belonging to the series exposed within the limits of the State of Kentucky. This does not mean that rocks can not be found at lower elevations, but the slope of the rock beds within the State is such that the lowest rocks in the series have been sufficiently elevated here to be magnificently exposed in the picturesque vertical cliffs lining the gorge. These rocks belong to the High Bridge section as defined by Campbell in the Richmond folio, published by the U. S. Geological Survey.

Three quarters of a mile east of Kennedy's mill, on the road to Buena Vista, the top of the Tyrone limestone is approximately at 900 feet above sea level. Half a mile northwest of the mill, along a road leading northward from the pike to Burgin, the top of the Tyrone limestone is approximately at about the same elevation. From this it is evident that any dam erected in the vicinity of Kennedy's mill will abut only against walls of rock belonging to the High Bridge division.

Characteristics of High Bridge Limestone.

The High Bridge division consisits almost entirely of limestone, with occasional thin seams of clay, or of more readily weathering limestone. As a whole, the limestone appears massive. It is very fine grained, has a conchoidal fracture, and fresh surfaces present a light blue color. As a rule, the layers do not separate readily, and the rock, therefore, is of little value except for road metal. However, 90 feet below the top of the

Tyrone limestone, there is a section about 25 feet thick, in which the rock is more even bedded. The layers separate more readily, and in former times this part of the High Bridge section was extensively quarried. Formerly it was known as the Kentucky river marble. At present it is known as the Oregon bed. Freshly quarried, the rock has a light gray or cream color, yellowing on exposure.

That part of the High Bridge limestone overlying the Oregon bed is known as the Tyrone bed, and that part which underlies the Oregon bed, is known as the Campnelson bed. The order of succession of these rocks, in descending order, is

		Thickness.
High Bridge Limestone	Tyrone bed	90 feet
	Oregon bed	25 feet
	Camp Nelson bed	285 feet

Camp Nelson Division of High Bridge Limestone Forms Wall of Gorge.

The preceding data indicate that in the vicinity of Kennedy's mill the top of the Campnelson bed is to be found about 115 feet below the top of the Tyrone limestone, which in this vicinity is about 900 feet above sea level. This would place the top of the Campnelson bed at about 785-foot the level. Since a dam rising 130 feet above the level of the water at the Kennedy mill dam would attain practically the same level, it is evident that only the lower, or Campnelson bed of the High Bridge limestone would be used as abutment walls in the erection of any dam not rising above the level of the dam belonging to the Danville water works.

The question as to the commercial value of a dam across the Dix river in the vicinity of Kennedy's mill, therefore, depends not only upon the quantity of water which would be delivered by the Dix river to the reservoir held back by the dam, but also upon the comparative impermeability of the rock masses forming the lateral walls of this reservoir. The water retaining powers of the largest dam under contemplation in the vicinity of Kennedy's mill can be readily assured, this being a problem in hydraulic engineering which can be readily solved The retaining of the waters by the natural walls now forming the cliffs lining the gorge, and which later must assist in retaining the waters of the rising reservoir, is another question, and not one so readily answered.

Value of Camp Nelson Rock for Holding in the Waters of a Reservoir.

Several characteristics of the Camp Nelson rock favor the view that it will prove efficient in retaining the waters of a reservoir, even under high hydraulic pressure. One of these is the comparative massiveness of the rock. Excepting some beds of calcareous shale, not over three or four feet in thickness, the rock consists of limestone. Although this limestone weathers into layers near the exposed surfaces, the separation into layers becomes less conspicuous as quarrying operations are continued farther from the surface and finally areas are reached in which the limestone masses become practically continuous. From this it is evident that the abutments of a dam must rest upon the still consolidated rock and not upon its weathered surfaces. The higher the dam, the greater will be the hydraulic pressure at the base, and the greater must be the precautions to abut the dam only against the consolidated rock, laterally as well as vertically.

Another characteristic of the Camp Nelson rock, favoring its ability to hold in the waters of a reservoir, is the exceeding fineness of its grain. The porosity of a rock diminishes rapidly with the fineness of its grain, and its ability to hold back the waters of a reservoir increases in the same ratio.

Danger Resulting from Ready Solubility of Limestone.

One of the features which militate against the availability of large natural masses of limestone as retaining walls of reservoirs is the comparative ready solubility of limestone in water containing carbon dioxide or decaying animal and vegetable matter. Where layers of rock are readily separable along their bedding planes, or where the masses of limestone are traversed by cracks or faults, the percolating waters frequently open up underground channels occupied by an ever expanding underground drainage system.

Presence of Limesinks in the More Northern Areas Drained by the Dix River.

The existence of such an underground drainage system in the vicinity of the Dix river, both above and below Kennedy's mill, is abundantly attested by the presence of numerous sink holes and the small number of surface channels occupied by streams excepting immediately after a rain. However, these sink holes and underground channels occur chiefly on the high lands bordering the Dix river gorge. Here they traverse not the High Bridge limestone, but the overlying, much coarser and more porous Lexington limestone. It is certain that underground channels penetrate also upper parts of these the High Bridge limestone, and some of the channels reach the lower parts of the High Bridge limestone, but in much smaller numbers.

On the map known as the Harrodsburg sheet, published by the United States Geological Survey, the presence of a few of the larger and more conspicuous sink holes is indicated by small circles from which lines radiate toward the center. The blue rings within some of these circles indicates that the bottoms of certain sink holes have become clogged with mud and now are filled with small ponds. This is the meaning also of the isolated small blue circles found on the same parts of the map. An examination of the map will indicate the presence of rather numerous sink holes within a moderate distance of the Dix river, between Hedgeville and a point about 2 miles north of Kennedy's mill. When it is remembered that only a small part of the limesinks is indicated upon the map, the general prevalence of an underground drainage in the vicinity of the Dix river becomes apparent. As stated in the preceding lines, most of this underground drainage lies within the comparatively coarse grained Lexington limestone. However, since these underground channels undoubtedly extend into the upper part of the High Bridge limestone and possibly might penetrate even the lowest beds, a canoe trip was taken down the Dix river gorge for the purpose of making an accurate survey of the exposures there presented.

Examination of Dix River Gorge, Below Davistown.

A short distance down stream from the bridge across the Dix river, southwest of Marcellus, there is a small flexure of the rocks shown on the western bank. This is a small anticline, probably of no special significance in connection with the question under consideration.

At the strong bend of the river north of Davistown, a small stream runs out rapidly from beneath a mud talus, at an elevation of only one foot above low water. This evidently is the exit of an underground stream. Since the top of the Tyrone limestone at this locality is 860 feet above sea level, and the top of the Campnelson bed is estimated at 745 feet, it is probable that the underground stream here detected finds an exit about 100 feet below the top of the Campnelson bed.

At the Fryingpan Bend.

A mile west of Davistown is the strong bend of the river known as the Fryingpan. The underground stream channels here probably attract much more general attention than the subject deserves. The meanderings of the river have carved out a triangular mass of rock with sides half a mile in length, the northern apex of which is still connected by a narrow ridge with the northern wall of the gorge. Numerous small underground streams here drop through the mud at river level and reappear on the opposite side of the connecting ridge along a line several hundred yards in length. At their exit these streams flow out from among the lower courses of rock lining the river bank, several feet above low water level in the river. It is probable that such a large triangular mass of rock, having become loosened from the walls of the gorge, would on account of inequalities of pressure, especially in case of high waters, tend to give rise to underground streams, even if underground streams were absent in surrounding rocks, and it is probable that no special significance should be attributed to the presence of underground streams at this specific locality. The elevation of these underground streams at the Fryingpan is approximately 625 feet above sea level.

A much more significant feature is presented by a heavily flowing spring located on the western bank of the Dix river, opposite the southwestern angle of the Fryingpan triangle. The mouth of this spring opens into the gorge at an elevation of 60 feet above the river level, or about 685 feet above sea level. Estimating the top of the Camp Nelson bed at this locality at 745 feet above sea level, the mouth of the spring at the Fryingpan bend is approximately 60 feet below the top of the Camp Nelson bed.

North of the Fryingpan Bend.

At a strong bend of the Dix river, 2 miles northwest of Davistown, and nearly a mile and a half southeast of Bushtown, a large stream plunges down the cliff, and a cold spring appears at a lower level in the immediate vicinity. Since no surface stream is located in this vicinity on the government map, inquiries were made on leaving the gorge, and these elicited the information that there was considerable underground drainage on the eastern side of the Dix river between this point and Camp Dick Robinson. During the Civil War a large camp was established at the latter locality owing to the presence here of abundant water obtained from an underground stream reached by a sink hole. This source of supply is still in use but access is had through a spring house. Several other sink holes occur in the immediate vicinity. A short distance north of Camp Dick Robinson a line of sink holes crosses the pike to Bryantsville. The waters of these sink holes have been traced westward toward the Dix river and a part of them are believed by the neighboring farmers to find their exit within the territory northwest of Davistown, here under consideration. The accurate determination of the direction of flow of these underground streams could readily be determined if the necessary expense were considered justifiable. Fluorescin has been used in the investigation of problems of this nature and with great success.

At the strong bend of the river near Bushtown, a strong stream of water comes down a ravine on the western side of the river, apparently in the absence of a corresponding surface stream on the high lands bordering the gorge. This. also, suggests the presence of some underground stream entering the gorge by some opening farther up the lateral ravine. Since the elevation of the exits of these streams would be considerably above the level of the river, at Kennedy's mill, at which it is proposed to erect a dam, no special examination was made of this ravine.

No Evidence of Underground Drainage Toward Kentucky River.

The chief object of the trip down the Dix river was determined whether it was possible to discover any channels through which water accumulated behind a dam at Kennedy's mill might drain away. A close study was made of the rocky walls lining the gorge in order to locate the presence of cracks or faults. The examination was sufficiently detailed to indicate that no faults crossed the gorge within the territory north of Marcellus, nor could any cracks be detected which were sufficiently conspicuous to suggest injury to the dam project. If such cracks are present, their existence can not be determined by a careful study of the surface of the cliffs lining the gorge.

For almost the entire distance down the Dix river gorge, from Marcellus northward, the rocky bottom of the river may be reached easily by means of the canoe paddle. In the quiet pools between the riffles any outflow of water from the riffle into an underground channel should be perceptible, if of any considerable proportion. Nothing of the kind was noticed.

In brief, a careful examination of the Dix river gorge suggests the feasibility of the erection of a dam, and the probability that the walls of the gorge will retain a reasonable percentage of the water, provided that an adequate water supply be furnished by the head waters and branches of the river.

Difficulties Encountered at Danville Water Works.

In a project involving such a large expenditure of money as that contemplated if the Dix river is to be used as a source of water power on a large scale, any evidence casting doubt upon the feasibility of the project should be carefully weighed.

It would be difficult to convince the engineers who have been connected with the Danville Water Works that the erection of a high pressure water power plant near the northern end of the Dix river gorge is feasible. They have had altogether too much trouble with their own dam, a much lower structure, erected across the Dix river at a point about a mile south of the pike from Danville to Marcellus. This dam has a height of only 16 feet. There is considerable leakage through the rocks forming the walls of the gorge at the level of the reservoir. The quantity of the water held back by the dam is not sufficient even for the comparatively moderate necessities of the water works system of Danville, during the drier months of summer and early autumn. Last year ditches were blasted from the reservoir southward, up the river, from water hole to water hole, utilizing pools only 2 feet in depth, in order to meet the immediate necessities of the water works. The present dam holds back the water for a distance of three quarters of a mile. A second dam crosses the same gorge farther up stream and will be in a condition for service during the latter part of the present year. With the assistance of this second dam it will be possible to meet the necessities of the water service of the comparatively small city, Danville. Any water power proposition in addition to the water supply of Danville appears out of the question at this locality.

There is abundant evidence of the leakage of water through the walls of the gorge lining the Danville Water Works reservoir. The deforesting of the lands bordering the Dix river caused the drying up, at least during the summer months, of many of the springs which formerly entered the Dix river gorge below the location of the reservoir dam. Since the erection of the dam a considerable number of these springs have opened up again, evidently securing their supply from the waters in the reservoir. It seems possible, that under the much greater hydraulic pressure developed by the much higher dams contemplated for the water power plants in the vicinity of Kennedy's mill, such leakage channels might be converted in a comparatively small number of years from springs to gushing streams of water.

The difficulty of locating the points of exit of the waters is illustrated by the fact that whenever the water at the Danville reservoir rises more than a foot above the dam, a large quantity of water gushes out from the river bed a short distance below the dam. Although the existence of this leak has been known for a long time, so far it has been impossible to find its origin above the dam, notwithstanding the fact that most of the time this leak must lie above water level. Evidently the difficulty of locating such a leak, if below the water level, must be much greater.

Examination of Rocks Forming Walls of Gorge at Danville Reservoir.

On account of the adverse evidence presented by the reservoir at the Danville Water Works, a special examination was made of this locality. The level of the water in the reservoir is given as 686 feet above sea level, on the Harrodsburg sheet, published by the United States Geological Survey. The top of the Tyrone limestone is somewhere near 850 feet. This would place the level of the water in the reservoir 164 feet below the top of the Tyrone limestone, or about 50 feet below the top of the Camp Nelson bed. The base of the dam is located 16 feet lower.

This suggests the leakage of water through walls formed by rock belonging about 65 feet below the top of the Camp Nelson bed. It will be remembered that the spring at the southwestern angle of the Fryingpan bend, 2 miles northwest of the Danville Water Works issues from the same rock. It is probable that a considerable part of the underground drainage connected with the sink holes in the more immediate vicinity of the Dix river extends down to this level, notwithstanding the fact that almost all of the sink holes begin in the comparatively coarse-grained limestones belonging to the overlying Lexington group of limestones.

In opposition to the unfavorable conclusions to be derived from a study of the situation at the Danville reservoir it might be suggested that there is no evidence that sufficient care was exerted in the erection of the dam to remove the more decayed portions of the limestones, both from the sides and the bottom of the stream channel, so as to retain only solid rock for the foundations and the lateral abutments of the dam. Care in this direction is of the highest importance in the case of all limestones on account of their comparatively ready solubility, but this care is especially necessary in proportion as the bedding of the limestone is more distinct and the seams between the layers are more readily discernible.

At the point where the Danville reservoir dam has been constructed the rocks actually used as lateral abutments for the dam are much less precipitous than those which would serve a similar purpose for the much higher dam proposed in the vicinity of Kennedy's mill. The latter, therefore, may show much less deeper weathering, and care in cutting back beyond the area of weathering before putting in the foundations and the lateral abutments may solve the problem for the Kennedy mill site.

Faulting a Mile South of Danville Water Works.

No faults were noticed at the Danville Water Works site. Possibly a much more extended search might reveal evidence indicating the loosening of rock due to faulting. This faulting may not have extended as far as the Danville Water Works, but the cracking of the rock may have extended as far as this point, without resulting in actual faulting. In other words, faulting is only the extreme expression of disturbance among the rocks, and cracking may extend far beyond the area of actual faulting. Usually this cracking extends along a continuation of the line of faulting and for a moderate distance on each side of the fault.

