REPORT ON THE WATER-POWER

OF THE

MIDDLE ATLANTIC WATER-SHED,

BY

GEORGE F. SWAIN, S. B.,

ASSISTANT PROFESSOR OF CIVIL ENGINEERING IN THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON, MASS.,

SPECIAL AGENT.

1012 W P—VOL 16——33

TABLE OF CONTENTS.

TABLE OF CONTENTS.

REPORT ON THE MIDDLE ATLANTIC WATER-SHED.

PREFATORY LETTER.

BOSTON, MASS., *June* 1, 1882.

Prof. W. P. TROWBRIDGE,
Columbia College, New York City.

SIR: I have the honor to submit herewith my report on the water-power of the middle Atlantic water-shed of the United States, embracing all the territory drained by streams flowing into the Atlantic ocean from the Hudson to the Chowan, not inclusive.

Following your directions, I have traveled over the region referred to in this report, but necessarily in a hasty manner; and although I visited many of the larger powers in order to form an idea of their availability, lack of time made it necessary to gather the facts regarding numerous important ones by oral inquiry or by correspondence. The only instrument of measurement used was a Locke pocket-level, and in some cases reliable measurements of fall could be obtained, while in others this was impossible.

In preparing the report I have freely used all the material that could be found, and am especially indebted to the reports of the Chief of Engineers, United States army, and to various state documents bearing on the subject. I am also indebted to numerous private individuals, state officers, engineers, railroad officers, and others, for valuable information and advice, and particularly to the officers of the United States Engineer Corps, and their assistants, who have afforded me every facility possible. My obligations are so many that it would be invidious to attempt to name those to whom my thanks are specially due.

In the arrangement of this report I have followed the general method adopted in the case of my previous reports. The drainage areas given were measured in a few cases geometrically, but in most cases with the planimeter, and are believed to be quite accurate. They agree very well with other measurements in all cases where I have had opportunity to compare them.

As regards the estimates of power available, the principles discussed in my former report have served as a guide here, and it is hoped that the estimates given, although they can not pretend to absolute accuracy, will be found to be tolerably close approximations to the truth. I am well aware that these estimates, as well as those given in the report on the New England water-sheds, will to some appear overstrained. It may be thought that they present a semblance of accuracy which they do not possess and which no estimates can possibly possess. In regard to a quantity so variable as the discharge of a stream, it will be asked whether the attempt to present estimates of four different states of flow is not worse than nothing, and whether it is not a needless and deceptive refinement to give more than one estimate. I am conscious of these objections, and my reasons for having given estimates as I have done is simply this: These reports will in all probability be read by persons who are not engineers, and whose ideas in regard to flow and power are not very clear or definite, and general statements would very likely be misunderstood by such persons. The very fact that the flow of a stream is such a variable and fluctuating quantity, and that the amount of power available would depend upon the storage reservoirs which might be constructed, as well as upon the natural flow of the stream, seemed to me to render it especially important to leave no room for misunderstanding as to the state of flow referred to in the estimates offered. If it were said, for instance, that the available power at a certain place varied from 500 to 3,000 horse-power according to the state of the water and the amount of storage utilized, that statement would, it seems to me, be of little value, not only because of its indefiniteness, but because even to those who might understand the meaning of the words, it would give no idea of the way in which the variation between 500 and 3,000 occurred, and how much was due to storage and how much to fluctuations in the natural flow of the stream. It seemed essential, then, in the first place, to give a separate estimate of the maximum power available with storage. In regard to the flow and power without storage reservoirs, the question arose: Upon what state of flow should the estimate be based? To determine the average flow during the year, or the low-season flow in ordinary or dry years, a series of gaugings is almost a necessity. On the streams in the district now under consideration, however, no such measurements have been made, and the only gaugings at my disposal were some measurements made on a few streams at very low stages of the water, or when the flow was nearly at its minimum. Data regarding this minimum flow being the most numerous, I thought it would be well to tabulate these data (see page 9 of the present report, and pages 9 and 10 of the report on the New England water-shed), and to give estimates of the minimum flow so that the reader could see how they were arrived at, and could disagree with the figures given according as his judgment led him to think the assumed flow per square mile per second was too great or too small. But I am aware of the fact that the minimum flow is not the most important quantity so far as water-power is concerned, because it occurs only at remote periods and lasts only a very short time; and I have felt, therefore, that, in addition to the two estimates referred to, at least one other was desirable. In view of the uncertainty attending all such estimates, and the large error to which they are liable, it would perhaps have been as well to have given an estimate simply of the average low-season flow. But I thought that I could make the subject a little clearer, and show a little more plainly the method of calculation that I had used, by giving the minimum low-season flow and the low-season flow in dry years; for if I had estimated the average low-season flow I should have had to do it by first estimating the two quantities just named, and adding to the latter of them one-fourth to one-third of itself. It seemed to me that in this way not only would the subject be made clearer and the estimates more definite, but that other persons would have better facilities for forming opinions for themselves in the matter, and for disagreeing with me intelligently and on reasonable grounds. In fine, of two evils I chose what seemed to me the lesser, preferring to give to the estimates the appearance of accuracy which they do not possess, rather than leave them in any way indefinite. If once it be understood that they are presented merely as estimates—in some cases almost guesses—that they make no pretensions to absolute accuracy, and that, although some of the estimates given (as the minimum low-season flow and the low-season flow in dry years) differ by only 15 or 20 per cent., either or both of them may be in error by a large fraction of that amount, I think there will be no difficulty and no misunderstanding.

The fact that this report has been written more than a year after the region to which it refers was visited, will serve to explain some of the inaccuracies which it will be found to contain. Not only will changes be found to have occurred in the mean time, but when so long a time elapses circumstances lose their freshness in the mind, and many things would no doubt have been presented in a clearer manner if the report had been written immediately after the region was visited. Some omissions will be found in the report, and lack of completeness in many instances; and while this is due in some cases to the fact that the time was not sufficient to allow of the necessary information being obtained, it is for the most part due to the fact that the attempt to obtain it was unsuccessful. The interest in the subject seems to be less in the district covered by this report, as a whole, than in the more northerly states, and, as a rule, it was more difficult to obtain the desired information. In some cases it was found to be absolutely impossible to obtain by correspondence the statistics desired.

I am, sir, very respectfully, your obedient servant,

GEORGE F. SWAIN,
Special Agent.

THE MIDDLE ATLANTIC WATER-SHED.

Having completed the description of the streams draining the New England water-shed, we proceed to discuss those draining the middle states. We begin, as before, by describing the general character of the region under consideration, after which each stream will be separately considered.

GENERAL CHARACTERISTICS.

1.—AREA AND FORM.

The area included in the district under consideration, comprising the region drained by all the streams flowing into the Atlantic between the Hudson and the Chowan, measures in all about 84,300 square miles, and is distributed approximately as follows among the different states:

	Square miles.
Virginia	23,600
West Virginia	3,700
Maryland	10,700
District of Columbia	64
Delaware	2,120
Pennsylvania	27,600
New Jersey	7,400
New York	9,076
Total	84,260

This area lies between the parallels of 37° and 43° north latitude, and the meridians of 74° and 80° west longitude, approximately. In shape, it is a strip lying along the Atlantic, with an average width perpendicular to the coast of from 225 to 240 miles, and bounded on the west by an irregular line forming the water-shed between the streams flowing directly into the Atlantic and those flowing west or north into the Mississippi and the Saint Lawrence. This western boundary-line is rather more irregular than in the case of the southern Atlantic water-shed, and topographically the two differ considerably, as will presently be seen. The coast-line, too, is much more irregular and indented than in the case of the southern Atlantic water-shed, and although its general direction is about north-northeast, yet its outline is broken at every step by arms of the sea and extensive bays which penetrate the land to a considerable distance.

2.—GEOGRAPHICAL AND CONTINENTAL POSITION.

Like the New England water-shed and the southern Atlantic water-shed, the middle Atlantic water-shed lies in the north temperate zone, and the prevailing winds in all are the return trades from the southwest. But as we go toward the north within the district considered, we gradually escape more and more from the influence of these winds, and those from other points of the compass become more common. As in the New England states, the winds from the east and southeast are maritime, and come laden with moisture from the ocean; but here the winds from the southwest, and even those from the south, have passed over large extents of country, and have discharged their load of moisture to a considerable extent, so that they do not partake of the character of sea-winds as much as in the case of the states farther north or south. That the influence of the gulf of Mexico on the region considered is here not of so much importance as regards rain and moisture as in the states farther south may be seen plainly from the Smithsonian charts showing the distribution of rainfall, in which the long finger-like projections extending from the Gulf, and indicating a large rainfall, show, by the fact that they do not extend into the Atlantic states north of North Carolina, that the moisture in those states is derived principally from the Atlantic; and in fact, we see along the coast a large rainfall, which diminishes quite steadily as we proceed inland, being even less in the mountains than on the immediate sea-board; while in the southern states we shall see that the rainfall is greatest in the mountains, because the principal carriers of moisture, the warm southwest winds from the Gulf, blowing parallel with the mountains, of course part with more of their burden in the mountains than in the lower lands. In the region we are now considering the principal carriers of moisture, the winds from the southeast, blow nearly at right angles with the mountains, instead of nearly parallel to them, and as the mountains are not high, and as they approach near to the coast in the northern and middle parts of the region, the rainfall diminishes from the coast inland quite uniformly.

The region now to be considered is bounded on the east by the ocean, on the west by the Alleghany mountains, on the south by the water-shed between the drainage-basins of the James and the Roanoke and Chowan, and on the north by that between the drainage basins of the Hudson and the great lakes, and those of the streams flowing into Delaware, Chesapeake, and Newark bays.

3.—TOPOGRAPHY.

In describing the topography of this region it will be convenient, now that we have completed the study of the rather detached New England water-shed, to call attention to the general structure of the Appalachian mountain system, and to the changes in its general features in different parts, and to contrast the region we are about to consider with that already discussed, and with the southern Atlantic water-shed.

The region under consideration, as well as that comprising the southern Atlantic water-shed, may be topographically divided into three quite distinct divisions, which we shall call the eastern, the middle, and the western. The former extends, in the middle Atlantic states, from the coast inland to the head of tide-water and navigation on the rivers, its western boundary being a line, which we may call the *fall-line*, and which marks the geological boundary between the Cretaceous and later deposits which lie between it and the coast, and the older geological formations which lie to the west. It is the most easterly line of outcrop of the older rocks, and marks the last considerable fall on the rivers. In the southern states it passes through Columbus, Georgia; Columbia, South Carolina, Rocky Mount and Weldon, North Carolina, here, however, being some distance above the head of tide-water, and often of navigation; and it may be traced northward quite through the district now under consideration. Passing in Virginia through Petersburg, Richmond, and Fredericksburg, it skirts the Potomac between the latter point and Washington, and, crossing it at a point some 10 miles above the national capital, it continues in a northeasterly direction, remaining nearly parallel to the shore of Chesapeake bay, crossing the Patapsco a little above Baltimore, and the Susquehanna near the state line; then, bending slightly to the east, it crosses the northern part of the state of Delaware, and follows the west bank of the Delaware river up to the great bend at Trenton, where it crosses it. Beyond this point it is not very prominent, but extends almost in a straight line between Trenton and Jersey City, crossing the Raritan near the town of New Brunswick, and the Hudson at its mouth, being there, however, entirely without influence as regards water-power. It will be seen, then, that the eastern division, which in the southern Atlantic states is a broad plain from 100 to 140 miles wide, gradually contracts in width toward the north until it nearly disappears at the mouth of the Hudson and in the northern part of the state of New Jersey; and the same will be seen to be the case with the middle division.

But although the eastern division becomes narrower toward the north, its slope does not vary to the same extent, becoming only slightly greater; and, as a consequence, the fall-line approaches nearer and nearer to navigable waters, until, when we reach the region we are discussing, we find throughout its whole length the fall-line at the head of navigable waters and at the head of tide-water, both navigation and tide being checked by the falls in the rivers at their crossing with that line. The effect of this circumstance, in bringing the water-powers on the fall-line nearer to transportation by sea, is of great importance.

Geologically, the eastern division preserves essentially the same character throughout its whole extent. The soil consists of sand and clay, and the large rivers afford no water-power in that part of their course lying within it, although some of the smaller tributaries, and some of the smaller streams flowing directly into the sea, afford in some cases very good power and belong to the class of sand-hill streams. As already incidentally remarked, the slope of the ground seems to increase somewhat toward the north, and the coasts are not bordered by swamps and lowlands to such an extent as in the southern states; so that, as we shall see in the case of some of the streams in New Jersey, in some cases fine water-powers are obtained, by damming, within a very few miles of the coast.

As regards the area of this division, it includes approximately two-elevenths of the state of Virginia, or about 7,500 square miles; nearly two-thirds of the state of Maryland, or about 7,850 square miles; the entire District of Columbia; about nine-tenths of the state of Delaware, or about 1,900 square miles, and six-tenths of the state of New Jersey, or about 4,600 square miles. Its area in Pennsylvania and New York is too small to be mentioned.

Before describing the middle division, it will be best to consider the principal facts relating to the general structure of the Appalachian mountain chain and the character of the western division. For most of the following notes and quotations I am indebted to Professor Guyot's article on "The Appalachian Mountain System", in the *American Journal of Science and Arts*, 1861.

This great system of mountains, which extends in an undulating line for a distance of 1,300 miles, from the gulf of Saint Lawrence to the state of Alabama, is composed of a number of sensibly parallel chains in the eastern part, and of an extended plateau in the west, which gradually descends to the valleys of the great lakes and of the Ohio and Saint Lawrence rivers. The Atlantic plain, which extends from the base of the mountains to the Atlantic ocean, and includes what we have called the middle and eastern divisions, has a width in New England of about 50 miles, almost vanishes near the mouth of the Hudson, and stretches out to a breadth of over 200 miles in the southern states; and as its slope does not vary much, the elevation of the base of the mountains rapidly increases toward the south and north, starting at the Hudson—being from 300 to 500 feet in New England, almost nothing about the bay of New York, from 100 to 300 feet in Pennsylvania, about 500 in Virginia near the James river, and between 1,000 and 1,200 in the southern part of North Carolina. On the west, the plateau above referred to, and which may be considered the base of the mountains, has a general elevation of about 1,000 feet.

The mountains present three remarkable characteristics: The first is that, as already remarked, they are composed of a series of nearly parallel chains, often very regular and uniform; and that "in the same part of the system the general height of the chains is sensibly equal", their summits showing neither many nor deep notches. Especially in Pennsylvania and New Jersey, the ridges "present the appearance of long and continuous walls, the blue summits of which trace along the horizon a uniform line seldom varied by any peaks or crags. In the extreme northern and southern portions, however, this character is considerably modified. There the system loses very much of its uniformity, and its physical structure becomes far more complicated; the form of simple parallel ridges almost entirely disappears".

The second prominent feature of the system is "its well-marked division into two longitudinal zones of elevation, one turned toward the shores of the Atlantic, in which the form of parallel chains just spoken of predominates, and the other turned toward the interior, which is composed of elevated and continuous plateaus", occasionally wrinkled by minor chains parallel to those on the east.

The third prominent feature is the existence, in the region of corrugations, of a "large central valley which passes through the entire system from north to south, forming, as it were, a negative axis through its entire length". This valley, known as the Great Appalachian Valley, is occupied in the north by lake Champlain and the Hudson river; in Pennsylvania it is known as the Kittatinny or Cumberland valley, and is occupied by the tributaries of the Susquehanna, and in part by the main river; in Virginia it is the great valley occupied by the Shenandoah and some tributaries of the James; and still farther south it is the great valley of East Tennessee, occupied by branches of the Tennessee.

At the northeast and at the center its average breadth is 15 miles; it contracts in breadth toward the south in Virginia, but reaches its greatest dimensions in Tennessee, where it measures from 50 to 60 miles in breadth. The chain, more or less compound, which borders this great valley toward the southeast is the more continuous, and extends without any great interruption from Vermont to Alabama. In Vermont it bears the name of Green mountains, which it retains to the borders of New York; in the latter state it becomes the Highlands; in Pennsylvania, the South mountains; in Virginia, the Blue ridge; in North Carolina and Tennessee, the Iron, Smoky, and Unaka mountains. On the northeast of the Great Valley, between the latter and the borders of the plateau parallel, there extends a middle zone of chains separated by narrow valleys, the more continuous of which is the range which bounds the central valley. This zone has a variable breadth in different parts of the system, and the number of chains which compose it is by no means uniform throughout.

As we proceed from the coast inland, therefore, we cross first the Atlantic plain, then the chain bounding the Great Valley on the east, with parallel ridges and longitudinal valleys, then the Great Valley, and finally the chain beyond, also with parallel ridges and longitudinal valleys, but irregular in structure.

The above are the general features common to the Appalachian system through its entire length, but it may be divided from north to south into three divisions presenting very remarkable differences in structure. The most northerly of these, extending south as far as the deep valleys of the Hudson and the Mohawk, which cut through the system to its base and across its entire breadth, need not here be considered, as it falls without the territory to be specially described. The middle division, which is about 450 miles in length, extends from the valley of the Hudson and Mohawk on the north to the New river, in Virginia, on the south; while the third or most southerly division comprises the remainder of the system. In the middle division the region of parallel chains, "at first very narrow about New York, presents toward the center, in Pennsylvania, its greatest breadth, which again diminishes toward the south. It is composed of a considerable number of chains much curved toward the west, and remarkable for their regularity, their parallelism, their abrupt acclivities, the almost complete uniformity of their summits, and their moderate elevation, both relative and absolute, which varies from 800 and 1,500 to 2,500 feet. The chains, however, increase in elevation toward the south, while they become more numerous and more indented. In the peaks of Otter, in Virginia, they attain to 4,000 feet". The plateau region west of the mountains is quite narrow in the southern part, but very wide in the north. Its high terraces occupy all the state of New York south of the Mohawk, a considerable part of Pennsylvania, and culminate in the plateaus in the neighborhood of lake Erie, where the mean altitude of the plateau reaches 2,000 feet, the valleys preserving a height of 1,500 feet, while the hills reach 2,600 feet.

This table-land forms a remarkable water-shed, from which the waters descend by the Susquehanna into the valley of the Chesapeake and the Atlantic ocean, by the Genesee and Saint Lawrence to the same ocean, and by the Alleghany and Ohio to the gulf of Mexico. The Susquehanna thus starts from lake Erie at the extreme western border of the plateau, and runs across all the Appalachian system and its mountain ranges to its eastern base. More to the southward the eastern escarpment of the plateau divides, as far as the sources of the Potomac, the waters of the Atlantic coast from those of the gulf of Mexico. It is the same escarpment which bears the local name of Allegheny mountain, a name which continues to be applied, south of the waters of the Potomac, to the dividing ridge along the sources of the various branches of the James river, and even to the irregular hills which form a water-shed between the waters of the upper Roanoke and the New river, across the Great Valley, near Christiansburg. Through all this middle region the name of "Blue ridge" is applied to the main eastern chain which separates the Great Valley from the Atlantic slope, and which is cut by all the rivers which flow out of it.

The southern division, from New river to the extremity of the system, is much the most remarkable for the diversity of its physical structure and its general altitude. Even the base upon which the mountains repose is considerably elevated, and in the interior of the mountain region the deepest valleys retain an altitude of from 2,000 to 2,700 feet.

From the dividing line in the neighborhood of Christiansburg and the great bend of New river the orographic and hydrographic relations undergo a considerable modification. The direction of the principal parts of the system is also somewhat changed. The main chain which borders the Great Valley on the east, and which more to the south, under the name of the "Blue ridge", separates it from the Atlantic plain, gradually deviates toward the southwest. A new chain attached on the east, and curving a little more to the south, takes now the name of "Blue ridge". It is this lofty chain, the altitude of which, in its more elevated groups, attains gradually to 5,000 and

5,900 feet, which divides in its turn the waters running to the Atlantic from those of the Mississippi. The line of separation of the eastern and the western waters which, to this point, follows either the central chain of the Alleghanies or the western border of the table-land region, passes now suddenly to the eastern chain, upon the very border of the Atlantic plain. The reason is that the terrace which forms the base of the chains, and the slope of which usually determines the general direction of the water-courses, attains here its greatest elevation and descends gradually toward the northwest. The base of the interior chain which runs alongside the Great Valley is thus depressed to a lower level; and though the chain itself has an absolute elevation greater than that of the Blue ridge, the rivers which descend from the summits of this last flow to the northwest toward the great central valley, which they only reach, in southern Virginia and North Carolina, by first passing across the high chain of the Unaka and Smoky mountains, through gaps of 3,000 or 4,000 feet in depth.

The fact just alluded to, namely, that south of the state of Virginia the water-shed separating the streams flowing into the Atlantic from those flowing into the gulf of Mexico is on the extreme eastern edge of the mountains, is of the greatest importance as affecting the character of the rivers. The Roanoke is the most southerly stream flowing into the Atlantic which has its sources really in the mountains or beyond the first ridge. The James and the Potomac rise in the western part of the system, their tributaries drain the narrow and parallel valleys between the ranges of mountains comprising the system, and they themselves break through these ranges one after another, flowing alternately through narrow gaps and meandering through the intervening valleys, reaching at last the true Atlantic plain; while the Susquehanna and the Delaware take their rise quite beyond the mountains proper, on the plateau which bounds them on the west and northwest, and cut through the entire system to reach the ocean. But the streams south of the Roanoke, which will be described in the following report, have their sources simply on the eastern slope of the mountains, do not drain the parallel valleys lying between the ranges, but are confined altogether to the true Atlantic slope. And it follows from this at once that in the case of the former streams the mountain or western division of their drainage basins is much the most important of the three divisions we have distinguished, while the middle division is of not so much importance; while in the case of the more southerly streams the mountain region is unimportant compared with the middle division. But the change in this respect is of course gradual, and we shall find that in the case of the James and in that of the Potomac the middle division is still as important as any of the three. The effect of the character just alluded to on the flow of the streams is of course very difficult to take into account, but some remarks concerning it will be found farther on.

The preceding quotations from Professor Guyot will serve to give an excellent idea of the character of the western or mountain region of the district to be considered. In regard to its elevation, the mountains rise from a height of 800 or 1,000 feet near New York to 6,000 feet and over in North Carolina, while the Great Valley ascends in a similar way from a height of 50 or 150 feet to 2,000 feet and over, and the Atlantic plain at the base of the mountains from 50 feet or so to 1,200 feet.

The following table of elevations along the Great Valley will show its rise very plainly:

	Feet.
Great Valley at Easton, on the Delaware river, Pennsylvania	159
Great Valley near Leesport, on the Schuylkill river, Pennsylvania	250
Great Valley at Harrisburg, on the Susquehanna river, Pennsylvania	305
Great Valley near Chambersburg, on Conococheague creek, Pennsylvania	600
Great Valley at Shepherdstown, on the Potomac river, West Virginia	280
Great Valley at Port Republic, on the Shenandoah river, Virginia	1,039
Great Valley at Lexington, on the North river, Virginia	894
Great Valley at Salem, on the Staunton river, Virginia	1,070
Great Valley at Newbern, in the valley of the New river	2,065
Great Valley at Mount Airy ridge, highest point near the sources of the Holston river (*a*)	2,595

South of this point the elevation decreases, sinking to 675 feet at Chattanooga.

Of the region draining into the Atlantic, the following are the areas in the different states which may be said to belong to the western or mountainous division:

	Square miles.
Virginia	6,630
West Virginia	3,700
Maryland	1,175
Pennsylvania	27,500
New Jersey	1,300
New York	9,076
Total	49,381

With regard to the middle division, lying between the fall-line and the base of the mountains, little is to be said. Its width increases toward the south from about 15 miles in New Jersey to 120 or more in the southern part of Virginia, and its area may be stated approximately as follows:

	Square miles.
New Jersey	1,550
Pennsylvania	100±
Delaware	80
Maryland	2,425
Virginia	9,525
Total	13,680

a Guyot.

Its elevation above tide at the fall-line is zero, and at the base of the mountains, as we have seen, from 50 to 500 feet. Its slope varies, therefore, from about 3 to 5 feet per mile. Like the middle region of the southern states, it comprises a region varying insensibly from the flat eastern division to the mountainous western one. The streams, in their course through the middle region, offer, as in the case of those farther south, many good sites for power. They are naturally navigable only up to the fall-line, but above that line some of them have been improved by locks, dams, and canals, carrying water communication far inland. It is not true here, however, as it will be found to be in the states farther south, that almost all of the utilized or available water-power is in this section; on the contrary, the great extent of the western district, and the fact that the streams flowing through it are often large, render the facilities for power often better in the latter than in the middle division, and a considerable amount of power is used and available in it.

Another very important topographical feature connected with the region we are considering is the fact that the facilities for storage are excellent in most parts of it. In the more southerly states the streams, not penetrating the mountains, flow through comparatively wide valleys, and are bordered with fertile bottom-lands, sometimes overflowed in freshets, and which could not be flooded permanently without withdrawing from cultivation some of the most valuable of farming-lands. Here, however, the streams penetrate the mountains, and flow through the longitudinal valleys between the parallel ranges often with a small fall; offering therefore facilities for damming and constructing storage reservoirs of tolerably large extent, without the necessity of such expensive dams as would be necessary farther south, and without flooding so much valuable land. And not only are there many sites where artificial reservoirs could be constructed, but there exist in many parts of the region numerous lakes and ponds which contribute in a very efficient manner to render the flow of the streams more uniform, and thus to make the water-power more valuable. The northeastern part of Pennsylvania, along the courses of the Delaware and the Susquehanna, is dotted with lakes; and there are a number in New York and New Jersey. Toward the south they diminish in number, and south of the Susquehanna there is not one in the entire region considered.

Finally, attention may once more be called to the effect of the topography of this region on the facilities for transportation. On account of the many bays which indent the coast, as well as the narrowness of the eastern district, sea-going vessels can often ascend even to the fall-line, and the water-powers are thus quite favorably situated as regards transportation by sea; and the fact that the middle Atlantic water-shed lies principally in the western or mountain district, and belongs to the region of narrow valleys and parallel ranges of hills, has, as will repeatedly be seen, an important effect on transportation by land; for while in the middle states the topography is such that the best and often the only practicable location for railroads is along the streams in the valleys, so that the water-powers are generally easily accessible, in the southern states it is often most economical to locate the roads along the divides, and many of the southern roads are in fact so located (as a glance at the map will show), the water-powers being therefore often many miles from transportation.

4.—Geology, soils, and forests.

So far as the influence of the geology on the water-power is concerned, it will be sufficient to mention briefly a few points. As regards the eastern division, it belongs to the Cretaceous, Tertiary, and later formations, and the soil is clay, sand, and marl. This division does not differ essentially in this respect from the corresponding part of the southern Atlantic states, and it affords a number of sand-hill streams, as we may call them. In the middle and western divisions the deposits are of an earlier age, and belong to the Azoic, Paleozoic, Triassic, and other formations. Some parts of the middle division lie in a belt of red sandstone which is intersected by numerous trap ridges, and this feature has an important bearing on the water-power, for where a stream crosses one of these trap ridges it is very apt to produce a prominent water-power, and some of the largest powers in the region are formed in this way.

One of the most important geological facts which we have to consider, and one in regard to which the middle states stand in contrast with the southern states, is that over the whole northern part of the region is scattered glacial drift, occurring in thick layers in many of the valleys, forming the bed of most of the streams, and covering the rock in some places to a depth of several hundred feet. These drift deposits are found as far south as the southern part of Pennsylvania, but not beyond. South of this limit comes a transition region between the northern glacial region and the southern non-glacial one, in which extensive beds of gravel and sand still occur, and in which the streams flow with quite uniform declivities and are broken by but few precipitous falls. Flowing over such beds of drift or movable material, the natural tendency is for the streams to even out their beds, and to bring down detritus from above to fill up deep places below; and the result is that many of the streams which we shall have to describe offer no falls whatever, but flow entirely in beds of gravel and sand and with uniform slopes; while those of the southern states, as we shall see, offer numerous sites where they fall abruptly a considerable distance over ledges of rock. But we shall also see that even these streams, although the material of their beds is not so movable as sand and gravel or drift would be, are nevertheless gradually attacking their banks and beds, and bringing down from the fields and the mountains detritus and silt, with which they are little by little filling up the falls and evening out their beds to a uniform slope; and that this result is hastened in some cases by the influence of man. (See description of the Pacolett, Enoree, and Tiger rivers, South Carolina, in the report on the southern Atlantic water-shed.)

The soil of the middle states, except where thick beds of drift occur, is generally not so deep as in the southern states, but it is rather more pervious. It does not shed quite so rapidly the water falling on it, neither does it, when once saturated, part with its water quite so easily as the soil in the southern states.

As regards forests, I have no accurate data regarding the proportion of woodland in the different states beyond the table which will be found in the report on the southern Atlantic water-shed, page 10, to which I must therefore refer. The middle states are doubtless much less thickly wooded than the southern states, and in fact the only Atlantic state which equals them in the proportion of woodland seems to be Maine. It must be remarked, however, that in the southern states a large proportion of the woodland probably occurs in the flat eastern division where there is no water-power, comprising the extensive cypress and pine forests which occur there, and which have no effect in regulating the flow of the streams.

5.—Climate.

The general discussions connected with climate have been so fully considered in the previous report, and tables have been given so much at length, that it will only be necessary here to consider briefly a few points which remain to be examined rather more in detail. We proceed in the same order as in the report alluded to.

a. Coast-line and ocean-currents.—Though the coast-line extends in general parallel to the mountain chains, yet, as we have seen, it approaches them much more nearly on the north than on the south. Reference has also been made to the fact that in the region under consideration the coast is much more indented than in the states farther south. As to the ocean-currents, the coast is bathed by the cold current from the north, which flows along the New England coast between the land and the Gulf stream, and gradually sinks below the latter toward the south. The winds from the sea, therefore, except those from the south and southwest, are apt to be cooler than in the case of the region farther south, and to a greater extent than would be due to their difference of latitude, having swept over cold waters instead of over the warm Gulf stream. Therefore, the winds from the south and southeast are moist and warm, while those from the northeast and east are much cooler. These circumstances, however, are of little importance.

b. Prevailing winds at different seasons.—Though the winds are variable, yet the direction of the prevailing wind is from some point between southwest and northwest, and the general movement of the atmosphere takes place in the same direction. In spring and summer, winds from the southwest, west, and northwest are most frequent; south winds are not so prevalent as in the southern states or in New England, but the southwest and west winds are the most prevalent of all. In winter the winds from the northwest are the most frequent. Winds from the east or north, or from the southeast, are least frequent of all in summer, while in winter north winds occur more frequently. Taken in connection with the shape of the coast, these facts serve to explain the distribution of rainfall over the region, as compared with that over New England and the states farther south, as we shall have occasion to show in brief farther on.

c. Temperature at different seasons.—As will be seen in the case of the southern states, the isothermal lines in the district under consideration extend in a general direction northeast and southwest, being deflected by various influences, principally by the mountains, from their normal course parallel to the equator; so that there are considerable differences in the temperatures for the year and for the seasons, these differences being almost as pronounced from east to west as from north to south. To the tables which have already been given, and to those which will be found on pages 11 and 12 of the report on the southern Atlantic water-shed, nothing need be added here. For more extended data the Smithsonian report (*Contributions to Knowledge*, vol. 21) may be referred to. The principal facts to be gleaned from these tables are the following:

1. The mean annual temperature in the middle states is about 52° F., or about the same as in the western region of the more southern states, and 8° or 10° lower than in the middle parts of those states. This is, however, from 3° to 7° higher than in the New England states.

2. The summer temperature is about 73°, or about 2° higher than in the western parts of the states south, and 4° or 5° lower than in their middle parts; while still 4° to 6° higher than in the New England states.

3. The winter temperature is about 32°, or about 4° or 5° lower than in the western, and 12° or 13° lower than in the middle region of the southern Atlantic states. In New England, however, the winter temperature is from 4° to 11° lower still.

4. The extremes of temperature differ more widely as we proceed north, the range in the middle states being greater than in the southern states, and less than in the New England states; but the difference is mainly in the minimum temperature, for the maximum is not more than 2° or 3° lower in Maine than in Alabama.