J. T. Sandidge Barytes Vein.

Evidence of moderate faulting is seen one mile south of the Danville Water Works, at the Barites mine on the property of J. T. Sandidge. This barytes vein runs approximately north and south. At the southern extremity, it includes a small quantity of zinc blende. The level of the ground at the so-called mine is about 900 feet above sea level. Since the top of the Tyrone limestone a mile north of the mine is about 850 feet above sea level, and 2 miles southeast of the mine, or half a mile south of Hedgeville, is 842 feet above sea level, the rock at the mine probably belongs to the lower 50 or 60 feet of the Lexington limestone. A contorted layer of limestone is seen in the lower part of the open cut forming the mine. On the west side of the cut this layer occurs at a level 4 feet lower than on the eastern side, indicating the presence of moderate faulting. While the amount of faulting is only moderate, the vein itself is an indication of cracking of the rock, and this vein trends directly toward the Danville Water Works site, only a mile away.

Lime-sinks are abundant a mile north of the Danville reservoir, along the pike from Danville to Marcellus. A third of a mile west of the junction of the road leading southward to the reservoir, there is a section in which the rocks dip rapidly southward, the strike following the pike for some distance. Since the rock immediately south of the pike, across the valley, appears horizontal, there may have been faulting here, although the tilting might be due to slumping of a large mass of rock into the valley.

The Great Camp Nelson Fault.

The great Camp Nelson fault passes about three miles east of the Danville Water Works, and then takes a westward turn about 5 miles southeast of the water works. This fault appears too distant to effect the conditions at the water works directly.

The Camp Nelson fault crosses the Kentucky river at Camp Nelson, 5 miles a little north of east from Kennedy's mill, measured in a direct line. The fault follows the pike from Camp Nelson to Toddville, bears a little to the east of Bryantsville, crosses Burdett's knob, and crosses the pike from Lancaster to Danville, by way of Hedgeville, about three quarters of a mile east of the bridge across the Dix river, directly east of the great bend of the river north of the pike. From this point the fault follows the ridge between the Dix river and Hanging Fork as far as Hubble, north of which it breaks up into some faults having a more westerly strike.

B. W. Givens Barytes Vein.

Along a considerable part of this distance the fault crack is filled with barites. An open barites mine is being worked at the present time on the ridge between the Dix river and Hanging Fork, 2 miles north of Hubble. A little zinc blende is associated with the barites. The vein branches irregularly, and the main branch varies in direction, but the general trend is a little east of north. Both High Bridge and Lexington limestone occur on the western side of the vein. The country rock east of the vein was not exposed. South of the mine the top of the Tyrone limestone occurs 885 feet above sea level. That part of the Lexington limestone which appears in the open cut of the mine probably belongs to the lower 50 or 60 feet of the Lexington beds. The land is owned by B. W. Givens, and the mine is said to be operated by the Nicholasville barite company.

Jerry Sandidge Barytes Vein.

The mine immediately north of the pike from Lancaster to Hedgeville, on the property of Jerry Sandidge, probably is a continuation of the Givens vein, since it lies along the same line of strike. At the pond immediately east of the house, the Eden beds, containing Dalmanella multisecta, are exposed. A barites vein, running north and south, occurs north of the pond. Small quantities of zinc blende occur in the barites. No galena was found. The Eden rock, with Dalmanella multisecta common, occurs west of the vein, and the Fairmount bed, with Strophomena maysvillensis, forms the eastern wall. Farther north, a continuation of this vein, on the same property, has been mined as an open cut. Here Lexington limestone, containing Rhynchotrema inequivalve, occurs on the western side of the vein, and a small patch of the same limestone is seen also on the eastern side. The fine grained rock on the eastern side of the vein at its northern extremity, resembling the High Bridge limestone was not identified definitely. It should be remembered that the Perryville bed contains layers resembling the High Bridge limestone. Evidently considerable faulting has occurred along the strike of the barite vein.

Large Fairmount Limestone Fault Block at Low Level.

About a quarter of a mile east of the Jerry Sandidge mine, along a steep gully north of the pike, Strophomena maysvillensis is abundant as low as 50 feet below the level of the pike, indicating the presence here of a considerable section of Fairmount rock. A short distance farther eastward a considerable thickness of Eden rock, containing Dalmanella multisecta and Plectambonites sericea in abundance, is exposed. Strophomena halli occurs near the upper part of the hill eastward. These facts suggest that a considerable block of Fairmount rock has dropped between the Lexington limestone exposed west of the Jerry Sandidge baryte vein and the Eden limestone exposed a third of a mile farther eastward. The amount of this drop is estimated at fully 250 feet, and possibly more than 300 feet, as a maximum.

Faulting at Burdett Knob.

The most southern exposure of the Lexington limestone along the pike from Bryantsville to Lancaster, is located a little over a mile south of Burdett knob, where a road turns off southward from the pike. A short distance north of the road corner, on the eastern side of the pike, a quarry may be seen near the top of the hill land. Here a very fine grained limestone, with numerous worm borings, probably represents the Perryville bed. This fine grained rock is 3 feet thick. The immediately overlying rock, 15 inches thick, is very irregularly bedded, and the overlying rock, containing an abundance of Hebertella frankfortensis at an elevation 4 feet farther up, must be regarded as forming the top of the Lexington limestone section. A short distance farther northward, an old county road branches off eastward. In the valley east of the pike this road exposes the Ohio Black shale, dipping northeastward, evidently faulted for a vertical distance of at least 400 to 500 feet below its former relative position, compared with the strata exposed farther westward, along the pike. This evidently is a continuation of the fault at the Jerry Sandidge mine, southward, and of the Burdett knob fault northward.

A mile southeast of Camp Dick Robinson, a lane branches off from the pike, northeastward, toward a farm house fully half a mile distant. At first this lane takes an almost easterly direction, and then turns suddenly northward. At this bend of the lane the very fine grained limestone resembling the High Bridge limestone, but belonging to the Perryville bed, is exposed. The worm borings in this Perryville limestone are very characteristic of this rock at many localities. Tetradium also occurs, as elsewhere at this horizon. West of this exposure of Perryville rock, the immediately underlying strata of the Lexington limestone are exposed.

Barytes Vein North of Burdett Knob.

Farther northward, about a quarter of a mile from the pike, the lane turns more toward the northeast. North of this angle of the road, a barytes vein was opened in the field. Its general trend is northward. On the western side of this barite vein, the country rock is formed by the Lexington limestone. East of the barytes vein the country rock consists of strata belonging to the Maysville formation. The fault probably follows the western side of Burdett Knob, the Lexington limestone continuing as the country rock on the western side of the fault.

Exposures Northeast of Burdett Knob.

East of the baryte vein mentioned above, the lane turns northward at a pond, toward the farm house. Immediately south of the pond, another road turns off eastward, and then southeastward, entering the valley east of the knob. About 200 yards southeast of the pond, blue limestone, containing Platystrophia ponderosa and Labechia ohioensis, occurs in the stream bed followed by the road. This limestone is referred to the upper part of the Arnheim horizon, owing to the presence of the Labechia. In this part of Kentucky, Labechia occurs at various localities in the Arnheim horizon, but has not been found so far in the lower parts of the Maysville formation, although abundantly represented in the Fairmount beds along the Cumberland river, much farther southward. The more characteristic fossils of the Arnheim bed were not found.

Westward from the Labechia locality, toward the pond at which the lane turns northward to the farm house, the immediately overlying massive argillaceous rock contains Platystrophia ponderosa. This also is referred to the Arnheim section. The unfossiliferous strata near the pond, however, probably belong to the base of the Waynesville section. Southwest from the pond, along the lane already frequently mentioned, the Ohio black shale overlies this lower Waynesville horizon, although tilted strongly southward. This brings the Ohio black shale in contact with the Perryville bed near the top of the Lexington limestone for a short distance along the lane. This contact represents a faulting of more than 600 to 700 feet, with the drop on the eastern side of the fault.

Crest of Burdett Knob.

Ascending the main elevation of Burdett Knob, directly south of the pond, the lower part of the so-called Waverly section is traversed. It is an argillaceous rock, weathering into softer material, and the cherty and quartziferous concretions lining the hill slope west of the knob evidently were obtained from the upper part of this Waverly or Knobstone section.

Directly west of the crest of the knob a wire fence extends north and south along the knob ridge, and only a short distance below the level of this fence there are abundant fragments of Fairmount limestone, containing Strophomena maysvillensis. The juxtaposition of strata as far apart as the Fairmount bed and the Waverly formation is another evidence of very considerable faulting. A wedge of Fairmount limestone evidently occurs here at about the same level as the lower part of the Waverly exposure on the west, and far above the upper part of the Maysville exposure in the valley east of the knob ridge. In the absence of sufficient exposures, it is not possible to account for this extreme change in the original position of the wedge of Fairmount rock.

East of the Burdett Knob.

At the southeastern corner of the Burdett knob ridge, the Ohio black shale is exposed, far down the valley, evidently east of a fault line crossing the knob in a northerly direction at some point farther westward. From this point northward, up the valley lying east of the Burdett knob ridge, the comparatively unfossiliferous strata regarded as belonging to the Corryville horizon are exposed. East of the valley the rocks dip evenly westward, so that the unfossiliferous rock section forms the hill slopes as far as the crest of the hill land east of the valley.

The Burdett Knob is a striking example of considerable faulting, accompanied by dislodged fault blocks of fairly large size. In general, the strata east of the fault line have dropped, as was the case also farther southward, as already described. Burdett knob appears to mark the area of maximum faulting along the Camp Nelson fault plane.

Camp Nelson Fault North of Toddville.

At Toddville, the lower part of the Eden formation, with Dalmanella multisecta common, is well exposed on the hill side directly east of the road junction, and still lower exposures of the same formation may be detected on the western side of the pike to Camp Nelson. The contact with the Catheys formation is seen 15 feet below the road junction at the northern end of Toddville. Farther north, the extreme top of the Lexington limestone, above the Perryville bed, is identified by the presence of Hebertella frankfortensis, Strophomena vicina, and Stromatocerium pustulosum. The rock here is tilted strongly southeastward. Still farther northward, the very fine grained Perryville limestone is poorly exposed. Evidences of moderate faulting are seen for half a mile northeast of Toddville.

Camp Nelson Fault South of Camp Nelson.

A mile south of Camp Nelson, a vertical fault plane follows the pike, with the High Bridge limestone on the east of the fault and the Lexington limestone on the west. The Lexington limestone dips west or northwest for a long distance along the road. The fault line may be traced along the pike as far as Camp Nelson, the High Bridge limestone continuing on the eastern side of the fault. This evidently indicates a reversal of the downthrow, the drop being on the western side of the fault line, instead of on the east, as farther southwad.

It would be just as pertinent to refer to the great upthrow of the High Bridge strata on the eastern side of the fault line at Camp Nelson, since at this locality the High Bridge limestone has its greatest elevation within the State of Kentucky, resulting in the exposure here of lower strata in the High Bridge limestone section than at any other locality within the state.

No Effect of Camp Nelson Fault on Lower Dix River Drainage Noted.

The question arises, what effect does the presence of such a long and strong fault as that extending from Camp Nelson southwestward across Burdett knob have upon the underground drainage in the vicinity of Kennedy's mills.

It would be folly to blind one's self to the possibility that faulting of such magnitude might resulting in cracking of the strata for long distances, resulting in the opening up of crevices giving rise to a considerable underground drainage. The only reply to the question which can be given at present is that careful search has failed to reveal the presence of such a drainage at the lower levels at which it would invalidate the utility of the Dix river as a source of water power.

Distance From Kennedy's Mill to Kentucky River.

A careful study was made of the territory lying east and northeast of Kennedy's mill, as far as the Kentucky river. It will be seen from the map that Kennedy's mill is exactly 3 miles from the nearest part of the Kentucky river, at Handy's Bend. It is nearly 4 miles distant from the bend of the river two miles west of Camp Nelson and 5 miles distant from the bend of the river one mile south of Camp Nelson.

Limesinks in Intervening Area.

In this connection the various limesinks east of the pike north of Buena Vista, from a point one mile north of Buena Vista toward Handys Bend should be mentioned. Several of these limesinks are of large size and suggest a considerable underground drainage toward the Kentucky river. Various limesinks on the road from Buena Vista to Kennedy's mill suggest the presence of a considerable underground drainage toward the Dix river. But no evidence was found indicating an underground drainage connecting the Dix and Kentucky rivers across the territory indicated.

Advisability of Fluorescin Tests.

Before the beginning of expensive operations at the Kennedy mill site, it might be advisable to undertake some of the fluorescin tests which have been so successful in foreign countries in determining the presence and direction of underground drainage, but it would be well to remember that such tests would reveal only the presence of the lowest channels, those below the level of the water at Kennedy's mill. Those at higher elevations would escape such a test.

No Evidence of Underground Drainage Toward Kentucky River Noticed.

There is a limit to the possibilities of geological investigation. A geologist can interpret only that which he sees. From actual exposures he must draw conclusions as to conditions removed from sight. All that can be said at present is not that underground drainage destructive of the use of the Dix river for water power purposes does not exist, but that careful search has failed to reveal such an underground drainage, and that a careful study of the territory in question rather favors the opinion that a dam can be constructed which will hold back as much of the water actually supplied as is the case in other dams of similar height as that contemplated.

Importance of Solid Rock Abutments for Dam.

No dam holds all of the water theoretically held up by it. The rocks forming the gorge walls absorb a part of the waters in the reservoir. A slow circulation takes place within the rock itself, the rate of this circulation depending upon the porosity of the rock. In this respect the rock forming the gorge walls bordering the Dix river are especially favorable owing to their great density and corresponding small porosity. It may safely be stated that few rocks exist through which the circulation would be less rapid.

The chief danger must lie in the crevices crossing the rock and in the seams between the horizontal layers. The necessity of quarrying back to the solid rock has been mentioned on preceding pages.

A much more important question than the retaining powers of a dam at Kennedy's mill appears to be the actual water supply which the river will deliver to the dam.

The contributions which a geologist can make to this problem are less important than the results that can be obtained by an actual accumulation of records of the water discharged each day during a large period of time.

Inclination of Rock Strata Probably of Little Effect on Underground Drainage in Dix River Area.

It is not believed that the inclination of the rock strata has much to do with the direction of underground drainage excepting in the case of an alternation of porous and relatively impervious strata. The direction of the underground drainage in the case of the massive High Bridge and Lexington limestones probably is determined more by the direction of crevices enlarged by solution than by the inclination of the layers which make up the rock masses. The chief controlling factor undoubtedly is the relative height reached by the ground water at neighboring localities and the resultant inequalities of hydraulic pressure.

Direction of Underground Drainage Determined by Differences of Hydrostatic Pressure.

The direction of flow of the underground water always is from the area where the top of the ground water reaches a higher altitude towards that at which the altitude is less. Given a difference in the level of ground water at two localities, the water always will flow from the higher to the lower level, irrespective of the direction of slope of the intervening rock. If it can not flow along the bedding planes it will follow the vertical fissures that here and there intersect the layers.

Nevertheless, a few observations on the general inclination of the rocks, among the many accumulated, will be of interest.

Dips of Strata Between Buena Vista and Camp Nelson.

At Buena Vista, two miles directly east of Kennedy's mill, the top of the Tyrone limestone is 866 feet above sea level. A mile and a quarter south of Camp Nelson, where a country road turns off from the pike, westward, the top of the Tyrone limestone is about 785 feet above sea level. Three quarters of a mile south of Camp Nelson, the top of the Tyrone limestone is not more than 670 feet above sea level. The rock on the western side of the Camp Nelson fault evidently is dipping rapidly toward the north. This dip continues northward, and a little over a quarter of a mile from the Kentucky river, the top is found somewhere near 610 feet, the dip continuing as far as the Kentucky river.

North of Camp Nelson, there is a corresponding rise of the strata, the top of the Tyrone reaching an elevation of 930 feet, a mile and a quarter north of the village. From this point northward the change of elevation appears inconsiderable, the top of the Tyrone limestone being somewhere near 900 feet at the bridge over Town Fork, two and a half miles south of Nicholasville.

Dips of Strata Between Buena Vista and Camp Dick Robinson.

While there is a dip of strata from Buena Vista eastward from an elevation of 866 feet to the lower levels indicated in the preceding lines, the rise of the rocks southwards, along the pike from Camp Nelson to Bryantsville continues. A mile west of Bryantsville, the top of the Tyrone is found at 860 feet. A mile southwest of Bryantsville, the elevation of this horizon is somewhere near 950 feet. This is the maximum elevation of the Tyrone limestone along this direction. Half a mile southeast of Camp Dick Robinson, the Wilmore bed of the Lexington limestone, with an abundance of large specimens of Prasopora simulatrix, is exposed at about the same elevation, indicating a drop of the strata in this direction.

Absence of Strong Dips Along the Northern Part of the Dix River.

That the elevation of strata between Camp Dick Robinson and Bryantsville is extreme is shown by the following data. Elevation of the top of the Tyrone limestone at Buena Vista, 866 feet above sea level. At a mile and a half west of Buena Vista, the elevation does not exceed 884 feet since chert from the Curdsville bed occurs down to this level. A little over two miles northwest of Bryantsville, and a mile south of the pike from the Kennedy Mill to Buena Vista, about 870 feet. A mile west of Bryantsville, 860 feet. At several localities about two miles southwest of Bryantsville, along the road entering Davistown from the north, 850 to 860 feet. Within a third of a mile south of Marcellus, 865 feet. At the Danville Water Works, somewhere near 850 feet. At the bridge a mile south of Hedgeville, 842 feet. A mile and a half east of this bridge, at the B. W.Givens Barite mine, on the ridge between the Dix river and Hanging Fork, 842 feet. Between one and two miles northeast of Hedgeville, somewhere near 840 feet. In contrast with the rapid change of level along the line of the Camp Nelson fault from Camp Dick Robinson northward, the elevations along the immediate channel of the Dix river are remarkably uniform.

Probable Absence of Faulting Along the Dix River Gorge.

This uniformity of elevation of the High Bridge strata between the area southeast of Hedgeville and Kennedy's mill certainly is in favor of the absence of important crevices due to faulting along the intervening part of the Dix river gorge.

Faulting Northeast of Hubble.

In the faulted area three quarters of a mile south of the Givens baryte mine, and about a mile north of Hubble, the top of the Tyrone limestone in one of the fault blocks is 885 feet, the Eden beds, with Trinucleus, being exposed within a short distance southwards, at an elevation only slightly higher. This is the most southerly appearance of the Tyrone limestone, the southward dip of the strata, beginning near the northern edge of Lincoln county, soon bringing in strata belonging to a much higher series of rocks, geologically.

Possible Faulting Three Miles Northeast of Danville.

Nearly three miles northeast of the center of Danville, along the pike to Davistown, the top of the Tyrone limestone is found at about 850 feet. This is the elevation also at the Danville Water Works, and the steep dips along the pike three and a half miles northeast of the center of Danville may be due to the tilting of the rock locally toward the valley south of the pike, but the explanation of this dip should receive further study. Apparently the rock dips eastward for a considerable distance along the pike, as far as the strongly inclined rock already mentioned.

Absence of Faulting Along Dix River Northeast of Kennedy's Mill.

About two miles directly east of Burgin, north of Cane Run, the top of the Tyrone limestone is exposed approximately at 880 feet above sea level. Along the railroad, a mile and a half south of High Bridge, the top of the Tyrone limestone is seen at 860 feet. At a culvert along the pike, two miles north of Buena Vista, the top is somewhere near 860 feet. Three and a half miles northwest of Buena Vista, along the same pike, the elevation is about 870 feet. A mile south of the mouth of the Dix river, on the eastern side of the river, the top of the Tyrone limestone is somewhere between 850 and 800 feet.

The preceding observations agree sufficiently well with those obtained south of the Burgin-Buena Vista pike to confirm the opinion that the area surrounding the Kennedy mill was not an area subjected in times past to considerable faulting. Data of a similar nature could be largely multiplied, but it is believed that the selection here presented will be sufficient to indicate the nature of the evidence favoring this view.

Westward Dip of Strata West of Burgin.

About a mile and a half west of the railroad at Burgin, the top of the very fine grained Perryville limestone is exposed about 950 feet above sea level; two and a half miles west of Burgin, at somewhere near 930 feet; one mile east of the center of Harrodsburg, at about 900 feet; within the limits of Harrodsburg, one square west of the point where the Pleasant Hill road branches off from the pike to Burgin, at about 850 feet. This is a distinct westerly dip of 100 feet in 3 miles.

Two and a half miles northwest of the center of Harrodsburg, just before reaching the railroad, the top of the Perryville bed is exposed at about 840 feet above sea level. West of Salt river, on the road to Bohon, the base of the fine grained Perryville limestone is seen at 820 feet, and the top should be about 7 feet higher. At Cornishville, 9 miles north of west from Harrodsburg, the top of the Perryville bed is somewhere near 740 feet, a dip of 110 feet in 9 miles. The westerly dip here evidently is much less than along the three miles directly east of Harrodsburg.

Northwesterly Dips in Western Boyle and Mercer Counties.

A mile and a half southwest of Harrodsburg, on the road to Perryville, west of Salt river, the top of the Perryville bed is exposed at 848 feet above sea level. About a mile southwest of Nevada, at 844 feet. A quarter of a mile southeast of Perryville, at about 870 feet. A little over a mile southeast of Perryville about 870 feet. Two and a half miles southeast of Perryville, at its most southern exposure, about 930 feet. Almost directly north of the last locality, at a point two and a half miles east of Perryville, the top of this bed occurs at 880 feet above sea level. Four miles east of Perryville, east of Quick Run, the top is found at about 923 feet. One mile north of Bac, at the mouth of Carmichael branch, the top of the Perryville bed must lie below the 740 foot level. From these data it is evident that there is a general northwesterly dip shown by the Perryville bed in the western parts of Boyle and Mercer counties, toward Perryville and the mouth of Carmichael branch. From the latter locality toward Bestonia, the dip of the strata is very slight. From Bestonia to Cornishville there is a slight rise of strata, resulting in a reappearrance of the typical Perryville bed.

Westerly Dips Southeast of Harrodsburg.

Southeast of Harrodsburg, the Perryville bed rises along the railroad, attaining an elevation of about 930 feet four miles southeast of town. The highest land along the railroad midway between Burgin and Faulconer, located midway between these stations, attains an elevation of 950 feet without reaching the typical very fine grained limestone horizon belonging to the Perryville bed, although the underlying beds are exposed. Two miles south of Faulconer, at an elevation of 950 feet, the exposures probably lie at least 30 feet below the typical Perryville horizon, and this is true also of the exposures a mile and a quarter north of the center of Danville, where the elevation likewise is 950 feet. At the same elevation, a mile north of the railroad station, the richly fossiliferous zone immediately below the typical Perryville bed is exposed, and the same richly fossiliferous zone isseen at an elevation of about 990 feet a mile and a half south of the railroad station at Danville. From this point southward the rock dips rapidly toward the south.

Summary Regarding Dips in the Northern Part of the Dix River Drainage Area.

The preceding data may be summarized in the form of the following conclusions. The elevations of the top of the High Bridge limestone at various localities indicate that the strata occupy comparatively horizontal positions from a line almost as far east as the Camp Nelson fault westward almost as far as the railroad between Burgin and Danville. Westward of this line of road the elevations of the top of the Perryville bed indicate a westerly dip which is especially strong in the area between a mile and a half and four miles west of the line between Burgin and Faulconer. This westerly dip, if it had any effect whatever on the underground drainage, would tend to throw this drainage away from the Dix river rather than towards it. However, only a small part of the natural surface drainage area of the Dix river is affected by this westerly dip since the watershed between the Dix and the Champlain river passes from Burgin to a point 3 miles west of Faulconer, and thence continues almost directly southward to the angle at which Boyle, Casey, and Lincoln counties meet. Moreover, the influence of the direction of this dip on the underground drainage probably is negligible.

Southerly Dips Along the Louisville and Nashville Railroad West of Junction City.

In the immediate vicinity of the Louisville and Nashville railroad between Mitchellsburg and Junction City there is a strong southerly dip, causing the Ohio black shale to be exposed immediately south of the railroad along this entire distance, and also north of the railroad in the area east of Alum Springs. North of Mitchellsburg and Parksville, this southerly dip begins about a mile north of the railroad. It is estimated that the beginning of the southerly dip north of Alum Springs lies somewhere between a mile and a mile and a half from the railroad. Along the railroad from Danville to Junction City, the southerly dip begins about a mile and a half south of the railroad station at Danville.

Southerly Dips Between Danville, Hedgeville, Stanford, and Junction City.

In general, there is also a southward dip from the pike between Danville and Hedgeville toward the Louisville and Nashville railroad between Junction City and Stanford. This southward dip is well shown along the pike between Danville and Shelby. It is seen also along the pike between Danville and Stanford. The Catheys formation is exposed 3 miles southeast of Danville at about 920 feet above sea level, while the Lexington limestone is exposed at higher levels north of the Danville-Hedgeville pike. Since the Paint Lick or Lower Garrard sandy limestone is about 940 feet above sea level a mile and a half farther south, there evidently is a strong dip in this direction. A mile and a quarter farther south, along a pike leading to Shelby, the Devonian chert rests upon the upper part of the Corryville bed at about 1000 feet above sea level.

Southerly Dips East of Danville-Stanford Pike.

A similar southward dip is noticed in the area east of the Danville-Stanford pike, as far as Hanging Fork. Along the pike between Danville and Hedgeville, the Lexington limestone is exposed along the highest hill crests, 950 feet above sea level. Neither the typical fine grained Perryville limestone, nor the richly fossiliferous cherty limestones immediately underneath are exposed, indicating that the base of the Catheys limestone, now removed by erosion, in former times must have been nearly 1000 feet, if not more, above sea level. Two miles south of the Danville-Hedgeville pike, however, along an east and west road, the typical Perryville rock is exposed at several localities along the bottom of the valley followed by the road, at elevations varying between 860 and 890 feet. These facts indicate a strong southward dip.

A mile farther southward, the less fossiliferous sandy limestone, belonging to the Paint Lick or Upper Eden beds, are exposed at elevations varying between 860 and 960 feet, again indicating a southward dip. As a matter of fact, the dip here is southwestward, rather than southward. The presence of Strophomena maysvillensis along the Stanford pike, six miles southeast of Danville, at an elevation of 860 feet, and, again, one mile farther southeast, at Lytle, near the same level, indicates the existence at these levels of the lower half of the Fairmount bed, suggesting a continuation in this direction of the southward dip. Two miles southwest of Lytle, along Hanging Fork, and its branches, Strophomena maysvillensis is common at 900 feet. There may be faulting in this direction. Between one and two miles north of Stanford, on the pike to Danville, the Corryville is exposed as high as 1000 feet above sea level. Since the Arnheim bed is exposed one mile southwest of Stanford at about 945 feet above sea level, it is evident that the southern dip continues, although possibly with interruptions, as far as Stanford.

Faulting North of Hubble.

Along the pike from Hubble to Stanford, entering Stanford from the northeast, similar southern dips are noticed. One mile north of Hubble, the Eden beds are exposed at about the same level as the contact between the top of the Tyrone limestone and the base of the Curdsville, immediately northward. There probably is a fault between the two exposures. Another fault crosses the road about a third of a mile north of Hubble. A large exposure of Eden strata lies north of the fault, and the Corryville bed, directly overlaid by Devonian limestone chert, forms the hill summit south of the fault, about 1000 feet above sea level.

Southerly Dips From Hubble Toward Stanford.

From Hubble, the strata dip rapidly southward. One mile south of Hubble, Strophomena maysvillensis, indicating the presence of the Fairmount bed, is exposed at about 850 feet above sea level. It is seen at about the same level three quarters of a mile farther south, overlaid by Orthorhynchula linneyi at a somewhat lower horizon than that occupied by the same fossil farther northward. About a mile and three quarters north of Stanford, along the pike to Hubble, the base of the Arnheim bed is exposed about 975 feet above sea level. The strata along the creek immediately south of the center of the town, at an elevation of about 900 feet above sea level, belong to the lower part of the Waynesville bed.

The southward dips in the area between Danville, Hedgeville, Stanford and Junction City are not uniform. Strong local folds and some faults intervene. However, the general dip is southward, or in a direction almost opposite to the general northward surface drainage of the Dix river.

Southerly Dips Between Lancaster and Stanford.

Similar southward dips may be noticed along the pike between Lancaster and Stanford. At the western edge of Lancaster, and also in the south central part of the town, the base of the Arnheim is exposed near 1000 feet above sea level. Two and a half miles southwest of Lancaster, the base of the Arnheim is exposed at 913 feet. About five miles southwest of Lancaster, the elevation of this bed is 900 feet. Half a mile north of the pike from Stanford to Rowland, on the western side of Logan creek, the base of the Arnheim bed is about 850 feet above sea level. The dip over a considerable part of this area, however, is southeast, in other words almost directly opposite to the surface drainage of the Dix river in the area between Lancaster and Stanford.

Dips Between Hubble and Lancaster.

Strong eastward dips occur also along the pike from Hedgeville to Lancaster. Upper Eden beds are exposed about a mile and a quarter east of the bridge across the Dix river. Eastward, for a distance of half a mile, the lower Garrard or Paint Lick bed is exposed at about the same elevation. A mile southeast from the last locality, the Orthorhynchula linneyi horizon from the upper part of the Fairmount bed is exposed at 970 feet and within the limits of Lancaster the base of the Arnheim is seen at 1000 feet. Southward dips are indicated by the frequent occurrences of the Orthorhynchula linneyi horizon along the road from Hubble to Lancaster, from the Dix river eastward. Here this horizon is seen at about 820 feet above sea level. At the bridge across the Dix river, nearly four miles southwest of Lancaster, the Orthorhynchula horizon is about 810 feet above sea level.

Dips Southeast of Lancaster.

In the area between Lancaster, Rowland, and Preachersville, the dip of the strata is more irregualar. Along the pike from Lancaster to Sweeney, the dip is southerly, the base of the Waynesville bed lying below creek level at the locality half a mile north of Sweeney. From the crossing of this pike over Gilbert creek toward Rowland, the dip is southwestward. Near the crossing of the Sweeney pike over Gilbert creek, the elevation of the Arnheim bed is 944 feet. About a mile southwest, it is 920 feet. At several points, a mile and a half southwest, it is about 890 feet. Half a mile northwest of the railroad station at Rowland, it is 850 feet.

Dips Between Preachersville and Stanford.

At Preachersville, the elevation of the Arnheim bed is about 950 feet, agreeing fairly well with the elevation a mile northwest of Sweeney. However, west of Preachersville, along the road to Needmore, the rock occurs at lower levels, being 890 feet above sea level three miles west of Preachersville. At Rowland, its elevation is below 850 feet. Northeast of Preachersville, the Arnheim probably drops slightly in elevation for about two miles. South of Preachersville, a fault crosses the road in a direction a little south of west. The rock on the southern side of the fault has dropped.

Eastward Dips Toward Crab Orchard and Broadhead.