5. The same thing is true, in general, for the extremes of mean daily temperature, and for those of mean monthly temperature, although the difference is here, as regards the daily temperature, not so much on the side of the minimum value. The tables given in the reports referred to show that the mean temperature of the hottest

month is about the same in Pennsylvania as in Georgia, while the mean temperature of the coldest month is 10° or 12° lower in the former state. If there is a disadvantage in warm weather as regards water-power, the southern Atlantic states have no reason to complain in this respect, for, contrary to general impression, their summers are not much hotter than those in the middle states.

d. RAINFALL.—For detailed information regarding the rainfall of the region to be considered, the Smithsonian report (Rainfall tables, *Smithsonian Contributions to Knowledge*, No. 353, second edition, 1881) must be referred to, which gives the annual fall, and also its distribution through the year. This region, as regards the character of the distribution of the precipitation, falls essentially under type I, which includes the Atlantic sea-coast from Portland to Washington, and for which the characteristics are given as follows: "Three nearly equal maxima, about the middle of May, August, and December, and one principal minimum, about the beginning of February; the range between the extreme monthly values is small; the August maximum is generally the highest." The following table is the one used in discussing the region, and it will be seen that most of the stations are on the immediate sea-board. It shows that, in the entire region, the monthly rainfall fluctuates between 0.84 of the mean monthly rainfall (in February), and 1.22 of that mean (in August), or that in the month of maximum fall the fall is only 1.45 time what it is in the month of minimum fall:

Month.	Gardiner, Me., 27 years.	Brunswick, Me., 32 years.	Worcester, Mass., 26 years.	Cambridge, Mass., 31 years.	Boston, Mass., 28 years.	New Bedford, Mass., 54 years.	Providence, R. I., 35 years.	West Point, N. Y., 20 years.	Flatbush, N. Y., 36 years.	Fort Hamilton, N. Y., 19 years.	Fort Columbus, N. Y., 24 years.	New York, N. Y., 31 years.	Newark, N. J., 23 years.	Lambertville, N. J., 17 years.	Philadelphia, Pa., 43 years.	Baltimore, Md., 28 years.	Fort McHenry, Md., 23 years.	Washington, D. C., 28 years.	Mean of 18 stations.	Mean of last 11 stations.
January	1.01	0.87	0.99	1.06	1.00	0.97	0.99	0.88	0.94	0.89	0.84	0.90	0.94	0.88	0.89	0.79	0.82	0.91	0.92	0.88
February	0.82	0.74	0.83	0.80	0.94	0.96	0.84	0.81	0.81	0.96	0.77	0.88	0.89	0.86	0.81	0.84	0.77	0.84	0.84	0.84
March	1.02	1.00	0.93	0.96	0.98	1.03	1.01	0.82	0.98	0.91	0.91	0.92	0.93	0.88	0.94	1.12	1.07	0.92	0.96	0.94
April	0.97	0.93	1.00	1.00	1.04	1.02	1.04	1.04	1.02	1.04	0.93	0.99	0.98	0.87	1.00	0.95	1.01	1.13	1.00	1.00
May	1.11	1.22	1.04	1.04	1.10	1.06	1.01	1.25	1.06	1.24	1.31	1.24	1.17	1.18	1.09	1.11	1.07	1.10	1.13	1.17
June	0.97	0.99	0.84	0.86	0.89	0.82	0.91	0.88	1.07	1.08	1.05	1.06	0.86	0.93	1.13	0.97	0.97	1.06	0.96	1.01
July	0.91	0.98	1.02	0.92	1.08	0.87	0.80	1.08	1.01	1.01	0.95	1.01	0.98	1.12	1.08	1.10	0.97	1.25	1.01	1.05
August	1.11	1.18	1.53	1.31	1.10	1.14	1.14	1.30	1.18	1.21	1.33	1.17	1.26	1.35	1.22	1.17	1.21	1.20	1.22	1.24
September	0.82	0.81	0.91	1.06	0.94	0.95	0.89	0.83	0.88	0.89	0.93	0.91	0.93	1.07	0.99	1.01	0.94	0.91	0.92	0.93
October	1.10	1.01	1.07	0.92	0.89	0.98	0.97	1.06	0.99	0.73	0.92	0.88	0.96	0.94	0.91	0.95	0.97	1.01	0.96	0.94
November	1.06	1.25	1.05	1.02	1.03	1.12	1.17	1.03	1.05	0.98	0.95	0.97	1.01	0.88	0.95	0.96	1.00	0.83	1.02	0.96
December	1.10	1.04	0.99	1.07	1.03	1.10	1.14	1.02	1.01	1.05	1.13	1.08	1.09	1.06	1.01	1.05	1.18	0.85	1.06	1.05

For the ratios of fluctuation of the other type curves, for other parts of the country, the report on the southern Atlantic water-shed, page 13, may be referred to. But there is, of course, no abrupt change in the fluctuation from one district to another, the extreme fluctuation in the southern states becoming gradually less as we proceed north; and the last column in the preceding table, which refers to those stations included in our district (to which should properly be added some stations farther south), shows a slightly larger fluctuation than occurs in the entire region covered by the table, namely, 40 per cent. instead of 38 per cent. But if we examine the fluctuation at each station we shall see plainly that it decreases as we go north. It becomes rather different as we recede from the coast, and for more complete information the reports on the separate rivers must be consulted, but the following table will give a general idea regarding stations farther inland:

Month.	Albany, N. Y., 28 years.	Cazenovia, N. Y., 25 years.	Penn Yan, N. Y., 39 years.	Lambertville, N. J., 17 years.	Carlisle, Pa., 22 years.	Lewisburg, Pa., 13 years.	Gettysburg, Pa., 25 years.	Philadelphia, Pa., 43 years.	Frederick, Md., 12 years.	Lynchburg, Va., 7 years.	Mean.
January	0.82	0.79	0.58	0.88	0.74	0.71	0.97	0.89	0.98	0.70	0.81
February	0.79	0.69	0.61	0.86	0.75	0.69	0.80	0.81	0.82	1.22	0.80
March	0.82	0.88	0.70	0.88	0.89	0.86	0.92	0.94	0.75	1.32	0.90
April	0.91	0.94	1.01	0.87	1.00	1.04	1.10	1.00	1.18	1.06	1.00
May	1.16	1.09	1.29	1.18	1.26	1.26	1.19	1.09	1.18	1.03	1.17
June	1.31	1.32	1.42	0.93	1.25	1.26	1.06	1.13	1.58	1.26	1.25
July	1.29	1.25	1.33	1.12	1.27	1.15	1.06	1.08	1.02	0.97	1.15
August	1.00	1.10	1.19	1.35	1.18	1.45	1.06	1.22	0.86	1.21	1.16
September	0.98	1.04	1.16	1.07	1.00	0.97	0.92	0.99	1.16	1.18	1.04
October	1.10	1.13	1.10	0.94	0.85	0.90	0.93	0.91	0.66	0.62	0.93
November	0.95	0.91	0.89	0.88	0.76	0.81	0.93	0.95	0.82	0.87	0.88
December	0.86	0.88	0.71	1.06	1.05	0.90	1.06	1.01	0.99	0.56	0.91

It will be seen that the rainfall is more irregular than on the coast, so that the means vary more from the separate values; but the fluctuation is evidently greater, amounting to 45 per cent. of the mean monthly fall, and at some of the stations it is seen to be even much greater than this. The minimum occurs, as before, in February, but the maximum is several months earlier than before, or in June, and at some stations even in May. But it is noticeable that over the whole district the rainfall is greater in summer than in winter, and never the reverse, as is the case in some of the southern states. A glance at the Smithsonian charts shows that the rainfall is distributed over nearly the entire area about as follows: Spring, 9 to 12 inches; summer, 10 to 14 inches; autumn, 8 to 12 inches; winter, 8 to 10 inches; year, 35 to 48 inches; and it is further noticeable that the distribution does not vary much in different parts of the district. We shall see that in the southern states there is a considerable difference between the sea-board and the western or mountainous parts, the rainfall being greatest in the mountains, and also very differently distributed; for, while on the coast nearly twice as much rain falls in summer as in winter, in the mountains nearly the same quantity falls in each of those seasons. The reason is probably this: The principal carriers of moisture are the winds from the Gulf and the Atlantic ocean, and in summer, winds from the south and southeast being more prevalent than at any other time, the winds which bring rain strike the coast directly from the ocean, or after having passed over a small area of low ground, and are therefore highly charged with moisture, which is condensed along the coast, the amount diminishing as we go inland, until the up-country and the mountains are reached, where, on account of the great height of the latter, almost all of the remaining moisture is condensed and the rainfall is again large; while in winter the winds bringing rain come more from the southwest, and thus reach the coast after having passed over the up-country, and having parted with much of their moisture there and in the mountains, so that in this season the rainfall is small on the coast and again large in the mountains.

In the district we are now considering, however, the mountains are, as we have just seen, lower and more regular than in any other part of the Appalachian system, while the ground rises more rapidly from the coast, leaving only a narrow eastern or tide-water division below the fall-line; so that with the exception of a narrow strip along the coast where the rainfall is greatest, due to the rapid condensation of the moisture in the sea-winds which sometimes blow, and a few isolated spots in the interior where the mountains are higher than usual, or where other influences are at work, the rainfall shows no great variation throughout the area. Toward its southern extremity, of course, the change is gradual from these features to those just described as applying to the southern states; and southern Virginia differs considerably from central Pennsylvania and New York in regard to amount and distribution of rain; but, broadly speaking, the general features above referred to are quite noticeable.

As regards the fluctuation of the annual rainfall in the district under consideration, the table given on page 14 of the report on the southern Atlantic water-shed shows that it offers no peculiarity, and that it is about the same as in the more northern or southern states.

Finally, as to the absolute amount of the rainfall, the data which will be given for each river will be sufficient for the purposes of this report. For more extended information the Smithsonian volume must be consulted.

As a smaller proportion of the winds are oceanic and the mountains are lower than in the states farther south, we should naturally expect the amount of the rainfall to be smaller in the district now to be considered, which is found to be the case; and, in fact, we may say that as regards rainfall there are three principal differences between the middle and the southern Atlantic states: First, the rainfall is greatest in the latter; second, it diminishes from the coast inland quite uniformly in the former, but not in the latter, except for a short distance; third, in the former there is always more rain in summer than in winter, while in the latter this is only true on the coast.

Of course the fact that as we proceed north the precipitation is more and more in the form of snow has an important bearing upon the flow of the streams and upon their water-power; but this effect is so well understood that it may be briefly dismissed here. The northern streams are subject to a winter drought, as the snow often lies on the ground for several months in the winter without melting, and the freshets are usually most severe in the spring when the snows melt; and the ice-jams which sometimes occur, as well as the large bodies of ice which are carried down by the streams, are often very dangerous and destructive to the dams.

FLOW OF STREAMS.

The general facts and circumstances influencing the flow of streams have been discussed with such detail on pages 8 to 10 of the report on the New England streams, that it is only necessary here to endeavor to trace the effects of the climatical and topographical conditions which have just been described, upon the flow of the streams to be described in the sequel, and to try to explain any peculiarities which gaugings have shown to exist; as well as to forecast the probable peculiarities of streams for which we have no measurements, and to draw some comparisons between the streams of the middle Atlantic water-shed and those to the north. The following tables are therefore repeated for convenience of reference and comparison:

Table showing extremes of flow for some American streams.

River.	Place.	Drainage area, square miles.	Mean rainfall, inches. Spring.	Summer.	Autumn.	Winter.	Year.	Remarks on character of drainage basin.	Extremes of flow. Maximum, cubic feet per second.	Minimum, cubic feet per second.	Ratio.	Minimum, cubic feet per second per square mile.	Ordinary low-water flow, cubic feet per second per square mile.	Authority and remarks.
Merrimack	Lowell..............	4,085	10	11	13	9	43	Lakes and artificial reservoirs. Wooded.	81,000	1,275	64	0.31	....	
Merrimack	Lawrence..........	4,599	10	11	13	9	43	......do	96,000±	1,400	70	0.31	....	
Concord	Lowell..............	361	11	11	12	10	44	Stream sluggish and swampy. Few woods. Hilly and rolling. Some reservoirs.	4,449	59.84	74	0.17	....	C. Herschel.
Sudbury	Framingham	78	11	11	12	10	44	Hilly and swampy. One-sixth to one-eighth wooded.	3,228	2.80	1,153	0.036	....	A. Fteley.
Charles	Newton Upper Falls.	215	11	11	12	10	44	Hilly and rolling......	....	44	......	0.20	....	J. P. Kirkwood.
Hale's Brook, Mass.	Mouth..............	24	11	11	12	10	44	....	....	3.24	......	0.135	....	J. P. Frizell.
Connecticut ...	Hartford...........	10,234	10	12	12	10	44	Numerous lakes and artificial reservoirs. Wooded. Mountainous in parts.	207,443	5,219	40	*a* 0.51	....	T. G. Ellis.
Connecticut ...	Dartmouth	8,287	10	12	12	10	44	......do	....	1,006	......	0.306	....	C. Herschel.
Housatonic	....	790	12	12	12	10	46	....	....	130	......	0.165	....	H. Loomis, Rept. N. Y. Com. Pub. Wks., 1879.
Croton	....	338.82	12	13	13	10	48	....	25,367	50.80	500	0.15	....	J. J. R. Croes and G. W. Howell.
Croton, West branch.	....	20.37	12	13	13	10	48	Very broken and undulating. Hilly, steep, and rocky. Largely wooded. Little cultivated.	1,109	0.407	2,722	0.02	....	J. J. R. Croes.
Passaic	Paterson...........	813	12	14	12	10	48	Some lakes and swamps. Hilly.	....	178	......	0.22	....	J. J. R. Croes and G. W. Howell.
Do.........	Belleville..........	962	12	14	12	10	48	.... .do	19,944	225.60	88	0.023	....	J. J. R. Croes and G. W. Howell.
Delaware	Lambertville	6,500±	11	13	11	9	44	Hilly and rolling. Many lakes. Well wooded.	350,000	2,000	175	0.30	....	Ashbel Welch.
Schuylkill	Philadelphia......	1,800	12	14	10	9	45	Hilly and rolling. No lakes. Some reservoirs.	....	307 to 378	......	0.17 to 0.21	....	E. F. Smith and H. P. M. Birkinbine.
Hackensack ...	....	84	12	14	12	10	48	Flat. No lakes or reservoirs, except mill-ponds.	....	27	......	0.33(?)	....	C. D. Ward.
Ohio	Pittsburgh	19,900	10	12	9	10	41	Hilly and mountainous. No lakes. Wooded.	....	2,271	......	0.114	....	J. H. Harlow.
Potomac.......	Cumberland	920	10	12	9	8	39	Narrow valleys. Steep slopes. Wooded. No lakes.	17,900	25	716	0.022	....	W. R. Hutton and Patterson.
Do.........	Dam No. 5........	4,640±	11	12	9	8	40	......do	92,772	363	255	0.0783	....	Quoted by W. R. Hutton.
Do.........	Great Falls	11,476	12	13	9	8	42	Country more open. No lakes.	175,000	1,063	165	0.093	....	W. R. Hutton.
Rock Creek	Hoyle's mill	64.40	11	12	11	8	42	....	....	7.50	......	0.114	0.458	Quoted by W. R. Hutton.
Kanawha	Charleston pool...	8,900	12	13	9	10	44	Mountainous. Steep. No lakes. Wooded.	120,000	1,100	110	0.123	....	Gill, Scott, and Hutton.
Greenbrier	Mouth of Howard's creek.	870	11	12	8	9	40	......do	....	97	......	0.12	....	McNeill.
Shenandoah ...	Near Port Republic.	770	12	13	8	8	41	Hilly. Limestone. No lakes. Many springs.	....	128	......	0.167	....	James Herron.
James	Richmond	6,800	12	12	9	10	43	Mountainous in upper part. No lakes. Wooded.	....	1,300	......	0.191	....	H. D. Whitcomb and W. E. Cutshaw.
Neuse	Near Raleigh	1,000	12	13	10	10	45	Open. Clay and loam. No lakes. Few extensive woods.	....	....	......	....	0.103	W. C. Kerr. "Low water".

a Since the date of Ellis' measurements the flow of the Connecticut has been as low as between 0.25 and 0.30 cubic foot per second per square mile, according to good authority.

Table showing monthly distribution of flow.

MONTHLY FLOW IN DRY YEARS.

Rivers.	Drainage area, square miles.	Flow in inches on water-shed.													Ratio of monthly to mean flow.											
		Driest month.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Eleventh.	Twelfth.	Total for the year.	First.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Eleventh.	Twelfth.
Croton	339	0.20	0.35	0.53	0.63	0.87	0.94	1.52	1.63	1.80	1.90	2.08	2.27	14.72	0.16	0.29	0.43	0.51	0.71	0.77	1.24	1.33	1.47	1.55	1.70	1.85
Concord	361	0.25	0.32	0.36	0.43	0.54	0.68	0.85	1.07	1.36	1.70	2.15	3.62	13.33	0.22	0.29	0.32	0.39	0.49	0.61	0.76	0.96	1.23	1.53	1.94	3.26
Merrimack (*a*)	4,599	0.68	0.70	0.77	0.85	1.00	1.13	1.30	1.53	1.98	2.55	3.22	5.42	21.13	0.38	0.40	0.44	0.48	0.57	0.64	0.74	0.87	1.12	1.45	1.83	3.08
Connecticut	10,234	0.65	0.68	0.71	0.74	0.88	0.90	1.28	1.51	1.80	2.02	3.28	4.71	19.16	0.41	0.43	0.45	0.46	0.55	0.56	0.80	0.95	1.13	1.26	2.05	2.95
Schuylkill (*b*)	1,800	0.27	0.30	0.38	0.40	0.53	0.62	0.68	0.79	0.88	0.98	1.08	1.59	8.50	0.38	0.42	0.54	0.57	0.75	0.88	0.96	1.12	1.24	1.38	1.52	2.24
MONTHLY AVERAGE FLOW FOR A SERIES OF YEARS.																										
Croton	339	0.56	0.95	1.12	1.21	1.43	1.82	2.30	2.57	2.77	3.02	3.60	4.00	25.35	0.26	0.45	0.53	0.57	0.68	0.86	1.09	1.21	1.31	1.43	1.70	1.96
Concord	361	0.39	0.46	0.51	0.61	0.76	0.96	1.25	1.52	1.92	2.38	3.00	4.86	18.62	0.25	0.30	0.33	0.39	0.49	0.62	0.81	0.98	1.24	1.53	1.93	3.13
Merrimack (*a*)	4,599	0.77	0.88	1.06	1.26	1.52	1.80	2.12	2.49	3.03	3.73	4.63	6.56	29.85	0.31	0.36	0.43	0.51	0.61	0.72	0.85	1.00	1.22	1.50	1.86	2.63
Connecticut	10,234	0.75	0.85	0.91	1.10	1.34	1.58	2.00	2.36	2.81	3.27	4.52	6.26	27.75	0.33	0.37	0.39	0.47	0.58	0.68	0.87	1.02	1.21	1.41	1.96	2.71
MONTHLY FLOW IN DRY YEARS OF STREAMS OF SMALL DRAINAGE AREA.																										
Cochituate	19.00	0.08	0.41	0.46	0.47	0.70	0.88	0.97	1.03	1.11	1.31	1.47	2.26	11.15	0.09	0.44	0.50	0.51	0.75	0.95	1.03	1.11	1.20	1.41	1.58	2.43
Croton, West branch	20.37	0.10	0.17	0.46	0.53	0.67	0.84	0.98	1.02	2.31	3.37	3.41	5.40	19.26	0.06	0.10	0.28	0.33	0.42	0.52	0.61	0.64	1.44	2.10	2.13	3.37
Sudbury	78.00	0.11	0.16	0.25	0.39	0.57	0.79	1.06	1.40	1.79	2.21	2.77	5.09	16.59	0.08	0.11	0.18	0.28	0.41	0.57	0.77	1.01	1.20	1.60	2.01	3.69
Passaic head-waters	50–100	0.11	0.15	0.21	0.27	0.49	0.67	0.90	1.22	1.77	1.87	2.13	3.65	13.44	0.10	0.13	0.19	0.24	0.44	0.60	0.80	1.09	1.58	1.67	1.99	3.26

a Regarding the figures given for the Merrimack river, it should be noted that as they are based on gaugings for only six months in each of a series of years, they can not be considered anything but approximations, and are simply given for want of some hing better. The figures for the last six months are especially liable to large errors.

b Charles G. Darrach, in *Engineering News*, April 3, 1880, p. 122.

The first point to be considered is the rainfall; and the fact that in the middle states the rainfall is greatest in summer has an effect which is perhaps very large, and which may go far toward explaining the large summer flow of some streams in those states. The table shows that although the minimum flow of the Schuylkill river is not much greater than that of the James, yet its average flow in the driest month is very large indeed; and when we bear in mind that the drainage area is not large, that it includes no lakes and only a few storage reservoirs of the canal company, that the forests are not exceedingly extensive, and that a good deal of the land is under cultivation, we may be disposed to attribute the principal part of this effect to the fact, which the table shows, that the rainfall on the basin in summer and fall is very large—larger, in fact, than in the case of any stream south. Still, how far this may be due to the artificial reservoirs or to errors in estimating the flow can not be stated. If we compare the streams in the middle Atlantic water-shed with those in the southern, we are, I think, entitled to conclude that, as regards this factor in the problem, the flow of the former is the more constant, except in the case of some streams in Virginia where the rainfall is distributed unfavorably. As to streams in New England, the large summer rainfall, and the numerous reservoirs, render their flow undoubtedly more uniform than that of any of the streams now under consideration.

Again, the fact that toward the north the winters are colder and the fall of snow greater has the effect of tending to make the winter flow of the streams less than the summer flow. The streams being really lower in summer than in winter on the Atlantic coast, a cold winter with much snow may therefore in some cases be regarded as favorable and as tending to equalize the flow. Compared with the streams of the southern Atlantic slope, those in the middle states have therefore the advantage in this respect, and we may say that, as regards this factor of the problem, their flow is more constant. It is unnecessary to refer further to the spring freshets in the north due to the melting of the snows, except to remark that if the winter snows lie long on the ground and are carried off suddenly in the spring they may do little toward increasing the summer flow of the streams, so that their effect in regulating flow would simply consist in diminishing the average winter flow and causing severer freshets, and thus that effect would be really unfavorable. The diversity of the conditions of the problem is so great, however, that general conclusions must be made cautiously.

The next point which it is necessary to consider is the effect on the flow which is exercised by the topographical peculiarities of the region under discussion; the most striking topographical feature being the fact that the streams now to be considered rise in the mountains, or toward their western extremity, and flow across them, while the more southern streams rise on their extreme eastern side. Of course the effect of this physical conformation can not be definitely stated or brought to mathematical form; but one result seems to be derivable from it, namely, that the extreme variability in flow of some of the streams which rise farthest in the mountains, draining with their tributaries the numerous narrow and parallel longitudinal valleys between the ranges, is in great part due to this topography. The remarkably low flow of the James and Potomac rivers in dry weather does not find a parallel in the table, except for streams of small drainage area. A glance at the table shows that the rainfall on the drainage basins of these streams is not distributed in a way favorable for a constant flow through the year, and it may be that this fact plays the principal part in causing the low flow observed; but until we possess more accurate data, and measurements sufficiently extended, to enable us to gain some numerical idea of the effect of the various circumstances which affect flow—a desideratum which can with difficulty be supplied—we are forced to estimate these effects according to our judgment; and to my mind it seems as if the topography would have a much greater influence than the distribution of the rainfall. The result thus reached is of value in showing us how to estimate the flow of other streams; and in judging of the power of streams draining a number of narrow valleys we have not lost sight of it.

The next circumstance which is to be borne in mind is that the soil in the region considered is, as a whole, rather more porous, though not deeper, than in the states farther south. The mountains are oftener rocky and bare and the depth of soil perhaps less on the average, but, the porosity being greater, the flow of the streams will not on that account be less uniform.

The third fact, and perhaps the most important of all, is that many of the streams in the middle states have numerous lakes tributary to them, and, further, that the form of the valleys is generally favorable for the construction of storage reservoirs. The power which will be found estimated in the tables as the "maximum with storage" may, in most cases of small drainage areas, be considered really available, while in the case of the southern streams we shall see that, though possible to utilize it, its complete utilization is in most cases impracticable or unadvisable. This fact is important in judging of the value of sites.

In regard to the forests, their action will be referred to at length in a subsequent report. No data are at hand sufficient to enable us to estimate the amount of woodland in the different states, and we are therefore unable to bring this factor much into consideration; but from the facts stated on page 20 of the report on the southern Atlantic water-shed it is clear that with the rainfall always greater in summer than in winter, as it is over our present district, the influence of the woods is most beneficial. Bearing these points in mind, I have estimated the power and flow at numerous points, following the same method which was explained on pages 8 to 10 of the report on the eastern New England water-shed. Although it is not necessary to explain the method of calculation in this place, it may be well to repeat the definitions given before of the various quantities which have been estimated, as follows:

1. Absolute minimum can be depended upon always and with no storage at all. Large waste all the time, except for a few days at a time, at intervals of several years.

2. Minimum low-season flow, with no storage, can be depended upon at all times, except for a short time in some dry seasons—perhaps for a few days in the dry season of each year. With small storage, can be depended upon all the time.

3. Mean flow in very dry years.—*Maximum amount permanently available with storage.*—Storage capacity, perhaps 3 or 4 inches on the water-shed. With larger storage a greater amount could perhaps be utilized for several years in succession, but not permanently. Generally impracticable except in the case of very small drainage areas.

4. Low-season flow in ordinary dry years, without storage, can be depended upon generally, except in the low season of dry years, when the supply will be deficient for perhaps several weeks; in very dry years, when the supply will be deficient for a longer time; and in ordinary years, when the supply may be deficient for a few days at a time. Can be rendered permanently available by storage. The *low-season flow of ordinary years* can be depended upon less than the above, but generally for nine months of every year.

In regard to the maximum with storage, the powers given for large drainage basins, although perhaps in some cases really available, could be made so only at great cost. Small basins are more favorable in this respect, and the amount of water available is also proportionally greater, because there is considerable loss by evaporation in the case of large basins while the water is flowing from the distant reservoirs to the points where it is to be used.

TIDAL WATER-POWER.

There is no tidal water-power in the middle Atlantic water-shed. The country along the coast is in most places too flat, and not suitable for building, the range of the tides is small, and there is no advantage to be obtained by using the power of the tides, as it is sometimes used in New England.

TOTAL AVAILABLE POWER.

I have made no attempt to estimate the total available power of the streams in the middle states. Such estimates are liable to mislead, and, although they will be given in the case of some of the southern streams, I have thought it best to omit them here. But the remark may again be made, that the elevation of the Atlantic plain at the foot of the mountains becomes smaller as we proceed north, being 1,200 feet in North Carolina, 500 feet in Virginia, and from 100 to 300 feet in Pennsylvania; so that, as regards those streams which do not rise beyond the first ridge of the mountains, their total theoretical power will be much less in the region we are considering than that of streams of equal size farther south; but from the fact that in our present region the larger streams do not rise on the eastern slope of the mountains, but near their western edge, or even on the elevated plateau beyond, as in the case of the Susquehanna and Delaware, this conclusion can not be drawn generally. The sources of the Susquehanna, for instance, lie at an elevation of about 1,200 feet, so that its total fall to tide-water is greater than that of any southern stream, if the small upper sources be left out of account. Any sweeping statements regarding total power available must therefore be taken with considerable allowance, and are likely to give a false impression.

6.—General results.

Before proceeding to describe each river in detail, a few of the general results of the characteristics which have just been discussed may be briefly mentioned. From the topography of the region it is clear that the water-powers are, as in New England, more evenly distributed over its whole extent than in the southern states, where will be found large areas without any powers whatever. The eastern division of the Atlantic slope being very narrow in the north, and the middle region small, the greater part of the water-power, especially in the northern part of the region, is in the western or mountainous division; and while the gradual fall of the streams makes concentrated falls and cataracts perhaps on the whole less numerous than in New England or in the south, yet the region now to be considered has an advantage over the southern states in the matter of storage, and especially in the fact that some of its streams are fed by numerous lakes.

In those parts of the region where the streams drain numerous parallel valleys of the mountains, often covered with soil to a smaller depth than in the south, the very variable flow of the streams, and the liability to sudden and severe freshets, is a disadvantage; and, in the cases referred to, it is not compensated by the presence of lakes or by particularly good facilities for storage. The rain falling on these narrow valleys is rapidly gathered into the water-courses—especially if the mountains are not deeply covered with soil—swelling the volume to a great extent, and rendering the flow much more variable than it otherwise would be. The James and Potomac rivers are especially subject to this influence.

Regarding the forests, their preservation is a matter of great importance, for their usefulness as regulators of flow is very great, especially as the rainfall is greater in summer than in winter. In some parts of the region the forests are, unfortunately, being rapidly destroyed by lumbermen, but no data are at hand regarding the actual extent of woods or the rate of destruction. The operations of the lumbermen have in some cases a very important influence on the water-power of the streams—especially the smaller ones—down which the logs are floated, as we shall have occasion to see when speaking of the west branch of the Susquehanna river, on account of the intermittent flow caused by suddenly opening the artificial reservoirs which are constructed for the purpose of floating down the lumber on the swell or wave which results, according to the same method which was formerly used on some of the rivers in France, as well as on the Thames and Severn in England (and still in use on the former stream), for purposes of navigation (*navigation par éclusées*). The wholesale destruction of our forests now being practiced must before long lead to unpleasant results, similar in kind (we hope not in degree) to those which have taken place in some of the streams of the Alps; and to the many words of warning which have been written from economical and agricultural points of view, must be added another—the undoubted injurious effect which such destruction will have on the water-power of the streams whose drainage basins are so being robbed of their natural protection.

In regard to the temperature of the region under consideration, the facts that the yearly mean is lower, and that the winter mean is considerably lower, than in the states farther south, are the principal ones which have a bearing on water-power. Although the streams in Virginia are seldom frozen over, and the mills suffer little trouble or interruption from ice, yet as we proceed north this source of trouble increases, and in the northern part of the district, and in New England, it sometimes assumes considerable proportions. Then, again, the freshets in spring, at the breaking up of the rivers and the melting of the snows, though perhaps not more severe than on some southern streams, are yet accompanied by such great masses of floating ice that their destructive effect on the dams is frequently greater, so that those structures have to be built often in a very substantial manner. The evil effects of ice-jams, which sometimes occur and cause the overflowing of considerable areas, are too well known to need more than mention here, having already been referred to in the previous report.

Again, regarding the objection sometimes urged respecting temperature against the advantages for manufacturing in the south, this point will be discussed with sufficient detail on page 23 of the next report, so that it is only necessary to state here that in the district now under consideration the temperature in the hottest month, or even the average in summer, is very little lower than in the southern Atlantic states and but little higher than in New England; and that it would seem that this matter of temperature is on the whole a factor of very little consequence in the question, except, of course, in so far as it goes to determine evaporation and other meteorological phenomena.

The facts regarding rainfall, which have been alluded to, have already been considered in their effects on water-power, when speaking of the flow of the streams. Their importance is great, and when we bear in mind the difference in distribution of rain, in the occurrence and number of lakes, and in the topography of the regions drained by the different streams, we shall have no difficulty, I think, in explaining the facts given in the table of flow of streams, and in arriving at tolerably close estimates of flow in cases where gaugings are not at hand.

Finally, the advantage as regards transportation must once more be mentioned which follows from the fact that the streams in the region now to be considered are navigable up to the fall-line, thus placing some of the largest powers in the whole region in a very favorable position in this respect. In Maine the water-power region has been seen to approach still nearer to the sea-coast, but in the southern states we shall see that the powers are often separated from tidal waters by over a hundred miles of a tortuous stream, and that although this distance can be made navigable for river-boats, sea-going vessels can not reach the powers as they can those farther north.

After these few general remarks, I proceed to give as detailed a description of each river as the material which I have been able to collect will allow. In order to compare the power available at different places to be described with that at well-known places in the New England and other states, the following information may be found interesting. It is taken from the statistics given in this volume, principally from the reports on the New England states. At Paterson, New Jersey, the Passaic river furnishes, when at its minimum, about 1,200 gross horse-power, night and day. At Lowell, Massachusetts, the Merrimack has a fall of 35 feet, and yields at a minimum about 12,000 gross horse-power during the usual working hours. At Cohoes, New York, the Mohawk falls 105 feet, and would yield at least 18,000 gross horse-power during working hours. At Manchester, New Hampshire, the Merrimack falls 52 feet, and gives a minimum of about 12,000 gross horse-power during working hours. At Lawrence, Massachusetts, the same stream falls 28 feet, yielding a minimum of about 11,000 gross horse-power during working hours. At Holyoke, Massachusetts, the Connecticut has a fall of 56 feet, and a minimum of about 14,000 gross horse-power during working hours. At Lewiston, Maine, the fall in the Androscoggin is 50 feet, and the minimum power, during usual working hours, is about 12,000 gross horse-power. At Birmingham, Connecticut, the Housatonic falls 22 feet, furnishing a minimum of about 1,400 gross horse-power during usual working hours. The improved fall of the Connecticut river at Turner's Falls is 41 feet, furnishing a minimum, during working hours, of about 14,000 gross horse-power.