From the area a mile westward of Cedar creek, the rock dips eastward toward Crab Orchard. These eastward, or, rather, southeastward dips continue beyond the headwaters of the Dix river, east of Broadhead. They characterize also the rocks east and northeast of Crab Orchard, as far as the drainage of the eastern branches of the Dix river extends.

Dips Southwest of Stanford.

In the area between Maywood station and Neal creek, southeast of Stanford, the dips are locally toward the west. Between Stanford, McKinney, Moreland, and Junction City, the strata are tilted in various directions, and distinct faulting is noticed at a number of localities. Three miles northwest of Stanford, immediately south of the railroad, the Tate layer dips strongly eastward, and the top of the Devonian limestone is seen on the south side of an approximately east and west fault. A similar strong eastward dip appears to exist about a mile and a quarter southward, along the road from Stanford to Milledgeville. Possibly a fault intervenes about 2 miles west of Stanford, where the Ohio Black shale is exposed. There is unquestioned faulting at the old Buffalo Spring, half a mile west of Stanford.

Three miles southwest of Stanford, and nearly two miles east of Turnersville, the strata dip northward or toward the northwest. From this locality two miles east of Turnersville, and from McKinney, the dip appears to be northwestward at least as far as Hanging Fork, and possibly as far as Moreland, Milledgeville, and the Harris creek valley. For some distance south of Junction City, the dips are southerly.

Influence of Dip on Direction of Underground Drainage Probably Small.

The preceding notes are sufficient to indicate that the dip of the strata south of a line drawn from Danville eastward frequently is in the opposite direction to that of the surface drainage of the Dix river and its more eastern tributaries. Along the headwaters of Hanging Fork, south of the Louisville and Nashville railroad, there is less disagreement.

There is no evidence that the disagreement between the dip of the strata and the direction of the surface drainage has had any considerable influence upon the direction of flow of the underground drainage. The direction of flow of the underground drainage is determined probably chiefly by the difference in hydrostatic pressure in neighboring areas, due to inequalities in the elevations attained by the ground waters.

Possible Gradient of Ground Waters from Dix River Toward Kentucky River.

The level of the waters in the Kentucky river at High Bridge are given by J. B. Hoeing as 492 feet; at Hickman Bridge or Camp Nelson as 503 feet; and at Clays Ferry, in Fayette county, at 533 feet.

Contrasted with these elevations are those of the Dix river: 550 feet at Kennedy's mill; 600 feet along that part of the river directly east of Faulconer, 650 feet at Davistown; 700 feet along that part of the river directly east of Danville; and 750 feet a mile north of the pike from Danville to Lancaster by way of Hedgeville.

These measurements indicate differences of about 50 feet between the elevation of the Dix river at Kennedy's mill and the nearest part of the Kentucky river, the latter being only three miles away, across the hills northeastward. At the locality directly east of Faulconer, the Dix river is almost 100 feet above the level of the Kentucky river either at Handy's Bend north of Buena Vista or at the Bend northeast of Toddville, about 7 miles away. At Davistown, the Dix river is about 150 feet above the level of the Kentucky river five and a half miles northeastward. A mile and a quarter southeast of the Danville Water Works, the Dix river is about 200 feet above the level of the Kentucky river about 7 miles northeastward. A mile north of the Hedgeville-Lancaster pike, the Dix river is about 250 feet above the level of the Kentucky river, also 7 miles away, northeastward.

From the preceding data it will be seen that the gradient from the level of the Dix river toward the nearest part of the Kentucky river is 17 feet per mile at Kennedy's mill, 14 feet per mile along the river east of Faulconer, 23 feet per mile at Davistown, 28 feet per mile about a mile and a quarter southeast of the Danville Water Works, and 36 feet per mile about a mile north of the pike from Danville to Lancaster.

Possible Effect on Water Supply During Summer Months.

Such gradients might readily give rise to a seepage of underground waters from the Dix river toward the Kentucky river, especially in view of the fact that the intervening rock consists of great thickness of limestone-several hundred feet thick, without any important interbedded layers of clay. The effects of such an underground drainage, if any exist in that direction, should be most effective in lowering the water supply in the Dix river during the drier months of late summer and early autumn. The presence of such a drainage should be sought by means of the fluorescin test, the chemical being inserted in the river somewhere near the Danville Water Works.

Gradients Between Dix River and Salt and Green Rivers.

Three miles south of Harrodsburg, Dry Run has an elevation of 250 feet above Dix river east of Faulconer, six and a half miles distant, but it contains little water, Salt river, a little over a mile west of Harrodsburg, has an elevation of 270 feet above the Dix river at Kennedy's mill, nine and a half miles distant. These are large eastward gradients, but it should be remembered that the gradients from the Salt river area are still greater northeastward, toward the Kentucky river, and, therefore, probably are of only moderate assistance in carrying underground waters toward the Dix river.

The differences between the levels of the headwaters of the Hanging Fork of Dix river and the nearest branches of Green River are too inconsiderable to be discussed in this connection.

Most Underground Drainage Probably Approximately Parallel to Surface Drainage.

By far the greater part of the underground drainage probably passes through that part of the soil, sand, and rock which is comparatively near the surface. The underground drainage, therefore, must be determined chiefly by topography, and have little relation to the dip of strata or to differences in level of streams several miles apart. Nevertheless, in attempting to explain the comparatively small run-off in the Dix river area, compared with the annual rainfall, the possibility of the considerable underground drainage from the Dix river northeastward toward the Kentucky should not be excluded. And in this connection it should be noted that the greatest gradient between these rivers lies in the area above Davistown and the Danville Water Works, where the inadequacy of the water supply has been most felt.

Why Does Water Flow at Kennedy's Mill When Water no Longer Flows Over the Dam at the Danville Reservoir?

The question has been asked: Why is it that considerable water is still flowing at Kennedy's mill when the river is perfectly dry above the Danville Water Works? Before answering this question it would be desirable to have an adequate series of data on hand giving the relative water supply at the two stations for a period of several years.

It is known very well why the supply of water at the Danville Water Works is inadequate. There is considerable leakage at the dam. But entirely aside from the leakage at the dam, there is little water during the dry months to hold. This is shown by the fact that recently ditches were blasted from water hole to water hole up the river above the Danville reservoir in order to secure water from the shallow water holes, many of them only about two feet deep. It is evident from this that the natural flow of water down stream must have come practically to a stand-still at this time in the upper part of the river.

During the dry months, the demand of the water supply stored up by the Danville water works is greatest. Under these circumstances it is very easy to account for an inadequate water supply at the Danville reservoir.

Of course, there is an underground drainage of waters towards the Dix river all along its course. This is the way in which all of the rivers of the world secure their water supply when it is not raining. There is not only a leakage from the Danville reservoir down stream, but additional waters enter the drainage channel all along the lower parts of the Dix river. This water is held back by the dam at Kennedy's mill. The question is: How much is held back by the Kennedy mill, and how does this amount compare with the amount held back at the Danville reservoir? The quantity of water used up during the dry season by the Kennedy mill must be known before such a question can be answered. It should be remembered that the Kennedy mill is a comparatively small mill. Moreover, the leakage at the Kennedy mill dam is unknown. Answers to questions of the nature here proposed should be based upon facts, and no one has taken the trouble to ascertain the facts so far. When accurate data regarding the total quantity of water passing down the river channel at the Danville reservoir and at the Kennedy mill are known it may turn out that the difference is not considerable, when the quantity abstracted by the Danville Water Works is considered, and when account is taken of a possible underground drainage northeastward toward the Kentucky river.

Effect of Porosity of Soil on the Stream Flow During the Drier Months.

All persons know that during the drier months the quantity of water passing down the stream channels becomes much less. This is due not only to the smaller rainfall, but also to the fact that there is a smaller run off when it does rain, and the percentage of rain which evaporates from the soil without entering the stream channels is greatly increased.

Most of the water which falls upon the ground during the summer months is readily absorbed by the soil and only a small percentage is added to the run off. The more porous the soil, the greater will be the percentage of water absorbed by it. In a crude way, the relative amount of water taken up by a soil during a rain may be determined by the depth to which the top of the soil is found moistened immediately after a rain. Heavy clays are often moistened only near the surface while porous loams may show the effects of the rain for a depth of several inches. The more porous the soil, the less will be the immediate run-off.

Richmond Soils.

In this connection attention should be called to the considerable porosity of the sandy Richmond soils southeast of a line connecting Lancaster and Stanford. These soils include the so-called Cumberland sandstone soils of W. M. Linney, and the Bald Hill soils. They are well exposed along the higher lands south of Lancaster, and in the areas surrounding the Silurian outlier northwest of Sweeney. They are abundantly exposed along the higher areas between Sweeney and Rowland, extending eastward beyond Needmore, Maywood, and Preachersville, to within several miles of Crab Orchard. They are well exposed south of Stanford. The sandy nature of these Richmond soils probably has been exaggerated, but there is no doubt of their porosity, and of their wide distribution over the southeastern part of the Dix river drainage basin.

Lower Corryville and Tate Soils.

Similar soils are formed by the disintegration of the lower part of the Corryville section. The Tate layer, recognized as far north as Maysville, in Kentucky, increases in importance southward. The Bellevue bed can not be recognized very far south of the Ohio river, and the thickness of the comparatively unfossiliferous argillaceous section increases toward central Kentucky, until in Lincoln and Garrard counties the lower half of the Corryville bed is involved. This forms soils comparable with the sandy Richmond soils. Soils belonging to this lower horizon are well exposed in the area between Lancaster and Stanford, and Hawkins branch, and thence westward toward Shelby. They are abundant in the higher lands south of the Louisville and Nashville railroad as far south as Turnersville, McKinney, Moreland, and for two or three miles beyond Hustonville, including a large part of the Hanging Fork drainage area.

Especial attention is called to the wide distribution of these porous Richmond and Tate or Corryville soils over the upper Dix river and Hanging Fork drainage areas, since their porosity readily accounts for the relatively small run-off resulting from rains during summer months. These soils are abundant there where the streams have their smallest gradients. It is probable that of the rain that falls on these soils during the drier months by far the greater part is returned to the atmosphere by evaporation, and never is added to the water actually reaching the stream courses.

Upper Waverly Soils.

Similar porous soils are formed by the upper part of the Waverly section, that part which overlies the New Providence clays. But these Waverly soils either occupy the steeper gradients along the knobs or occupy only relatively small areas in the valleys between Broadhead and Maretburg, and other similar areas.

Garrard or Paint Lick Soils.

Sandy soils are formed also by the decay of the so-called Garrard sandstones. These are argillaceous limestones, the lower part of which, the Paint Lick beds, weather to distinctly porous soils. While the Paint Lick horizon is of considerable thickness in Lincoln and Garrard counties, usually it is not well exposed over considerable areas. It is found along the crest of some of the ridges west of Hubble, and along the higher hills between Danville and Shelby. It is seen also northwest of Lancaster, before reaching the Dix river. Elsewhere it forms the steeper gradients of hill sides. The total area covered by these soils is too inconsiderable to have any distinct influence upon the Dix river drainage.

Limestone Soils.

In contrast with the considerable distribution of the more porous sandy soils formed by the decay of the Garrard or upper Eden, Tate and lower Corryville, Richmond, and upper Waverly soils is the relatively small amount of heavy or water shedding soils formed by the decay of intervening limestones or by the presence of heavy beds of clay belonging to the original rock section.

Fairmount Limestone Soils.

Between the Paint Lick and the Tate and lower Corryville sections there is a considerable thickness of Fairmount limestone, producing the most fertile soil out-side of the Blue Grass areas. This weathers to a less porous soil than the sandy soil already named and to that extent should throw more water into the stream courses. The limestone layers themselves, however, are thin, are separated by horizontal crevices, and are crossed by numerous vertical cracks, making of the Fairmount horizon one of the best water carrying horizons south of the line connecting Danville and Lancaster.

The Fairmount horizon, therefore, should be a feeder of the underground drainage entering the stream courses during dry weather.

Upper Corryville and Arnheim Limestone Soils.

Between the lower Corryville and by far the greater part of the Richmond section is a limestone horizon consisting of the comparatively even bedded, dense, upper Corryville limestones, and the coarser grained, much broken up, rubbly Arnheim limestones. The clays formed by the decay of the upper Corryville limestone frequently are very sticky, and add considerably to the immediate run-off in case of heavy rains. These sticky red clays are well exposed south of Moreland, and at numerous other localities along the head waters of the streams entering the Hanging Fork.

Silurian Limestones and Clays.

The red clays formed by the decay of the Silurian limestones, and the clays interbedded with the upper parts of these limestones are exposed only along the foot of the knob area southeast of Stanford, as far as Crab Orchard, and around the small outliers near Needmore Hill, northeast of Sweeny, southeast of Preachersville, and along Drake, Harmon, and Fall Lick creeks. To these must be added the very considerable Crab Orchard clay areas forming the upper part of the Silurian section east of Cedar creek. These Crab Orchard clays shed water readily, and usually hold up most of the water traversing the Devonian limestones and the immediately overlying Ohio black shale, thus giving rise to numerous springs.

New Providence clays.

The New Providence clays form another great water shedding horizon, and give rise to springs by holding back the waters traversing the much more porous upper Waverly argillaceous strata.

Eden Soils.

Immediately below the Paint Lick or upper Eden sandy rock, the middle Eden strata consist of a considerable proportion of limestone, but the lower part of the middle Eden includes a larger percentage of interbedded clay so that the middle and lower Eden in general may be regarded as a clay horizon, holding back the waters in the Paint Lick beds, and giving rise to springs.

Catheys, Lexington, and Highbridge Limestones and Soils.

The entire Catheys, Lexington, and High Bridge section is so nearly composed of limestone to the almost entire exclusion of interbedded clays, that it forms one of the most stupenduous masses of continuous limestones in the country. Of this mass, the Lexington limestone, and a part of the Catheys limestone is composed chiefly of granular limestones. Over wide areas, this limestone has weathered to a porous rock, and is frequently traversed by limesinks and the connecting underground drainage. The rock usually weathers into a rather porous soil, although not sandy. The upper layers of the Lexington limestone are decidedly phosphatic locally, and the soils formed from this part of the limestone are the best part of the famous Blue Grass soils of Kentucky.

The underlying Tyrone and High Bridge limestone is very fine grained, and the underground drainage passing through it must occupy chiefly the crevices.

The striking feature of the geological section in Lincoln and Garrard counties is the enormous thickness of almost continuous limestones forming the lower part of the Ordovician section, and the great quantity of relatively porous, argillaceous, or so-called sandy strata in the overlying, upper part of this section. The former characterize the area traversed by the lower part of the Dix river drainage. The latter cover a large part of the area south of the line connecting Danville and Lancaster. The tendency of these upper, porous strata, and of the soils produced from them, is to decrease the run-off into the Dix river during the drier summer months.

Importance of Accurate Statistics on Stream Flow.

In the determination of the usefulness of a river as a source of water power it is much more important to know the amount of water which the river can be depended upon to supply than to know why it does not supply more. Moreover it is much more important to know how much water passes down the river, month by month, for a long series of years, than to know what the amount of precipitation within its drainage area may be. The total precipitation within any drainage area is useful only in setting a limit to the maximum quantity of water to be expected from this area. It can give but a very uncertain idea of the amount actually to be expected from the stream from month to month, since there are many factors besides total rainfall determining the latter. The important requisite in determining the reliability of a water supply is to know what is the minimum supply to be expected, during what season of the year, and for how long a time. For this purpose, records of rainfall are of little use. Only actual records of the water passing the proposed site of the dam, day by day for a series of years can give reliable information. Nevertheless, a record of the rainfall for a series of years is of interest, and a number of such records can be given.

SHELBY CITY, KY. (Elevation 1087 feet.)

Monthly Precipitation in Inches.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1891													
1892							1.44		4.58		3.92	4.27	
1893	2.68	3.71	3.41	5.54	5.66	6.16	2.54	1.67	1.93	2.28	3.22	2.73	41.33
1894	2.63	4.07	1.98	2.15	2.82	2.98	0.75	2.84	2.12	1.13	1.71	4.17	29.35
1895	6.86	0.80	3.74	3.57	3.52	3.32	3.71	1.77	0.50	1.68		4.53	
1896	0.15	2.92	6.06	0.53	3.77	3.63	10.92	2.06					
1897						1.51	4.83	1.59	0	0.18	3.88	4.17	
1898	9.55	2.29	9.24	3.62	3.80	1.91	6.36	3.77	5.93	5.39	2.74	3.74	58.34
1899	7.80	4.92	8.08	3.44	4.14	2.33	3.86	3.80	2.13	3.47	1.68	3.94	49.59
1900	2.92	5.08	4.32	2.16	2.25	4.56	4.08	3.62	1.66	0.57	8.73	2.32	42.27
1901	1.89	0.58	3.56	5.05	2.82	4.20	2.95	3.90	3.49	0.99	1.63	4.82	35.88
1902	7.65	0.67	5.51	2.37	3.44	4.66	3.39	3.44	3.03	2.41	4.33	9.60	50.50
1903	2.37	8.96	5.52	4.63	2.61	1.87	4.06	3.80	0.36	2.86	3.89	2.86	43.79
1904	2.77	1.97	4.64	2.05	6.24	2.64	2.39	3.50	2.09	0.28	1.00	3.98	33.55
1905	2.43	2.70	6.60	2.79	3.15	4.49	5.82	3.89	2.38	3.85	2.78	4.23	45.11
1906	3.86	2.38	6.85	1.94	3.25	5.12	6.71	3.00	8.39	2.05	3.84	5.94	53.33
1907	6.93	3.16	4.09	2.28	5.73	5.86	4.21	2.91	2.59	1.84	4.05	2.76	46.41
1908	2.07	5.36	5.95	6.58	4.10	2.74	3.25	3.39	0.70	0.77	2.90	2.16	39.97
1909	3.26	8.56	5.42	5.78	4.43	5.39	4.45	5.95	2.16	1.20	2.35	2.97	51.92
1910	5.56	4.95	0.92	5.21	0.75	5.99	7.06	3.74	8.23	2.14	1.95	2.68	54.18
1911	3.32	3.74	1.60	6.65	0.86	4.15	2.06	1.84	4.84	3.79	4.82	7.57	45.24
Means	4.15	3.72	4.86	3.68	3.52	3.87	4.23	3.18	3.03	2.05	3.47	4.18	43.94

HIGH BRIDGE, JESSAMINE COUNTY.

Monthly Precipitation in Inches.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1901													
1902						5.64	1.31	1.35	2.65	2.56	3.81	5.67	
1903	2.21	5.57	3.25	3.25	3.18	3.64	4.46	3.36	2.04	2.24	1.95	1.96	37.11
1904	2.59	3.05	7.45	2.28	1.37	2.03	2.03	2.54	2.95	0.53	0.63	3.79	31.24
1905	2.14	1.95	3.30	2.43	7.13	4.77	4.06	4.69	1.92	5.49	3.92	3.63	45.43
1906	3.02	1.30	6.09	1.24	0.63	3.05	6.20	5.47	6.79	1.00	3.32	3.35	41.46
1907	7.39	1.14	5.32	2.40	2.38	4.73	6.14	4.77	1.91	3.65	2.23	2.69	44.75
1908	1.34	4.42	4.27	4.42	3.71	3.44	1.78	0.45	0.31	0.93	1.36	1.72	28.15
1909	3.34	6.78	4.75	6.07	6.10	4.73	5.17	3.52	3.00	1.59	2.39	3.20	50.64
1910	4.55	3.99	0.83	5.34	5.47	7.47	6.95	3.31	8.55	1.90	2.68	3.07	54.11
1911	3.19	3.35	1.82	5.34	2.71	5.71	3.35	2.92	5.18	4.15	4.80	7.00	49.52
Means	3.31	3.51	4.12	3.64	3.63	4.54	4.14	3.24	3.53	2.40	2.71	3.71	42.48

BEREA, KY. (Elevation 1070 feet.)

Monthly Precipitation in Inches.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1901		0.70	2.80	4.89	3.78	4.62	2.73	7.45	4.15	0.83	1.73	5.40	
1902	6.58	1.19	5.05	1.93	2.77	6.81	2.49	2.69	3.98	2.53	4.33	7.26	47.61
1903	2.01	7.48	6.39	6.41	2.02	2.97	5.44	3.33	0.66	2.99	4.04	2.59	45.33
1904	3.14	1.63	5.89	2.01	5.10	1.81	2.29	5.01	0.90	0.93	0.57	3.20	32.48
1905	2.16	2.54	6.02	3.49	5.27	6.66	4.01	4.97	2.06	5.47	2.50	4.61	49.76
1906	3.20	1.84	5.93	1.41	3.02	4.91	3.10	4.28	3.86	1.55	2.82	6.08	42.00
1907	7.48	3.59	4.05	2.58	5.10	4.78	2.85	3.74	3.52	1.90	5.37	3.74	48.73
1908	2.99	5.33	6.58	4.01	3.95	3.60	6.00	3.44	1.04	0.94	1.57	2.80	42.25
1909	2.99	7.08	4.69	6.78	4.53	10.20	5.69	4.90	2.00	1.22	2.41	1.17	53.66
1910	3.22	4.49	0.50	3.40	5.77	6.29	10.83	6.09	4.83	2.67	2.67	3.05	53.81
1911	4.33	2.06	1.38	6.04	0.64	3.53	2.63	4.79	4.08	5.68	4.96	5.43	45.55
Means	3.81	3.45	4.48	3.81	3.81	5.11	4.37	4.61	2.82	2.43	2.99	4.53	46.25

SHELBY CITY.

Daily Precipitation for 1910.

1910	January	February	March	April	May	June	July	August	September	October	November	December
1									2.44			.04
2	T		.23				.31		.07		.08	
3	.03	.11		.54	.04		.31					
4				.05		.46	1.42	.06	1.38			.20
5	.30			.08		1.10	.31		.20		.05	.38
6	2.00			.09		T	.60		.03	1.00		.55
7	.17				1.10		.40	.21	.01	.52		
8		T			T		.02		T			
9		.28				1.28	.01					
10			.58			1.48	T					.06
11		.80		T		.01	T					
12		.30		.96	1.33		.14					
13	.70						.42					
14	.10									.01	.11	
15				.60		.30	.36					
16		.11		.81	.19	.03	.62					
17	.32	1.61		.52	1.04		.22					
18	1.52	.08		.17	.07			.14	.03			T
19			T	.24				.23	3.03			
20	.12		.02	.07	1.18	.31			.03			
21	.20	.67	.09		T			2.17		.22		
22	.10	.18			.05				.04	.11		
23				T	.07	.10	.21				.03	.34
24					.44		T					.12
25				.37	.24	.05			.97			
26		T		.26			.76	.92				
27		.27		.45			.14		T	.26	1.00	
28		.54				.88	.80				.68	.01
29					T		.16			.02		.59
30							.35	.01				.39
31	T											
Sums....	5.56	4.95	0.92	5.21	5.75	5.99	7.06	3.74	8.23	2.14	1.95	2.68

SHELBY CITY.

Daily Precipitation for 1911.

1911	January	February	March	April	May	June	July	August	September	October	November	December	
1	.47	.25	.03		.21	.02				.11			
2	.05				.03			.22		.43			
3	.20	.24		.34								T	
4		.83		.70			T			.09	.07		
5			T			T	.29		.45				
6		.54	.11			1.03		T	.15		2.37		
7			.48	.60					.48	.58			
8	.05	.16		.17			.09		1.28		T		
9			.03		.04		.02		.30	.13			
10									.11	.54			
11		T		.12			.28				.04	.22	
12		.05		.75			.37	.20			.62	1.12	
13				.29			.03	.05	.83			.39	
14	.02	.10		.30		.05		T		.05		1.16	
15	.01			.11		.28				.58		.72	
16							.65			.06		.22	
17	.23					T				.76			
18		.13	T			.12			.14		1.05		
19		.88	.01	.25		1.96			.35				
20		.52					.20					.09	
21	.47	T		.08	.10				T			.07	
22	.10		.05	.02	.25					.42		.22	
23						T	T				.26	.07	
24						.22		.10			.23	.23	
25	T					.30		.26					
26	.47		.50			.17	.13	.06				1.77	
27	.44			T								.46	
28	.04	.04		.24					.27		.18		
29	.51		.25	.18			T	.57					
30	.15		.14	2.50	.06			.32				.39	
31	.10		T		.17		T	.06		.04		.44	
Sums.....	3.32	3.74	1.60	6.65	0.86	4.15	2.06	1.84	4.84	3.79	4.82	7.57	45.24

HIGH BRIDGE.

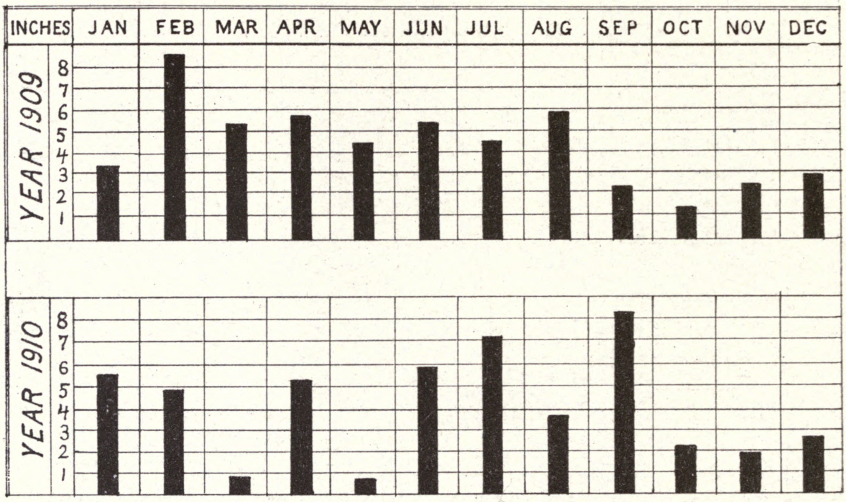
Daily Precipitation for 1910.

1910	January	February	March	April	May	June	July	August	September	October	November	December
1		T							.08			.03
2			.05				1.10		.66		.05	.01
3	.07	.12		.30	.08		.08		.90			T
4	.01	.02		.48	.06		.25					.22
5	.08			.05		1.22	.60		1.02	.06	.07	.14
6	1.30		.20	.31		.44	.45		.04	.39		.95
7	.30			.01	.22		.51			1.06		T
8	T.				.73			.25				
9						1.14			.02			
10		.20	.19			1.12	.04	.06			.05	
11			.04			1.16						.13
12		.60		1.04	.78	.05						
13	.14	.02		.27			.08					
14	.66						1.04					
15				.09			.03					
16				.90	.01	.39	.05					
17	.18	1.24		.62	.05		.44					
18	1.06	.46		.10	1.36		.30		.04			
19	.16			.08				.30	1.70			.01
20				.16	.51	.52			2.46			T
21	.43	.39	.35		.88			.53				
22	.15	.26			.12			.65		.21		
23	.01			.25	.02							.02
24					.28	.47					.02	.61
25					.36	.13	.10		.65			
26				.15	.01	.02	.40	1.40	.98			
27		.05		.49				.02		.10	.19	
28		.63		.04		.78	.60			.05	2.20	
29						.03	.75			.03	.10	.13
30							.13					.82
31								.10				
Sums	4.55	3.99	0.83	5.34	5.47	7.47	6.95	3.31	8.55	1.90	2.68	3.07

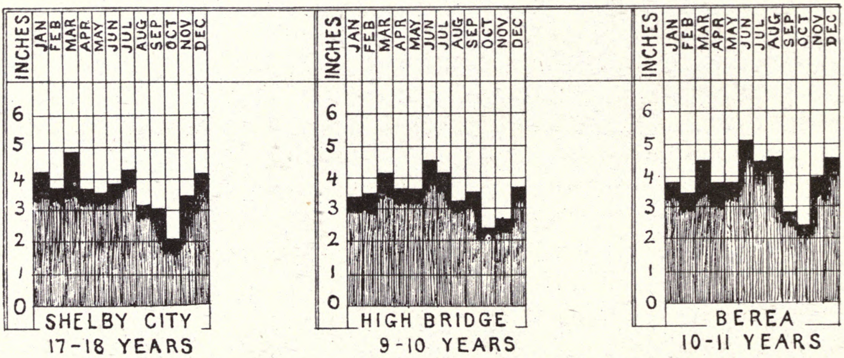
HIGH BRIDGE.

Daily Precipitation for 1911.

1911	January	February	March	April	May	June	July	August	September	October	November	December	
1	.11	.08	.05		1.54	.38		.10			T		
2	.22		.02		.10			.05		.78			
3	.20			.60	.01			.14		.92			
4	.10	.70		.85		.05							
5				.53					.19	.09	.12		
6		.64	.25			1.26			.22		1.80		
7			.28	.57				.05		.05	.27		
8	.04	.06	.39	.24						.55			
9				.14	.03		1.57		.90				
10					.01		.32			.46			
11									1.86	.10		.32	
12				.58			.92				.82	.85	
13	.06			.10					.20		.04	.98	
14		.06		.28					.33			.26	
15	.02			.30		.59		.05		.19		1.38	
16								.87		.01		.45	
17	.15						.42			.21			
18	.10		.04			1.08		.47		.46	1.08		
19		.22	.01	.26		.50			1.02				
20		1.51		.13		.01	.02						
21	.12	.05					.10					.14	
22	.42			.15	.84					.21		.01	
23					.18					.06		.16	
24						.54					.57	.25	
25						.87					T		
26	.60	.02	.16			.02		1.11				.21	
27	.03	.01	.24			.36						1.24	
28	.47			.05		.05					.10		
29	.11		.22	.24				.08	.17				
30	.44		.13	.32					.29			.01	
31			.03							.06		.74	
Sums.....	3.19	3.35	1.82	5.34	2.71	5.71	3.35	2.92	5.18	4.15	4.80	7.00	49.52



RELATIVE PRECIPITATION AT SHELBY CITY IN TWO SUCCESSIVE YEARS



COMPARATIVE MONTHLY DISTRIBUTION OF PRECIPITATION

Months with Abundant Precipitation.

The preceding data are sufficient to indicate that, within the Dix river drainage area, March is the month during which precipitation is greatest. No attempt is made here to distinguish rainfall from snow fall. It should be remembered that a large percentage of a snowfall may evaporate into the air without first being added to the waters in the stream channels, and in fact, without becoming ground water. The same statement should be made regarding the precipitation during the months January and February.

June and July are the next most important months as regards precipitation. December also is a month of considerable precipitation.

Dry Months.

September and October are dry months, with October as the driest month of the year. The latter part of August and the early part of November often must be included in this dry season, making a period of two and a half or three months during which precipitation is small.