I.—THE JAMES RIVER AND TRIBUTARIES.

THE JAMES RIVER.

The James river is formed in the extreme northern part of Botetourt county, Virginia, by the union of Jackson's river with Cowpasture river, both of which take their rise in the mountains of Highland county, and flow in a direction rather west of south, traversing longitudinal and comparatively narrow valleys between the nearly parallel ranges of the Alleghenies. From their junction the James pursues a general course nearly east, flowing first through Botetourt and Rockbridge counties, and for the remainder of its course forming the boundary line between the counties of Bedford, Campbell, Appomattox, Buckingham, Cumberland, Powhatan, Chesterfield, Prince George, Surry, Isle of Wight, and Nansemond, on its right, and Amherst, Nelson, Albemarle, Fluvanna, Goochland, Henrico, Charles City, James City, and Warwick, on its left, emptying into Chesapeake bay through Hampton roads, not over 20 miles from the Atlantic ocean. The stream, with all its tributaries, lies wholly within the state of Virginia. Its total length, measured along its course, is about 335 miles, while in a straight line it is only about 200 miles. Its total drainage area is about 9,700 square miles, and its principal tributaries are the following streams, mentioned in their order as the river is ascended:

Drainage areas.—Tributaries of the James river.

	Square miles.
From the north:	
Chickahominy river	410
Rivanna river	668
Hardware river	245
Rockfish river	240
Tye river	425
North river	784
From the south:	
Appomattox river	1,565
Willis river	247
Slate river	223
Catawba creek	112
Craig's creek	357

The head-waters—Jackson's and Cowpasture rivers—drain, respectively, areas of 988 and 580 square miles.

The basin of the James is varied in character, being mountainous in the upper part, and very low, flat, and often swampy in the lower part. Jackson's and Cowpasture rivers wind through narrow and picturesque valleys, over beds generally of sand and gravel, with rock ledges in places, and are bordered with fertile bottom-lands. Their fall is on the whole not great, although in places there are local falls of some consequence. The James, cutting as it does through the ridges of the mountains to reach the Atlantic plain, flows alternately across the valleys, with a gentle current, a bed of sand and gravel, and fertile level lands along its banks, and through breaks in the ridges, with steep, rocky, and sometimes precipitous banks, the fall being in these localities often considerable, and the bed solid rock, sometimes overlaid to a small depth with movable material. The most noticeable places of this kind are near Buchanan, near the mouth of North river, and at one or two other places above Lynchburg. Below the latter place the country is more open, but the stream has considerable fall all along its course through the middle or hill country, as far down as Richmond, where it crosses the fall-line, and below which the basin is flat and low. The accompanying map shows the position and form of the basin. It extends farther into the mountains than the basin of any Atlantic stream farther south, excepting perhaps the Roanoke, so that all three divisions of the Atlantic slope—the western, middle, and eastern—are well represented. The latter, however, extends only up to the head of tide-water, where the Virginia streams cross the fall-line. Geologically, the eastern division is alluvial, just as in the states farther south, and the middle division is for the most part of the Eozoic formation, with some patches of sandstone. The western division is more varied in character than farther south, and is divided by the Valley region into two quite distinct parts—the Blue ridge on the east and the true mountain region on the west—and it is through the Blue ridge that the river breaks near the mouth of North river, passing from the Valley to the Piedmont region or middle division.

The products of the James River basin are chiefly cereals, fruit, vegetables, etc. A large part of the area is covered with pine forests, but no data are at hand for determining the proportion of the basin so covered. In the entire absence of lakes and artificial reservoirs, excepting the canal ponds on the James, the woods are doubly important.

The James is remarkable as being navigable for sea-going vessels drawing 16 feet up to the head of tide-water, or to the fall-line at Richmond, a distance from the mouth of the river of 111 miles in a channel line and 130 miles from the ocean. The falls at Richmond form an insurmountable obstacle to the further navigation of the river, but by means of the James River and Kanawha canal, which was built along the stream many years ago, transportation has until recently been afforded as far as Buchanan, 196½ miles above Richmond, and it was expected to extend the canal across the Alleghenies to join the Ohio; but having recently been purchased by the Richmond and Allegheny Railroad Company, which is constructing the road directly along the tow-path, it is now entirely abandoned as a means of communication, and is superseded by the railroad. There are no very large towns on the river except Richmond, and Lynchburg 146 miles above. Buchanan, though a small place, has been of some importance as the western terminus of the canal. The accompanying map shows the railroad traversing the basin of the James, rendering the stream accessible for its entire length, while the canal, having been abandoned for navigation, can be made to afford a very large amount of water-power, as will be seen hereafter, and with the very best facilities for transportation.

The following table will show that the fall of the James river is considerable; but with the exception of the falls at Richmond, I obtained no information of any particularly large falls in short distances:

Table of declivity of the James river.

Locality.	Distance from Richmond.	Elevation above tide.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Richmond—foot of falls	0	0			
Grant's dam	3	84	3	84	28
Bosher's dam	11	124	8	40	5
Maiden's Adventure dam	29	143	18	19	1.06
Tye River dam	109 ±	375 ±	80	232	2.9
Joshua Falls dam	135½	463	26½	88	3.32
Lynchburg Water Works dam	148½	513	13	50	3.85
Judith's dam	152	540	3½	27	7.7
Bald Eagle dam	157	558	5	18	3.6
Pedlar dam	160	572	3	14	4.66
Coleman's Falls dam	162½	588	2½	16	6.4
Big Island dam	166½	606	4	18	4.5
Cushaw dam	170½	649	4	43	10.75
Blue Ridge dam	175½	706	5	57	11.4
Quarry Falls dam	178½	720	3	14	4.66
Varney's Falls dam	185½	759	7	39	5.57
Indian Rock dam	189½	786	4	27	6.75
Wasp Rock dam	194	812	4½	26	5.77
Buchanan	198	812	4	0	....
Junction of Jackson's and Cowpasture rivers	225	1,014	27	202	7.5

The preceding table gives the elevation of each dam on the river; but as the dams pond the water for some distance in many cases, it does not give an exact idea of the natural fall of the stream. It will be seen that the fall between the head of the falls and Lynchburg, about 145 miles, is at the rate of about 3 feet per mile; while from Lynchburg to the junction of the two head-waters, about 77 miles, it is at the rate of 6.5 feet per mile.

The rainfall on the valley averages from 42 to 45 inches. Near the coast it is 50, and between the coast and Richmond it varies from 50 to 44, while above Richmond it diminishes, reaching 38 in the mountains. The table of utilized and available power, on page 23, will give details regarding the amount and distribution above various points.

The flow of the river is subject to very great fluctuations and the freshets are very heavy. Those of 1870 and 1877 were remarkable for their violence, and did considerable damage along the river, and that of 1870 is said to have been the heaviest freshet within a century, up to that time. In 1877 the river is said to have risen 28.9 feet below the falls at Richmond, and 26 feet at the pump-house a mile or so above. The cause of this variability in flow is probably to be sought in the absence of lakes, the narrowness of the valleys, and the steepness of the hill-sides, and in the small rainfall in autumn, which tends to reduce the low-season flow to a small amount (see table on page 9). The stream is not subject to heavy ice-freshets, and ice-gorges seldom occur. In 1879, however, a heavy gorge occurred just below Richmond which was the cause of some damage, the water having been backed up to a considerable height. Those mills at Richmond and at Manchester which do not use water from the canal are generally obliged to stop at intervals in times of high water. I have only one record of a gauging of the stream, viz., that given in the table just referred to, and it has served as a guide in many estimates. No measurements of the maximum flow have come to my knowledge. The bottom-lands along the stream seem to be on the whole less extensive and less subject to overflow than on the streams farther south. Notwithstanding the severe freshets, however, no trouble is experienced in keeping the canal dams in good order, on account of the excellent foundation for such structures which is to be found all along the river—generally solid rock covered with a thin layer of gravel and sand. The facilities for the construction of storage reservoirs in the upper valleys, to restrain the floods and to render the flow more uniform, are on the whole not very good, on account of the narrowness of the valleys and their rapid fall, although sites could doubtless be found. The necessity for such reservoirs has, however, not yet been felt, and no accurate examinations have been made on this point, so far as I could learn.

The fine opportunity which is at present afforded of utilizing a large amount of power by means of the now abandoned canal can not be too strongly emphasized. It has fine collateral advantages—climate, means of transportation, building-materials, etc.—but in my limited work it was, of course, not possible to make a detailed examination of the canal to determine just what sites would be most favorable. The total fall of the river between Richmond and Buchanan, amounting to 812 feet, having been overcome by a series of locks, dams, and canals, there is every reason to believe that a large proportion of the total theoretical power of the stream between those points may be considered available if the canal can be made of sufficient capacity to carry the low-water discharge of the river. With such a large amount of power available it is evidently unnecessary to attempt to specify any particular points where it could be used better than at others.

The falls at Richmond constitute the first power on the stream, and extend over a distance of about 3 miles, the fall being 84 feet in that distance, the bed rocky, and the width of the stream from about one-eighth to one-quarter of a mile. From Grant's dam, at the head of the falls, and the first of the navigation dams, the canal extends without locks to the basin at Richmond, which is therefore 84 feet above tide. This is connected with the river below the falls by locks. Although considerable power is used at Richmond from the canal, there is also a large amount utilized from dams constructed below Grant's, so that in describing the powers it will be best to consider them in the order in which the dams occur as the river is ascended.

1. The first dam is the one which supplies power to the Haxall flour- and corn-mills. It extends from the north side of the stream in a very broken and zigzag line diagonally up the river from rock to rock, terminating in an island near the center of the stream, which is here perhaps 1,200 feet wide. A portion 330 feet long and 6 feet high was built of stone in 1880 at a cost of $2,500, while the remainder, about 1,200 feet long and 2½ feet high, is of wood. A race 500 yards long leads to the mill, where a fall of 22 feet is used, the power used being stated at 700 horse-power, which can be obtained during about ten months, while during the remaining two months about two-thirds as much can be obtained. The mills are run all the time, and at low water there is little or no waste over the dam. The pond covers only a few acres and affords no storage. In times of freshet, the machinery is sometimes stopped for a few days. The wooden dam is more or less injured by freshets almost every year, but there is seldom any trouble with ice; in 1879, however, the great ice-gorge below Richmond backed the water up into the mill. The mills of the Haxall-Crenshaw Company are the only ones using power from this dam.

2. The next dam is the one which supplies power to the various manufacturing establishments at Manchester, just opposite Richmond. The dam extends from the south bank in a very broken line diagonally up the river from rock to rock, ending just below the end of the Haxall dam. Its total length is about 1,650 feet, of which about 900 is of stone, and 3 or 4 feet high. About 50 feet of the stone part was built in 1878, and the rest about the year 1858 (said to have cost $2,570). The remainder of the dam is of wood. The pond is insignificant. A canal 500 or 600 yards long, 40 feet wide, and from 5 to 7 feet deep, leads from the dam, and along the lower part of this

canal are situated the mills mentioned below. The water-power is owned by the city of Manchester, and power is leased in 50-year leases at the rate of $4 per square inch of orifice under a head of 3 feet. No special precautions, however, are taken to regulate exactly the amount of water taken by each mill, and it seems that there is generally, except in very dry seasons, sufficient water for all the mills at present running. The following table gives the number of square inches paid for, and some other data. It is to be remarked that the price of $2 50 per square inch was formerly the regular rate, but it is now $4 for all new leases.

Table of power used at Manchester, Virginia.(a)

Proprietor or firm.	Kind of mill.	Number of square inches taken.	Price per square inch.	Total rent per annum.	Head and fall, in feet.	Horse-power used, net.	Number of months full capacity.	Capacity the rest of the time.	Number of hours per day run.	Steam-power used.
Martin Brothers & Baker	Sumac	150	$4 00	$600	14	30	b 12			
Richmond Cedar Works	Bucket	150	4 00	600	20	120	12		10	
Manchester paper-mill	Paper	300	4 00	1,200	10	100	12		24	
Old Dominion mill	Cotton	800	2 50	2,000	18	c 150	12		12	
Walker & Saunders	Flour	600	2 50	1,500	18	100	11	One-half	12	
Dunlop & McCance	do	800	2 50	2,000	20	200	12		24	
Marshall Manufacturing Company	Cotton	500	2 50	1,250	20	d 175	e 12		11	
Manchester corn-mill (f)	Corn				14	15-20	10-12			
City pump-works (f)					20	36				
						925				

a The figures giving the power used were obtained from the manufacturers, and may not be exact. The figures giving the amount of water taken and paid for were obtained from the city auditor. A calculation would probably show that the two statements do not agree in all cases, but the error could not be located without measurements.

b Sometimes obliged to stop on account of backwater.

c Power stated at 227 horse-power in returns of enumerators.

d Power stated at 140 horse-power in returns of enumerators.

e Average loss of about eight days on account of high water.

f Owned by the city.

The power available at the two dams just described would depend upon how the water could be distributed between the two and how much could be taken from the river above. The available power of the entire stream per foot fall can be seen by referring to the table on page 18.

3. The next dam is that of the Old Dominion Iron & Nail Works Company, and extends diagonally from the head of Belle Isle to the south bank of the river. The foot of the island is a quarter of a mile or so above the Manchester dam, and on the island are situated the works of the company. The dam is of wood and stone, about 3 feet high and from a quarter to a half mile long, and from it a canal about 400 yards long leads to the works, where the fall is from 16 to 18 feet. The power used is stated at 1,000 horse-power, and it is said that this amount can be secured during eight months of the year, the capacity during the remaining four months being about two-thirds as much.(*a*) The power is used to drive the rolling-mills. This dam is really a continuation of the one next to be described.

4. The Richmond water-works, on the north bank of the river, are supplied with power from a dam extending diagonally in a broken line, from rock to rock, to the head of Belle Isle. For the first 400 feet it is of stone, walled up in cement, about 6 feet high, and with a nearly vertical face. The remainder, about 800 feet, is of wood, not over 3 feet high. The stone part was built in 1844 at a cost of $13,000, and the wooden part in 1874 at a cost of $2,500. A race 700 feet long, 40 feet wide, and 6 feet deep leads to the wheels, where the fall is 10 feet. One turbine- and six breast-wheels are used to drive the pumps, the total power used being about 280 horse-power, and the amount of water taken by the city about 6,500,000 gallons per day, or about 10 cubic feet per second. Full capacity can be obtained during about ten months, and during the remainder of the time about one-half, there being little leakage or waste over the dam. A steam-pump of small capacity (800,000 gallons in twenty-four hours) is used in cases of emergency. The bed of the stream is very rocky, and the dam has never been carried away, although in the freshet of 1877 the water is said to have risen 26 feet at the works. The scarcity of water during the dry season has led to the establishment of new works, which will be referred to below.

5. The next dam is 3 miles above Richmond, and is known as Grant's dam, or Three-Mile dam. It is the first of the dams of the canal company, and was built as a feeder to supply the lower level with water, and not to afford slack-water navigation. It is 1,700 feet long and 4 feet high, extending only partly across the river, and is a wooden structure, built about 1854, and would probably cost $20,000. The Richmond level terminates below in the basin, which is connected by a series of 5 lift-locks with a dock which extends for a mile below the basin and is connected with tide-water by a ship-lock, thus enabling vessels to come up almost to the basin. The canal having now been abandoned, this lower level is free to be used to its full capacity for supplying water-power; but even while the canal was in use for navigation a number of manufacturing establishments were supplied with water-power from it.

a Power stated at 500 horse-power in enumerators' returns.

The use of navigation canals as a means of supplying water-power is limited, on account of the velocity of flow thereby occasioned; and as there are various other circumstances peculiar to this case, it may be well to say a few words regarding the power as it has heretofore been used. The dimensions of the canal are as follows: Width at top, 50 feet; width at bottom, 30 feet; depth, 5 feet; area of cross-section, 200 square feet. According to the chief engineer of the canal, Mr. J. M. Harris, there has been and is now used for power from this lower level about 340 cubic feet per second, so that the velocity in the canal from this cause alone is 1.7 foot per second. This velocity has necessitated the use of a larger number of horses to haul the boats up the canal, and it has been concluded that a velocity of a mile per hour, or about 1½ foot per second, is the maximum which can be allowed on canals without considerable detriment to the interests of navigation. On account of the current it was proposed to enlarge the lower level of the canal, but the work was never carried out. In a report of the former chief engineer of the canal, Mr. Lorraine, "on the capacity of the first level for supplying water-power", it is stated that the cross-section could be enlarged to 300 square feet, making the top and bottom widths respectively 60 and 40 feet, and the depth 6 feet, so that, with a velocity of 1.5 foot per second, the capacity would be 450 cubic feet per second, affording 51 theoretical horse-power per foot fall. As regards power obtained from navigation canals, it is also to be borne in mind that the water is in some cases drawn off for a longer or shorter period for repairs, or during the winter. On the James River and Kanawha canal, however, the water was not drawn off during the winter and the mills obtained water almost uninterruptedly. There has sometimes been a little trouble with ice, but it is never serious. Water was rented by the company at the annual rate of $3 per cubic foot per second for each foot head and fall on the first level, while above the first level and below Lynchburg the rate was $1 10, and above Lynchburg and on North river it was 70 cents. Although these were the regular rates, there were some old agreements in some cases, rendering the details very complicated, and in some cases special rates were made, such as allowing to an establishment water free for five years, at half price for the following five, and at full price subsequently, in consideration of traffic brought to the canal. The amount of water delivered to each mill was regulated by the engineer of the company, and was delivered through an orifice accurately adjusted by him.

Postponing mention of the powers on the canal above Grant's dam, it remains to name those on the lower or Richmond level. They are as follows:

1. The Tredegar Company (rolling-mills, founderies, car-shops, machine-shops) use, according to Mr. Harris, about 122 cubic feet per second, discharging into the river below the city water-works and above the Haxall dam, with a fall of about 50 feet, in two falls of 23 and 27 feet. This would afford a theoretical power of 693 horse-power,(*a*) and full capacity can always be obtained.

2. Richmond Paper Manufacturing Company, using, according to Mr. Harris, 80 cubic feet per second, with a fall of about 21 feet, giving a theoretical power of 191 horse-power. (The enumerators' returns give the fall as 20 feet, and the power as 120 horse-power.) This water is ultimately discharged into the race leading to the Haxall mill, but before reaching it is used again by three different establishments, viz.:

a J. J. Montague's planing-mill, sash, blind, and door factory, using half the water coming from the paper-mill, with a fall of 20 or 21 feet, and 75 horse-power, which can always be secured. Steam-power to the extent of 65 horse-power is also used.

b T. W. McCance, jute-bagging factory, with 19 feet fall and 9 or 10 horse-power.

c Grist-mill, with 20 feet fall or thereabout; power about 25 horse-power.

3. The mills of the Gallego Mills Manufacturing Company (flour), situated at the lower end of the basin, are the last mills using water directly from the canal. They use, according to Mr. Harris, about 138 cubic feet per second, with a head and fall of 36½ feet, giving a theoretical power of 572 horse-power. The water is discharged eventually into the dock below the basin, after being used by the Gallego corn-mill and Whitehurst & Owen's sash- and blind-factory. There are 23 runs of stone in the flour-mill and 8 in the corn-mill, and full capacity can be secured generally during about half the year.

a The Gallego corn-mill uses a head and fall of 13½ feet, and perhaps about 80 to 100 horse-power, taking the water after it leaves the flour-mill.

b Whitehurst & Owen's planing-mill, and sash-, blind-, and door-factory use a fall of 16 feet and about 40 horse-power, and full capacity can always be secured, of course. The water is discharged to the dock after passing over a wheel formerly used for a paper-mill, with 7 feet fall. The ground, power, and mill are rented from the Gallego Company.

4. The Shockoe mills (corn, sumac, plaster, and bark), owned by Warner Moore, esq., take water from the dock, and discharge it into the river, using a fall of 14 feet and about 60 horse-power. No other mills take power from the dock, and this is therefore the lowest mill using power from the canal.

---

a The power used was given, in a blank filled out by the company, at 1,100 horse-power. It is stated to be 829 horse-power in the enumerators' returns.

The power used from the canal on the Richmond level is therefore approximately as follows, assuming the efficiency of the wheels to be 75 per cent.:

	Net horse-power.
Tredegar Company	520 (?)
Richmond paper-mill	143 (?)
Montague's planing-mill	75
McCance's bagging-mill	10
Smith's grist-mill	25
Gallego flour-mill	430
Gallego corn-mill	80
Whitehurst & Owen's planing-mill	40
Moore's Shockoe mills	60
Total	1,383

The total power used from the James below Grant's dam is as follows, approximately:

	Net horse-power.
From the James River and Kanawha canal	1,383
City water-works	280
Old Dominion Iron Company	500 (?)
Manchester water-power	925
Haxall-Crenshaw Company	700
Total	3,788

These figures are liable to considerable error, but it is impossible to make them more accurate.

It is evident from the preceding description that the method of using the water-power at Richmond is rather complicated, and also that only a very small proportion of the total available power is at present utilized. There seems to be no technical reason why Richmond should not be one of the great manufacturing centers of the Atlantic slope, for it may safely be asserted that so far as water-power goes such advantages are seldom to be found. If all the water of the river could be diverted into the canal at Grant's dam its available fall at Richmond would be 84 feet at the lower end of the canal, while along the canal above the basin and above the Tredegar works is a strip of land which could be occupied by factories for a distance of between half a mile and a mile, or even more, with an average fall of 48 or 50 feet. A glance at the estimate of power below will show the large amount of power which could thus be rendered available. But even if it were not practicable—for legal or other reasons—to divert the entire flow, or a large part of it, above the city, a considerably larger amount of power could be utilized if the dams were raised and tightened, and extended entirely across the river. A detailed discussion of these points, however, does not belong here. It has been said that the Three-Mile dam could be raised several feet; but on the other hand, it is also asserted that this would be accompanied, in times of freshet, by damage to the Richmond and Danville railroad, which here follows the river.

The drainage area of the James above Richmond is about 6,800 square miles, and the average rainfall over the entire basin is probably about 42 or 43 inches, varying from 44 at Richmond to 38 in the mountains. Of this about 12 inches fall in spring, 12 in summer, 9 in autumn, and 10 in winter. The flow is very variable, as already mentioned, but no series of gaugings has been made. Two different measurements of the flow, however, made in very dry seasons, when the river was lower than for many years, and probably not far from its minimum stage, agreed quite well in giving the discharge at about 1,300 cubic feet per second. I have therefore estimated the power available as follows:

Table of available power of the James river at Richmond.

State of flow (see pages 8 to 11).	Drainage area.	Fall.	Flow per second.	Horse-power available, gross.		
	Sq. miles.	*Feet.*	*Cubic feet.*	*1 foot fall.*	*50 feet fall.*	*84 feet fall.*
Minimum	6,800	84	1,300	147.7	7,385	12,400
Minimum low season			1,500	170.4	8,520	14,300
Low season, dry years			1,750	200.0	10,000	16,800
Maximum with storage			6,000	681.8	34,000	57,000

It is not probable that any storage during the night could be obtained. The above figures, therefore, refer to power available during twenty-four hours.(*a*)

a During the summer and fall of 1881 the James river has been lower than for many years past. The mills on the canal and on the river have been obliged to run at a small fraction of their capacity, and it is stated that the river could be crossed almost anywhere along the falls without wetting one's feet. It is probable that the flow has fallen considerably below that given as the minimum, 1,300 cubic feet per second, or 0.19 cubic foot per second per square mile, and it is possible that it may have fallen nearly as low as in the case of the Potomac (0.093 cubic foot per second per square mile). Nevertheless, I have retained the figures given, having no accurate data regarding the flow in 1881.

The existing canal would carry perhaps 350 cubic feet per second with a fall of 1 foot per mile, and about 500 cubic feet per second with a fall of 2 feet per mile (supposing its dimensions to be 50 feet width at top, 30 feet at bottom, depth, 5 feet), and still more with a greater fall. If its dimensions were 60, 40, and 6 feet, it would carry perhaps 600 and 900 cubic feet per second with the declivities given above.

The following table gives the power which would be available under these conditions:

Section of canal.	Fall of bed per mile.	Estimated capacity of canal per second.	Horse-power available, gross.		
	Feet.	*Cubic feet.*	1 *foot fall.*	50 *feet fall.*	80 *feet fall.*
Width at surface, 50 feet; width at bottom, 30 feet; depth, 5 feet.	1	350	40. 0	2, 000	3, 200
	2	500	56. 8	2, 840	4, 544
Width at surface, 60 feet; width at bottom, 40 feet; depth, 6 feet.	1	600	68. 2	3, 410	5, 456
	2	900	102. 3	5, 115	8, 184

From what has been said it is evident that the advantages for the use of water-power at Richmond are very great. The facilities for transport, both by sea and by land, are scarcely surpassed; building-materials can be obtained near by, and an excellent quality of granite is quarried within a very short distance. In fact, almost every advantage seems to be here.(*a*)

There is no power taken from the river between Richmond and Lynchburg, a distance of 146 miles along the stream. The fall between these points is, as already stated, 513 feet from tide-water to the Lynchburg water-works dam, or 429 feet from the crest of Grant's dam. The latter figure gives an average fall of 2.94 feet per mile. Within this distance there are 6 canal dams, with a total height of about 60 feet, and this subtracted from 429 leaves 369 feet as the total fall between ponds, or an average of 2.53 feet per mile. Within this distance there are, no doubt, some falls and some sites that might be utilized for power, perhaps to a considerable extent, besides those on the canal and at the dams. But the fact that the canal is now abandoned as a means of communication, and that consequently almost the total fall of the stream from Richmond to Buchanan is available for power, with as much water as the canal will carry or could be made to carry, seemed to me to render a detailed examination of the stream unnecessary for the purposes of this report. It would seem to be in the power of the railroad company to offer the very finest inducements to manufacturers desiring to use water-power. Mills could be established at each dam and lock along the entire length of the canal where the conformation of the ground would permit, those at the dams using falls equal to the heights of the dams, and discharging the water into the river below, and those at the locks using falls equal to the lifts of the locks, and discharging the water into the lower levels, to be used again at the next lock below; and in favorable places mills might also be established along the canal, discharging the water into the river—withdrawing it, to be sure, from the lower levels and thus lessening the amount available at the locks. And by increasing the dimensions of the canal at suitable points a much greater amount of power could be utilized than is now available, until at the limit the whole fall of the stream, minus that which is sufficient to maintain the velocity in the canal (which may be taken as *not less than* 1 foot per mile, and probably more), would be available for power. It is scarcely necessary to do more than call attention to the large amount of power which could thus be rendered available. Scarcely any of it being utilized, the field is almost entirely open, and the location has only to be selected from among numerous good ones. A few remarks, however, regarding the capacity of canals of different dimensions may serve to convey a clearer idea of the circumstances of the case.

When water flows in open channels its velocity is due to the slope of its surface, not to that of the bed of the canal. If the bed be horizontal, as in many navigation canals, then, as any velocity must be accompanied by a slope of the water-surface, the depth will be smaller at the lower end of the channel than at the upper end, and the cross-section will vary from point to point. The motion thus becomes varied, as it is called, and the mathematical investigation of its laws more complex. For a rough calculation, however, the discharge may be considered the same as if the bed were inclined and parallel to the surface, and the section the same as it is at the lower end—especially as the capacity of the canal depends upon the number of bends on its course, and many other circumstances, all more or less uncertain. A tolerably close estimate for the discharge could be obtained in any particular case by a series of approximations; but it is evident from what has been said that on long levels the capacity will be considerably smaller than it would be if the bed were inclined, and it would probably be necessary to give the canal-bed a slope on many levels, or to raise the water at its head—proceedings which would either reduce the fall available at the locks, or necessitate the raising of the dams and the embankments. Assuming, however, that the fall of the bed of the canal is 1 and 2 feet per mile, then the capacity of the canal, the total available fall between Richmond and Lynchburg, and the total theoretical power between those points, are given in the following table.

a Between the years 1848 and 1868, the number of days during which the James River and Kanawha canal was closed by ice varied from 0 to 56, the average for the 20 years being 15 days.

The capacity of the canal is the same as previously given for the Richmond level, the same dimensions being assumed:

Section of canal.	Fall of bed per mile.	Fall between Richmond and Lynchburg.	Distance between Richmond and Lynchburg.	Available fall between Richmond and Lynchburg.	Estimated capacity of canal per second.	HORSE-POWER AVAILABLE, GROSS.	
						Per foot fall.	Total.
	Feet.	*Feet.*	*Miles.*	*Feet.*	*Cubic feet.*		
Width at surface, 50 feet; width at bottom, 30 feet; depth, 5 feet.	1	429	146	283	350	40.0	11,320
	2			137	500	56.8	7,782
Width at surface, 60 feet; width at bottom, 40 feet; depth, 6 feet.	1			283	600	68.2	19,300
	2			137	900	102.3	14,015

The table shows that the total power available is about 40 per cent. greater with a fall of 1 foot per mile than with one of 2 feet. The table given on page 21 for the power at Lynchburg will show that the flow of the stream at that place is probably seldom less than 600 cubic feet per second, so that the power given in the table above could probably be realized if favorable ground for location could always be found. It is sufficient to call attention here to these figures as giving a rough idea of the power lying here unemployed.

Although there is no power used directly from the river between Richmond and Lynchburg, a certain amount is already used from the canal. The first power is just opposite Grant's dam, where there are two locks with 10 feet lift each. The water is passed round these locks, and the fall of 20 feet is used for the new water-works of the city of Richmond. The amount of water to be used was stated at 283 cubic feet per second, which would give 643 gross horse-power with a fall of 20 feet. The amount of water to be taken for supplying the city was stated at 12,000,000 gallons daily, with provision for an eventual increase.

Between the Richmond level and the Lynchburg level there are sixteen other establishments taking power from the canal, using in all about 278 cubic feet per second, for which $5,975 per annum is paid; but none of these establishments are of much importance. They are all, or nearly all, flour-, grist-, and saw-mills.

The table on pages 22 and 23 gives a list of the dams on the stream between Richmond and Lynchburg, as well as above, with their dimensions. All of these dams, except Grant's and Seven-Island, offer good sites for power, an approximate estimate of which will be found in the table on page 23. Regarding intermediate falls on the stream it is said that power could be obtained a short distance above Scottsville, and at Fallsburg, 1 mile above Warren, but I did not verify these statements. There are 51 lift-locks on the canal between Richmond and Lynchburg, averaging 8½ feet lift, and 4 guard-locks at the dams. At each of the lift-locks, according to what has been said, a certain amount of power could be utilized if the land is favorable for building.

The next place above Richmond where power is used to any considerable extent is at Lynchburg. The river has at this place a fall of about 23 or 24 feet in a distance of 4 miles, at the center of which, or rather below, is the city. The bed of the stream is rock and gravel, the channel is interspersed with islands, especially at the head of the fall, and the banks are favorable for building, being above all but the highest freshets, yet not steep. Power is used here in two ways—from the navigation canal, and from a second canal running parallel to the first, both supplied from the same dam. The south end of the dam is about 2 miles below the head of the falls, and from this point it extends very irregularly and diagonally across the river, reaching the opposite bank nearly 2 miles farther up stream, or near the head of the falls. From the south bank a stone dam, built as an arc of a circle with a chord of 120 feet and an ordinate at the center of about 20 feet, extends to the foot of an island. It was built in 1839, and is 12 feet high. From the head of this island a wooden dam extends nearly up and down stream, to the lower end of a second island, and in this way the dam is carried across the river from island to island. The wooden dams are generally not over 3 or 4 feet high and are not substantial. It is proposed to raise the stone dam 2 feet and to extend it straight across the river, the cost of this improvement having been estimated by Mr. Harris at about $60,000. From the Lynchburg level of the navigation canal nine establishments are supplied with water-power, using together about 391 cubic feet per second, with an average fall to the river of about 17 feet, giving therefore about 750 gross horse-power. The fall on this level from canal to river varies from about 13 feet at the dam to 22 or 23 feet at a point 2 miles below. The mills on the level are as follows:

	Horse-power.
Morris' barytes-mill, 17 feet fall	36
Hall's flour-mill	—
Heald's bark-mill, 16 feet fall	30
Snead & Winston's planing-mill, 16 feet fall	25
Lynchburg Iron Company's rolling-mill, 12 to 14 feet fall	40
Piedmont flour-mill, 12 feet fall	150
Piedmont corn-mill, 13 feet fall	40
Percival's machine-shop	—
Dabney's foundery	—
City flour-mill, 12 feet fall	200

The water-rents for these establishments amount to $3,295 30 annually.

The head-gates of the second canal are by the side of the guard-lock of the canal, between it and the river. The canal is about one-quarter of a mile long, and averages 30 feet in width and 5 to 6 feet in depth, but is very variable in section. On it are located the following mills, discharging their water into the river:

	Horse-power.
James River Foundery and Manufacturing Company, 11½ feet fall	20
J. P. Pettyjohn's planing-mill, 12 feet fall	40
R. S. Dawson's tobacco-box mill, 12 feet fall	15
Sumac-mill, 12 feet fall	18 to 20
City water-works, 12 feet fall	100
Total	195

The water-power from this canal is controlled by the city, but water is not leased at any regular rate, on account of old agreements and contracts. At present the city also controls the water-power from the navigation canal, according to some special agreement.

All the mills at Lynchburg are troubled sometimes by high-water, but the interruption from this cause does not exceed two weeks or thereabout in the year. The freshets of 1870 and 1877 did considerable damage to property, carrying away each time part of the dam (one of the small wooden dams), and in the latter year overflowing and breaking through the water-works race and carrying away considerable lumber. There is no trouble with ice, there being no liability to ice-jams in the river. During the dry season there is often scarcity of water, even on the navigation canal, but this is due to imperfections of the dams or want of sufficient capacity on the canals. On the water-works canal more trouble is experienced in this respect, some of the mills being able to run at full capacity only during eight months, and the capacity falling as low as between one-half and two-thirds in dry seasons.

The drainage area above Lynchburg is about 3,650 square miles, and the rainfall about 41 or 42 inches—12 in spring, 12 in summer, 8 in autumn, and 10 in winter. The minimum flow is stated by some engineers at 1,000 cubic feet per second, but I have no doubt that it is much less. In the absence of further measurements, I have estimated the flow and power as in the following table:

Estimate of flow and power at Lynchburg.

State of flow (see pages 8 to 11).	Drainage area.	Fall.	Flow per second.	Horse-power available, gross.		
	Sq. miles.	*Feet.*	*Cubic feet.*	*1 foot fall.*	*13 feet fall.*	*22 feet fall.*
Minimum	3,650	13–22	540	61.3	797	1,350
Minimum low season			650	73.8	959	1,625
Maximum with storage			3,200	363.6	4,727	8,000
Low season, dry years			740	84.1	1,093	1,850

There seems to be no reason why the whole of the power could not be utilized, excepting, probably, the maximum with storage, regarding which it is impossible to state definitely whether sufficient reservoir room could be secured. As regards facilities for transportation, Lynchburg is very favorably situated, as the map shows. Already of importance, its manufactures could be greatly enlarged if the whole of the available power were properly utilized.

Between Lynchburg and Buchanan, the western terminus of the canal, water-power is used directly from the river at only one point, known as Irish falls, in Amherst county, where about 50 horse-power is used for an iron furnace, saw- and grist-mill. The dam is of crib-work, 1,200 feet long and about 8 feet high, backing the water half a mile, and the fall used is 9 feet, with a race of 400 yards. There is also very little power used from the canal, the quantity of water amounting to only 55 cubic feet per second, supplied to a rolling-mill. At each of the canal dams, however, and at various points along the canal, and at the locks, power could be used without difficulty. As the table on page 23 shows, there are in this distance 12 dams; 5 of these are of stone and 7 of timber, varying in length from about 400 to 800 feet and over, and in height from about 8 to 30 feet, at all or nearly all of which a large amount of power could be used. The total fall in the river between the points mentioned is 299 feet, or nearly 6 feet per mile. The following table is similar to that on page 20:

Section of canal.	Fall of bed per mile.	Fall between Lynchburg and Buchanan.	Distance between Lynchburg and Buchanan.	Available fall.	Estimated capacity of canal per second.	Horse-power available, gross.	
						Per foot fall.	Total.
	Feet.	*Feet.*	*Miles.*	*Feet.*	*Cubic feet.*		
Width at surface, 50 feet; width at bottom 30 feet; depth, 5 feet	1	299	50	249	*a* 350	40.0	9,960
	2			199	500	56.8	11,303
Width at surface, 60 feet; width at bottom, 40 feet; depth, 6 feet	1			249	600	68.2	16,982
	2			199	900	102.3	20,358

a The flow of stream in dry weather is probably not 350 cubic feet per second except in lower portion of the distance.

In this case, however, the enlarging of the canal would, without doubt, be exceedingly expensive; but as the minimum flow at Lynchburg is, according to the table on page 21, only 540 cubic feet per second, and probably only about 330 cubic feet per second at Buchanan, the enlargement would practically be unadvisable. The principal locations on this section of the canal would seem to be at the dams, and estimates of the power at these places are given on page 23. These dams are very substantial structures, the stone ones being built up in hydraulic cement with nearly vertical faces, and the wooden ones being composed of crib-pens filled with stone, with sloping tops and backs and almost vertical faces, sheeted behind and on top, and all being founded on rock.(a) The Richmond and Alleghany railroad, when completed, will afford a most convenient means of transportation along the river, and it is needless to say that building materials are to be had in great abundance and of fine quality.

From Buchanan to the head of the river—the junction of Jackson's and Cowpasture rivers—the distance is about 29 miles and the fall about 202 feet, or at the rate of about 7 feet per mile. No power whatever is used on this part of the stream, although there are numerous sites where power could be obtained. The declivity of the stream being tolerably uniform, there are no precipitous falls, but at numerous points dams could easily and advantageously be located. It was at one time intended to continue the canal up the river and over the Alleghenies, and all the upper part of the James and part of Jackson's river were surveyed with this object in view, and the locations for two dams between Buchanan and the head of the dam were determined upon and the dams themselves partially constructed. One, the Cabell dam, 9 miles above Buchanan, was built to a height of 5 feet entirely across the river, being constructed of wood on a rock foundation; and the other, at the Old Forge, 15 miles above Buchanan, to be built entirely of stone, was not carried quite so far. At the former place, which is about 2 miles above Saltpetre Cave station, on the railroad, the banks are good, and a dam could be built probably 8 feet high, while for a mile below there is some fall which might be worth utilizing, so that with a canal half a mile long, probably a fall of 10 or 12 feet could be used, while with a shorter race 8 or 10 feet could probably be easily obtained. At the Old Forge, about 1½ mile above Salisbury Furnace, it would be easy to utilize power on the left bank, and probably from 6 to 10 feet could be rendered available. None of the other sites seem of much importance, though there are a number of rifts where power could be developed, but at no place, it is said, is there a fall of over 4 or 5 feet. The fall is gradual, the bed and banks gravel, clay, sand, etc., with rock at a small depth in most places. The river in this part of its course is, on the average, perhaps 250 or 300 feet wide. Although no power is at present used, there have been in times past several grist-mills above Buchanan, but none using large powers.

The following tables give the statistics of dams and of power utilized, and estimates of the power available at the dams. Regarding the latter, it is to be mentioned that Mr. E. Lorraine, the late chief engineer of the canal, in a report made in 1866, "on the points at which water-power can be spared from the dams and canal", does not mention Judith's or Blue Ridge dam; and it may be that the land at those localities is not favorable for location.

Table of statistics regarding dams of the James River and Kanawha Canal Company on the James river.

[Heights given above foundation and above water-surface.]

Name of dam.	DAM.						POND.		Remarks.
	Distance from Richmond.	Length.	Height.	Material.	Date of erection.	Cost.	Length.	Whether used for navigation.	
	Miles.	*Feet.*	*Feet.*				*Miles.*		
Grant's	3.0	1,700	4	Wood	1855 (?)	$20,000	....	Feeder only	Dam does not extend entirely across river. No water-power.
Bosher's	9.0	902	12 / 9	Cut granite in cement	1857–'58	70,000	10	Navigation	
Maiden's Adventure	29.0	1,026	12 / 10	Cut granite in cement	1852–'53	80,000	5	5 miles navigation.	
Seven-Island	....	....	....	Wood	1840	....	....	Feeder only	Low dam. Enables boats to enter canal from other side of river. Does not extend entirely across. No water-power.
Tye River	109.0	550	12 / 10	Cut granite in cement	1860	60,000	....	2½ miles navigation.	
Joshua Falls	135.5	600	12 / 9	Cut granite in cement	1870	50,000	3	2½ miles navigation.	Rebuilt in 1870.
Lynchburg	148.5	....	....	Part stone, part wood	1839	....	2	2 miles navigation.	Extends in a broken line from island to island.
Judith's	152.0	725	33 / 25	Cut stone in cement	1850–'51	? 100,000 or over.	4	4 miles navigation.	
Bald Eagle	157.0	498	14 / 14	Cut stone in cement	1849–'51	35,000	2½	2½ miles navigation.	

a On this section of the canal (Lynchburg to Buchanan) there are 22 miles of canal, 28 miles of slack-water navigation, 38 locks, 2 aqueducts, 17 tow-path bridges, and two farm bridges.

Table of statistics regarding dams of the James River and Kanawha Canal Company on the James river—Continued.

Name of dam.	DAM.						POND.		Remarks.
	Distance from Richmond.	Length.	Height.	Material.	Date of erection.	Cost.	Length.	Whether used for navigation.	
	Miles.	*Feet.*	*Feet.*				*Miles.*		
Pedlar	160.0	454	{18 / 12}	Cut stone in cement	1849-'51	$35,000	2	2 miles navigation.	
Coleman's Falls	162.5	572	{18 / 14}	218 feet stone, 354 feet wood.	1849-'51	30,000	3	3 miles navigation.	
Big Island	166.5	683	{12 / 12}	Stone	1849-'51	35,000	2	2 miles navigation.	
Cushaw	170.5	843	{10 / 10}	Wood	1849-'51	20,000	1	....	Boats cross river in pond.
Blue Ridge	176.0	455	13	150 feet stone, 305 feet wood.	1849-'51	20,000	3 and 1½	{3 miles on James / 1½ miles on North}	{At confluence of North river. Stone part in front of old wooden part.
Quarry Falls	178.5	582	{13 / 13}	136 feet stone, 446 feet wood.	1849-'51	25,000	2½	2½ miles navigation.	Not very favorable for power.
Varney's Falls	185.5	488	{18 / 14}	Wood	1849-'51	20,000	3	3 miles navigation.	Not so favorable for power as the two below.
Indian Rock	189.5	613	{19 / 16}	Wood	1849-'51	30,000	3	3 miles navigation.	Easy to utilize for water-power.
Wasp Rock	194.0	384	{20 / 15}	Wood	1849-'51	30,000	3	3 miles navigation.	Easy to utilize for water-power.

James river—Table of power available at Richmond and at canal dams.

Locality.	Distance from Richmond.	Drainage area.	RAINFALL.					TOTAL FALL.		HORSE-POWER AVAILABLE, GROSS. (a)				UTILIZED.		Remarks.
			Spring.	Summer.	Autumn.	Winter.	Year.	Height.	Length.	Minimum.	Minimum low season.	Maximum with storage.	Low season, dry years.	Horse-power, net.	Fall.	
	Miles.	*Sq. m.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Feet.*	*Miles.*						*Feet.*	
Richmond	0.0	6,800	12	12	9	10	43	84	3	12,400	14,300	57,000	16,800	3,765	....	
Bosher's dam	9.0	6,700	12	12	9	10	43	9	0	1,300	1,500	6,000	1,750	0	....	
Maiden's Adventure dam	29.0	6,560	12	12	9	10	43	10	0	1,400	1,650	6,600	1,900	0	....	
Tye River dam	109.0	4,350	12	12	9	10	43	10	0	750	900	4,250	1,150	0	....	
Joshua Falls dam	135.5	3,750	12	12	9	10	43	9	0	575	700	3,400	800	0	....	
Lynchburg	148.5	3,650	12	12	8	10	42	13-22	0-2	{800 / 1,350}	950 / 1,625	4,700 / 8,000	1,100 / 1,850	} 750±	12-16	
Judith's dam	152.0	3,525	12	12	8	10	42	25	0	1,500	1,800	8,800	2,050	0	....	
Bald Eagle dam	157.0	3,475	11	12	8	10	41	14	0	850	1,000	4,800	1,150	0	....	Some power used from canal, but none directly at the dams.
Pedlar dam	160.0	3,475	11	12	8	10	41	12	0	700	850	4,200	970	0	....	
Coleman's Falls dam	162.5	3,345	11	12	8	10	41	14	0	800	950	4,700	1,100	0	....	
Big Island dam	166.5	3,285	11	12	8	10	41	12	0	675	800	3,950	900	0	....	
Cushaw dam	170.5	3,265	11	12	8	10	41	10	0	550	650	3,250	750	0	....	
Blue Ridge dam	176.0	3,245	11	12	8	9	40	13	0	700	850	4,200	975	0	....	
Quarry Falls dam	178.5	2,400	11	12	8	9	40	13	0	525	625	3,100	700	0	....	
Varney's Falls dam	185.5	2,375	11	12	8	9	40	14	0	550	650	3,350	750	0	....	
Indian Rock dam	189.5	2,340	11	12	8	9	40	16	0	650	775	3,750	900	0	....	
Wasp Rock dam	194.0	2,300	11	12	8	9	40	15	0	575	700	3,500	800	0	....	
Buchanan	198.0	2,200	11	12	8	9	40	....	....	....	....	....	....	....	....	

a See pages 8 to 11.

TRIBUTARIES OF THE JAMES RIVER.

The first important tributary of the James is the Chickahominy, which enters from the north, on the boundary line between the counties of Charles City and James City, after having pursued a course of about 50 miles, measured in a straight line, and draining an area of about 412 square miles. But though important by reason of its size, it is altogether without water-power. Taking its rise just about on the fall-line, it is sluggish and altogether unfavorable for power for its entire length.

The next tributary, and the most important affluent of the James, is the Appomattox, which enters from the south between Chesterfield and Prince George counties. It takes its rise in Appomattox county, and pursues a general easterly direction, forming the boundary line between the counties of Buckingham, Cumberland, Powhatan, and Chesterfield on the north, and Prince Edward, Amelia, Dinwiddie, and Prince George on the south, and flowing through the town of Petersburg, where it crosses the fall-line, giving rise to a fine water-power at that place, which is the head of navigation and of tide-water. The length of the stream, measured in a straight line, is about 85 miles, but by the river it is considerably greater, the distance from tide-water to a point 38½ miles above Farmville, and therefore probably not far from the source of the stream, being about 135 miles.(*a*) The river drains an area of about 1,565 square miles, of which 1,325 are above Petersburg. The principal tributaries of the stream are: Swift creek, which enters from the north, below Petersburg, after draining about 165 square miles; Deep creek and Flat creek, which enter from the south, in Amelia county, and drain, respectively, 173 and 112 square miles. The drainage basin of the Appomattox lies entirely east of the Blue ridge, in the middle and eastern divisions of the state, and seems to offer no peculiarities. It contains no lakes; the rainfall averages about 43 inches—12 in spring, 12 in summer, 10 in autumn, and 9 in winter; and the stream is similar in all essential respects to the James in corresponding parts of its course. Like that river, it is subject to sudden and heavy freshets, but they are said to be rather less violent than those on the former stream; and the flow of the Appomattox is said to be on the whole more uniform and proportionally greater in dry seasons than that of the James—facts which find their explanation in part in the distribution of the rainfall.

The following table gives an idea of the declivity of the stream:

Table of declivity of the Appomattox river.

Locality.	Distance from tide-water.	Elevation above tide.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Petersburg	....	....			
			6.25	110	17.60
Lowest dam of Upper Appomattox Company	6.25	110			
			47.75	65	1.36
Richmond and Danville Railroad crossing	54±	175			
			38.00	90	2.40
Atlantic, Mississippi, and Ohio Railroad first crossing	92±	265			
			5.00	35	7.00
Atlantic, Mississippi and Ohio Railroad second crossing	97±	300			

This table is in many respects inaccurate, the distances having been roughly measured from a map; but it serves to show that the declivity is small above the falls at Petersburg, being even smaller than that of the James. The stream is, moreover, quite inaccessible between Petersburg and Farmville, and its water-power—whatever there may be of it—is not extensively used above the former place.

As already mentioned, Petersburg is at the head of tide-water, and vessels drawing 11 feet of water come up to the city. In this respect the stream resembles the James, the fall-line being at the head of tide and navigation. Above Petersburg, navigation has been carried on by flat-boats, the river having been made navigable long ago by the Upper Appomattox Company—still in existence—which has the chartered right to navigate the stream up to Farmville. It is said that the river is susceptible of being made navigable by bateaux carrying 20,000 pounds up to Plantersville, 16 miles above Farmville, and that navigation was at one time established up to this point; but that part of it above Farmville was abandoned some thirty years ago on account of the building of the railroad. At present, navigation extends up to Clementown, 70 miles above Petersburg, and it is said that it could be extended to Farmville at small cost; but above this the stream is very small. At the present time the river is navigated only to a small extent, the railroad having absorbed most of the traffic, although it is often a number of miles from the stream. The navigation works consist of locks and dams, and one canal extending from Petersburg to the lowest dam, a distance of 5¼ miles, with a fall in that distance of about 32 feet,(*a*) overcome by locks. Above this is a series of dams, converting the river into a series of navigable pools. The locks are 60 feet long, 10 feet wide, with lifts of 7 feet, and there are 8 dams between Petersburg and Clementown.

Describing the powers on the river in their order, the first is that at Petersburg. According to what has been said, the fall from the canal-basin at Petersburg to tide-water is 77½ feet, the fall on the canal 32 feet, and the fall from the lowest navigation dam to tide—in a distance of 6¼ miles—about 110 feet. (*a*) The principal part of this fall, however, occurs in the first mile or two above tide-water, amounting to 70 or 80 feet, and is used by various establishments, supplied from 4 dams:

1. The lowest dam—1¼ mile above the head of navigation and about 13 miles from the James—is 350 feet long and 8 feet high, and is a crib-work structure extending in the shape of a > across the stream. It has been built many years, and supplies power to the following establishments:

a. Williams' corn- and sumac-mill and cotton-gin—10 feet fall; 45 horse-power; full capacity during eight months, rest of the year one-third.

b. City flour-mills (Davis, Roper, & Co.)—10 feet fall; 100 horse-power; full capacity eight to nine months, rest of the year one-third.

c. Jones & Co.'s sumac- and bark-mill—10 feet fall; 30 horse-power; full capacity twelve months.

---

a Twenty-seventh Report of Board of Public Works of Virginia.

These mills run night and day and are all on the south side of the river. In the summer and fall, when the stream is lowest, there is no water wasted, and even then it seems that there is a great lack of water. It will be be noticed hereafter that a portion of the water of the river is diverted several miles above, at the lowest navigation dam, passing through the canal, and affording power to several mills in Petersburg. These mills, however, discharge their tail-water into the pond of the dam which has just been described, so that the mills above mentioned use the entire flow of the stream.

2. The second dam is also of crib-work, 400 feet long and 6 feet high, originally built about the year 1835, but rebuilt in 1865 at a cost of $3,000, and ponding the water for about a quarter of a mile. From it two races about a quarter of a mile long, one on each side of the river, lead to the mills, which are situated at the head of the pond below:

a. Eagle mills, corn and flour—17 feet fall; 80 horse-power; full capacity eight months; one-half capacity ten months; one-fourth capacity twelve months.

b. Eames' saw- and planing-mill, sash and blind factory—16 feet fall; 20 horse-power; full capacity nine months; one-half capacity twelve months.

c. Allen's corn-mill and cotton-gin—17½ feet fall; 45 horse-power.

d. Powhatan mill, flour and corn—16 feet fall; 50 horse-power.

The above are all on the north side of the river. On the south side are the following:

a. Kevan's flour-mill—14 feet fall; 80 horse-power; full capacity nearly all the time.

b. "Merchants'" cotton factory—closed since 1875; ran 2,500 spindles and 100 looms; fall 14 feet. This mill was run wholly or in part by water taken from the canal of the Upper Appomattox Company, and therefore diverted from the river over 5 miles above.

It is stated that although in summer no water wastes over the dam, yet the mills have to run at a small fraction of their full capacity during several months.

3. The third dam is of wood and stone, some 700 feet long and 5 or 6 feet high, and supplies power to the cotton-mill of the Ettrick Manufacturing Company on the north side of the river, and to that of the Battersea Manufacturing Company on the south side. The former uses a fall of 17½ feet and an estimated power of 200 horse-power; the latter uses 12 feet fall and 140 horse-power. Both mills run between eleven and twelve hours per day, but the pond is not large enough to store the water completely at night. In summer there is no waste during the day-time. Full capacity can be secured during about eight months, averaging from two-thirds to three-fourths during the rest of the year.

4. The fourth dam is of wood and stone, about 300 feet long and 2½ feet high, and supplies power to the cotton-mill of the Matoaca Manufacturing Company on the north side of the river. The fall is 16 feet and the power 265 horse-power. In summer there is no waste during the day-time, but the pond is not large enough to store the water completely during the night, the mill being run eleven hours. Full capacity can be secured nine months, and three-fourths during the remaining three months.

None of the mills referred to use steam except the Matoaca, which has reserve steam for periods of low water. There is little unimproved fall between these dams. Notwithstanding the freshets, there is no trouble in maintaining the dams, the bed of the stream being rock. The banks are close and shelving, but not steep, and the facilities for constructing canals and buildings are everywhere good. During freshets the mills are sometimes obliged to stop running for a few days, but there is little or no trouble with ice.

5. The fifth dam is the lowest navigation dam, which diverts part of the water into the canal, so that the mills above mentioned, except those fed from the first dam (and Kevan's flour-mill), obtain only what water flows over the navigation dam. How much water the navigation company may turn into its canal is a question not decided. Leaving the river about 5 miles west of Petersburg, the canal conducts to the basin at the city, which is the lowest point that can be reached by boats. The dam at the head of the canal extends entirely across the river, which is here divided into two arms by an island; its total length is about 400 feet and its height 4 or 5 feet; its crest is 109 or 110 feet above low tide. About half-way between the dam and the basin, or 2 miles west of the city, is a flight of four locks, with together a fall of 32 feet. At these locks there are two powers of about 15 feet each; the upper one was used during the war by the Confederate government for a powder-mill, and the lower one was used until very recently for a snuff-mill, but is now idle. The entire fall of 32 feet, it would seem, could easily be utilized for power, if necessary. From the basin at Petersburg, which is about 77 feet above low tide, the water which comes down the canal passes to the river, driving in succession several mills, as follows:

1. Munts' grist-mill—fall about 14 feet; about 50 (?) horse-power.
2. Box factory, with a fall of about 2 feet, run by an undershot wheel driven by the tail-water from Munts' mill.
3. The Lynch cotton-mill—fall 14 or 16 feet; about 100 horse-power.
4. Davis, Roper, & Co.'s cotton-mill—fall about 16 feet, with an overshot wheel; about 70 horse-power.

From the latter mill the water flows into the race leading to Kevan's flour-mill. It was formerly utilized to run the "Merchants'" cotton-mill, which had a fall of 14 to 16 feet, and is said to have used about 125 horse-power, but which is now not in operation, and for sale. Kevan's flour-mill, however, as well as the mills from the lowest dam on the river, use this water.

All the mills using power from the canal can run at full capacity during about nine months; during the remaining three months the capacity falls to from one-half to three-fourths; none of them use any steam-power.

As regards the method of renting power, Munts' mill and the box factory belong to the persons running them, and the power is rented from the canal company according to special agreement, and with no regular rates. The other mills now running are owned by the canal company, and are rented, with the power, according to special contract. The Merchants' mill was owned and operated by a stock company, the power only being rented from the canal company.

Recapitulating, then, the power used from the Appomattox in the 6 miles of its course above tide-water is as follows:

	Feet fall.	Horse-power, net.
From first dam:		
Williams' corn- and sumac-mill	10	45
City flour-mills	10	100
Jones' sumac- and bark-mill	10	30
Total		175
From second dam:		
Eagle mills	17	80
Saw- and planing-mill, etc	16	20
Allen's corn-mill	17½	45
Powhatan flour- and corn-mill	16	50
Kevan's flour-mill	14	80
Merchants' cotton factory	14	....
Total first and second dams		450
From third dam:		
Ettrick cotton factory (*a*)	17½	200
Battersea cotton factory (*b*)	12	140
Total		790
From fourth dam:		
Matoaca cotton factory (*c*)	16	265
Total		1,055
From fifth (navigation) dam:		
Venable's snuff-mill	15	....
Munts' grist-mill	14	50
Box factory	2	(?)
Lynch cotton factory	16	100
Davis, Roper, & Co. (*d*)	16	70
Total from river		1,275

The drainage area above Petersburg has already been stated to be 1,325 square miles, and the rainfall at 43 inches (page 24). The flow and power may therefore be estimated as follows, in the entire absence of gaugings:

Table of estimated power of the Appomattox river at Petersburg.

State of flow (see pages 8 to 11).	Drainage area.	Fall.	Flow per second.	Horse-power available, gross.			Remarks.
	Sq. miles.	*Feet.*	*Cubic feet.*	*1 foot fall.*	*77 feet fall.*	*110 feet fall.*	
Minimum	1,325	*a*77½–*b*110	175	20.0	1,540	2,200	Probably not available.
Minimum low season			200	22.7	1,750	2,500	
Maximum with storage			1,100	125.0	9,625	13,750	
Low season, dry years			235	26.7	2,050	2,940	

a Basin to tide. *b* Dam No. 5 to tide.

It would probably be impracticable to increase this power to any great extent by concentrating it into fewer than twenty-four hours. It will be seen that in all probability, if the entire fall of the stream from the navigation dam to tide-water were well utilized, about 3,000 gross horse-power could reasonably be expected during the low season of tolerably dry years. The table just given shows that probably little over one-half of this power is at present utilized. The power is an excellent one, with the best advantages of transportation, both by sea and by land.

Above Petersburg the stream is controlled as far as Farmville by the navigation company, but I have found it impossible to obtain complete details regarding the dams, mills, and powers not utilized. It is said, however—and

a Power stated at 205 horse-power in returns of enumerators.
b Power stated at 160 horse-power in returns of enumerators.
c Power stated at 313 horse-power in returns of enumerators.
d Power stated at 70 horse-power in returns of enumerators.

it seems altogether probable—that a certain amount of power can be used at each of the 8 canal dams below Clementown. How much water would be available would depend upon the amount needed for locking boats through, regarding which I have no data on which to base estimates; but as only few boats at present navigate the river, it is probable that nearly the entire flow of the stream could be utilized for power. For want of data regarding heights of dams and their locations I present no estimates. It was stated, however, that the lift of the locks was 7 feet, so that this would probably be the average height of the dams. Some of the power at the dams is at present utilized, but details could not be obtained. From one of the dams the Exeter mills, on the south side of the river, were formerly supplied, but the buildings were burned down some eight years ago, and the site is not now used, though it is said to be one of the best above Petersburg. At Farmville there is a grist-mill, and a few small ones are above, none of consequence.

The tributaries of the Appomattox, although they have some power, are not of much importance. Swift creek has one power worth mentioning, at Chesterfield city, the Swift Creek cotton factory, using 75 horse-power, with a fall of 3 (?) feet (according to the returns of the enumerators), and using all the water of the stream in summer. Full capacity can be secured during about nine months, and one-half during the remainder of the year. There are also several grist-mills on the stream. Regarding the other tributaries I have no detailed information.

The next considerable tributary to the James is Willis river, from the south, but its fall is gradual, and no unemployed sites of importance were spoken of.

The Rivanna river, the next large tributary, is formed in Albemarle county by the union of the North and South forks, both of which rise on the eastern slope of the Blue ridge, in Greene and Albemarle counties; and from their junction it pursues a southeasterly course, passing within a mile of Charlottesville, the county-seat of Albemarle county, and entering the James river in Fluvanna county, near the town of Columbia. It drains a total area of 668 square miles, the North fork draining 164 and the South fork 226, comprising a hilly and rolling region, and it has considerable fall, although the declivity is quite gradual. The bed is generally sand and gravel, with rock a short distance below, and sometimes on the surface. There are no lakes, and the stream is, like all the others in the vicinity, subject to sudden and heavy freshets, which, however, are of brief duration. The rainfall on the basin is about 43 inches—12 in spring, 13 in summer, 8 in autumn, and 10 in winter. The flow of the stream has never, so far as I could learn, been accurately gauged. Its fall from the junction of the two forks to its mouth—a distance of 40 miles—is 135 feet, according to an old survey.(a) Up to Milton, 32 miles, the stream was made navigable, over 50 years ago, by means of dams and locks, some of which are in existence, many in bad condition, and some of which are at present used for water-power. At present the stream is navigable for a distance of about 23 miles from its mouth. Its elevation at the crossing of the Chesapeake and Ohio railroad, a few miles from Charlottesville, is 278 feet above mean tide. The map shows that the stream is accessible at its mouth from the Richmond and Alleghany railroad, and in the neighborhood of Charlottesville from the Chesapeake and Ohio railroad and the Virginia Midland railroad.

The first power on the stream is 5 miles from its mouth, at the second navigation dam, known as Stillman's, with a fall of 16 (?) feet, 25 horse-power being used for a flour-mill, the drainage area above being about 650 square miles. I should estimate the flow and power as follows, there being no gaugings of the flow:

Table of estimated power at mouth of Rivanna river.

State of flow (see pages 8 to 11).	Fall.	Drainage area.	Flow per second.	Horse-power available, gross.	
	Feet.	*Sq. miles.*	*Cubic feet.*	*1 foot fall.*	*16 feet fall.*
Minimum	16	650	75	8.5	135
Minimum low season			90	10.2	160
Maximum with storage			600	68.0	1,100
Low season, dry years			110	12.5	200

Although the original navigation works were built over 50 years ago, I am informed that the present dam was built in 1855 at a cost of $30,000, being a crib-dam 350 feet long and 18 feet (?) high, backing the water 6 miles. There was formerly one dam below this point, with a fall of 5 or 6 feet.

Six or 7 miles above is the Carysbrook dam, with a fall of about 8 feet, used by a grist-mill. The available power would be rather less than half that estimated in the above table.

The third is the Palmyra dam, about 10 miles above Stillman's. It is 250 feet long, about 12 feet high, and a fall of 12½ feet is utilized by a flour-mill. The drainage area above is about 630 square miles, so that the available power per foot will be only very little less than at Stillman's dam.

Three miles above Palmyra is the Broken Island dam, with a canal perhaps a quarter of a mile long, and a fall of 10 or 12 feet, not utilized. The available power per foot is probably about the same as in the table above.

Three miles still farther up is Bernardsburg dam, said to have a canal nearly 2 miles long, and a total fall of somewhere about 15 feet, not used for power.

a *Eleventh Report of Board of Public Works of Virginia.*

Union dam, 2 miles farther up, is about 200 feet long and 10 feet high, constructed mostly of stone, and is said to have cost $10,000. It was built in 1850. A race of 600 feet affords a fall of 12 feet, used for a corn-mill and a small cotton factory (the latter idle since about 1866), only a small amount of power being utilized. The drainage area above this place is about 500 square miles. The power available may be estimated with sufficient accuracy from the table preceding, by taking the horse-power per foot as about eight-tenths of that there given.

Three and a half miles above Union dam is the Buck Island dam, a crib-work structure 200 or 300 feet long and 10 or 12 feet high. It was formerly used by a cotton factory which is not now in use. The drainage area is but slightly less than that above Union dam.

Stump Island dam, which is the next, is used by a small grist-mill with a fall of about 6 feet. The dam is of crib-work, about 400 feet long and 6 feet high, and backs the water nearly up to the next dam.

Milton dam, about 12 miles above Union dam, is a crib-work dam about 200 feet long and 4 feet high. A race of a quarter of a mile affords a fall of 11 feet at a grist mill with four runs of stones. The flow here is about the same as at Shadwell, so that the power can be calculated from the table below. This site is for sale.

It will be seen that up to this dam—which, so far as I could learn, is the last of the original navigation dams—there are 9 dams, of which 3 are not used for power, while at the remaining 6 a portion of the available power is utilized. A summary of the available power (estimated) at these dams is given in tabular form farther on. Many of the dams being leaky, however, the power given could rarely be secured, even if correctly estimated.