Necessity of Water Supply During Dry Months.

The great problem in connection with a high pressure water power system at Kennedy's mill is how to provide for an adequate supply of water during the dry season, especially during September and October. During the winter months, a great part of the precipitation may be tied up in the form of snow and ice, but there is never a water famine.then. During the early spring months, the ground is so much saturated with water that a large percentage of the precipitation appears as run-off. During later spring and most of the summer, a much larger percentage enters the soil, and the percentage of run-off is decreased. During September and October, however the run-off becomes small and the streams dwindle in size. This is the serious season of the year as regards an adequate water supply.

Two Projects for Impounding Water Supply at and Above Kennedy's Mill.

In the case of the proposed high pressure water supply plant at Kennedy's mill it is proposed to hold back a sufficient part of the waters entering the gorge during the rainy months to meet the demands of the dry months. Several plans have been suggested. The most ambitious of these involves the building of a dam 150 feet high. The quantity of water which would be held back by such a dam would be enormous. Should the dam ever give way, it would be a national calamity. Nevertheless, dams of this height already are in existence, and the problem becomes one of proper construction under the guidance of competent engineers.

Another proposition involves the erection of three dams, each having a height of 50 feet. In this case the third dam would solve the troubles of the Danville Water Works. since it would hold the water back at least as far as their reservoir, and possibly for some distance beyond. No exact record of the difference in elevation is at hand.

The second proposition involving the construction of three dams would be much less expensive, but it also would result in holding back a vastly smaller quantity of water.

Importance of Accurate Data on Stream Flow During the Dry Months.

If the second proposition be considered, it becomes highly important to figure closely on the quantity of water which would be held back by such a system of dams, during the rainy season, and upon the amount which would be added during the dry season. Hence the importance of records of the amount of water passing down the gorge past Kennedy's mill, especially during the dry months. For engineering purposes, it is highly important to have an exact record of the water flow during the driest months of the driest years ever known.

All hydraulic engineers recognize the importance of competent data for the solution of these problems. It is not sufficient to have the data only for part of the year. The data should cover many years. The fact that so many water power propositions are taken up without reference to such data is an indication of the extent to which such constructions may be regarded as gambler propositions, rather than as business propositions.

The intelligent developer of coal properties on a large scale nowadays insist in putting down a number of diamond drill test holes before planning for an expensive coal mine plant. In the same manner, the hydraulic engineer must base his operations on adequate measurements of stream flow, before beginning his operations. A record for one year, unless it be one of exceptional drought, must be actually misleading, since it is the exceptional year which tests the reliability of the plant.

Observations on Stream Flow at Kennedy's Mill.

For these reasons a series of observations have been inaugurated at Kennedy's mill. These observations include not only a series of daily gauge readings, but also calculations of the actual stream flow at different stages of the water, using a Price Current Meter, belonging to the United States Geological Survey. While these readings do not cover a sufficiently long period of time to give valuable results, they are the beginning of such a series, and for this reason mark an important stage in the study of the water power possibilities of the Dix river.

Rate of Discharge of Dix River at Kennedy's Mill.

The accompanying diagrams will illustrate the relation between the rate of discharge of the Dix river and the rainfall.

The rates of discharge have been calculated from the gage heights taken by C. P. Kennedy at the bridge across the Dix river, about an eighth of a mile below Kennedy's mill, 5 miles due east from Burgin, Kentucky. These rates of discharge indicate the number of cubic feet of water which pass the point of observation during one second. Multiplying by 86400, or the number of seconds in a day, the total discharge per day can be determined.

Daily Gage Height in Feet and Discharge in Second—Feet of Dix River, at Kennedy's Mill, near Burgin, for 1910.

C. P. KENNEDY, Observer.

Day.	July. Gage height.	July. Discharge.	August. Gage height.	August. Discharge.	September. Gage height.	September. Discharge.	October. Gage height.	October. Discharge.	November. Gage height.	November. Discharge.	December. Gage height.	December. Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	3.9	135	5.05	434	7.7	1710	5.25	502	3.7	102	6.05	822
2	3.9	135	4.5	268	10.35	4020	4.9	385	3.8	118	5.7	672
3	3.8	118	4.2	194	8.45	2260	4.45	255	3.7	102	5.3	520
4	5.85	734	4.0	163	8.1	1990	4.12	177	Gage not read		5.05	434
5	5.3	520	4.0	153	11.05	4765	4.0	153			5.0	418
6	8.3	2140	3.8	118	10.0	3670	4.2	194			7.85	1815
7	7.5	1580	3.8	118	8.25	2100	5.35	538			7.45	1550
8	9.0	2720	3.8	118	6.05	822	8.75	2500	3.4	61	6.45	1005
9	6.8	1175	3.6	87	5.55	663	6.65	1100	3.45	67	5.8	713
10	5.7	672	3.6	87	5.0	418	5.75	692	3.5	73	5.7	672
11	5.3	520	3.6	87	4.75	339	5.3	520	3.4	61	6.0	800
12	5.1	451	3.4	61	4.55	281	5.05	434	3.5	73	6.0	800
13	5.0	418	3.3	50	4.65	310	4.9	385	3.5	73	5.6	632
14	6.9	1225	3.3	50	4.3	217	4.75	339	3.35	55	5.0	418
15	6.5	1025	3.3	50	4.05	163	4.65	309	3.2	30	4.8	354
16	9.0	2720	3.28	38	3.88	131	4.6	295	3.2	30	4.8	364
17	11.15	4875	3.28	38	3.75	110	4.36	229	3.3	50	4.6	295
18	7.82	1794	3.3	50	3.7	102	4.05	163	3.35	55	4.6	295
19	6.0	800	3.28	38	8.8	2540	4.0	153	3.35	55	4.6	295
20	5.35	538	3.7	102	11.5	5260	3.85	126	3.3	50	4.55	281
21	5.0	418	4.6	295	7.55	1610	3.8	118	3.0	20	4.55	281
22	4.65	310	9.05	2765	6.4	980	3.9	135	3.0	20	4.5	268
23	4.5	268	5.6	632	5.9	756	4.05	163	3.15	34	4.55	281
24	4.3	217	5.05	434	6.05	822	4.25	205	3.1	29	4.75	339
25	4.1	173	4.45	255	6.55	1100	4.1	173	3.15	34	4.85	370
26	3.95	147	5.2	485	10.65	4325	3.95	144	3.15	34	4.8	354
27	3.9	135	5.05	434	7.45	1550	3.9	135	3.55	80	5.05	433
28	4.15	183	6.5	1025	6.45	1002	3.8	118	9.0	2720	5.3	520
29	5.1	451	5.5	593	5.85	734	3.7	102	9.15	2855	5.75	692
30	6.25	912	5.15	468	5.5	593	3.8	118	6.45	1005	12.55	6480
31	6.5	1025	4.9	385			3.75				9.9	3670
Total		28534		8065		45443		10860		8190		26739
Mean		921		325		1470		356		273		862

Daily Gage Height in Feet and Discharge in Second—Feet of Dix River at Kennedy's Mill, for 1911.

C. P. KENNEDY, Observer.

Day.	JANUARY.		FEBRUARY.		MARCH.		APRIL.		MAY.		JUNE.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec. ft.
1	6.5	1025	8.95	2675	5.05	435	4.3	217	17.35	12690	3.65	94
2	9.2	2900	7.3	1460	4.95	401	4.2	195	9.95	3620	3.65	94
3	8.1	1990	6.85	1220	4.8	354	4.35	230	7.85	1815	3.6	87
4	7.3	1460	14.05	8315	4.75	339	8.7	2460	7.4	1520	3.45	67
5	7.1	1340	10.4	4070	4.7	324	7.6	1640	6.05	822	3.35	55
6	6.9	1225	9.5	3170	4.75	340	6.5	1025	5.6	632	3.8	118
7	6.6	1075	8.65	2420	4.9	385	6.95	1885	5.3	520	3.85	126
8	5.75	692	7.75	1745	5.35	540	8.35	2180	4.95	401	3.65	94
9	5.8	713	7.9	1850	5.45	574	7.3	1460	4.7	324	3.5	73
10	5.7	672	7.15	1370	5.3	520	6.65	1100	4.55	281	3.45	67
11	5.65	652	6.85	1200	5.1	451	6.5	1025	4.4	242	3.4	61
12	5.45	574	6.45	1002	4.95	401	6.8	1175	4.3	217	3.2	30
13	5.35	540	6.10	845	4.8	354	8.7	2460	4.25	206	3.1	19
14	5.3	520	5.8	713	4.6	295	8.25	2100	4.15	183	3.05	15
15	5.3	520	5.65	652	4.6	295	10.55	4220	4.05	163	3.0	10
16	5.2	485	5.3	520	4.55	281	8.5	2300	3.95	144	3.0	10
17	5.1	451	5.0	418	4.5	268	6.65	1100	3.9	135	3.0	10
18	4.95	401	4.85	369	4.5	268	6.0	800	3.85	126	3.0	10
19	4.95	401	5.6	632	4.45	255	5.45	574	3.8	118	3.05	15
20	4.85	369	12.55	6480	4.5	268	5.65	652	3.8	118	4.75	339
21	4.8	354	10.5	4170	4.4	242	5.5	593	3.75	110	4.6	295
22	8.45	2260	8.25	2100	4.35	230	5.45	574	3.9	135	3.9	135
23	8.5	2300	7.55	1580	4.35	230	5.35	540	4.15	183	3.45	67
24	6.9	1225	6.45	1002	4.25	206	5.2	484	4.0	153	3.35	55
25	6.55	1050	6.00	800	4.2	194	5.0	418	3.9	135	3.3	50
26	6.65	1100	5.8	713	4.15	183	4.75	339	3.8	118	3.3	60
27	7.15	1370	5.5	593	4.3	217	4.6	295	3.7	102	3.3	50
28	7.90	1850	5.35	540	4.3	217	4.65	309	3.65	94	3.9	135
29	8.10	1990			4.25	206	4.9	385	3.6	87	3.9	135
30	11.45	5205			4.3	217	5.4	556	3.85	126	3.55	80
31	9.15	2855			4.3	217			3.75	110		
Total		39564		52624		9707		32691		25630		2441
Mean		1276		1880		313		1086		827		81

Daily Gage Height in Feet and Discharge in Second—Feet of Dix River, at Kennedy's Mill, for 1911.

C. P. KENNEDY, Observer.

Day	July Gage height	July Discharge	August Gage height	August Discharge	September Gage height	September Discharge	October Gage height	October Discharge	November Gage height	November Discharge	December Gage height	December Discharge
	Feet.	Sec.-ft	Feet	Sec.-ft	Feet	Sec.-ft	Feet	Sec.-ft	Feet.	Sec.-ft.	Feet.	Sec.-ft
1	3.3	50					3.3	50	3.4	61		
2	3.2	30					3.4	61	3.3	50		
3	3.1	19					3.3	50	3.3	50		
4	3.0	10					3.5	73	3.3	50		
5	3.0	10					3.9	135	3.3	50		
6	3.0	10					3.6	87	5.3	520		
7	3.0	10					3.6	87	10.8	4490		
8	2.95	9					3.5	73	6.8	1175		
9	2.9	8					3.4	61	5.5	593		
10	3.2	30					3.5	73	5.3	520		
11	3.3	50					3.5	73	5.1	451		
12	3.55	80					3.5	73	10.2	3870		
13	4.4	242					5.0	418	6.9	1225		
14	4.1	173					4.9	385	6.3	935		
15	4.7	324					5.0	418	5.6	632		
16	4.2	194					5.0	418	5.6	632		
17							5.1	451	5.6	632		
18							6.0	800	9.5	3170		
19							5.5	593	8.7	2460		
20							5.1	451	6.7	1125		
21							4.9	385	6.4	980		
22							4.7	324	6.1	845		
23							4.5	268	5.8	713		
24							4.1	173	5.5	593		
25							4.0	153	5.3	520		
26							3.8	118	5.0	418		
27							3.8	118	4.8	354		
28							3.7	102	4.7	324		
29							3.7	102	4.7	324		
30							3.6	87	5.0	418		
31							3.4	61				
TOTAL								6721		28220		
Mean								216.		940		

Discharge Measurements of Dix River at Kennedy's Mill, for 1910.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Ft. per sec.*	*Feet.*	*Sec.-ft.*
July 18	Aug. F. Foerste	141	898	1.85	7.65	1650
" 19	G. F. Bogard	141	715	1.37	6.44	977
" 20	G. F. Bogard	141	607	1.08	5.64	653
" 20	G. F. Bogard	141	574	1.05	5.44	600
" 21	G. F. Bogard	141	519	0.87	5.10	454
Aug 14	Aug. F. Foerste	—	—	—	3.3	50
" 25	G. F. Bogard	143	372	0.59	4.3	219
Sept 2	L. B. Herrington	142	1610	3.89	12.35	6260
" 20	L. B. Herrington	142	1280	3.02	10.2	3870

Rating Table for Dix River at Kennedy's Mill.
July 18, 1910 to September 20, 1910.

Gage height	Dis-charge	Differ-ence	Gage height	Dis-charge	Differ-ence	Gage height	Dis-charge	Differ-ence	Gage height	Dis-charge	Differ-ence	Gage height	Dis-charge	Differ-ence
Feet	Sec.-ft.	Sec.-ft.	Feet	Sec.-ft.	Sec.-ft.	Feet	Sec.-ft.	Sec.-ft.	Feet	Sec.-ft.	Sec.-ft.	Feet	Sec.-ft.	Sec.-ft.
3.00	10	9	5.00	418	33	7.00	1280	60	9.00	2720	90	11.00	4710	110
.10	19	10	.10	451	34	.10	1340	60	.10	2810	90	.10	4820	110
.20	30	11	.20	485	35	.20	1400	60	.20	2900	90	.20	4930	110
.30	50	11	.30	520	36	.30	1460	60	.30	2990	90	.30	5040	110
.40	61	12	.40	556	37	.40	1520	60	.40	3080	90	.40	5150	110
.50	73	14	.50	593	39	.50	1580	60	.50	3170	100	.50	5260	110
.60	87	15	.60	632	40	.60	1640	70	.60	3270	100	.60	5370	110
.70	102	16	.70	672	41	.70	1710	70	.70	3370	100	.70	5480	110
.80	118	17	.80	713	43	.80	1780	70	.80	3470	100	.80	5590	120
.90	135	18	.90	756	44	.90	1850	70	.90	3570	100	.90	5700	120
4.00	153	20	6.00	800	45	8.00	1920	70	10.00	3670	100	12.00	5820	120
.10	173	21	.10	845	45	.10	1990	70	.10	3770	100	.10	5940	120
.20	194	23	.20	890	45	.20	2060	80	.20	3870	100	.20	6060	120
.30	217	25	.30	935	45	.30	2140	80	.30	3970	100	.30	6180	120
.40	242	26	.40	980	45	.40	2220	80	.40	4070	100	.40	6300	120
.50	268	27	.50	1025	50	.50	2300	80	.50	4170	100	.50	6420	120
.60	295	29	.60	1075	50	.60	2380	80	.60	4270	110	.60	6540	120
.70	324	30	.70	1125	50	.70	2460	80	.70	4380	110	.70	6660	120
.80	354	31	.80	1175	50	.80	2540	90	.80	4490	110	.80	6780	120
.90	385	33	.90	1225	55	.90	2630	90	.90	4600	110	.90	6900	120

Rating Table for Dix River, at Kennedy's Mill.
July 18, 1910, to September 20, 1910.