A mile or two above Milton is the most important unimproved site on the river—the former site of the Shadwell factory. The available fall here is about 20 feet in a distance of 2¼ miles. The bed is rock, the stream is about 300 feet wide, and the facilities for dams, races, and buildings are very good, as a personal examination showed. The old dam was 6 or 7 feet high, and the race a quarter of a mile long, giving a fall of 18 feet or thereabout at the mill, the principal part of the fall occurring at the lower end of the shoal. The site is a good one, and I have estimated the power as follows:

Table of estimated power at Shadwell.

State of flow (see pages 8 to 11).	Drainage area.	Fall.	Flow per second.	Horse-power available, gross.	
				1 *foot fall.*	18 *feet fall.*
	Sq. miles.	*Feet.*	*Cubic feet.*		
Minimum	448	18 to 20	45	5.1	90
Minimum low season			60	6.8	125
Maximum with storage			400	45.5	820
Low season, dry years			70	8.0	145

This power is very conveniently located directly on the railroad.

At the head of the old Shadwell pond, or 2¼ miles above the foot of the falls, is the most important utilized power on the river, the Charlottesville woolen-mills, situated 1½ mile from the city. The dam is of cut sandstone, about 200 feet long and 10 or 12 feet high, built about the year 1855. A race 600 feet long and 15 feet wide leads to the mill, where the fall is 12 feet. The power used is said to be about 60 horse-power, with a waste of water at all times. The power is a good one, and is very conveniently located on the line of the railroad.

Between this point and the forks of the river there are no important powers utilized or available, though there is one site, at Pen Park, where it is said some power could be developed, though it has never been employed.

The two forks of the Rivanna, with their tributaries, offer some good sites for small powers, and are utilized by numerous saw- and grist-mills. Their fall is rapid, and the bed and banks are generally favorable. None of the powers, however, are large enough to run more than two pairs of stones, in dry weather, with the wheels in use.

The following table gives the drainage area and fall at each dam on the stream, with the best practicable estimates of the power, since no gaugings have been made:

Summary of power on Rivanna river.

Locality.	Drainage area.	Fall.	Horse-power available, gross.			
			Minimum.	Minimum low season.	Low season, dry years.	Maximum with storage.
	Sq. miles.	*Feet.*				
Stillman's dam	650	16(?)	135	160	200	1,100
Carysbrook dam	640	8	65	80	100	550
Palmyra dam	640	12½	100	120	150	850
Broken Island dam	550±	8-10	50	65	80	475
Bernardsburg dam	525±	15±(?)	90	115	140	825
Union dam	505	12	70	90	110	650
Buck Island dam	490±	8-10	45	60	70	430
Stump Island dam	470±	6	35	45	50	300
Milton dam	450	11	60	75	90	525

Between the Rivanna river and the North river, the next tributary of the James worthy of a special description, a number of streams enter, all having the same general characteristics. Their declivities are gradual; their beds gravel and sand, with occasional rock ledges; their flow quite variable, and they are all utilized to some extent by saw- and grist-mills, generally with dams. There are probably sites on all of them where power can be obtained by damming, but no natural falls. Such are Slate river, from the south; Hardware river, Rockfish river, Tye river, and Pedlar river, from the north, besides a number of smaller streams from both sides. On a small tributary entering at Lynchburg is a car-shop of the Atlantic, Mississippi, and Ohio railroad, with a fall of 12 feet and about 20 horse-power, but with this exception all the power used is for grist- and saw-mills, the former with two or three pairs of stones, as a rule. Some of these streams have considerable fall, Rockfish river, for instance, having a fall of 250 feet in the lower 28 miles of its course, or about 9 feet per mile, according to an old survey.

North river takes its rise in the northern part of Rockbridge county, where it is formed by the union of the Great Calfpasture and Little Calfpasture, both of which streams rise in the mountains of Augusta county, and pursue courses a little west of south, draining narrow and parallel valleys. From their junction the North river pursues a nearly southerly course, first cutting through a gap in the mountains to reach the broader valley separating the Blue ridge on the east from North mountain on the west, and thence pursuing its course through this valley, receiving as tributaries South river and Buffalo creek, and entering the James in the southeastern corner of Rockbridge county, just above where the river cuts through the Blue ridge. It flows through the town of Lexington, the county-seat of Rockbridge county, a flourishing town noted for its educational institutions; and it drains a total area of 784 square miles, distributed as follows: Great Calfpasture, 140; Little Calfpasture, 41; Buffalo river, 161; South river, 150. Of this area a large portion lies in the valley between the Blue ridge and North mountain, and the remainder is a hilly and mountainous region among the parallel ranges which form the western part of Rockbridge and Augusta counties. There are no lakes in the basin, and the flow of the stream is quite variable. The character of its bed is the same as that of the other tributaries of the James. The rainfall on the basin is about 40 inches—11 in spring, 11 in summer, 9 in autumn, and 9 in winter. The stream has a very considerable fall, which is not so gradual as in the case of many tributaries of the James. The following table shows the declivity:

Table of declivity of the North river.

Locality.	Distance from mouth.	Elevation above tide.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Mouth	0	706	20	188	9.4
Lexington	20	894	30±	485	16.1±
Great Calfpasture crossing of the Chesapeake and Ohio railroad	50±	1,379			
Little Calfpasture crossing of the Chesapeake and Ohio railroad		1,491			

Above Lexington the fall is very rapid, especially where the stream passes through the gap in the mountains from the valley of the Calfpasture, where there is a rapid fall over a rocky bed for several miles, perhaps at the rate of from 30 to 50 feet per mile.

The fact that the North river is quite inaccessible has no doubt prevented the development of its water-power. Until the construction of the Richmond and Alleghany railroad, which follows the James past the mouth of the river, it was impossible to reach it except from Goshen, on the Chesapeake and Ohio railroad, from which place a stage runs to Lexington, or by taking a canal-boat from Lynchburg, between which place and Lexington boats run every two days. A branch of the James River canal extends up the North river to the latter place, and it is possible that a branch of the railroad may be built along the tow-path, as is being done on the James. There are, besides, several other railroads in contemplation, all passing through Lexington, so that it seems probable that the disadvantage of inaccessibility will before long be removed.

Between the mouth of the river and Lexington there are 10 navigation dams and 24 locks, varying in lift from 7 to 17 feet. With one exception the dams are built of rubble limestone, without cement, sheeted on top and behind with timber, and varying in length from 250 to 450 feet, and in height from 8 to 20 feet. They were all built in the years 1852 and 1853. Within the distance referred to there are about 10 miles of canal, the remainder being slackwater navigation. Should the canal on this river be superseded entirely by the railroad, as on the James, there seems to be no reason why a large amount of power could not be utilized at the locks and dams. In order, however, to utilize the entire flow of the stream, the dams would probably have to be tightened. According to Mr. Harris, "all the dams offer good sites for power". According to Mr. Lorraine's report "on the capacity of the canal to furnish water-power, and on the expediency of making grants generally", navigation on the river at that time was such that "on the North River canal no water-power can be spared till the dams are made tight". A personal examination showed, however, that if the dams are tightened, and if all the flow of the stream is not needed for navigation, there are numerous excellent sites for power. At present very little is utilized, as the table on page 33 will show, there being only a few small flour-mills, a cement-mill, and others, each with perhaps 20 or 30 horse-power. In order to give some idea of the power available, I have estimated the flow and power at the mouth and at Lexington.

Estimated power of the North river.

State of flow (see pages 8 to 11).	AT MOUTH.			AT LEXINGTON.		
	Drainage area.	Flow per second.	Horse-power available, gross.	Drainage area.	Flow per second.	Horse-power available, gross.
	Sq. miles.	*Cubic feet.*	*1 foot fall.*	*Sq. miles.*	*Cubic feet.*	*1 foot fall.*
Minimum	784	80	9.0	416	50	5.7
Minimum low season		100	11.4		60	6.8
Maximum with storage		700	80.0		375	42.5
Low season, dry years		125	14.2		75	8.5

If it is desired to estimate roughly the total power available between those points, the flow may be taken as the mean of that at the two places, and the fall as perhaps 150 feet, the results being as follows: Minimum, 1,100 horse-power; minimum low season, 1,360 horse-power; low season, dry years, 1,700 horse-power; maximum with storage, 9,200 horse-power. The flow at Lexington was measured in the low season of 1876, by W. G. McDowell, civil engineer, who found it to be about 121 cubic feet per second. This measurement is undoubtedly accurate; but if this flow is the minimum, the stream must be very different in character from the other streams of Virginia. At the same place the river is said to have risen 25 feet in the freshet of 1870. It may be that springs in the drainage basin render the flow of the stream more constant than would be expected, and all mere estimates are of course sometimes liable to be far from the truth.

Above Lexington, notwithstanding the rapid fall, little power is used, but grist- and saw-mills are scattered here and there on the tributaries. Where the river cuts through the gap in the mountains the fall, though large, is not well available. Buffalo and South rivers are similar in character to North river, and no details regarding their power could be obtained.

The other tributaries of the James below the forks are small streams draining a mountainous country, often with rapid fall, and in some cases with cataracts or rapids. None of them are utilized except by small grist- or saw-mills and a furnace or two. Power might be developed on all of them, but it would fluctuate greatly in amount.

The head-waters of the James, Cowpasture, and Jackson's rivers resemble the North river in all essential respects; their fall is quite rapid, but very little power is utilized. As regards bed and banks, there is no difficulty, but no rapids of importance occur on them except in perhaps one or two instances. The Cowpasture takes its rise in Highland county, flows through Bath and Alleghany and joins Jackson's river in Botetourt. Its length in a straight line is about 50 miles and its drainage area 580 square miles. Regarding its flow and declivity no data could be obtained. It has numerous small shoals, but none with falls of over 4 or 5 feet in a short distance. Its power is utilized only by grist- and saw-mills, with falls of from 6 to 10 feet, all with dams. Jackson's river takes its rise in Highland county, and flows generally parallel to the Cowpasture, and through the same counties. Its length is about 65 miles along its general course, and its drainage area about 981 square miles. It flows through the towns of Covington and Clifton Forge, and between these places it is followed by the Chesapeake and Ohio railroad. Above Covington, however, it is very inaccessible. Regarding its declivity and flow no accurate data are at hand. From Buchanan, on the James, to Clifton Forge, about 2 or 3 miles above the mouth of the Cowpasture—a distance of 32 or 33 miles—the fall is 221 feet, or about 7 feet per mile; and between Clifton Forge and Covington—a distance of 15 miles—the fall is 167 feet, or about 11 feet per mile. The rainfall on the basin, as well as on that of the Cowpasture, is about 38 inches—11 in spring, 11 in summer, 8 in autumn, and 8 in winter. Estimates of the flow at Covington and at Clifton Forge are given farther on. The shoals on Jackson's river seem to be more numerous and to have greater fall than those on the Cowpasture, although this may be due to the greater amount of information which could be obtained regarding the former stream.

The first power met with in ascending the river is at Clifton Forge, at which place there is a dam 10 feet high and 290 feet long, built in 1874, of crib-work, at a cost of $2,800, and founded on solid rock. It was formerly used for a grist-mill, but at present no power is utilized. The river at this place passes through a rocky gorge in the range of mountains which separates its valley from the adjacent one, and for half a mile below the dam—which is at the upper end of the gorge—the banks are steep and the power is difficult to utilize, as all the available space is occupied by the Richmond and Alleghany railroad, which passes through the gorge, on the south side, to its terminus just above. No race could be built without blasting it out on the north side of the river, or building a high wall on the south side between the race and the river. The site may therefore be called practically unavailable. The dam backs the water about three-quarters of a mile, with an average width of 250 feet. Between this point and Covington there are several shoals where power might be developed. At one point, a few miles above Clifton Forge, there was once a mill, washed out in the freshet of 1877. About 6 miles by road below Covington there is another shoal, where a fall of several feet could be obtained; and 5 miles below Covington, at Island Ford, a fall of 6 to 8 feet is probably available, while there are several other small shoals below Covington. At the latter place there is a mill using about 60 horse-power with a fall of about 7½ feet, and a dam 7 feet high and 325 feet long, built of logs, like most of the dams in the vicinity. Full capacity can be obtained during only nine months, with two breast-wheels, and sometimes only half capacity can be secured, all the water of the stream being utilized. At this mill the water rose 22½ feet during the great freshet of November, 1877, which was the largest ever known on the river.

Above Covington the width of the stream averages 150 feet for some distance, and its fall is rapid but gradual. There are several mills using power from it, but all are small. Among the shoals, the one best known is at the Narrows, about 14 miles above Covington, where the fall is said to be 8 feet or so in a few hundred yards, the place being very rocky and the power difficult to utilize.

Of the tributaries to Jackson's river the following may be mentioned: Warm Spring run, which has one mill with a fall of about 28 feet, and a carding-mill, with 14 feet; the temperature of the water is 90° F.; Hot spring, a small stream with a temperature of 110° F.; Back creek, with several saw- and grist-mills, but said to be unfavorable for power by reason of a sandy and shifting bed; Mill creek, with a cascade near the mouth, about 8 miles north of Covington; Dunlap's creek, along which the Chesapeake and Ohio railroad runs after leaving the river, a stream said to be exceedingly variable in flow, and of no value for power, almost drying up in summer, although it drains 194 square miles; and, finally, Potts' creek, draining 152 square miles, a rapid stream, said to offer considerable undeveloped power and to be a good mill-stream.

Table of estimated flow and power at Clifton Forge and at Covington.

State of flow (see pages 8 to 11).	Clifton Forge.					Covington.				
	Drainage area.	Fall.	Flow per second.	Gross horse-power.		Drainage area.	Fall.	Flow per second.	Gross horse-power.	
	Sq. miles.	*Feet.*	*Cubic feet.*	*1 foot fall.*	*10 feet fall.*	*Sq. miles.*	*Feet.*	*Cubic feet.*	*1 foot fall.*	*7 feet fall.*
Minimum	925	10	100	11.3	110	675	7+	75	8.5	60
Minimum low season			150	17.0	170			110	12.5	90
Maximum with storage			820	93.2	930			600	68.2	475
Low season, dry years			175	20.0	200			130	14.8	100

In recalling what has been said regarding the James river and tributaries one can not fail to be struck with the large amount of power lying idle, and yet easily available, on the main stream and on North river along the line of the canal. Dams and races built and almost ready for use, transportation as convenient as could possibly be wished, the railroad passing by the very door, a healthful climate, abundance of building materials of good quality—all these advantages are combined in a way seldom found. There is no doubt, however, that the flow of the stream is very variable, and the establishment of large storage reservoirs impracticable.

The following table gives the statistics of utilized power in the basin:

Table of utilized power of the James river and tributaries.

Name of stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.	Remarks.
						Feet.		
James river	Chesapeake bay	Virginia	Henrico	Flour and grist	1	22	700	
Do	do	do	do	do	1	36½	430	From canal.
Do	do	do	do	do	3	47½	165	
Do	do	do	do	Planing, etc	2	36	105	
Do	do	do	do	Bagging	1	19	10	
Do	do	do	do	Paper	1	20	120	
Do	do	do	do	Iron-works	1	50	(?)520	From canal (see description).
Do	do	do	do	Water-works	1	10	280	
Do	do	do	do	do	1	20	480	From canal.
Do	do	do	do	Nails, etc	1	18	(?) 500	
Do	do	do	do	Blast-furnace	1	22	....	Not in operation.
Do	do	do	Chesterfield	Cotton	2	38	325	
Do	do	do	do	Water-works	1	20	86	
Do	do	do	do	Paper	1	19	100	
Do	do	do	do	Bucket	1	20	120	
Do	do	do	do	Sumac	1	14	30	
Do	do	do	do	Flour and grist	3	52	320	
Do	do	do	Goochland	do	2	37	116	Probably from canal.
Do	do	do	Fluvanna	do	4	56	69	
Do	do	do	Albemarle	do	1	10	30	
Do	do	do	Nelson	do	1	9	20	

Table of utilized power of the James river and tributaries—Continued.

Name of stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.	Remarks.
						Feet.		
James river	Chesapeake bay	Virginia	Campbell	Flour and grist	4	37+	400	
Do	do	do	do	Barytes	1	17	36	
Do	do	do	do	Bark	1	16	30	From canal.
Do	do	do	do	Furniture	1	16	25	
Do	do	do	do	Rolling-mill, etc.	1	12–14	40	
Do	do	do	do	Steel company	1	22	......	
Do	do	do	do	Foundery	1	11½	20	
Do	do	do	do	Planing	1	12	40	
Do	do	do	do	Tobacco-box	1	12	15	From water-works canal.
Do	do	do	do	Sumac	1	12	20	
Do	do	do	do	Water-works	1	12	100	
Do	do	do	do	Woolen	1	17	(?)40	
Do	do	do	Amherst	Iron-works	1	9		
Do	do	do	do	Saw	1	9	50	
Do	do	do	do	Grist	1	9		
Do	do	do	Bedford	Rolling-mill	1	......	......	From canal.
Do	do	do	Rockbridge	Flour and grist	2	31	16	
Do	do	do	do	Cement	1	9	20	From canal.
Tributaries of	James river	do	Isle of Wight	Flour and grist	1	8	50	
Do	do	do	Prince George	do	3	44	70	
Chickahominy river	do	do	Hanover	do	2	28	65	
Do	do	do	do	Saw	1	14	25	
Tributaries of	do	do	James City	Flour and grist	4	51	52	
Do	do	do	Charles City	do	4	76	56	
Do	do	do	Henrico	do	5	......	91	
Do	do	do	do	Sumac	1	24	40	
Do	do	do	Hanover	Saw	2	39	36	
Do	do	do	do	Flour and grist	6	80	105	
Do	do	do	Chesterfield (*a*)	do	3	40	58	
Do	do	do	do	Saw	1	17½	5	
Do	do	do	Powhatan	Flour and grist	6	89	92	
Do	do	do	do	Saw	3	......	79	
Do	do	do	Goochland	do	3	40	30	
Do	do	do	do	Flour and grist	12	177	181	
Do	do	do	Cumberland	do	7	107	153	
Do	do	do	do	Saw	3	......	78	
Do	do	do	Buckingham	do	8	118	147	
Do	do	do	do	Wheelwrighting	1	7	4	
Do	do	do	do	Flour and grist	24	350	475	
Do	do	do	Appomattox	do	2	24	28	
Do	do	do	Campbell	do	9	156	268	
Do	do	do	do	Woolen	1	17	20	
Do	do	do	do	Saw	2	26	60	
Do	do	do	Bedford	do	1	16	10	
Do	do	do	do	Woolen	1	......	5	
Do	do	do	do	Flour and grist	7	104	100	
Do	do	do	Roanoke	Woolen	1	22	12	
Rivanna river	do	do	Fluvanna	Flour and grist	3	41	73	
Do	do	do	Albemarle	do	5	58	109	
Do	do	do	do	Woolen	1	12	60	
Tributaries of	Rivanna river	do	Fluvanna	Flour and grist	6	68	51	
Do	do	do	do	Sumac	1	25	31	
Do	do	do	Albemarle	Saw	6	......	71	
Do	do	do	do	Woolen	1	22	8	
Do	do	do	do	Flour and grist	12	177	212	
Do	do	do	Greene	do	7	113	89	
Do	James river	do	do	Saw	1	19	16	
Do	do	do	do	Agricultural implements.	1	20	45	
Do	do	do	do	Flour and grist	10	169	161	
Rockfish river	do	do	Nelson	do	7	105	122	
Do	do	do	do	Saw	4	56	79	
Tributaries of	Rockfish river	do	do	do	1	18	20	
Do	do	do	do	Flour and grist	4	63	84	
Do	do	do	do	Leather	1	18	18	
Tye river	James river	do	do	Flour and grist	3	......	59	

a For Appomattox river and tributaries, see below.

Table of utilized power of the James river and tributaries—Continued.

Name of stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.	Remarks.
						Feet.		
Tributaries of	Tye river	Virginia	Nelson	Flour and grist	4	...	60	
Do	do	do	Amherst	do	7	105	115	
Do	James river	do	do	do	8	126	127	
Do	do	do	do	Saw	4	59	92	
Do	do	do	Botetourt	Blacksmithing	1	12	6	
Do	do	do	do	Foundery	1	28	10	
Do	do	do	do	Flour and grist	28	554	408	
Do	do	do	do	Saw	20	388	250	
Do	do	do	do	Wool	1	16	12	
Do	do	do	do	Blast-furnace	1	20	20	Not in operation.
Do	do	do	Craig	Flour and grist	5	74	86	
Do	do	do	do	Saw	4	50	42	
Do	do	do	do	Furniture	1	12	5	
Do	do	do	do	Foundery	1	...	6	
North river	do	do	Rockbridge	Flour and grist	10	148	162	
Do	do	do	do	Saw	1	20	8	
Tributaries of	North river	do	do	do	5	...	48	
Do	do	do	do	Agricultural implements	1	40	8	
Do	do	do	do	Wheelwrighting	1	25	12	
Do	do	do	do	Furniture	1	26	12	
Do	do	do	do	Flour and grist	22	392	344	
Do	do	do	do	Wool	1	16	12	
Do	do	do	Augusta	Flour and grist	2	43	34	
Do	James river	do	Rockbridge	do	1	20	20	
Do	do	do	do	Blast-furnace	1	...	20	Not in operation.
Jackson's river	do	do	Alleghany	Flour and grist	1	6	35	
Do	do	do	do	Saw	1	6	8	
Tributaries of	Jackson's river	do	do	Flour and grist	2	25	26	
Do	do	do	Bath	do	1	20	12	
Do	do	do	do	Wool	1	...	...	
Cowpasture river	James river	do	do	do	1	7	12	
Do	do	do	Highland	do	2	34	19	
Tributaries of	Cowpasture river	do	Alleghany	Blast-furnace	1	78	30	
Do	do	do	Bath	Flour and grist	2	30	28	
Do	do	do	do	Blast-furnace	1	15	20	Not in operation.
Do	do	do	Highland	Flour and grist	4	80	42	
Appomattox river	James river	do	Chesterfield	do	3	50	175	
Do	do	do	do	Sash, doors, etc	1	16	20	
Do	do	do	do	Cotton	2	33	465	
Do	do	do	Dinwiddie	do	3	44	310	
Do	do	do	do	Flour and grist	4	48	275	Petersburg.
Do	do	do	do	do	2	38	18	
Do	do	do	do	Sumac	1	10	30	Petersburg.
Do	do	do	do	Snuff	1	...	20	Petersburg—not in operation.
Do	do	do	do	Box	1	2	...	Petersburg.
Do	do	do	Amelia	Flour and grist	3	66	39	
Do	do	do	do	Saw	2	58	20	
Do	do	do	Powhatan	do	1	4½	7	
Do	do	do	do	Flour and grist	2	10½	26	
Do	do	do	Cumberland	do	2	13½	40	
Do	do	do	Prince Edward	do	2	19½	40	
Do	do	do	do	Saw	1	6½	10	
Tributaries of	Appomattox river	do	Chesterfield	do	1	12	18	
Do	do	do	do	Flour and grist	5	80½	62	
Do	do	do	do	Cotton	1	3	75	
Do	do	do	Nottoway	Flour and grist	3	56	58	
Do	do	do	do	Saw	1	16	12	
Do	do	do	Amelia	do	1	16	8	
Do	do	do	do	Flour and grist	9	138	137	
Do	do	do	Powhatan	do	1	15	18	
Do	do	do	Cumberland	do	2	24	22	
Do	do	do	Buckingham	do	1	...	10	
Do	do	do	Prince Edward	do	8	...	109	
Do	do	do	do	Saw	1	25	15	
Do	do	do	Appomattox	do	3	30	30	
Do	do	do	do	Flour and grist	6	91	87	

II.—THE YORK RIVER.

The York river, the next important stream north of the James, is a broad and navigable stream for its entire length, about 35 miles, and offers no power. It is formed by the union of the Pamunkey and Mattapony rivers, and flows in a southeasterly direction between the counties of Gloucester and King and Queen on its left, and New Kent, James City, and York on its right, emptying into Chesapeake bay. At the head of the river is the town of West Point, connected by a railroad with Richmond, and the general government has appropriated $10,000 for the purpose of improving navigation up to this point, the present project contemplating the establishment of a navigable depth at all times of 22 feet. The ruling depth at low tide is now 19 feet, and at high tide 22 feet. The stream lies entirely below the fall-line.

The Pamunkey river, which with the Mattapony forms the York, is itself formed by the union of two streams—the North Anna and South Anna rivers—which unite not far from the fall-line, so that the Pamunkey lies almost wholly, if not wholly, in the eastern or tide-water division of the state. It pursues a general southeasterly course, is about 40 miles long, measured in a straight line, and drains a total area of about 1,313 square miles. In the upper part of its course (above Hanovertown) it is narrow and very tortuous, and much obstructed by logs and trees, while below that point it is navigable to a certain extent, and it might be made so above. The banks of the river are bold, and even precipitous in places, and have an average height of 50 feet. The extreme rise of the river in freshets is 22 feet.(*a*) There is no power whatever on the stream. The South Anna river, one of its head-waters, rises in Albemarle county, near the sources of the Rivanna, and flows in a southeasterly direction through Louisa and Hanover counties, to join the North Anna. Its drainage area measures about 440 square miles, and lies almost wholly above the fall-line; yet I was unable to learn of any power of importance on the stream, and the table on page 35 will show that if there is much, only a small proportion is utilized. At its crossing with the Richmond, Fredericksburg, and Potomac railroad, only a mile or two above its mouth, the stream has an elevation above tide of but 50 feet,(*b*) so that the fall of the Pamunkey must be very small. No information could be obtained regarding any power where the stream crosses the fall-line. The North Anna river, a stream similar to the one just referred to, rises in Orange county and flows southeast between Spottsylvania and Caroline on its left, and Louisa and Hanover counties on its right, to join the South Anna. It drains a total area of about 504 square miles, and its length in a straight line is about 40 miles. Its elevation at the crossing of the Richmond, Fredericksburg, and Potomac railroad is also 50 feet above tide. According to an old survey, the fall of the stream between its mouth and the junction of its north and south forks, the distance being a little over 49 miles, is 164½ feet, or about 3.4 feet per mile.(*c*) In this distance there were, at the time of the survey, 10 mills with falls of from 7 to 14 feet each, using together a fall of about 96 feet. Above the junction of the two forks the fall was found on one of them to be about 50 feet in 15 miles, or at about the same rate as below, and in this distance there were two mills, with, together, about 16 feet fall. As in the case of the South Anna, I was not able to gain any information regarding any large fall on the river at the place where it crosses the fall-line, or at any other place. In the report above referred to, mention is made of the Great falls, but they seem to be where the stream is small, and of no value for power. No information could be obtained regarding them, nor could I even learn where they are located.

The Mattapony river rises in Spottsylvania county, and pursues a southeasterly course through Caroline and between King and Queen and King William counties, joining the Pamunkey at West Point. Its length in a straight line measures about 70 miles, and it drains an area of 846 square miles, a considerable portion of which lies below the fall-line. The stream is navigable for about 50 miles, and can be improved so as to afford navigation for lighters or barges for a distance of 25 or 30 miles farther, or a total distance of 80 miles.(*d*) The fall of the stream between tide-water and Milford, near where the fall-line is crossed, in a distance of 48 miles, has been found to be 73 feet, or at the rate of 1.5 foot per mile. The elevation at the crossing of the Richmond, Fredericksburg, and Potomac railroad is 70 feet. I was unable to learn of any powers of importance on the stream.

The average rainfall on the entire drainage basin of the York river is about 44 inches—12 in spring, 14 in summer, 8 in autumn, and 10 in winter. Estimates of the flow and power are unnecessary. The statistics of power utilized are given in the following table:

---

a *Annual Report of the Chief of Engineers*, 1880, p. 773.

b I am indebted for the elevations on the Richmond, Fredericksburg, and Potomac railroad to Major E. T. D. Myers, general superintendent.

c *Thirteenth Report of Board of Public Works of Virginia*, 1828, p. 311.

d *Annual Report of the Chief of Engineers*, 1880, p. 771.

Table of utilized power of the York river.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
Mattapony river	York river	Virginia	King William	Flour and grist (*a*)	4	65	65
Do	...do	...do	King and Queen	...do	3	44	75
Do	...do	...do	...do	Saw	1	15	35
Do	...do	...do	Caroline	...do	1	7	10
Do	...do	...do	...do	Flour and grist	2	25	30
Tributaries of	Mattapony river	...do	...do	...do	11	155	135
Do	...do	...do	...do	Saw	2	25	28
Do	...do	...do	Spottsylvania	...do	4	55	48
Do	...do	...do	...do	Flour and grist	9	109	106
Pamunkey river	York river	...do					
North Anna river	Pamunkey river	...do	Caroline	Flour and grist	5	41	48
Do	...do	...do	...do	Saw	2	18	28
Do	...do	...do	Louisa	...do	1	4	9
Do	...do	...do	...do	Flour and grist	4	30	60
Do	...do	...do	Spottsylvania	...do	1	9	28
South Anna river	...do	...do	Hanover	...do	6	32	121
Do	...do	...do	Louisa	...do	9	72	160
Do	...do	...do	...do	Saw	1	9	12
Other tributaries of	York river	...do	Orange	Flour and grist	2	36	85
Do	...do	...do	Louisa	...do	8	135	90
Do	...do	...do	...do	Saw	1	26	12
Do	...do	...do	Spottsylvania	Flour and grist	1	10	16
Do	...do	...do	Hanover	...do	9	93	111
Do	...do	...do	Caroline	...do	3	70	36
Do	...do	...do	...do	Saw	1	22	23
Do	...do	...do	King William	Flour and grist	2	....	40
Do	...do	...do	King and Queen	...do	7	89	105
Do	...do	...do	...do	Saw	1	7	7
Do	...do	...do	New Kent	Flour and grist	9	106	120
Do	...do	...do	...do	Agricultural implements	1	16	16
Do	...do	...do	James City	Flour and grist	2	24	18
Do	...do	...do	York	...do	5	56	68
Do	...do	...do	...do	Saw	1	....	18
Do	...do	...do	Gloucester	...do	1	12	18
Do	...do	...do	...do	Flour and grist	1	13	12

a Perhaps on tributaries.

III.—THE RAPPAHANNOCK RIVER.

The Rappahannock river takes its rise in Rappahannock and Fauquier counties, Virginia, on the eastern slope of the Blue ridge, and flows in a southeasterly direction through a fertile and hilly country belonging to the middle, or Piedmont, section of the state, forming the boundary line between the counties of Fauquier and Stafford on its left, and Rappahannock, Culpeper, and Spottsylvania on its right. At the city of Fredericksburg it crosses the fall-line with a considerable fall and a large amount of power, and below that point it is a sluggish, tidal, and navigable stream, spreading out sometimes to a width of several miles, and forming the boundary line between the counties of King George, Westmoreland, Richmond, and Lancaster on its left, and Caroline, Essex, and Middlesex on its right. It empties into Chesapeake bay at a point about 36 miles from cape Charles. The length of its course in a straight line is about 132 miles, and it drains a total area of about 2,700 square miles. Its principal tributary is the Rapidan river, which enters from the right, 10 or 12 miles above Fredericksburg, and drains an area of about 745 square miles. The only town of importance on the river is Fredericksburg, with a good water-power and several mills and factories, which will be fully described. Up to this place, 104 miles from the mouth of the river, there is a navigable depth of 9 feet at low tide and 12 feet at high tide, and the river is now being improved by the government to secure a navigable depth of 10 feet. Many years ago the river was made navigable as far as Waterloo, in Fauquier county, a distance of 50 or 60 miles above Fredericksburg, by means of locks, dams, and canals, terminating at the lower end in the basin at Fredericksburg. These old navigation works, however, having long been disused, except in one or two places, have been mostly destroyed. The locks still exist in many places, but the dams are nearly all gone. The works will be described in detail in the proper place.

There are no lakes in the basin of the Rappahannock, and the flow of the stream is very variable, but no records of gaugings could be found, and resort was therefore had to estimates. The bed of the stream is generally rock overlaid with gravel and sand, and the banks generally high enough to confine the river, except in high freshets—there being comparatively few bottoms subject to overflow, as in the case of the more southern streams. The slope of the stream is not uniform, but is broken by considerable falls at several places, at which good water-power could be secured. The elevation of the stream above tide at Fredericksburg is zero, and at the crossing of the Virginia Midland railroad, 35½ miles above, it is 252 feet, showing a fall at the rate of 7.1 feet per mile. The rainfall on the basin is about 42 inches, of which about 12 fall in spring, 13 in summer, 8 in autumn, and 9 in winter. The small fall in autumn must have for its effect a corresponding variability in the flow, which would seem even more pronounced than in the case of the James.

The accompanying map shows that the river is crossed by two railroads, the Richmond, Fredericksburg, and Potomac, and the Virginia Midland. Between the two it can not be called very accessible, and any utilization of the water-power to a large extent would probably require a better means of communication than exists at present.

The first power occurs at Fredericksburg—the crossing of the fall-line—and, as in the case of the James, this point is the head of tide-water and of navigation. The dam is located about 2 miles above the city, at the head of the falls, and extends straight across the river. It is a crib-work structure, 900 feet long and 18 feet high, bolted to the rock which forms the foundation, and backing the water about a mile with an average width of 600 feet. It was built in 1860 by Mr. John Chase, of Holyoke, Massachusetts, and is said to have cost $60,000. From it a race, about 1½ mile long, 30 or 40 feet wide, and 5 or 6 feet deep, leads to the basin at the upper edge of the city, between which and the river there is a fall of 48½ feet, which is used in two parts. From the basin or upper level two mills are fed, as follows:

1. Washington woolen-mill (Kern, Bentley, & Co.); 18 feet fall; 45 horse-power, with two turbine wheels.
2. "Germania" flour-mills (Myer & Brülle); 23 or 24 feet fall; 50 or 60 horse-power (?), with three turbines; 8 runs of stones.

Both these mills discharge their water to the second or lower level, from which the following mills take it, discharging into the river:

3. R. K. Knox & Brothers' sumac- and bone-mill; 18 feet fall; 50 to 60 horse-power.
4. J. B. Ficklen & Sons' "Bridgewater flour- and corn-mill"; 21 feet fall; 110 horse-power, with three turbines and 9 runs of stones.
5. There was formerly a paper-mill using water directly from the basin, with a fall of 12 feet, and discharging its water through a separate tail-race, at the lower end of which, a mile below, and just where the railroad crosses the river, it was again used, and discharged into the river by the—
6. Excelsior mill (Thomas & Pettit), now running as before, although the paper-mill has not been in operation for some years. This mill has 5 runs of stones, and uses 50 to 60 horse-power, with a fall of 28 feet, and an overshot wheel.

These mills can generally run at full capacity during the entire year, so far as amount of water is concerned, but those discharging directly into the river are sometimes obliged to stop because of high water. The flour-mills run night and day. The power is controlled by the Fredericksburg Water Power Company (L. S. White, president, Baltimore, Maryland), and is leased by them at the rate of from $5 to $15 per horse-power (net?) per annum, according to the level from which it is taken and the amount taken. There being at present generally an excess of power, no care is taken to measure exactly the amount used by each mill. The following are the amounts paid for and the prices:

	Horse-power.	Per annum.
Germania mills	50	$750
Woolen mill	60	....
Thomas & Pettit's flour-mill	50	500
Knox's sumac-mill	60	0
Ficklen's flour-mill	110	120
Total used	330±	

In the case of the last two mills a certain amount of power is secured to them by prior rights.

The land around the basin is very favorable for the development of power and for the construction of buildings and races. The interruption from freshets occurs so seldom as to be of little consequence, and there is very little trouble with ice. The dam has never been carried away or injured. The entire cost of the works, including dam, canals, land, etc., was about $250,000, but the canal was already built—being the old navigation canal—and had only to be repaired and raised.

The drainage area above Fredericksburg is about 1,600 square miles, and the rainfall about 42 inches—12 in spring, 13 in summer, 8 in autumn, and 9 in winter. In the absence of gaugings I have estimated the power as follows:

Table of estimated power of the Rappahannock river at Fredericksburg.

State of flow (see pages 8 to 11).	Drainage area.	Fall.	Flow per second.	Horse-power available, gross.(a)	
	Sq. miles.	*Feet.*	*Cubic feet.*	*1 foot fall.*	*48 feet fall.*
Minimum	1,600	48+	176	20.0	960
Minimum low season			220	25.0	1,200
Maximum with storage			1,414	160.7	7,700
Low season, dry years			250	28.4	1,360

a At present utilized, 300 to 400 horse-power net, or say 550 horse-power gross.

In their circular the company claims 4,000 horse-power, said to be based on Mr. Chase's report, but the stage of the water is not specified. It was stated to me, however, that in dry weather the water even now falls 6 or 8 inches below the level of the crest of the dam, the entire flow being diverted into the canal; that in dry years there is no waste at all during two months or more in working-hours; and that when the paper-mill (referred to as No. 5) was running, and using about 75 horse-power, there was one summer when the mills could not obtain full capacity. Still, with economical utilization of the fall and good motors, a considerably larger amount of power than is now used could no doubt be rendered available even in the driest seasons, and in ordinary seasons much more. It is also probable that the power can be and is increased to some extent by storing the water during the night, as the pond is large enough to store several hours' flow in the driest seasons. It is stated that in winter there are generally 8 or 10 inches of water on the dam, in large freshets 10 feet, and in ordinary freshets 5 or 6 feet. As regards the maximum available with storage, it is probable that sites for reservoirs can be found in the upper valleys, though probably not by any means sufficient to render the whole available.

The power at Fredericksburg, though not large, comparatively, is deserving of attention as being very conveniently located. The facilities for transportation by water and by land are excellent.

As regards the river for 25 or 30 miles above Fredericksburg, I have been able to collect information quite in detail regarding the old navigation works, but regarding particular sites for power not much could be learned, except in one case. From a description of the locks and dams formerly existing, however, an idea can be formed of the amount of power which could be developed on the stream, and at what points.(*a*) The heights of the dams, in the following description, are measured from the bed of the stream.

From the basin at Fredericksburg the canal extended nearly 2 miles to a lock with a lift of 11 feet, and beyond one-quarter of a mile, to dam No. 1, which was 7 feet high, and the feeder of the lower levels.(*b*) This dam is not the dam of the water-power company, but was nearly a mile above the latter, and is now washed away, the navigation works having been abandoned before the construction of the present dam. In the pool of this dam boats crossed to the left bank of the river, thence by canal 2 miles to a lock with a lift of 12 feet, and beyond one-quarter of a mile to dam No. 2 (Banks' dam), about 10 feet high. At the lift-lock just referred to there was at one time a grist-mill. Above Banks' dam there was slack-water navigation for 2½ miles, to a lock of 10 feet lift; thence one-quarter of a mile canal to dam No. 3 (Ballad's or Ballard's dam), about 10 feet high; thence slack-water, 2 miles, to a lock with 10 feet lift, and dam No. 4 (Smith's dam), 11 feet high; thence slack-water again 2 miles, to locks at United States mill (at Barrows' ford), 22 feet lift; then canal 1 mile to lift-lock of 9 feet lift, and 1 mile farther to dam No. 5 (United States dam), 6 feet high, just below the junction of the Rappahannock and Rapidan, above which was slack-water for 1½ mile to locks at Richards' ferry, 20 feet lift; thence canal one-half mile to dam No. 6 (Richards' dam), about 6 feet high. Before proceeding further, attention must be called to the large fall in this part of the river, as shown by the large amount of lockage. There seems to be no doubt that a considerable amount of power could be developed in this vicinity; and as the canal and locks, although in bad condition, are not entirely destroyed, it is possible that a good deal of power might be cheaply utilized. The

a For detailed information regarding the canal I am indebted to Wellington Gordon, esq., of San Francisco, California, who was president of the navigation company.

b The following is quoted from a report on the canal in one of the reports of the board of public works of Virginia: "Between Fox's mill [43 miles above Fredericksburg] and Fredericksburg the Rappahannock presents three passes of peculiar difficulty and danger. The first is near Fredericksburg, the second at the junction of the Rappahannock and the Rapidan, and the third in the vicinity of Kelly's and Wheatley's mills. The first is overcome by a dam 7 feet in height and a canal 2 miles in extent, carried for a considerable distance under a precipitous cliff, and terminating in a basin 26 feet above the level of the river at its nearest point. Between the dam and the basin are a guard-lock, a lift-lock of 11 feet, a second guard-gate, and 3 waste-weirs. In the second a fall of 35 feet is overcome by two dams, two canals—one of 800, the other of 900 yards in extent—and four locks. The third is under construction, but not completed."

drainage area of the Rappahannock above its junction with the Rapidan is about 784 square miles, and that of the latter stream about 745, the total below the junction being 1,529 or thereabout. I should estimate the flow and power for these three drainage areas about as follows:

State of flow (see pages 8 to 11).	Drainage area in square miles.			Flow, cubic feet per second.			Horse-power available, 1 foot fall, gross.		
	Rappahannock.	Rapidan.	Both.	Rappahannock.	Rapidan.	Both.	Rappahannock.	Rapidan.	Both.
Minimum	784	745	1,529	78	75	168	8.9	8.5	19.1
Minimum low season				102	98	220	11.8	11.2	25.0
Maximum with storage				693	658	1,350	78.8	74.8	153.6
Low season, dry years				117	112	250	13.3	12.7	28.4

Above dam No. 6 there was slack-water for half a mile to a lock with 12 feet lift; thence canal for 1½ mile to dam No. 7 (Deep Run dam), about 7 feet high; thence slack-water 1¾ mile to a lock with 12 feet lift and canal half a mile to dam No. 8 (Skinker's dam), about 5 feet high; thence slack-water to locks with a total lift of some 23 feet and canal for a quarter of a mile to dam No. 9 (Ellis' dam), about 8 feet high. Near this place is a grist- and flour-mill with 4 runs of stones, a race three-quarters of a mile long, into which the water is turned by a rough wing-dam, and a fall of 18 feet—no doubt an excellent power. Although it is the first power utilized above Fredericksburg, there have been in former times various mills in the intervening distance. Two miles below Ellis' mill there was at one time a mill (known as the Skinker mill) using a fall of some 20 feet, with a race a quarter of a mile long. The fall in this part of the river for a distance of 5 or 6 miles seems to be very great, and capable of giving a number of fine powers. The power per foot may be taken as estimated above in the table. Above dam No. 9 there was slack-water for 2 miles to a lock with a lift of 7 feet and dam No. 10 (Kemper's dam), about 9 feet high, the back-water from the dam below reaching up to this one. Then came slack-water for 2 miles to a lock of 8 feet lift and dam No. 11 (Mountain Run dam), about 10 feet high; thence slack-water for 2 miles to Kelly's mill and a flight of 5 locks, aggregating a lift of about 42 feet; thence canal half a mile to dam No. 12 (Wheatley's dam), about 7 feet high. The fall of the stream in the mile below this dam is very great and the site one of the best in the vicinity, so that it merits a more particular description. Wheatley's dam was about 2 miles below the present crossing of the Virginia Midland railroad and about 2½ miles from Rappahannock station. Wheatley's mill (now destroyed) was on the left bank, using the old canal as a race, and using a fall of about 23 feet. Below his tail-race, or about three-quarters of a mile by the river below his dam, was Kelly's dam, still in existence, from which a race of a quarter of a mile led to Kelly's mill on the right bank, still in use, with a fall of 19 feet, making the total fall about 42 feet. There would be no difficulty in utilizing the whole of this fall. The best building-ground is on the right bank, and by putting a dam about half a mile below the head of the shoal and making it 12 or 15 feet high a considerable pond could be obtained—sufficient, I think, to allow the power due to the natural flow to be increased 30 per cent. during twelve hours; while by using the power on the left bank the old canal could be cleaned out and used as a race. The bed of the stream is rock, gravel, and bowlders, the banks in places steep, but generally shelving, of clay or rock, and the width of the bed of the stream about 200 feet. Kelly's dam is a crib-work structure, rebuilt in 1867 or 1868, about 320 feet long and 3 or 4 feet high, not ponding the water over 100 yards. At the mill about 60 horse-power is used. The flow is stated to be much more variable than formerly, and in heavy freshets the river is said to rise 20 feet and more at the foot of the shoal and 10 feet at the head, although in ordinary freshets the rise at the foot is not over 8 or 10 feet. There is little trouble with ice. I have estimated the power at this place in the following table, the rainfall being about the same as above Fredericksburg:

State of flow (see pages 8 to 11).	Drainage area.	Fall.	Flow, per second.	Horse-power available, gross.		
	Sq. miles.	*Feet.*	*Cubic feet.*	*1 foot fall.*	*23 feet fall.*	*42 feet fall.*
Minimum	614	42	61	6.9	160	290
Minimum low season			80	9.1	210	380
Maximum with storage			543	61.7	1,400	2,600
Low season, dry years			92	10.4	240	448

I have already alluded to the possibility of increasing this power in dry seasons by ponding the water during the night. This site is quite conveniently located as regards transportation; and good building-materials, it is said, can be obtained in the neighborhood.

From Wheatley's dam (No. 12) there was slack-water for 1½ or 2 miles, to dam No. 13 (Morgan's dam), about 7 feet high, and a lock with 6 feet lift. This dam is still in existenec, and is about 200 feet long, and 6 feet high, above low water, affording power to run a grist-mill with about 30 horse-power, just at the crossing of the Virginia Midland railroad. Above it was slack-water about 1 mile to dam No. 14 (Beverly's Ford dam), about 7 feet high, with a lock of 6 feet lift; thence slack-water to lock and dam No. 15 (7 and 9 feet); thence slack-water a mile to a lock (7 feet); thence canal one-eighth of a mile to dam No. 16 (Lee's dam); thence slack-water 1½ mile to lock (9 feet); thence canal one-eighth of a mile to dam No. 17 (Fox's dam), about 9 feet high; thence slack-water to lock (7 feet), and dam No. 18 (Sulphur Spring dam), 8 feet high; thence slack-water 2 miles to locks with 16 feet lift, and beyond, canal for 1½ mile to dam No. 19 (Hart's dam), about 10 feet high, which was the last of the navigation dams. Above this point the river is very small. All the old dams referred to were founded on rock, which was generally found about 2 feet below the bed of the stream. The dams were of timber cribs filled with stone, and the abutments were in most cases either of natural rock or of masonry in cement, very substantially built. Notwithstanding the considerable length of slack-water navigation, it is said that very little land was flooded.

From what has been said, it is clear that the Rappahannock river offers a large amount of unimproved power. The conditions seem to be decidedly favorable for its development, the principal objections being the inaccessibility of the stream, and especially its very variable flow. But the fact that at most of the points where power could be used to the best advantage there is a canal already cut, in some cases needing little work to put it in repair, should counterbalance these objections to some extent.

Of the tributaries of the Rappahannock, the only one of importance is the Rapidan, which takes its rise in Greene and Madison counties, and flows rather north of east, forming the boundary between Orange and Spottsylvania counties on its right, and Madison and Culpeper on its left, and joining the Rappahannock 10 or 12 miles above Fredericksburg. Its total length, in a straight line, is about 40 or 45 miles, and its drainage area, as already mentioned, is 745 square miles. The stream resembles the Rappahannock in all essential particulars. Its elevation at the crossing of the Virginia Midland railroad is 278 feet, so that its fall is not much different from that of the Rappahannock, the distance from the junction to the railroad being probably a little greater in the case of the Rapidan.

The first power on the stream is one not utilized, near the mouth of Flat run. There was at one time a mill here with a fall of 8 feet, and some stamps were run in connection with a gold-mine in the vicinity, but at present there is nothing.

There are several other unimproved powers in this part of the stream, the next one above, which was specially mentioned, being known as "Germania", where there was a mill thirty-five years ago, with a fall of 6 or 7 feet. According to the map, this place is 10 or 12 miles above the mouth of the river.

At Raccoon Ford, perhaps 10 miles farther up, there is a grist-mill with a fall of 7 feet and about 25 horse-power, with a dam 300 feet long and 7 feet high. It is stated that full capacity can be secured during only eight or ten months, and that there is not much waste by leakage. The kind of motor is not known.

Next comes a grist-mill with a fall of 8 or 9 feet; and then, at Rapid Ann Station, a flour-mill using 50 horse-power and a fall of 9 feet, the dam being 240 feet long and 9 feet high. Full capacity can be obtained during nine months, with some leakage in summer. The drainage area above this place is about 440 square miles. Above are a number of small mills, and one site not used, known as Peyton's, with 6 or 7 feet fall, just above Rapid Ann Station.

The tributaries of the Rapidan and those of the Rappahannock afford small powers, and some of the streams are utilized to a considerable extent. None of the powers, however, are large.

Table of statistics of utilized power on the Rappahannock river and its tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	No. of mills.	Total fall used.	Total horse-power used. net.
						Feet.	
Rappahannock river	Chesapeake bay	Virginia	Spottsylvania	Woolen	1	18	45
Do	do	do	do	Flour and grist	3	75	220
Do	do	do	do	Fertilizers	1	18	50
Do	do	do	Stafford	Flour and grist	1	18	40
Do	do	do	Culpeper	do	1	16	40
Do	do	do	Fauquier	do	1	6	30
Do	do	do	Rappahannock	do	3	66	36
Do	do	do	do	Saw	1	25	12
Rapidan river	Rappahannock river	do	Orange	Flour and grist	2	16½	92
Do	do	do	Madison	do	2	34	20
Other tributaries of	do	do	Lancaster	do	4	43	57
Do	do	do	Middlesex	do	6	64	105
Do	do	do	do	Saw	3	39	40
Do	do	do	Richmond	do	1	......	18
Do	do	do	do	Flour and grist	5	64	136
Do	do	do	Essex	do	10	......	196
Do	do	do	do	Saw	1	12	20
Do	do	do	King George	Flour and grist	2	27	55
Do	do	do	Caroline	do	3	36	28
Do	do	do	Spottsylvania	do	2	35	24
Do	do	do	Orange	do	5	68	76

Table of statistics of utilized power on the Rappahannock river and its tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	No. of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
Other tributaries of	Rappahannock river	Virginia	Culpeper	Flour and grist	17	211	300
Do	do	do	do	Saw	2	25	22
Do	do	do	do	Furniture	1	14	10
Do	do	do	Fauquier	Flour and grist	3	60	85
Do	do	do	Rappahannock	do	16	240	217
Do	do	do	do	Saw	1	19	20
Do	do	do	do	Leather	1	18	15
Do	do	do	do	Wheelwrighting	1	10	15
Do	do	do	do	Woolen	1	16	15
Do	do	do	Madison	Flour and grist	11	144	149
Do	do	do	do	Saw	4	40	58
Do	do	do	do	Woolen	1	6	15
Do	do	do	Greene	Flour and grist	3	44	48
Do	do	do	do	Leather	1	9½	2

IV.—THE POTOMAC RIVER AND TRIBUTARIES.

THE POTOMAC RIVER.

The Potomac river is formed by the union of its two branches, the North branch and the South branch, on the line between Hampshire county, West Virginia, and Alleghany county, Maryland, whence it pursues a course at first north of east and then southeast, forming for its entire length the boundary between the state of Maryland and the states of West Virginia and Virginia, and emptying into Chesapeake bay about 60 or 70 miles from cape Charles. It drains a total area of about 14,500 square miles, but its course is so devious that some of its head-waters are not over 180 or 190 miles from its mouth, measured in a straight line. The principal streams tributary to the river are the following, in their order, beginning at the mouth:

Drainage areas.—Tributaries of the Potomac river.

	Square miles.
From the north:	
Seneca creek	163
Monocacy river	1,010
Antietam river	343
Conococheague creek	493
Licking creek	185
Conetowarts creek	165
Sideling creek	121
Town creek	190
North branch	1,316
From the south:	
Occoquan creek	573
Goose creek	466
Shenandoah river	2,850
Opequan creek	286
Buck creek	220
Sleepy creek	214
Great Cacapon creek	616
Little Cacapon creek	163
South branch	1,580

The two branches which form the river rise in the Alleghanies, the North branch near the western corner of the state of Maryland, and the South branch in Virginia and West Virginia, near the sources of the Cowpasture and Jackson's rivers (the head-waters of the James), whence it flows nearly north. These branches, with their affluents, and the tributaries of the main stream as far down as the Shenandoah, drain a series of narrow and generally fertile valleys lying between the parallel ranges which make up the system of the Alleghanies in this region. Their falls are, as a rule, not very large, their declivities uniform, and their beds gravel and sand. Their chief peculiarity lies in the great fluctuations to which their flow is liable. The rain falling on the mountains is shed rapidly into the water-courses by the steep side slopes leading to the narrow valleys below, and there being few lowlands to overflow, and so to store the freshet water, and no lakes whatever in the region, these streams, and with them the Potomac river, are subject to very sudden and heavy freshets, while in dry seasons their discharge becomes very small. A glance at the table on page 9 of the present report, which contains the results of all the gaugings on the Potomac which could be obtained, shows this peculiarity very plainly. The flow of the North branch at Cumberland, when at its minimum, is found to be only one-tenth as large in proportion to its drainage area as would be expected from a stream of similar size in New England; and the minimum flow of the Potomac at the Great falls is seen to be exceedingly small for so large a stream. This characteristic seems to be more marked in the case of the tributaries from the south than in the case of those from the north, in which direction the country opens out somewhat, the mountains diminish in height, and the width of the valleys becomes rather greater.

From the junction of its two branches the Potomac cuts through the mountains nearly at right angles. Its valley in this part of its course is narrow, its fall at places quite rapid, the bed generally gravel, bowlders, and sand, with rock at a small depth, and often at the surface, and the banks generally high and sometimes precipitous, with not many low grounds subject to overflow. After receiving the Shenandoah at Harper's Ferry, the stream cuts through a narrow gap in the Blue ridge and reaches the true Atlantic plain. It crosses the fall-line a few miles above Washington, and reaches tide-water at Georgetown. From this point to its mouth it is sluggish, tidal, and navigable, there being at present a navigable depth up to Georgetown, 105 miles from its mouth, of 16 feet at low tide and 19 feet at high tide. Above Georgetown there are various shoals which prevent further navigation.

The rainfall in the valley varies from 44 inches in the lower part to 38 inches in the upper part. Regarding its amount and distribution above various points, it will be seen by the table on page 9, that, as in the case of the Rappahannock and the James, the distribution through the seasons is very irregular, there being a small fall in autumn and winter. The effect of this will be seen in a small minimum and low-season flow, occurring probably late in the autumn; and this fact goes far toward explaining the very small measured values of the minimum flow.

The declivity of the stream is shown by the following table:

Slope of the Potomac river.

Locality.	Distance from tide.	Elevation above tide.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Georgetown	0	0			
			61.5	245	4.0
Harper's Ferry	61½	245			
			9.5	35	3.7
Shepherdstown	71	280			
			14.0	39	2.8
Dam No. 4	85	319			
			22.0	38	1.7
Dam No. 5	107	357			
			78.0	253	3.2
Cumberland	185	610			

NOTE.—Distances are in some cases inaccurate.

It will be noticed that the elevation of the Potomac when it passes through the Blue ridge is about 245 feet, while that of the James at its passage through the same range of mountains (at Blue Ridge dam, see page 14) is 706 feet. The fall of the Potomac is therefore much smaller than that of the James, though still quite large. Of the 245 feet below Harper's Ferry about 90 occur in a short distance at the Great falls; and if this be subtracted, the fall in the remaining distance is found to average about 2.5 feet per mile.

As a water-power stream the principal disadvantage of the Potomac is the great variability of its flow. In all other respects it seems favorable. Good rock foundations for dams can generally be obtained at small depth, the banks are as a rule favorable, and there are several sites where large falls could be rendered available, as will be seen hereafter. Building-materials can generally be found, and the facilities for transportation are excellent. The map shows that the Baltimore and Ohio railroad follows the river for its entire length, receding at places several miles from it, but for long distances keeping within sight of it. In addition to this, the Shenandoah Valley railroad and the Cumberland Valley railroad cross the stream. Finally, the Chesapeake and Ohio canal follows it almost within sight at every point, from Georgetown to Cumberland, on the North fork, using it in a few places for slack-water navigation. The ponds are not large, and the facilities for storage on the main stream are very small. On some of the tributaries sites for small reservoirs could be found, while on many there are no facilities.

Aside from a small amount of power which is used from the Chesapeake and Ohio canal, there is only one mill using power from the river—a very remarkable fact, considering that there are several large falls.

Water is leased by the canal company—to be discharged either around the locks into lower levels or into the river—generally by the square inch of opening; "opening to be placed with its lower edge 2 feet above canal bottom, and to be cut square through an iron plate half an inch thick". No head or quantity of water is guaranteed, as the canal is to be used primarily for navigation. The original rates for water were $2 50 per square inch per annum, leased for twenty years, a bonus of $3 per inch payable upon every renewal. The experience in regard to leasing water has been that it is not advisable to lease large quantities, that it is a source of inconvenience to navigation, and does not pay. The velocity allowed on the canal is considered to be about 1½ mile per hour, or 2.2 feet per second, or rather larger than on the James River and Kanawha canal. Loaded boats coming down get the benefit of the current, and the greater part of the traffic is down the river; moreover, the dimensions of the canal are rather greater than those of the James River canal, so that a larger velocity would be required here to offer the same resistance to boats. Considerable power could be rendered available above Georgetown by using the flume-water at the locks, or the water which passes around the locks to supply the levels below; but the amount of power which might thus be rendered available can not be estimated, varying at different places and according to the weather, the traffic, etc. As the company does not guarantee any special head or quantity of water, the mills on the canal have to regulate their work according to the navigation in the canal. Those above Georgetown can, however, get their full capacity as long as there is water in the canal, but the water is entirely drawn off during the months of December, January, and February. The mills on the Georgetown level run nearly all the year, subject only to occasional short interruptions; and the water is drawn off from this level for ten days in the year for ordinary repairs. None of the mills use auxiliary steam-power, however.

The canal is fed entirely from the Potomac and the North branch, and there are no artificial reservoirs connected with it except the ponds of the dams on the river, of which there are eight between Georgetown and Cumberland. At some of these dams power could be used, as will be seen hereafter, but the ponds are all so small that they afford no great storage-room. The original dimensions of the canal were as follows: From Georgetown to Harper's Ferry, 60 feet wide at top, 42 at bottom, 6 feet deep; from Harper's Ferry to dam No. 5 the corresponding dimensions being 50 feet, 32 feet, and 6 feet; and from dam No. 5 to Cumberland, 54 feet, 30 feet, and 6 feet.

The following table gives the mills and power supplied from the canal:

Name of place.	Kind of mill.	Number of square inches.	Head.	Quantity of water per second.	Head and fall.	Horse-power, gross.	Remarks.
			Feet.	*Cubic feet.*	*Feet.*		
Georgetown	Paper	417	*a*4		34.5		Head and fall of 34.5 feet to mean high tide; discharge to river.
Do	Corn	328	*a*4		34.5		
Do	Fertilizers	229	*a*4		34.5		
Do	Flour	2,595	*a*4		34.5		
Do	Not used	731	*a*4		34.5		
Total in Georgetown		4,300	*a*4	310±	34.5	1,214±	
Berlin, Frederick county	Flour and fertilizers			(Estimated) 55	6	37	Flume-water of one lock.
Weverton	Flour				17	25–30	Waste water leased; discharged to river.
Above Antietam aqueduct	Saw	50		Small	8–10		Discharged to river.
Williamsport lock	Saw				8		Flume-water.
Williamsport aqueduct					28		Discharged to river.
Above dam No. 5		33	2	Small			Discharged to river.
Hancock	Grist	200	4		24±		
Above Hancock	Cement	500±	3–4		24±		

a Or less.

NOTE.—For my information regarding the canal and the power used from it, as well as for much valuable information regarding the flow of the river, etc., I am indebted to Mr. William R. Hutton, civil engineer, now of New York, consulting engineer of the canal company.

The power supplied is therefore very small in amount, though it might be increased greatly. In view of the fact that the amount available depends entirely upon the state of traffic on the canal, and other circumstances, estimates can not be made and are not necessary. The amount of water necessary for the purposes of navigation is very variable, and in dry seasons the flow at Cumberland is not sufficient to supply these wants, so that the height of the water in the levels below gradually sinks, from evaporation and leakage, and at Patterson's creek a steam-pump raises 100,000 or 120,000 gallons per minute to supply the canal. In the above table "waste water" means the surplus which comes down to a given level over what is required for lockage, etc., below, and which is therefore returned to the river.

Ascending the river itself, the first power is about 5 miles above Georgetown, at Little falls, where canal dam No. 1 supplies the Georgetown level. The dam is 1,750 feet long, 7 feet high above low water, and is built of riprap. Its crest is about 37 feet above tide. The river is shoaly for some distance below, and it is probable that a fall of 10 feet or more could be used here. The dam, however, is not tight, so that at present, as already stated, the canal company can not always supply their present leases on the Georgetown level; but with a close dam a large amount of power could be used, either near the dam or below at various places on the level. If the allowable velocity on the canal be taken at 2.2 feet per second, the canal could carry about 670 cubic feet per second, which would afford at Georgetown, with a fall to mean high tide of say 30 feet, a gross power of nearly 2,300 horse-power. The following table contains estimates of the flow of the river, from which an idea of the power at the dam itself can be formed:

Estimate of flow and power at Little falls.

State of flow (see pages 8 to 11).	Drainage area.	Fall.	Flow per second.	Horse-power available, gross.	
	Sq. miles.		*Cubic feet.*	*1 foot fall.*	*10 feet fall.*
Minimum	11,588	Height of dam, 7 feet; available fall, probably about 10 feet.	1,075	122.0	1,220
Minimum low season			1,970	223.8	2,240
Maximum with storage			10,300	1,170.0	11,700
Low season, dry years			2,300	261.3	2,600

The pond of the dam is not used for navigation, and the facilities for building are good just below the dam.

The next site above is at the Great falls of the Potomac, 14 miles above Georgetown. The water pours here over a solid mass of rock, with banks of the same material, often very steep and precipitous just at the edge of the water, but with level or nearly level places on top of the bluffs, extending back in some places a hundred yards or more, the facilities for building being ample on both sides of the river. The stream descends at the principal fall perhaps 35 or 40 feet in 100 or 150 yards, and the total fall in a distance of about a mile or a mile and a half is 80 or 90 feet. The stream is narrow for the greater part of this distance, and in freshets the water is said to rise 30 or 40 feet at some points. It is said that many years ago a canal 1½ mile long was built around the falls on the Virginia side, which, in the event of the development of the power, could be used as a race, though it is now almost entirely filled up.

The drainage area above the Great falls is about 11,476 square miles, and the rainfall is given in the table on page 9. The stream has been gauged at this point, and the minimum flow found to be 1,069 cubic feet per second. The ordinary low-water flow, however, is stated at over 2,000 cubic feet per second. I have estimated the power as follows:

Estimate of flow and power at the Great falls of the Potomac.

State of flow (see pages 8 to 11).	Drainage area.	Fall.	Flow per second.	Horse-power available, gross.	
	Sq. miles.	*Feet.*	*Cubic feet.*	*1 foot fall.*	*80 feet fall.*
Minimum			1,069	121.5	9,720
Minimum low season	11,476	80–90	1,950	221.6	17,730
Maximum with storage			10,213	1,160.5	92,840
Low season, dry years			2,300	261.3	20,900

No power is used at this site. The water for supplying the cities of Washington and Georgetown is drawn from the river just above the falls and conducted to its destination through a large aqueduct; but the quantity of water taken is very small compared with the flow of the stream. One disadvantage of the site is that it is not easily accessible except by the canal. The latter, however, affords good advantages for transportation.

The next site is at canal dam No. 2, at the mouth of Seneca creek. The dam is 2,500 feet long, and from 2 to 10 feet high from the rock foundation, and is a rubble dam and frequently damaged by floods. Its crest is about 180 feet above tide. The site is not a very favorable one, the fall being small and the facilities for building not very good. Not knowing the fall, estimates of the power would be of little value.

The next site is where the river breaks through the Blue ridge, just below Harper's Ferry. From Weverton, 3 miles below Harper's Ferry, to dam No. 3, a mile above that place, the fall is almost continuous, forming really but one shoal or rapid; but as the part above the ferry could best be used at or above the town, it is best to consider the shoal in two parts. From Harper's Ferry the stream falls 25 feet in a distance of 3 miles,(a) the bed being rocky, and the banks, though in places steep, as a rule, favorable for a dam, and with numerous sites for building. It was at one time attempted to develop this power, and in 1834 the Weverton Manufacturing Company was incorporated with this object in view. The site was surveyed by E. N. Dickerson, of Paterson, New Jersey, who reported on the property in glowing terms, and subsequently a dam was built and a cotton-mill and some other mills started; afterward a file factory was put up, together with a large flour-mill on the other side of the river; but for some reason none of them continued long in operation, and at present the site is altogether unimproved. The available power is estimated in the annexed table:

Estimate of flow and power of the Potomac river at Weverton.