Gage height	Dis- charge	Differ- ence	Gage height	Dis- charge	Differ- ence	Gage height	Dis- charge	Differ, ence	G he
Feet	*Sec.-ft.*	*Sec.-ft.*	*Feet*	*Sec.-ft.*	*Sec.-ft.*	*Feet*	*Sec.-ft.*	*Sec.-ft.*	
13.00	7020	120	15.00	9550	130	17.00	12200	140	
.10	7140	120	.10	9680	130	.10	12340	140	
.20	7260	120	.20	9810	130	.20	12480	140	
.30	7380	120	.30	9940	130	.30	12620	140	
.40	7500	120	.40	10070	130	.40	12760	140	
.50	7620	120	.50	10200	130	.50	12900	140	
.60	7740	120	.60	10330	130	.60	13040	140	
.70	7860	130	.70	10460	130	.70	13180	140	
.80	7990	130	.80	10590	130	.80	13320	140	
.90	8120	130	.90	10720	130	.90	13460	140	
14.00	8250	130	16.00	10850	130	18.00	13600		
.10	8380	130	.10	10980	130	.10			
.20	8510	130	.20	11110	130	.20			
.30	8640	130	.30	11240	130	.30			
.40	8770	130	.40	11370	130	.40			
.50	8900	130	.50	11500	140	.50			
.60	9030	130	.60	11640	140	.60			
.70	9160	130	.70	11780	140	.70			
.80	9290	130	.80	11920	140	.80			
.90	9420	130	.90	12060	140	.90			

The above table is not applicable for ice or obstructed channel conditions. It is based on 9 discharge measurements made during 1910 by Foerste, Bogard and Herrington, and is fairly well defined between gage heights 3 feet and 13 feet. Above gage height 13 feet the rating curve is an approximation.

PLATE A.

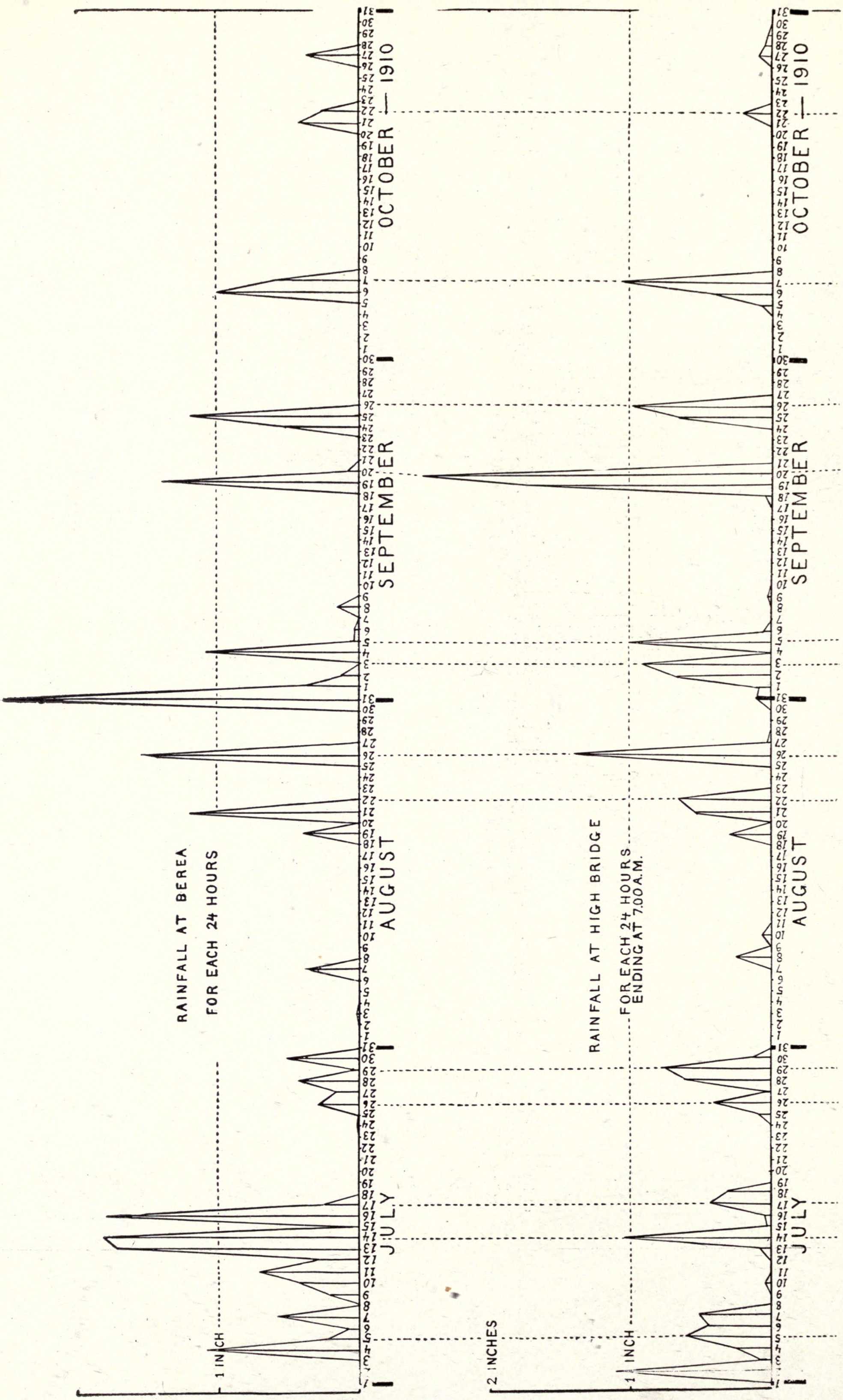
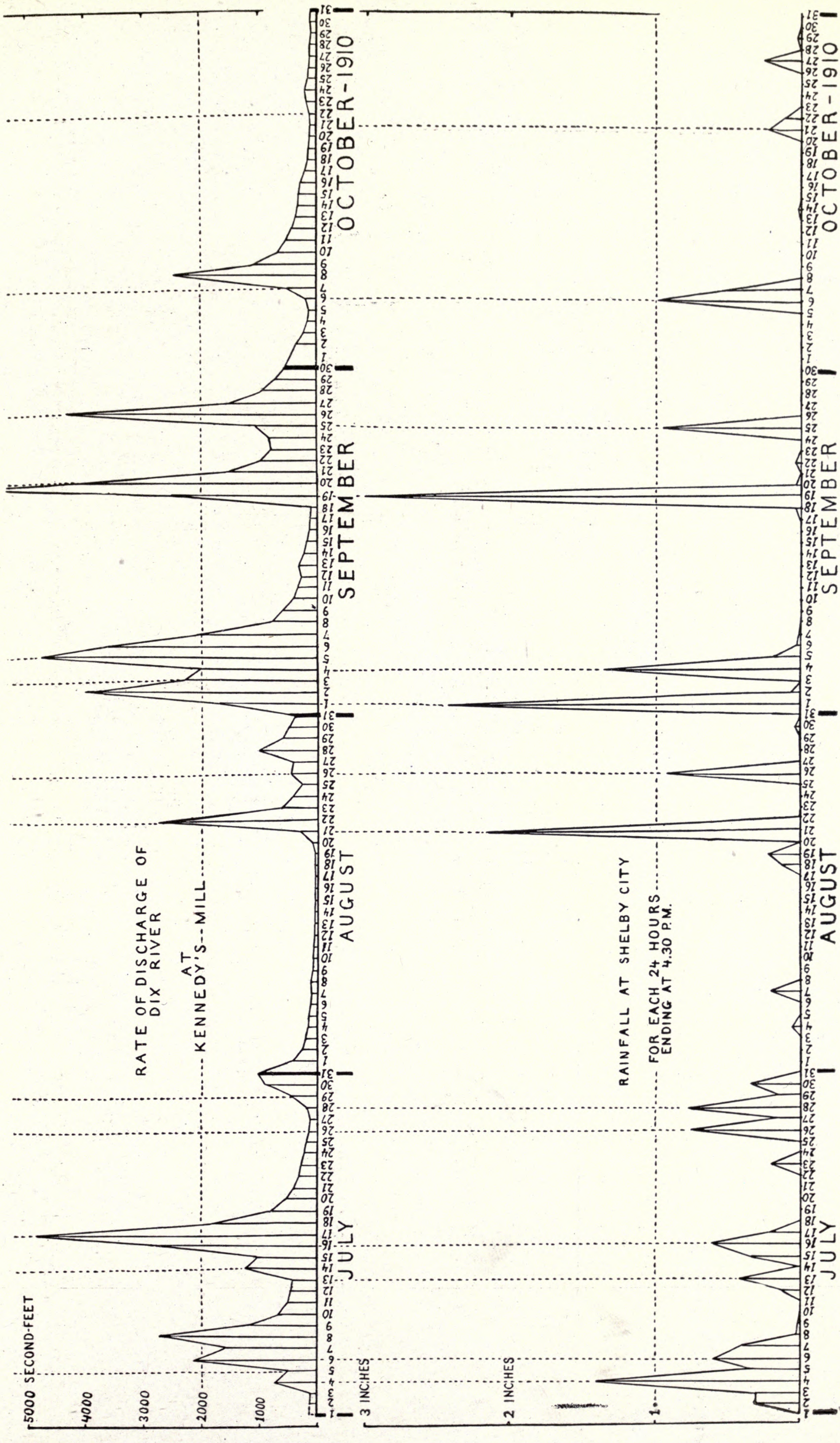
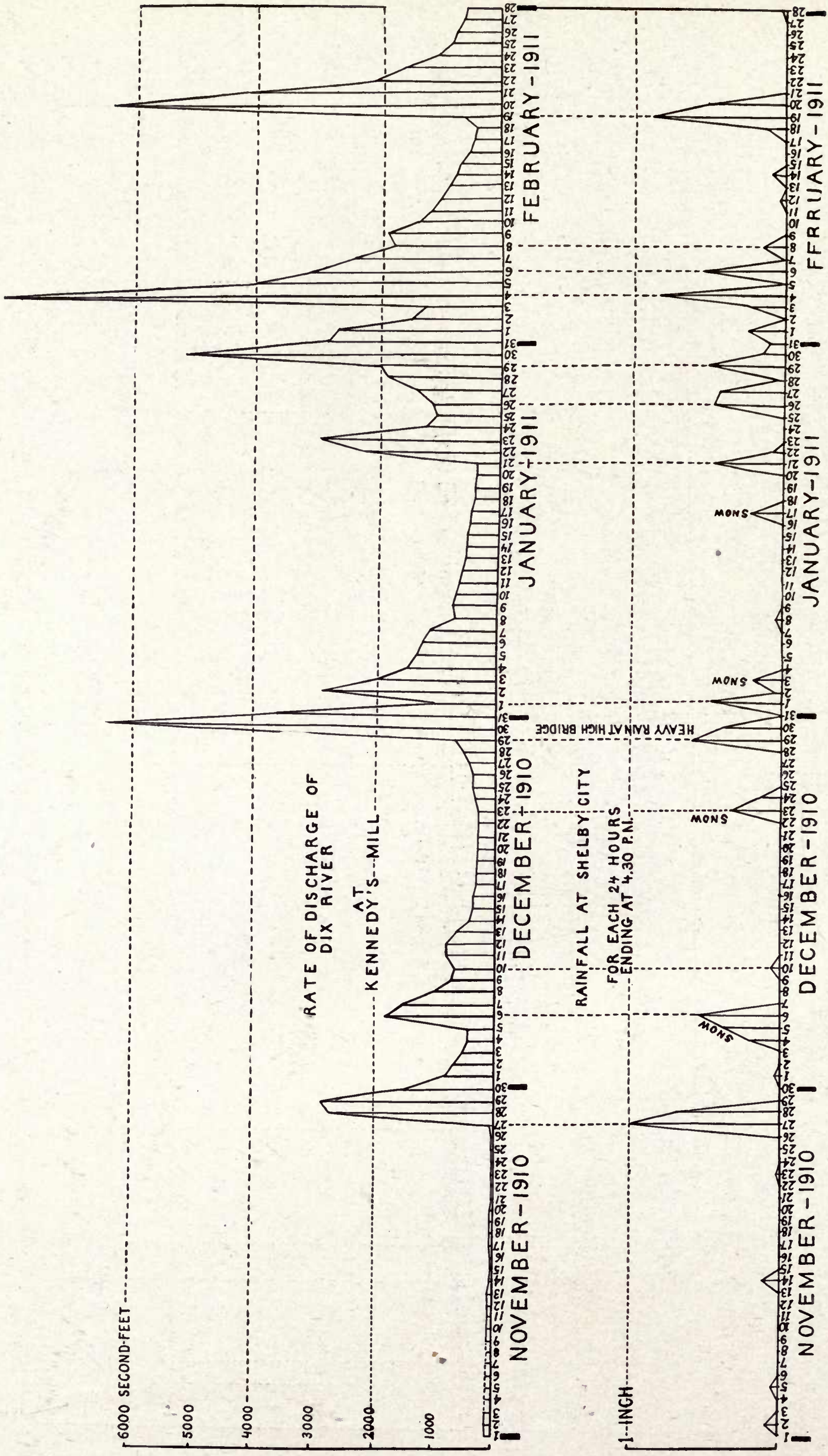

RAINFALL AT BEREA
FOR EACH 24 HOURS
1 INCH
RAINFALL AT HIGH BRIDGE
FOR EACH 24 HOURS
ENDING AT 7.00 A.M.
2 INCHES
1 INCH
JULY
AUGUST
SEPTEMBER
OCTOBER — 1910

PLATE B.