State of flow (see pages 8 to 11).	Drainage area.	Fall.	Flow per second.	Horse-power available, gross.	
	Sq. miles.	*Feet.*	*Cubic feet.*	*1 foot fall.*	*25 feet fall.*
Minimum			860	97.7	2,440
Minimum low season	9,260	b 25	1,570	178.4	4,460
Maximum with storage			8,240	936.3	23,400
Low season, dry years			1,800	204.5	5,100

a E. N. Dickerson's report, 1845.

b Dickerson states the total available fall at 45 feet, including, no doubt, a large part of the fall above Harper's Ferry.

On account of the rapid fall of the stream above, the pond would be small unless the dam were very high. It is stated that fine building-materials abound in the immediate vicinity; and as far as transportation is concerned the advantages are excellent, the canal and the railroad passing directly by the place. As regards facilities for dams and races there would also be no difficulty, except perhaps that the freshets might cause a stoppage of work at intervals.

At Harper's Ferry, where the Shenandoah joins the Potomac, the latter stream passes through a deep and rocky gorge with almost perpendicular banks for a short distance. Above that point the fall of the river is rapid, and about 1½ mile above we come to dam No. 3, which was originally built, it is said, to supply power to the government works at Harper's Ferry; but those works were destroyed during the war and have not been in operation since, and the dam, being now used only as a feeder to the canal, is not in good order. It was formerly built of low cribs, but is now partly riprap and partly dry wall 2 to 5 feet high above the rock. The fall of the river from the dam down to the mouth of the Shenandoah is about 27 feet. On the north side of the river the canal skirts the bank so closely that no room remains for the utilization of power; but on the south side, where the government factory was located, the facilities for canals and buildings are tolerably good, though rather limited as regards space. The old canal, leading from the dam to the factory, is now dry and partially filled up. It is said that a fall of about 22 feet was formerly used at this place, and it is probable that no more than this could be utilized without raising the dam, the building-sites being located about an eighth to a quarter of a mile above the mouth of the Shenandoah. At present no power whatever is used here. The following table contains estimates of the power available:

Estimate of flow and power of the Potomac river at Harper's Ferry.

State of flow (see pages 8 to 11).	Drainage area.	Fall.	Flow per second.	Horse-power available, gross.	
	Sq. miles.	*Feet.*	*Cubic feet.*	*1 foot fall.*	*22 feet fall.*
Minimum	6, 380	22±	575	65. 3	1, 430
Minimum low season			1, 020	115. 9	2, 550
Maximum with storage			5, 740	652. 0	14, 350
Low season, dry years			1, 166	132. 5	2, 900

The freshets in the river are felt quite severely at this point, and it is said that at one time the river rose 25 feet above low water. Ice-jams, however, rarely occur. The facilities for transportation are excellent, building-materials are abundant, and there seems to be no reason why a large and fine power could not be utilized here. The site is probably the most favorable one on the river.

The next site is about a mile below Shepherdstown, and about 10 or 12 miles above Harper's Ferry. At this place there is a wooden dam about 600 feet long and 8 feet high, which supplies power to a cement-mill on the right bank, the fall used being 8 feet and the power 30 to 50 horse-power. The race is 500 feet long and 60 feet wide, and the dam is said to pond the water for several miles. This mill is the only one supplied directly from the Potomac river. The available power is estimated in the table on the following page.

The next site is at dam No. 4, about 25 miles above Harper's Ferry. The dam is of masonry, 800 feet long and 15½ feet high above low water (20½ feet from rock foundation). Along the canal, on the Maryland side, the tow-path is too narrow and too low to allow of any mills being located there, but on the Virginia side there are sites for building. The estimates of available power are given with sufficient detail on page 45. The pool of this dam is used for navigation for a distance of 3½ miles.

We next come to dam No. 5, about 7 miles above Williamsport. It is 720 feet long and 16½ feet high above low water (20½ to 24 feet from rock foundation), and is built of masonry. Before the war a large flour-mill—the Honeywood mill—used water on the Virginia side, and there is no favorable site for others on that side; but on the Maryland shore the canal-bank could be used for some distance, though in many places the tow-path is built up from the river, leaving no sites for buildings. The pool of the dam is used for navigation for half a mile. The power is estimated below.

Dam No. 6, 10 miles above Hancock, is a crib-work dam filled with stone, and is 470 feet long and 15½ feet high above low water (20½ feet above rock foundation). Its crest is about 428 feet above tide.[1] There are some sites on the Virginia side, and on the Maryland side the whole length of the canal could be used.

Dam No. 7 was never built. The stream has considerable fall in this part of its course, and power could probably be developed at many places, but it might be difficult to find convenient locations, as the railroad on one side and the canal on the other often occupy all the ground which would be available for building. The only sites on the river which seem to be of great importance are those at the Great falls, at Weverton, at Harper's Ferry, and at the other canal dams. For reasons already stated, estimates are not given of the amount of power which could be obtained from the canal, although there are many places where power could conveniently be used in that way, as, for instance, below dam No. 6.

Dam No. 8, being on the North branch, at Cumberland, will be considered when that stream is described.

Summary of estimates of flow and power of the Potomac river.

Name of place.	Distance from Georgetown.	Drainage area.	RAINFALL. Spring.	Summer.	Autumn.	Winter.	Year.	TOTAL FALL. Length.	Height.	HORSE-POWER AVAILABLE, GROSS.(a) Minimum.	Minimum low season.	Maximum with storage.	Low season, dry years.	UTILIZED. Fall.	Horse-power, net.	Remarks.
	Miles.	*Sq. miles.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Miles.*	*Feet.*					*Ft.*		
Dam No. 1 (Little falls)	5	11,588	11	12	9	8	40	......	10±	1,220	2,240	11,700	2,600	....	....	Dam 7 feet high. Power utilized below, at Georgetown.
Great falls	14	11,476	11	12	9	8	40	1½	80–90	9,720	17,730	92,840	20,900	....	....	
Dam No. 2	....	11,389	11	12	9	8	40	......	Small.	....	....	....	....	....	....	
Weverton	57	9,260	11	12	9	8	40	3	25	2,440	4,460	23,400	5,100	....	....	
Harper's Ferry	60	6,380	11	12	9	8	40	1½	22±	1,430	2,550	14,350	2,900	....	....	
Shepherdstown	70±	5,975	11	12	9	8	40	......	8	489	800	4,880	920	8	30–50	Dam 8 feet high.
Dam No. 4	85	5,899	11	12	9	8	40	......	15½	775	1,500	9,300	1,725	....	....	Dam 15½ feet high.
Dam No. 5	106	5,066	11	12	9	8	40	......	16½	700	1,420	8,550	1,625	....	....	Dam 16½ feet high.
Dam No. 6	136±	3,550	11	12	9	8	40	......	15½	440	875	5,600	1,000	....	....	Dam 15½ feet high.

a See pages 8 to 11.

TRIBUTARIES OF THE POTOMAC RIVER.

The first tributary whose water-power is worth mentioning is Occoquan creek, which is formed by the union of Broad run and Cedar run, in Prince William county, Virginia, whence it pursues an easterly course for a distance of about 13 miles in a straight line, and after forming for some distance the boundary line between Prince William and Fairfax counties empties into the Potomac river about 25 miles below Washington. Broad and Cedar runs have their sources in Fauquier and Prince William counties, the former draining 87 square miles, and the latter rather less. The Occoquan receives as its principal tributary below these two, Bull run, which rises at the extreme northern corner of Prince William county, and forms for its entire length the boundary between that county and Fairfax, draining about 212 square miles. All of these streams flow through a hilly or rolling country, and have gradual declivities, with beds of gravel and sand, and they offer little power. The Occoquan, however, crosses the fall-line just before it reaches the town of Occoquan, which is the head of tide-water, and up to which there is a navigable depth of 5 feet at low tide and 7 feet at high tide. The fall begins about 3 miles above the head of tide-water, and continues down to tide, the stream falling about 80 feet in that distance "through bold and extensive masses of gneiss rock".(*a*) The banks are quite abrupt and very rocky for a mile above the head of tide-water, but above that they are in places more favorable for canals and buildings. Some power at the lower part of the shoal is used by a flour- and saw-mill at Occoquan, supplied by a race half a mile long, 10 to 15 feet wide, and 2 feet deep, one bank of which is a solid stone wall for a considerable distance, built up in some places to a height of 20 or 30 feet. At its head is a rough dam, very leaky, and built partly of brush and partly of stone in cement—the latter being tight. The mill has an available fall of 32 feet, but uses only 23, the remaining 9 feet having been at one time used by a cotton factory, discharging its tail-water to the present mill. The power used is perhaps 50 horse-power, but on account of the leakage of the dam, and interruption during about a month in winter on account of ice, this can be obtained during only ten months. By building a tight dam the entire flow of the stream could be used at Occoquan, with a fall of 32 feet, and by raising the dam a still greater fall could be rendered available. It would be possible to develop power above the dam, but it would be expensive compared with the power to be obtained. About 1½ mile above the dam a second one could be built, there being apparently a good site, where a high dam could be built without damaging land by backwater. In this way a fall of 14 or 15 feet could be used, and, by carrying a race farther down stream, a much greater fall, but it is not probable that much storage-room could be obtained. The total drainage area above tide-water being about 573 square miles, I have endeavored to estimate the available power in the following table:

Estimate of flow and power of the Occoquan river at Occoquan.

[NOTE.—Rainfall, about 42 inches—12 in spring, 13 in summer, 9 in autumn, 8 in winter.]

State of flow (see pages 8 to 11).	Drainage area.	Fall.	Flow per second.	Horse-power available, gross. 1 foot fall.	23 feet fall.	52 feet fall.	80 feet fall.
	Sq. miles.	*Feet.*	*Cubic feet.*				
Minimum	570	80	57	6.5	150	210	520
Minimum low season			74	8.4	190	270	670
Maximum with storage			510	58.3	1,340	1,860	4,660
Low season, dry years			85	9.6	220	300	770

a Report of Board of Public Works of Virginia.

As regards transportation by sea, this place—at least the lower part of the falls—is very conveniently located, as boats can load directly from the mill. The town is 2 miles from the Alexandria and Fredericksburg railroad.

For the next 20 miles of its course the Occoquan has an average fall of 3.39 feet per mile, according to an old survey, and there are no powers worth naming. Bull run and Broad run furnish a few small powers, but none of much importance. On the latter stream there is quite a fall at Thoroughfare gap, where a mill uses a fall of 27 feet, but the power is only 20 or 30 horse-power. It is stated that in a distance of a mile at this place there is a fall of 150 feet. Four miles below there is a woolen-mill, not now in operation.

Some of the other small tributaries of the Potomac in this neighborhood cross the fall-line, giving rise to quite large falls but affording only very small powers; and in the neighborhood of Alexandria there are several such streams running small grist-mills; but there are really no other tributaries from the south side worth mentioning, east of the Shenandoah. Goose creek, Broad run, and Kittocton creek all supply small grist-mills with from 1 to 4 pairs of stones, and falls averaging 10 feet or thereabout. But these streams, as well as those from the north in this vicinity, are not of much value for water-power, on account of their running so very low in summer. They are, moreover, as a rule, sluggish, afford small facilities for storage without overflowing valuable lands, and are subject to heavy freshets.

The only stream from the north worth mentioning, east of the Blue ridge, is the Monocacy river, which has its sources in Adams county, Pennsylvania, and flows nearly south, entering the Potomac at the southeast corner of Frederick county, Maryland, and draining an area of about 1,010 square miles. It flows through a hilly and rolling country, is as a rule sluggish, and offers little power. The bed is gravel and sand, and there are no falls of note. Its flow, although not so variable as that of the tributaries farther west, is still liable to considerable fluctuations, and the freshets are sometimes of violence, the water rising 10 or 15 feet in places. The stream is used at several places to run flour-mills, but there are only two mills where the power is large enough to be mentioned specially. The first is about 12 miles below Frederick, at Greenfield Mills, where a fall of 7 feet is used and about 108 horse-power. The dam is of wood, 450 feet long and 5½ feet high, backing the water about 1½ mile, and was originally built in 1850, at a cost of $4,200. The head-race is 100 yards long. Full capacity can always be obtained, and there is always a waste of water. The drainage area above this place is about 1,000 square miles. The next power is about 6 miles above, near Buckeystown, where a fall of 7 or 8 feet is used, with about 75 horse-power, the dam being 6 or 7 feet high. The drainage area above is about 935 square miles. Above this there are small mills with falls of from 5 to 8 feet, and there are said to be no good sites not used. It seems to be evident that the power of the stream is of not much importance.

Some of the tributaries of the Monocacy seem to have a greater fall and to be more favorable for power than the main stream. Bennett's creek, though not a rapid stream, runs several small grist- and saw-mills. Bush creek is similar in character, but both of these streams run very low in summer, and some of the mills use steam part of the time. Linganore creek, draining 77 square miles, has more fall than those thus far mentioned, and has one mill with a fall of 15 feet and running six pairs of stones. Full capacity can be secured during only six months, the average during the rest of the time being about one-half. The drainage area of the Monocacy above the mouth of the Linganore measures about 800 square miles. Double Pipe creek, the largest tributary of the Monocacy, drains 264 square miles, and is formed by the union of Big Pipe creek and Little Pipe creek, which drain respectively 170 and 91 square miles. Although a very short stream, Double Pipe creek has one good mill with a fall of 9 feet and about 4 pairs of stones, the dam being 8½ feet high; and on the head-waters of the stream are many small grist- and saw-mills. Although mills might be located at some points by damming, the general testimony is that there are no sites worth mentioning on the Monocacy or any of its tributaries.

The next tributary of the Potomac, and the most important one of all, is the Shenandoah river, which joins it just as it passes through the Blue ridge, at Harper's Ferry, West Virginia. The Shenandoah has its head-waters in Augusta and Rockingham counties, Virginia, and pursues a general northeasterly course, draining the northern part of the great Virginia valley included between the Blue ridge on the east and the main chain of the Alleghanies on the west. The main stream is formed by the union of the North and South forks, which unite near the town of Front Royal, in Warren county, Virginia, whence the stream flows through Clarke county, Virginia, and Jefferson county, West Virginia, the length of its course, which is very tortuous, being about 54 miles (38½ in a straight line), and the total area drained 2,850 square miles. Of the two forks, the South fork is formed by the junction (at Port Republic, Rockingham county) of the South and Middle rivers—which above their junction are mere mountain streams—whence it pursues a very tortuous course through Page and Warren counties, between the Blue ridge and the Massanutten mountain, the length of its course being nearly 96 miles (52¼ in a straight line), and its drainage area 1,535 square miles; while the North fork has its head-waters in the northern part of Rockingham county, and flows through Shenandoah and Warren counties, between the Massanutten mountain on the east and North mountain on the west, its course being also very tortuous, and its drainage area 925 square miles.

The river is to a certain extent navigable, and works have at various times been executed for improving it. Early in this century some locks and canals were built on the lower part of the stream—below Little's falls, which are 6 or 7 miles above Harper's Ferry—while above that point the more important rapids and ledges were passed by means of sluices. Surveys of the river have been made at various times in the interest of navigation, all of which are collected in the report of Colonel William P. Craighill, in the *Annual Report of the Chief of Engineers* for 1880, page 661, to which I am indebted for a great part of the following information regarding the stream.

The following extract from the report of Mr. N. H. Hutton, civil engineer, will serve to give an idea of the character of the main stream and the South fork. That of the North fork may be presumed to be similar:

The whole water-way from Port Republic to Harper's Ferry, excepting the lower 6½ miles, flows between alluvial banks, from 10 to 25 feet above low water, and has on either side, except for short distances and at wide intervals, areas of bottom-land from a few hundred feet in width to several thousands of feet; the spurs from the adjacent mountains rarely impinge directly on the water-way, and only for short distances. The lower section, however, extending from the head of Little's falls (6½ miles) to the mouth, is entirely unlike the upper portions, as here the mountains shut closely in on either bank, the bottom-land disappears, and the river descends over a succession of slate ledges with more than double the average fall per mile of its whole length.

As is usual with mountain streams, the river flows alternately through pools of comparatively slack water, and over ledges and shoals forming rapids and falls. As is also usually found in such cases, the pools are shorter and the ledges more numerous on the upper reaches than on the lower; on the upper 40 miles of the stream the pools rarely if ever exceed a mile in length, with from 2 to 4 feet depth of water, while on the remainder of the stream (to the head of Little's falls) they frequently attain a length of 3 or 4 miles with depths of from 4 to 7 feet of water. The depths over the ledges and shoals vary from 4 or 5 inches to 8 or 9 in their lowest places, as they generally, for considerable portions of their length, are above the plane of low water.

The South branch commences with a width of about 170 feet, and, with many irregular contractions and expansions between 150 and 250 feet, gradually increases to a width of about 350 feet at its junction with the other branch; the main stream thence gradually widens to 500 or 600 feet at its junction with the Potomac.

The whole fall, from Port Republic to Harper's Ferry, as given by Mr. Herron, is 793 feet, or about 5.4 feet per mile. This slope, however, is not equally distributed throughout the whole distance.

From Port Republic to Ammon's dam (7 miles) the river descends 50 feet, or over 7 feet per mile; thence to the forks at Front Royal (if we except a fall of 17 feet in 5,000 feet at Kemper's) the stream has for 86 miles an average fall of 6 feet per mile. From the forks to the head of Little's falls the slope averages, for 45½ miles, only 2¾ feet per mile, while from the latter point to the mouth it falls nearly 12½ feet per mile. It will thus be seen that the third section counting from above, or that extending from Front Royal to the head of Little's falls, is the only one on which open-river up-stream navigation would be practicable if the slope were made uniform throughout.

Both the South branch and the main stream below are traversed by numerous ledges of slate and limestone, the latter predominating on the upper 40 miles of South branch and the slate below that point; the stream is also, more especially in the upper 25 miles, obstructed by shoals formed by loose rock or bowlders brought down by the freshets.

The whole number of ledges noted above Little's falls was about 700, and the total length of the bowlder and gravel shoals in the same distance was estimated at about 17,000 feet. Between the head and Mallon's iron-works (22 miles) the ledges average 9 per mile, and the bowlder and gravel bars aggregated 10,000 feet, or over 450 feet per mile; between the iron-works and Front Royal (junction of North branch) the ledges averaged 5 per mile, and below that to head of Little's falls they averaged a little over 3 per mile; the bowlder and gravel shoals on both sections averaging about 56 linear feet per mile. Below Little's falls the river is almost one continuous succession of ledges, over which navigation has never been attempted except by the aid of the locks, sluices, and canal of the Shenandoah Navigation Company. Aside from this lower reach, none of the ledges form falls of any magnitude, except at Kemper's falls, where the river runs close under the mountain cliffs, and falls 17 feet in 5,000 feet over a succession of limestone ledges.

As might be expected from its narrow, steep, and rocky water-shed, the river is said to be subject to frequent and rapidly-rising freshets. No exact data were attainable as to their usual and ordinary heights, but they do not seem to have generally exceeded 7 to 12 feet above low water except on such extraordinary occasions as that of the autumn of 1870 and 1877, when it rose from 25 to 30 feet in a few hours. Their effects can not generally, however, be very severe on the river bed and banks along the upper portions, for the general configuration of the river and the extent and shape of low points and islands were nearly the same during this reconnaissance as were indicated in the topographical notes of Mr. Herron's survey in 1832.

The absence of lakes in the drainage basin increases the violence of the floods, and were the fall of the stream not so large the water would rise to much greater heights. It is said, however, to have risen over 40 feet at the junction of the North and South forks in the freshet of 1870. Ice-jams are said to occur sometimes, but they are of course not so dangerous as on the streams farther north. The rainfall over the basin averages about 40 inches—12 in spring, 12 in summer, 8 in autumn, and 8 in winter. The gauging in the table on page 9 is given by Mr. Herron.(*a*)

The elevations above tide of some points on the stream are given in the following table:

Slope of the Shenandoah river.

Locality.	Distance from mouth.	Elevation above tide.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Harper's Ferry, junction with Potomac	0.0	242			
			2.5	44	17.6
Bull's falls	2.5	286			
			5.5	40	7.3
Near mouth of Evitt's creek	8.0	326			
			10.0	34	3.4
Castleman's ferry	18.0	360			
			13.0	40	3.1
Berry's ferry	31.0	400			
			23.0	53	2.3
Confluence of North and South forks (*b*)	54.0	453			
			96.0	586	6.1
South fork, near Port Republic	150.0	1,039			

a *Seventeenth Report of the Board of Public Works of Virginia.* *b* Profiles of the Shenandoah Valley railroad give this elevation as 445 feet.

Until recently the main stream and the South branch have not been very accessible, except for a few miles above Harper's Ferry, being removed on the average about 10 or 12 miles from the Baltimore and Ohio railroad (Valley branch), which follows the North branch. By the construction of the Shenandoah Valley railroad, however, almost every point of the stream is brought within easy reach.

The large fall of the river is sufficient evidence that it affords a very large amount of power theoretically available. Very little, however, is utilized, as the table on pages 52 to 54 will show. With a few exceptions, which will be indicated, the rapids and falls referred to in the extract from Mr. Hutton's report, though numerous, have but small fall; so that, although mills might be located at many of them, the falls available would be small (probably not over 5 to 8 feet, as a rule), and it would generally be necessary to build dams. At a number of these sites mills were located 15 or 20 years ago; but the freshets of 1870 and 1877 proved so destructive, and carried away so many dams, that people have been deterred from utilizing power on the river in later years. The old dams, however, were generally built of logs and brush, and were for the most part leaky and unsubstantial; and considering the good foundation which can generally be obtained, there seems to be no reason why there should be difficulty in building dams strong enough to withstand any freshet to which they might be subjected.

The following are the principal powers met with as the river is ascended:

The principal fall on the stream occurs in the lower 8 miles of its course, according to the above table. This fall was overcome by the navigation company by means of a series of locks, canals, and sluices, which are described by Mr. Hutton as follows:

For a great many years anterior to the civil war, a system of down-stream navigation, per flat-boats, was maintained throughout the main stream and South branch, the works above Little's falls consisting of low wing-dams and sluices, and, below that, of a system of locks and canal combined with sluices and open-river navigation. No attempt appears ever to have been made to establish an up-stream navigation, unless possibly on the lower reach, where remains of a towing-path still exist; though, with a fall in the water-way, outside the locks, of nearly 7 feet per mile, it may well have been called an uphill business.

The navigation works between the head of Little's falls and the mouth of the river, commencing at the head of Little's falls, consisted of: 1. A lock of 6 feet lift; 2. A sluice 2,000 feet long, falling 5 feet; 3. Open river for 4,000 feet, falling 8 feet; 4. A sluice and mill-race 1,800 feet long, falling 1 foot; 5. A lock of 10 feet lift; 6. Open river for 3¾ miles, falling 15 feet to the foot of Bull's falls; 7. A canal behind Virginius island, 9,200 feet long and about 30 feet wide, with a single lock of 5 feet lift and a double lock of 15 feet lift, leaving 16 feet of fall to be passed over outside of the locks.

All traces of the works above this section have disappeared, and the works, as above named, are in a dilapidated condition, no attempt having being made to use them since the freshet of 1877.

The lock at Little's falls is a comparatively recent one, built to replace an old one washed out, and is so badly built that it is not worth repairing. The other locks are the original ones put in by the old navigation company, and are fairly constructed. One of them needs a new wall, and they all need new gates, cleaning out of sand, *débris*, etc. They are all 90 by 12 feet in the chamber.

The training-wall at Little's falls, originally built of small slabs of slate laid dry, has almost entirely disappeared.

The canal and mill-race at Snyder's mill, as well as the main canal below, require cleaning out of the *débris*, and possibly the removal of some projecting points of ledges.

I have endeavored to estimate the available power at this place in the following table:

Estimate of flow and power of the Shenandoah river at Harper's Ferry.

State of flow, (see pages 8 to 11).	Drainage area.	Fall.	Flow per second.	Horse-power available, gross.			
	Sq. miles.	*Feet.*	*Cubic feet.*	*1 foot fall.*	*14 feet fall.*	*20 feet fall.*	*84 feet fall.*
Minimum	2,800	84	280	31.8	450	635	2,670
Minimum low season			476	54.1	750	1,080	4,540
Maximum with storage			2,520	286.3	4,000	5,725	24,000
Low season, dry years			540	61.3	860	1,225	5,150

As regards the utilization of this power, bed and banks are favorable to the construction of dams, but space for canals and buildings is sometimes limited. Nevertheless a large amount of power could be developed if necessary, and without great trouble. It is said that at Little's falls a fall of nearly 20 feet could be utilized; and just below the second lock, coming down, there is a mill, taking its water from the old canal, just above the lock, and using a fall of about 14 feet. Just above the canal leading behind Virginius island there is a mill, not now in operation, with a fall of 6 feet; and on Virginius island was formerly located the government rifle factory, taking water from the canal behind the island, above the double locks, with 15 feet lift, and discharging it across the island into the river, with a fall of 14 feet. By building a dam at the head of the island and turning the water into the old canal, this fall could be used without difficulty, and with considerable building-room on the island; and a much greater fall than 14 feet could be used, if necessary, depending on the height of the dam. At Bull's falls, although the descent is considerable, there are no facilities for races and buildings. Finally, below the point where the water was discharged from the rifle factory there is a fall of about 16 feet to the Potomac, about 14 of which is easily available, and is used at present by a flour-mill, with a wooden dam 400 feet long and 4 feet high, and a race of two or three hundred yards. The power used is perhaps 125 horse-power, and there is no trouble with want of water, although sometimes the machinery is stopped in freshets. It is said that the river has risen 25 feet at this place.

The power above described is worthy of notice. Facilities for transportation are excellent, and building-materials can be obtained in the immediate neighborhood.

Between Little's falls and the forks of the river there are no sites of importance and no tributaries worth mentioning. There were formerly a few small grist-mills on the main stream, with falls of 5 or 6 feet, but some of the dams were carried away in 1870 and have not been rebuilt.

On the South fork there is a flour-mill just above the junction with the North fork, using a fall of about 7 feet and 60 horse-power, with a wooden dam 400 feet long and 6 feet high. This is the best dam on the stream, the others being generally of brush. I should estimate the flow of the stream at this place, in cubic feet per second *per square mile*, at about the same as for Harper's Ferry, for which see table above

A mile or two above this mill there is a site once occupied, with a fall of 5 or 6 feet, and there are many similar ones farther up. Except at Kemper's falls, however—where the descent is 17 feet in 5,000—the falls are all small, and there are no mills on the stream with falls of over 9 feet. The quotations previously given render further remarks here unnecessary. There is doubtless a large amount of available power on the river, the principal trouble being due to the freshets, and this by no means serious.

Some of the tributaries of the South fork below the junction of the South and Middle rivers have rapid falls and offer some power, but they are all small streams and subject to considerable variation in flow. South river, which drains 257 square miles, has for some distance the same general character as the main stream, but is utilized more extensively for power. Its fall between Waynesborough and its mouth (at Port Republic), a distance of somewhere near 25 miles, is 220 feet, its elevation above tide at the former place being 1,259 feet. The upper part of the valley of the Shenandoah, and especially that part drained by the head-waters of the South fork, is, as already remarked, a limestone region. The streams here are generally fed by many bold and constant springs, and their flow is much more uniform than in the lower part of the basin; and this, together with the fact that the mills are small, will serve to explain why they are so much more extensively utilized than the main stream. The mills in the vicinity are uniformly grist-mills, with falls of from 5 to 10 feet, and, as a rule, 2 or 3 runs of stones. With few exceptions, most of the good sites in this vicinity are said to be occupied, there being mills on the main streams at intervals of a few miles. Middle river, which unites with South river, drains 770 square miles; but just above Port Republic it receives as an important tributary North river, draining 344 square miles, leaving about 425 square miles for the drainage area of Middle river above the junction. Both of these streams are fed by numerous springs, and are utilized to a considerable extent by grist-, flour-, and saw-mills, especially North river. The only freshets which are spoken of as having done any damage in this region are those of 1870 and 1877. The ordinary rise of the rivers in freshets in this neighborhood is from 2 to 6 feet, but in 1870 they rose in places 20 feet. The mills on these streams have, like those on South river, from 2 to 4 pairs of stones, which they can generally run all the time, with falls of from 5 to 10 feet.(*a*) North river is especially well utilized, having no fewer than 17 mills of various kinds, including the woolen mill of the Bridgewater Manufacturing Company, which uses a fall of 10 feet and 20 or 30 horse-power. Some very small tributaries, like Cook's creek and Mossy creek, heading in springs, run small mills. The fall from Port Republic to Mount Crawford, on North river, a distance of 16.35 miles, is 92.64 feet, or at the rate of 5.67 feet per mile.(*b*)

Perhaps the most prominent unimproved power in this neighborhood is one situated on Middle river (*c*) at Port Republic, just above where it joins the South river, although the fall is small. It is said that a dam 6½ feet high could be erected—the bed of the stream being solid limestone, and very favorable for its construction—giving an available fall of 8 feet, with banks favorable to the utilization of the power, and high enough to be perfectly safe in times of freshet. The width of the stream is about 350 feet, the drainage area being about 770 square miles. I should estimate the power about as follows:

State of flow, (see pages 8 to 11).	Drainage area.	Fall.	Flow per second.	Horse-power available, gross.		Remarks.
	Sq. miles.	*Feet.*	*Cubic feet.*	*1 foot fall.*	*8 feet fall.*	
Minimum	770	8	110	12.5	100	Flow more constant than on lower parts of Shenandoah.
Minimum low season			131	14.9	120	
Maximum with storage			680	77.3	620	
Low season, dry years			150	17.0	135	

The powers given in the table could be increased to some extent during twelve hours by drawing down the water in the pond. This site is owned by Mr. John W. Palmer, of Port Republic.

a My acknowledgments and thanks are especially due to Edward S. Kemper, esq., county surveyor of Rockingham county, and to G. W. Berlin, esq., of Harrisonburg, for detailed and valuable information regarding this part of the state.

b *Annual Report of the Chief of Engineers*, 1880, p. 675.

c There seems to be a little uncertainty regarding the names of these streams, some considering North river a tributary of Middle river, and others considering the former the main stream.

There is another site at Port Republic, on South river, where, with a dam 4½ feet high and a race of 250 yards, a fall of 11 feet is said to be available. But, as the stream is only about one-third as large as Middle river, the power is small; before the war it was utilized. Both of these sites are very favorably located as regards transportation.

Finally, there is a third site, not used, about 2 miles above Port Republic, on North river, at Scott's ford. A fall of 6 feet was once used, with a dam 5 feet high, but in 1870 all of the buildings were carried away by the flood.

The North fork of the Shenandoah is similar in general character to the South fork, and its water-power is used only to run small grist- and saw-mills. Its fall, from the turnpike near Strasburg to the junction with the South fork, a distance of 13.32 miles, is 52.36 feet, or nearly 4 feet per mile. The following extract from the report of James Herron, reprinted in the *Annual Report of the Chief of Engineers* for 1880, page 668, will give an idea of the stream:

From the forks the survey took up the North fork, through good bottom-lands, with but one short bluff before reaching Cedar creek. Above this the river seems to have cut through a spur of the Three-top mountain, round the base of which it winds, forming a good bottom in the bend. The valley-side, however, which was occupied by our survey, consists of high and steep slate rocks, forming a deep crescent of a mile and a half in extent, against which the river impinges with great violence in times of freshets; beyond this, very good bottoms continue to some distance above Strasburg.

From near Strasburg to the mouth of Stony creek the North fork is extremely crooked, so much so indeed that no adequate idea of it can be conveyed. The tongues of land that form its numerous bends consist alternately of the high slate spurs from the Fort mountain, interlocked with equally high limestone ridges of the valley. There are 29 of these tongues, each one of which forms one or more small but highly-cultivated farms, in a distance of about 20 miles. The distance to the mouth of Stony creek, by the survey, is 42 miles 43.03 chains, showing an increase of distance amounting to 22½ miles; the course of the stream is still longer, for the survey cut off the bottoms in the bends.

The level of the river at the mouth of Stony creek was ascertained to be 515.53 feet above the Potomac, 757.96 feet above tide, and consequently 256 feet above its surface near Strasburg, which is at the rate of 6 feet to the mile; and did it run in a straight line it would be 12.8 feet. The latter is the general fall of the country, and has been found to hold with regard to the ridges and streams crossed by the line I have selected for a railroad, though remote from the river, the latter being left at Stony creek.

The mills on the stream are small, as will be seen by referring to the table of utilized power below. The dams are generally of wood or brush, and the mills have 2 or 3 pairs of stones, but, on account of leakage, are not able to run them all the year. The flow of the stream is quite variable, although some of its tributaries, especially in the upper part of the valley, are constant. The discharge at the mouth may be estimated at about 130 cubic feet per second when at its minimum, and about 180 cubic feet during the low season of dry years. The drainage area above Woodstock is about 618 square miles, and above Mount Jackson, 425. The rainfall is about the same as already given for the South fork.