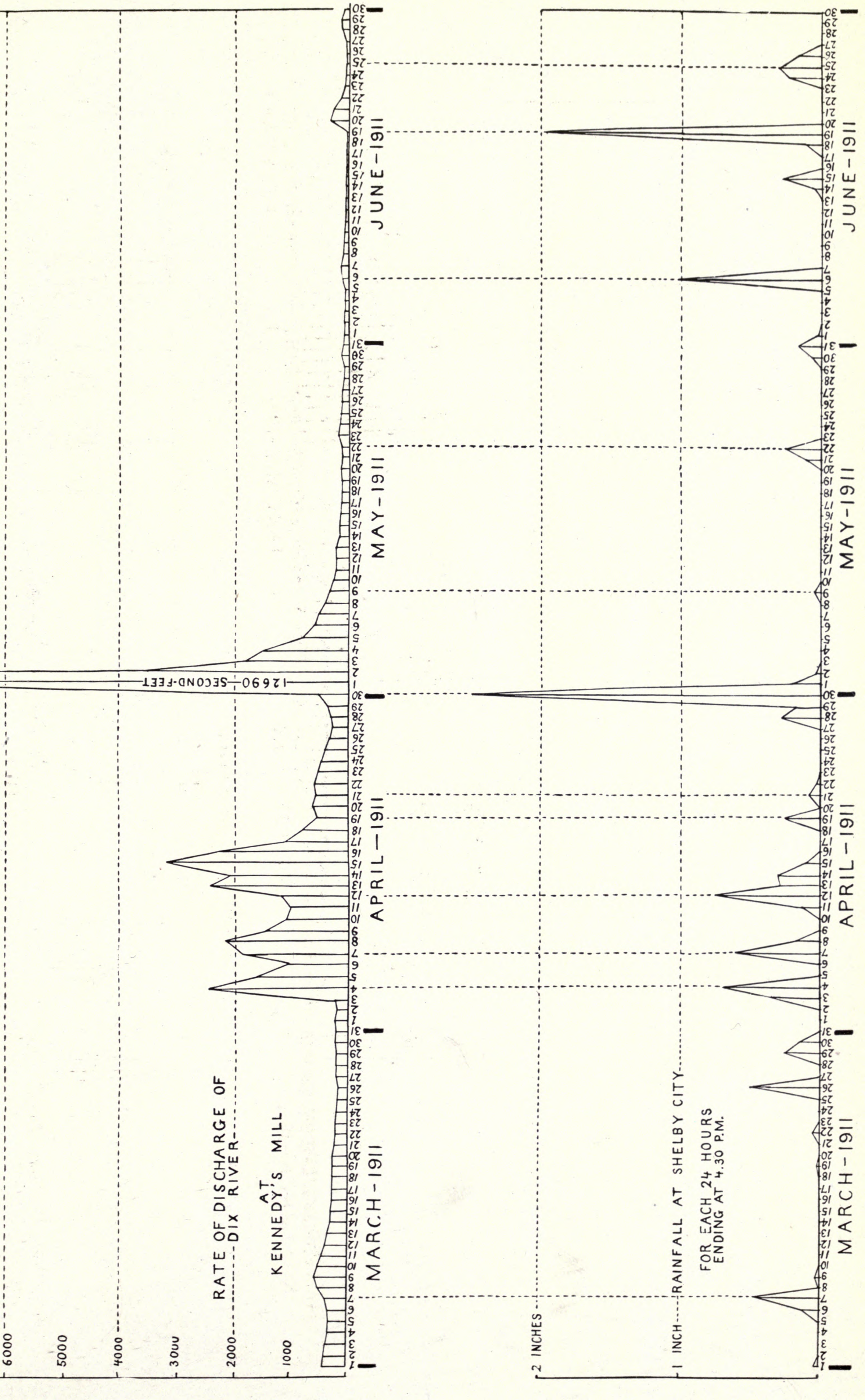
5000 SECOND-FEET
4000
3000
2000
1000
RATE OF DISCHARGE OF DIX RIVER
AT
KENNEDY'S MILL
3 INCHES
2 INCHES
1
RAINFALL AT SHELBY CITY
FOR EACH 24 HOURS
ENDING AT 4.30 P.M.
JULY
AUGUST
SEPTEMBER
OCTOBER-1910

PLATE C.



6000 SECOND-FEET
5000
4000
3000
2000
1000
RATE OF DISCHARGE OF DIX RIVER
AT KENNEDY'S MILL
RAINFALL AT SHELBY CITY
FOR EACH 24 HOURS ENDING AT 4.30 P.M.
1-INCH
NOVEMBER-1910
DECEMBER-1910
JANUARY-1911
FEBRUARY-1911
HEAVY RAIN AT HIGH BRIDGE
SNOW

PLATE D.



RATE OF DISCHARGE OF DIX RIVER AT KENNEDY'S MILL
6000
5000
4000
3000
2000
1000
12690 SECOND-FEET
RAINFALL AT SHELBY CITY FOR EACH 24 HOURS ENDING AT 4.30 P.M.
2 INCHES
1 INCH
MARCH-1911
APRIL-1911
MAY-1911
JUNE-1911

In the diagram, the vertical lines indicate by their length the number of cubic feet of water passing the bridge per second, and the scale used in the diagram is indicated on the left side.

The diagrams also illustrate the daily rainfalls at Shelby City, High Bridge, and Berea, in inches. The rain is caught in a vertical cylinder of appropriate width, and the depth of the water which has fallen during each period of 24 hours is actually measured. The length of line in the diagrams, indicates the amount of the rainfall, the scale used being placed on the left.

In all of these diagrams, the oblique lines connecting the tops of the vertical lines have no special significance. They merely are intended to guide the eye swiftly from the top of one line to the top of the next, and to that extent may prove convenient in the rapid interpretation of these diagrams.

High Bridge is 5 miles north of Kennedy's mill, and Shelby City is 13 miles southwest of the mill. Formerly observations were kept at the Danville Water Works, 7 miles south of the mill. As far south as the line connecting Shelby City with Lancaster, the gradients toward the Dix river, and especially those down the Dix river, toward Kennedy's mill, are very steep, so that the effects of any heavy rainfall within this area are perceived at the mill within only a few hours. For the purpose of estimating this rainfall, the stations at High Bridge and Shelby City are fairly well placed. The one at High Bridge, unfortunately, lies at the narrowest end of the Dix river valley, and is situated below, instead of above the mill, so that local showers in that vicinity usually would not seriously effect the water supply at Kennedy's mill. The station at Shelby City is about 7 miles away from the Dix river, but serves excellently for an estimation of the rainfall in the Hanging Fork valley, one of the chief tributaries of the Dix river, occupying the western part of Lincoln county. If the station at the Danville water works could be revived, it would serve excellently in estimating the rainfall for that part of the Dix river which lies north of the line connecting Shelby City and Lancaster.

There are no observation stations at present in the upper part of the Dix river area, in Lincoln, Garrard, and Rockcastle counties. For this reason, the observations taken at Berea are here utilized as at least better than nothing. It is highly desirable, for the project under discussion, that at least one weather observation station should be located in this upper area, preferably at Crab Orchard. Another station might be placed at Stanford. An ideal combination, if the number of stations were for reasons of economy limited to three, would be Shelby City, Lancaster and Crab Orchard.

It is highly desirable, that whenever possible, in the selection of stations for weather observations, those sites should be chosen which would give the most valuable data in connection with stream flow problems. As cities grow in size, the questions of water supply increases in importance, not only in connection with engineering problems, but also in connection with the questions of water supply for drinking purposes, for the extinction of fires, and for other purposes served by the local water works. The damage done by streams often is considerable, especially when in the immediate vicinity of large towns, and it is desirable to know with some degree of accuracy what quantities of water are discharged down a valley after a heavy rain if future engineers are to devise means for lessening dangers from such a source.

Within the limitations already discussed, the accompanying diagrams illustrate fairly well the connection between rainfall and the rate of discharge of the Dix river. As might be expected, the rise of the waters in the river follow the rainfall. Usually the maximum rise of the waters in the Dix river at Kennedy's mill occurs on the day following the maximum rainfall. This is due to the small size of the river basin and to its rapid gradient, especially toward the lower part of its course. It is evident that the higher tides at Kennedy's mill are due to the waters which have fallen along the lower part of the river area. Hence these tides rise rapidly and fall rapidly. The waters falling in the upper parts of the Dix river area, near Shelby City, Stanford, Crab Orchard, and Broadhead, merely delay the fall of the river to its normal rather low rate of discharge, but rarely causes the so-called high tides.

It is evident that in the use of the waters of the Dix river for securing high pressure hydraulic power, the conservation and proper control of the large quantities of water pouring down the gorge during the so-called tides will prove an important problem. It is the conservation of these waters which will make possible the continuation of a sufficient head of water during the considerable periods in late summer and early fall when the streams are at their lowest levels, and entirely inadequate for the purposes of water power. The rapid rate at which the streams drop back to their former levels is a point to be specially emphasized.

In interpreting the diagrams, it should be remembered that the rainfall records for High Bridge terminate each day at 7 a. m. while those at Shelby City terminate at 4:30 p. m. The fact that the highest record for rainfall at High Bridge frequently is recorded one day later than at Shelby City is due to the fact that so many rains in summer and autumn occur during the day time, the sky clearing again toward night, thus causing the rainfall to be recorded one day later at High Bridge, if this rainfall takes place between 7 a. m. and 4:30 p. m. of any one day. Hence it frequently must be assumed that the maximum rainfall at High Bridge recorded for any one day as a matter of fact really fell on the preceding day; in other words at about the same time as the maximum rainfall recorded at Shelby City.

In general, it will be seen, that the maximum height of the so-called tides in the Dix river at Kennedy's mill shows a fairly definite relation to the maximum rainfall in the lower part of the Dix river area, as indicated by the rainfall records of Shelby City.

For instance, the maximum rainfall on August 21 was followed by a tide at Kennedy's mill on August 22. The maximum rainfall on September 1st was followed by a tide on September 5th. With a smaller rainfall at Shelby City, the tide on September 5th reached a higher level than on September 2nd. Two reasons may be assigned for this. The second tide came only three days after the first tide, before the waters had a chance to fall to less than half the height of the first tide. Moreover, it probably rained heavily in the upper part of the Dix river area on August 31st, five days preceding the second tide, and in the meantime these waters from the upper branches of the river were approaching the gorge of the Dix river and were assisting in keeping the river up above its normal level.

The maximum rainfall on September 19th was followed by a tide which at midnight, between September 19th and 20th, reached a height of 16.1 feet at the gauge beneath the bridge. The maximum rainfall on September 25th was followed by a tide on September 26th.

The accumulative effect of several days of moderate rain usually produces the maximum tide two or three days after the rain. For instance, the several days rain in the first part of July did not result in a maximum tide until July 8th. The moderate rains between July 13th and 16th produced a maximum tide on July 17th of such height as to suggest that much heavier rains must have fallen at an earlier date in the upper parts of the Dix river drainage area. According to the rainfall data secured at Berea, these heavier rains probably took place on July 13th and 14th, the run-off reaching the Dix river gorge by July 17th.

The several days of rain between July 26th and 30th produced the highest tide on July 31st. The rains on October 6th and 7th produced the maximum tide on October 8th. The small rains on October 21st and 22d produced a little rise in the river at Kennedy's mill on October 24th.

An examination of the data here presented fails to suggest that a proper proportion of the rainfall in the Dix river area does not reach the gorge at Kennedy's mill, as was suggested to the writer when he began his investigation in the field. The fact of the matter is that it has been attempted heretofore to form conclusions from insufficient data, and the present investigation has not covered enough time to give much better results although they indicate the direction in which such investigations should proceed. For instance, heretofore it has been customary to multiply the area covered by the Dix river drainage by the total rainfall at the Danville Water works or some similar set of figures, and assume that this represents the total rainfall within the area in question. This entirely ignores the local nature of many of these rains, and the great differences in rainfall even within the narrow limits of the territory here under investigation. Then it was assumed that a certain percentage of this total rainfall should appear in the gorge. Nothing can be more misleading. Nature pays little attention to percentages gotten up in offices where thorough investigation is not the ordinary method of procedure. Such percentages are gotten up for children, to give them some tangible elementary ideas regarding the relationship between rainfall and run-off, and never were intended for the practical engineer. It is good advice to discount the value of the opinions of an engineer who is willing to recommend the inauguration of expensive engineering undertakings on the basis of such insufficient data. He is either ignorant or untrustworthy.

Eventually, it may be possible to determine some approximate mathematical relationship between the amount of rainfall and the rate of discharge of the Dix river. At present the data are not sufficient. It is evident, of course, that the relative amount of run-off, compared with the rainfall, must be greater during the winter and early spring months, when the percentage of ground water is greatest, and the absorption of rain-water is less.

In general it may be stated, within rather large limits of error, that for each inch of total rainfall per month a daily rate of discharge of approximately 140 second-feet may be expected. According to these figures, the rate of discharge for July should average about 990 second-feet; for August, 525 second-feet; for September, 1150 second-feet; and for October, 300 second-feet. As a matter of fact, the rates of discharge for these months average 920 second-feet for July, 325 second- feet for August; 1470 second-feet for September, and 320 second-feet for October. In other words, the ratio of the rate of discharge to the rainfall is greater than the average during wet months, because there is more ground water in the soil, and less of the rainfall is taken up by the soil before reaching the stream channels. On the other hand, the ratio of the rate of discharge to the rainfall is less during the dry months, when a larger percentage of the rainfall is taken up directly by the dry soil.

During the dry months of the year, the rate of discharge of the Dix river should fall per inch of rainfall. During these months, the effect of the large areas along the upper head waters of the Dix river, in which sandy soils occur, should be effective in readily taking up much of the rainfall, and diminishing the run-off. This diminished run-off should be especially noticeable in the very dry years, of which the summer and early fall of 1910 were not good examples. Much drier seasons have been experienced in years past, and for these much drier years, provisions must be made if a high pressure water supply of permanent value is desired.

Resume of Observations on the Dix River Drainage Area.

A study of the drainage area of the Dix river has led to the following conclusions.

1. The erection of a high dam at Kennedy's mill is an engineering possibility.

2. Conditions appear to be favorable for such a dam holding water. At least nothing was discovered suggesting the impossibility of such a project.

3. Nothing was discovered suggesting that an underground drainage exists at present between the Dix river and the Kentucky of sufficient magnitude to imperil the project of a dam, provided that sufficient water is supplied by the river during the dry season of the year, or sufficient could be held back during the rainy season.

4. The preceding remarks apply to the gorge within which the water would be held back by the dam.

5. The most important problem is not the engineering possibility of the dam, or its power and that of the walls of the gorge to hold water, but whether there is any water to hold back, especially during the dry months of the year.

6. It is highly important that stream flow observations should cover a period of several years. The people interested in the erection of a power plant at Cumberland Falls, for instance, are quietly going on with their stream flow observations, and there is no danger of their beginning actual operations until adequate records are at hand.

7. It is an error to secure options on land for such a short period of time that adequate observations can not be made, in the interval.

8. Any expression of opinions, unless based upon adequate records of observations on stream flow, can have no permanent value, and might be misleading.

9. There is no doubt about the enormous quantities of water which pass down the gorge during the winter months, or after a heavy rain in summer.

10. The quantity of water necessary for running a

high pressure water power plant is well known by hydraulic engineers.

11. The quantity of water held back by one large dam, or by several dams, can be readily determined by a civil engineer.

12. Whether a sufficient amount can be held back all year can be determined only when more is known of the stream flow, week after week, year after year.

13. The determination of the reason why such a small percentage of the rainfall appears as stream flow as low as Kennedy's mill, is chiefly of academic interest and does not have any very direct bearing upon the water power proposition as a practical business venture.

14. As a matter of fact, the rocks, in a large part of the Dix river drainage area, especially south of a line passing from Danville to Hedgeville, and thence toward Burdett knob, dip in an opposite direction to the chief surface drainage.

15. The dip of the rocks is not believed to have any important bearing upon the direction of flow of the ground waters in the special area here under discussion.

16. The direction of flow of underground waters is determined chiefly by differences of hydrostatic pressure.

17. There is a possibility that there is a sufficient difference of hydrostatic pressure between the Dix river and the Kentucky river northeastward, to give rise to a flow of the ground waters in that direction.

18. Such a flow might account for the small quantity of water passing down the stream, especially during the drier months of the year.

19. The porous nature of a considerable part of the soils, especially south of a line connecting Danville and Lancaster, apparently gives a more adequate reason for the much diminished stream flow.

20. The walls of the gorge below the Danville reservoir probably will hold as large a part of the water supply delivered by the head waters of the Dix river, as other dams in similar positions.

21. No dam holds all of the waters delivered to a reservoir. A part of the waters are absorbed by the walls

of the reservoir. A reservoir adds to the amount of the ground waters on each side. All that can be expected of any reservoir is to hold a certain percentage of the water delivered to it.

22. The amount escaping from the reservoir, naturally, must increase with the height of the dam.

23. The great hydrostatic pressures generated may open up underground drainage paths at present not in existence. However, the actual observations made in in the gorge of the Dix river do not suggest that any special danger is to be feared in this direction, if the construction of the dam be submitted to experienced hydraulic engineers.