The next tributary of the Potomac worthy of mention is the Antietam river, which has its sources in Franklin county, Pennsylvania, and flows nearly south through a distance of about 30 miles in a straight line, emptying into the Potomac in Washington county, Maryland, after draining an area of about 340 square miles. It drains a rolling and fertile country, but its declivity is uniform and uninterrupted by falls and rapids. It is utilized to a considerable extent, together with its tributaries, to run principally grist-, flour-, and paper-mills, and there are said to be no sites of importance unimproved, though some of the improved powers are at present idle. The flow of the stream is very variable, the freshets sudden and quite violent, and the powers small, as a rule. The drainage area above Funkstown is about 200, and above Hagerstown about 190 square miles.

Conococheague creek, which rises in Adams and Franklin counties, Pennsylvania, and pursues a general course parallel to that of the Antietam, joining the Potomac near Williamsport, in Washington county, Maryland, and draining an area of about 500 square miles, is the next tributary of importance. It resembles the Antietam in all essential respects, and, like it, is utilized for grist- and paper-mills, none of which are very large. Further particulars regarding the water-power of the stream could not be obtained with the time at disposal.

The remaining tributaries of the Potomac below the junction of the two forks are similar in their general characteristics, and drain the narrow longitudinal valleys between the ridges through which the Potomac breaks in this part of its course. Their fall does not seem to be great, and their power is unimportant. Their tributaries—secondary tributaries of the Potomac—often have, it is true, large falls, descending as they do from the ridges to the narrow valleys, but they are so small that they run nearly dry in summer. These streams have in some cases rocky beds, and rock is always found at a small depth; but their declivities, at least those of the primary tributaries of the Potomac, are on the whole uniform. The table of utilized power on pages 52 to 54 will show that they are used to some extent for power; but they are quite variable in flow, some of them being subject to quite heavy freshets, and their water-power may be said to be of little importance. The table on page 40 gives the drainage areas of some of these streams.

The following approximate elevations above tide are given by Chauncey Ives, esq., assistant engineer of the Cumberland Valley railroad:

	Feet.
East branch of Conococheague creek at Scotland, Pennsylvania, crossing of Cumberland Valley railroad	656
Falling Spring creek at Chambersburg, Pennsylvania, crossing of Cumberland Valley railroad	608
East branch of Conococheague creek at lower crossing of Cumberland Valley railroad	473
Back Creek crossing of Cumberland Valley railroad	456
West Branch of Conococheague Creek crossing of Cumberland Valley railroad	500
Potomac River crossing of Cumberland Valley railroad	316

These elevations are referred to *high* tide in the Schuylkill river at Philadelphia.

It only remains to say a few words regarding the North and South forks of the Potomac.

The North fork takes its rise in Grant county, West Virginia, nearly on the line between West Virginia and Maryland, and for nearly its whole length forms the dividing line between those two states, pursuing a general course about 60 miles in length, and draining a mountainous area of about 1,300 square miles. The table on page 9 shows that its maximum discharge at Cumberland is over 700 times its minimum, a ratio which is exceedingly large for a stream draining such a large area (684 square miles without Wills creek) and which finds its explanation in the absence of lakes, the steepness of the mountain slopes, and the narrowness of the valleys, all characteristics which seem especially pronounced in this case. These great fluctuations in flow, however, are fatal to the extensive use of water-power on the stream. Reference to the table on page 9 shows that the minimum flow of the stream at Cumberland is about 25 cubic feet per second, or not enough to supply the canal, which terminates at this point; so that although there is a canal dam (there (dam No. 8) 400 feet long and 8 feet high above low water, built of masonry, and with favorable sites for utilization of power, at some seasons no power could be obtained. The fall of the stream both above and below Cumberland is large, and the facilities for dams excellent, but its water-power is practically valueless.

Some of the tributaries of the North fork partake of its general characteristics, while others are said to be quite constant in flow, and to be fed by perennial springs; but all of them are comparatively small, and although their fall is often rapid, their power is still, on the whole, of no importance. The principal of these streams are Patterson's creek, which rises in Grant county, West Virginia, and flows northeast into Mineral county, draining an area of about 225 square miles, and Wills creek, which enters at Cumberland from the north, draining about 235 square miles, in Pennsylvania and Maryland; but no details could be obtained regarding them.

The South fork of the Potomac has its sources in Highland county, Virginia, and Pendleton county, West Virginia, near the head-waters of the James. Below the junction of the numerous forks which go to form the stream, and which pursue almost parallel courses through narrow valleys, it flows in a northeasterly direction through a narrow and fertile valley, draining a total area of 1,580 square miles. The drainage basin is thinly settled, and very inaccessible, not being traversed by a single railroad. The bed of the stream is mostly coarse gravel, and the banks are of loose sediment, and, on account of the sudden and local swells to which the river is subject, the channel is in a continual state of change. The facilities for dams are not very good, for they are liable to be undermined, and require extensive aprons. The fall of the stream is gradual, and varies from 7 to 8 feet per mile on the upper part (above Moorefield, about 54 miles from its mouth, measured along its course) to 4 feet per mile near the mouth. At no places are there concentrated falls of any magnitude, though in one place, about 20 miles below Moorefield, a rift is mentioned having a fall of 6 feet and over in 275 yards. The following table gives the elevations of four points on the stream :(a)

Slope of the South fork of the Potomac river.

Locality.	Distance from mouth.	Elevation above mouth.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet*
Mouth	0.0	0			
			29.6	127	4.3
Opposite Romney	29.6	127			
			24.0	151	6.3
Moorefield	53.6	278			
			12.0	97	8.1
....	65.6	375			

Very little definite information could be obtained regarding the water-power of the stream; but as regards that which is utilized the table on pages 52 to 54 shows that it is very small in amount. There are probably numerous sites where power could be developed by damming, but no particular ones can be mentioned. No information regarding the flow of the stream could be obtained, but the freshets are said to rise from 9 to 15 feet, and the flow is no doubt very variable, like that of the North branch.

The following table gives the drainage areas of the South branch and some of its tributaries:

	Square miles.
South branch at mouth	1,580
South branch at Romney	1,484
South branch below junction of forks	1,264
South fork of South branch at mouth	361
North fork of South branch at mouth	903
Middle fork of South branch at mouth	306
North fork of South branch above mouth of Middle fork	346

a Eighth Report of the Board of Public Works of Virginia, 1823.

Table of utilized power on the Potomac river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
Potomac river	Chesapeake bay	District of Columbia (a)		Paper (b)	1	34½	118
Do	do	do		Corn (b)	1	34½	92
Do	do	do		Fertilizers (b)	1	34½	65
Do	do	do		Flour (b)	5	172	730
Do	do	Maryland	Frederick	Flour and fertilizers (b)	1	6	37
Do	do	do	Washington	Flour (b)	1	17	25
Do	do	do	do	Saw (b)	2	16	....
Do	do	do	do	Sumac (b)	1	25	....
Do	do	do	do	Carpentering (b)	1	21	....
Do	do	do	do	Grist (b)	1	24	....
Do	do	do	do	Cement (b)	1	24	....
Do	do	West Virginia	Jefferson	do	1	8	40
Tributaries of	Potomac river	Virginia	Northumberland	Flour and grist	5	50	42
Do	do	do	do	Saw	3	30	36
Do	do	do	Westmoreland	Flour and grist	3	44	32
Do	do	do	King George	do	4	49	100
Do	do	do	Stafford	do	2	35	26
Do	do	do	Fauquier	do	8	167	115
Do	do	do	do	Plaster	1	24	27
Do	do	do	Prince William	Flour and grist	7	....	259
Do	do	do	do	Saw	2	38	30
Do	do	do	Fairfax	do	2	47	40
Do	do	do	do	Sumac	1	26	10
Do	do	do	do	Flour and grist	6	112	200
Do	do	do	Loudoun	do	32	490	529
Do	do	do	do	Saw	4	58	56
Do	do	do	do	Woolen	2	....	18
Do	do	District of Columbia		Flour and grist	3	40	125
Do	do	Maryland	Saint Mary's	do	7	100	156
Do	do	do	do	Saw	2	27	58
Do	do	do	Charles	do	1	23	8
Do	do	do	do	Flour and grist	7	115	96
Do	do	do	Prince George	do	8	112	149
Do	do	do	Montgomery	do	21	325	392
Do	do	do	do	Saw	2	27	34
Do	do	do	Frederick	do	17	233	177
Do	do	do	do	Blast-furnace	1	60	60
Do	do	do	do	Leather	1	12	4
Do	do	do	do	Machinery	1	5	3
Do	do	do	do	Woolen	8	47	26
Do	do	do	do	Flour and grist	84	1,197	1,710
Do	do	do	Carroll	do	29	400	469
Do	do	do	do	Saw	20	....	208
Do	do	do	do	Agricultural implements	1	10	8
Do	do	do	do	Woolen	2	....	15
Do	do	do	do	Blacksmithing	1	....	6
Do	do	do	do	Cheese and butter	1	9	8
Do	do	do	do	Fertilizers	1	10	40
Do	do	do	do	Iron foundery	1	....	6
Do	do	do	Washington	Flour and grist	51	697	1,192
Do	do	do	do	Saw	12	169	128
Do	do	do	do	Fertilizers	1	9	90
Do	do	do	do	Agricultural implements	2	19	24
Do	do	do	do	Blast-furnaces	c 2	56	90
Do	do	do	do	Furniture	1	22	20
Do	do	do	do	Paper	1	7	70
Do	do	do	Garrett	Flour and grist	4	57	62
Do	do	do	do	Saw	3	47	72
Do	do	do	do	Woolen	1	6	18
Do	do	do	Alleghany	Saw	2	30	35
Do	do	do	do	Flour and grist	13	196	309
Do	do	do	do	Printing	1	....	5
Shenandoah river and tributaries	do	West Virginia	Jefferson	Flour and grist	12	214	....

a Power returned by enumerator in District of Columbia is as follows—Paper: 1 mill, 30 feet fall, 95 horse-power used, net. Fertilizers: 1 mill, 32 feet fall, 27 horse-power used, net. Flour and grist: 6 mills, 30 to 40 feet fall at each; 636 horse-power used, net.

b Supplied with power from the canal.

c One not in operation.

Table of utilized power on the Potomac river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
Shenandoah river and tributaries	Potomac river	West Virginia	Jefferson	Saw	4	65	66
Do	...do	...do	...do	Iron foundery	1	4½	6
Do	...do	...do	...do	Leather	1	4	7
Do	...do	Virginia	Clarke	...do	3	88	22
Do	...do	...do	...do	Flour and grist	10	235	148
Do	...do	...do	...do	Cheese and butter	1	2	1
Do	...do	...do	Frederick	Flour and grist	4	73	89
Do	...do	...do	...do	Saw	1	10	25
Do	...do	...do	...do	Woolen	6	......	......
Do	...do	...do	Warren	...do	5	......	82
Do	...do	...do	...do	Sumac	1	14	25
Do	...do	...do	...do	Flour and grist	15	202	318
Do	...do	...do	Shenandoah	...do	35	516	613
Do	...do	...do	...do	Blast-furnaces	*a* 3	74	63
Do	...do	...do	...do	Saw	23	322	304
Do	...do	...do	...do	Forges	*a* 2	......	41
Do	...do	...do	...do	Furniture	1	2¼	10
Do	...do	...do	...do	Leather	2	15	10
Do	...do	...do	...do	Machinery	1	12	12
Do	...do	...do	...do	Woolen	1	10	15
Do	...do	...do	Page	Flour and grist	20	......	204
Do	...do	...do	...do	Saw	2	12	24
Do	...do	...do	...do	Leather	1	16	6
Do	...do	...do	...do	Woolen	1	10	24
Do	...do	...do	Rockingham	Flour and grist	32	426	610
Do	...do	...do	...do	Saw	14	180	213
Do	...do	...do	...do	Leather	2	36	18
Do	...do	...do	...do	Plaster	1	8	10
Do	...do	...do	...do	Agricultural implements	2	11	38
Do	...do	...do	...do	Furniture	1	28	12
Do	...do	...do	...do	Fertilizers	1	6	12
Do	...do	...do	...do	Blast-furnace	*b* 1	6	25
Do	...do	...do	...do	Marble and stone works	1	10	13
Do	...do	...do	...do	Forge	*b* 1	18	30
Do	...do	...do	...do	Woolen	4	64	54
Do	...do	...do	Augusta	...do	3	......	......
Do	...do	...do	...do	Flour and grist	50	737	1,069
Do	...do	...do	...do	Saw	12	190	270
Do	...do	...do	...do	Agricultural implements	1	9	15
Do	...do	...do	...do	Blacksmithing	1	14	2
Do	...do	...do	...do	Foundery	1	12	6
Do	...do	...do	...do	Machinery	1	12	6
Do	...do	...do	...do	Sash factory	1	7	30
Do	...do	...do	...do	Wheelwrighting	1	6	6
Other tributaries of	...do	...do	Clarke	Flour and grist	1	14	25
Do	...do	...do	Frederick	...do	18	319	374
Do	...do	...do	...do	Furniture	1	18	6
Do	...do	...do	...do	Woolen	6	......	77
Do	...do	West Virginia	Hampshire	Blast-furnace	1	15	15
Do	...do	...do	...do	Woolen	3	78	52
Do	...do	...do	Jefferson	Saw	5	87	95
Do	...do	...do	...do	Flour and grist	9	161	203
Do	...do	...do	...do	Leather	1	1	1
Do	...do	...do	...do	Paper	1	10	10
Do	...do	...do	...do	Woolen	1	20	20
Do	...do	...do	Berkeley	Flour and grist	22	368	363
Do	...do	...do	...do	Saw	10	136	115
Do	...do	...do	Morgan	...do	5	51	81
Do	...do	...do	...do	Flour and grist	4	43	76
Do	...do	...do	...do	Woolen	1	13	12
Do	North branch Potomac	...do	Mineral	Flour and grist	6	88	104
Do	...do	...do	...do	Woolen	2	27	45
Do	...do	...do	Grant	Saw	5	68±	82
Do	...do	...do	...do	Flour and grist	5	84	145
Do	...do	...do	...do	Woolen	3	39+	35

a One not in operation. *b* Not in operation.

Table of utilized power on the Potomac river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
South branch Potomac river	Potomac river	West Virginia	Hampshire	Flour and grist	3	18	48
Do	do	do	do	Saw	2	22½	24
Do	do	do	Hardy	Flour and grist	1	4½	20
Do	do	do	Grant	do	2	15	35
Do	do	do	do	Woolen	1	......	6
Do	do	do	Pendleton	Flour and grist	8	73	88
Do	do	do	do	Saw	1	5½	10
Do	do	do	do	Woolen	1	6	15
Tributaries of	South branch Potomac	do	Hampshire	Saw	1	14	8
Do	do	do	do	Flour and grist	3	45	59
Do	do	do	Hardy	Saw	2	29	33
Do	do	do	do	Flour and grist	1	7½	18
Do	do	do	Pendleton	do	3	50	43
Do	do	do	do	Woolen	1	2	8
Do	Potomac river	do	Hampshire	Saw	9	......	96
Do	do	do	do	Flour and grist	12	180	187
Do	do	do	Hardy	do	9	148	100
Do	do	do	do	Woolen	1	10	6
Do	do (*a*)	do	do	do	2	......	11
Do	do	Pennsylvania	Adams	Saw	12	172	139
Do	do	do	do	Flour and grist	19	298	269
Do	do	do	do	Woolen	1	......	......
Do	do	do	Franklin	Flour and grist	74	916	1,479
Do	do	do	do	Saw	21	271	203
Do	do	do	do	Leather	2	28	26
Do	do	do	do	Agricultural implements	2	......	22
Do	do	do	do	Furniture	1	4	25
Do	do	do	do	Machinery	1	......	5
Do	do	do	do	Paper	3	26	170
Do	do	do	do	Blast furnace	1	10	10
Do	do	do	do	Woolen	4	40	60
Do	do	do	Fulton	Flour and grist	18	260	357
Do	do	do	do	Saw	3	32	65
Do	do	do	do	Woolen	2	42	80
Do	do	do	do	Fertilizers	2	10	32
Do	do	do	Bedford	Flour and grist	1	16	16
Do	do	do	Somerset	Saw	2	......	37

a Perhaps tributary to South branch.

V.—THE SMALLER TRIBUTARIES OF CHESAPEAKE BAY.

Before proceeding to describe the Susquehanna river, there remain to be noticed a few small tributaries of Chesapeake bay, some of which, however, are notable on account of their utilized power, serving to run in part some of the largest manufacturing establishments in this part of the country.

Those streams entering the bay from the east may be dismissed with a few words. The region they drain is flat and often low, with a soil of clay and sand, and they belong to the class of sand-hill streams, their flow being quite constant, and the declivities, as a rule, uniform. They are utilized to a large extent to drive grist- and saw-mills, but their powers are all very small. The total power utilized is tabulated at pages 58 and 59, *infra*.

The streams from the west and north possess considerable power in proportion to their size, their principal part being, of course, above the fall-line, up to which they are often tidal. This fall-line, as remarked in the introduction, crosses the Potomac several miles above Washington, passes nearly through Baltimore, and follows the bay in a northeasterly direction, leaving Maryland not far from its northeastern corner, and probably passing through the northern part of the state of Delaware. Below the fall-line there are some small powers on streams belonging to the sand-hill class, and similar in character to those on the other side of the bay.

The rainfall over the entire region referred to may be taken at about 47 inches, of which 12 fall in spring, 13 in summer, 12 in autumn, and 10 in winter.

The first stream above or north of the Potomac which is worthy of special mention is the Patuxent river, which has its sources in Howard and Montgomery counties, Maryland, and pursues a southeasterly and then a southerly course, forming the boundary line between the counties of Howard, Anne Arundel, and Calvert, on its left, and Montgomery, Prince George's, Charles, and Saint Mary's, on its right, emptying into the bay 18 or 20 miles above the mouth of the Potomac. It drains an area of about 960 square miles, and its length, measured in a straight line, is about 80 miles. It is navigable for 40 or 50 miles from its mouth, and crosses the fall-line, passing from the middle to the eastern or alluvial district, near Laurel, in the vicinity of which place there are several powers. Above this point the drainage area of the stream measures a little over 200 square miles, and includes a hilly and rolling country, with no lakes, a soil of sand and clay, and some limestone in parts. The flow of the stream is very variable, with heavy freshets and sudden rises, and a very small flow in the dry season. In 1868 a freshet occurred which carried away, it is said, every dam on the stream. The bed is often rock, sometimes overlaid with a thin layer of gravel, and the fall is quite rapid. The mills are not much troubled with ice, but the complaint is made that the flow is becoming more variable, the summer flow less, and the freshets more violent.

The following are the most important powers on the stream:

Near Laurel is the Avondale flour-mill, with a fall of 8 or 9 feet, and some 60 or 70 horse-power used. Just above it is the Laurel cotton factory, with a stone dam 300 feet long, 28 or 29 feet high, a race about 1,000 feet long, and a utilized fall of about 30 feet. A power of 200 horse-power is used, which can generally be obtained during only nine months or less, so that an engine of 150 horse-power is used in the dry season.(*a*) Judging from analogy, one would not expect the stream to afford over 5 gross horse-power per foot fall in the minimum low season, or from 7 to 8 in the low season of ordinary years. There is no artificial storage (except in the mill-ponds) in the basin of the Patuxent.

About a mile and a quarter above Laurel there is an unimproved power, consisting of a rapid fall amounting, it is said, to 20 feet or over in a short distance. I am unable to speak authoritatively of the value of this site.

The Guilford cotton factory, farther up, has a stone dam 200 feet long and 8 feet high, a race 2,500 feet long, and a utilized fall of 14 feet. The power used is 50 horse-power, which can be obtained during eleven months generally, while during the remaining month sometimes only one-half can be obtained. Steam-power is used during the dry season to the extent of 75 horse-power.(*b*)

There are other powers on the stream above this, including a woolen-mill, grist- and saw-mills, but they are all small. The statistics regarding them will be found tabulated at pages 58, 59.

The Patuxent receives as a tributary below Laurel the Little Patuxent, a stream draining some 60 or 70 square miles, and with one power worth naming, the Savage cotton factory, near Savage station on the Baltimore and Ohio railroad. The dam is 185 feet long and 18 feet high, the race is half a mile long, and the fall used is 55 feet, capable of being increased, it is said, to 60 feet. A power of 250 horse-power is used, and can generally, it is said, be obtained all the year, but probably by drawing down the water in the pond during the day-time.(*c*) There are said to be two unimproved sites on the Little Patuxent near this factory, with falls of 15 feet and over.

The next stream of importance is the Patapsco river, which is formed by the union of its North and South forks, and flows rather south of east, between the counties of Howard and Anne Arundel on the south, and Baltimore on the north, emptying into Chesapeake bay just below the city of Baltimore. Of its two branches, the North fork rises in Carroll county and flows south, draining about 129 square miles, and the South fork rises in Carroll and Howard counties and flows east between them, draining about 100 square miles. The total area drained by the Patapsco measures about 350 square miles, and lies almost entirely above the fall-line, so that the area valuable for water-power is greater than in the case of the Patuxent. The character of the basin is similar to that of the latter stream. It has no lakes or artificial reservoirs, and the flow of the stream is quite variable; but the freshets do not occasion very large rises of the water, on account of the fall of the stream, which is rapid for the greater part of its course, and is utilized for power to a considerable extent. The width of the stream averages 100 to 150 feet, and the rise in a heavy freshet is said seldom to exceed 6 or 7 feet in the lower part of its course. The bed is generally rock, the banks are abrupt or shelving, very little land is subject to overflow, and the facilities for power, so far as the location goes, are in every respect favorable. The Baltimore and Ohio railroad follows the stream closely from Relay Station almost to the source of the South fork, thus rendering every point easy of access.

The following are the powers on the stream:

At Relay Station, about 5 miles from Baltimore and 15 miles from the bay, is the Hockley flour-mill, the first power on the stream, and at the lower extremity of the fall caused by its crossing of the fall-line. The dam is of wood, 250 feet long and 8 feet high, almost entirely rebuilt in 1874, and the fall at the mill, 200 yards below, is 8 feet. A power of 100 horse-power is utilized, running 8 sets of stones. Full capacity can be secured during only nine months, the mill being run night and day, and in dry seasons only 5 or 6 sets can be run. The drainage area above this place being about 310 square miles, analogy would lead us to expect that the stream here would afford a power of about 8 horse-power (gross) per foot fall in the minimum low season, and about 12 in the low season of ordinary years; but these figures may really be increased to some extent, during the day-time at least, by the storage effected by the numerous mill-ponds above.

a Steam-power stated at 200 horse-power in statistics of cotton-mills.

b In Statistics of Cotton Mills the mill is stated to be on the North branch of the Patuxent river, the fall is given as 13 feet, the water-power used as 75 horse-power, and the steam-power as 50 horse-power. I am not able to say whether the information given me or these statements just given are in error.

c In Statistics of Cotton Mills this mill is given as on the Patuxent river. Fall stated at 55 feet; power at 200 horse-power.

The next utilized power is about a mile and a half above, at the Orange Grove mill, but between the two there is considerable fall in the river, amounting, it is said, to between 20 and 25 feet. Of this, a fall of about 15 feet was formerly used to run iron-works, but the dam was washed out in the freshet of 1868, and at present the site is idle. The remainder of the fall referred to has never been utilized.

The Orange Grove flour-mill (C. A. Gambrill & Co.) has a dam of wood and stone, 180 feet long and 15 feet high, built in 1857, and ponding the water over 5 or 6 acres, it is said. A fall of 12 feet is used by 5 turbine wheels, affording 250 horse-power. The mill has 23 sets of stones, of which 13 are run by water and 10 by steam exclusively. The full capacity of the water-wheels can be utilized during only about six months, the capacity becoming at times less than one-half. According to what has been said regarding the capacity of the stream, a power of 144 horse-power gross would be all that could be expected here in the low season of ordinary years; and as the mill runs night and day there is no storage except what is due to the mills above. During the day-time it is said that water always wastes, a large amount being let down by the mills above.

Above this mill there are said to be two unimproved powers, the first with a fall of some 25 or 30 feet, which has never been utilized; the second with a fall of some 11 feet, formerly used, but now entirely unimproved. The latter site is at Ilchester. From the above remarks regarding capacity, an idea can be formed of the available power at these places.

The next power is the Thistle cotton factory, but no details could be obtained regarding it. The fall is said to be about 12 feet.(a)

Next above is Gray's cotton factory, at Ellicott City, where a fall of about 9 feet is used, and a power of 75 to 80 horse-power is obtained.(b) A 50 horse-power steam-engine is used in the low season. The dam is of wood, about 172 feet long and 8 feet high, ponding the water over about 6 acres.

Just above is the Patapsco mill of C. A. Gambrill & Co., with a fall of 12 feet and 250 horse-power. The mill has 12 pairs of stones run by water and 10 by steam, a 200 horse-power engine being run all the time. Full capacity can be obtained for less than six months, as would be expected. The dam is of wood and stone, 180 feet long and 3 feet high, built in 1879 at a cost of $2,000.

Next comes an unimproved site of the Union Manufacturing Company, with an available fall said to amount to 15 feet in three-quarters of a mile. The site was once used, but the works were washed away.

Next above is the cotton factory of the Union Manufacturing Company of Maryland. The dam is of wood, 185 feet long and 10 feet high, and was built in 1867 at a cost of about $15,000. It ponds the water over about 17 acres, and from it a race 2 miles in length leads to the mill, where the fall is 30 feet. A power of 310 horse-power is utilized, and can be obtained all the year, so that no steam-power is used.(c) The mill is run ten hours a day, and water generally wastes over the dam except at very low stages. The drainage area above this site, as well as above the three preceding and the three following, may be taken as 275 square miles, so that we may estimate the flow at about 10 per cent. less than at Relay Station—that is, we should expect the stream to afford about 7 horse-power (gross) per foot fall in the lowest season in a series of years, and 11 in the low season of ordinary years, an estimate which agrees remarkably well with the power stated for the Union factory, when we consider the loss from imperfect motors, and the fact that the supply during the day-time is greater than at night, on account of the mills above.

Below Elysville is the Alberton cotton factory, with a fall of 19 or 20 feet, and using 430 horse-power, which, however, can be obtained only during eight months.(d) During the remaining time, steam-power is used to the extent of 175 horse-power on the average, and sometimes as much as 300 horse-power. The dam, which is 2,000 feet above the mill, is of wood, 160 feet long and 19 feet high, and was built in 1867 at a cost of $30,000. In the summer the water is drawn down in the pond during working-hours.

Next comes a site formerly used by a flour-mill, but now entirely unimproved, known as "Ellicott's old upper mill", with a fall of 8 or 9 feet.

At Elysville is a second unimproved power, once used by a woolen-mill, and afterward by a grist-mill, the fall being about 10 feet.

Above this there are several small powers, some improved and others not, but none of them remarkable, so far as could be learned. The fall issaid to be rapid all along the stream, but the declivity is gradual.

On the two branches of the Patapsco there are a number of small mills, generally grist- and saw-mills, with some paper- and woolen-mills, but none of them are large. On the North fork, for instance, J. A. Dushane & Co. have a paper-mill with a fall of 9 or 10 feet and are using about 100 horse-power, but this can be obtained during only from five to eight months. There are, of course, some sites not used, offering small powers. Near Sykesville there is said to be one, formerly used, with a fall variously stated at from 12 to 19 feet.

The Patapsco river is the most important manufacturing stream of Maryland, and its water-power is excellent, as we have seen. No other stream in the state, with the exception of the Potomac, offers so many advantages or so many favorable sites for power.

a Fall given as 12 feet and power as 221 horse-power, in returns of enumerators.

b Power given as 120 horse-power in returns of enumerators.

c Fall given as 26 feet and power as 369 horse-power, in returns of enumerators.

d Fall given as $17\frac{1}{2}$ feet and power as 480 horse-power, in returns of enumerators. Steam-power, 350 horse-power.

Mention should be made here of two small streams which enter the lower part of the Patapsco, and are utilized to a considerable extent, viz, Gwynn's falls and Jones' falls. They are very small streams, very variable in flow, and really of almost no value for power. They have, however, considerable fall, and are utilized by a number of mills which run about half the year at full capacity by water-power, and during the rest of the time either use steam-power extensively or use very little power of any kind. On Gwynn's falls there is a flour-mill with a fall of 18 feet, and 75 horse-power during about seven months; above it is an unimproved privilege with a fall of about 16 feet; and above that are two flour-mills fed from one dam, one with a fall of 22 feet, and 100 horse-power during eight or nine months, and the other with a fall of 18 feet, and 60 or 75 horse-power during six months. This last site is only half a mile above Baltimore. Above it, and below Wetherdsville, is an unimproved privilege formerly used by a flour-mill, with a fall of 20 to 25 feet. Farther up are the Ashland woolen-mills, at one of which the fall is 22 feet, and the power 80 horse-power during about nine months, and at the other the fall is 28 feet, and the power 70 horse-power during nine months. Above, we come to the Powhatan cotton factory, where a fall of 22 feet is used, with 75 horse-power during, in some years, less than six months. Finally, there are a few grist-mills near the head-waters. Although used to such an extent, the water-power of the stream is of little value, because the flow is so variable that no dependence can be placed on the power, and steam must be relied on principally. Jones' falls is a still smaller stream, and is used by the city of Baltimore for supplying the city with water, so that, although there were formerly several mills on the stream run by water-power, they are now almost entirely run by steam, and the water-power of the stream is valueless.

The only other tributary entering from the west which is worth mentioning is Gunpowder river, a very short stream, being formed only a few miles from its mouth by the union of Big and Little Gunpowder creeks, or "falls", as many creeks in this neighborhood are called. Big Gunpowder falls drains an area of about 275 square miles, lying in Baltimore and Carroll counties, and comprising a rolling and hilly country. The power at its mouth may be estimated at about the same as that of the Patapsco at Elysville, that is, at about 7 horse-power gross in the lowest season, and about 11 in the low season of ordinary years; but the lower part of the stream is not available for power, as one of the reservoirs to supply the city of Baltimore has been located on the stream and all the water-rights below the proposed site have been purchased by the city, including power formerly used by several metal-working establishments, one of which, the Gunpowder Copper Works, is still running with what water can be obtained. Above the reservoir site the stream has a uniform declivity, and a bed of gravel and sand, with rock sometimes at the surface. Considerable power is utilized, there being a number of small grist-, saw-, paper-, woolen-, and other mills on the stream and its various tributaries. The most important powers are the following: At Phœnix there is a cotton-mill, but for some reason it has not been running for six or seven years, although everything is said to be in good order. The fall is 12 or 15 feet, but the power I am unable to estimate. The Warren factory, another cotton factory, has a stone dam 300 feet by 12, and uses a fall of 14 feet, with 175 horse-power during most of the time, it is said, while steam-power is used in summer to the extent of 100 horse-power. A grist- and a saw-mill are run from the same dam. Above this there are a number of paper-mills, arranged to utilize all the power available during the winter, and sometimes getting full capacity during only three months. Thus, the Marble Vale mill, near Phœnix, has a fall of 9 feet and 120 horse-power; the Rock Dale mill, 20 feet and 150 horse-power; and there are other similar powers. At many of them steam is used during the summer, and often during a much longer period. There are a number of unimproved privileges on the stream; one at Monkton, where there was formerly a mill; one below the Rock Dale mill, said to have a large fall, and others farther up. The volume of water, however, is very small in the summer time.

Western run and Little Gunpowder creek, the latter draining about 73 square miles, are the principal remaining tributaries. They are utilized to a considerable extent, but the powers are so small as to call for no further comment.

Crossing the Susquehanna, a few of the small streams entering the bay from the north are utilized to a considerable extent for power, but their flow is very variable, and only a small amount of power is available in the low season. Principio creek runs an iron-furnace with a fall of 32 feet, and several grist- and saw-mills; North East creek and its tributaries run several woolen-mills, grist- and saw-mills, and the works of the McCullough Iron Company at North East. None of the powers are large. One site not used, on North East creek, known as Gilpin's falls, has the large fall of not less than 120 feet in a quarter of a mile, the stream pouring over masses of rock down a narrow valley, and forming a very picturesque spot. Although quite a resort for excursionists, the place is of little value as a site for power, because the stream is so small that in summer it will afford only about 1 horse-power per foot fall. The total area drained by North East creek is about 65 square miles, but probably not over half of this lies above Gilpin's falls.

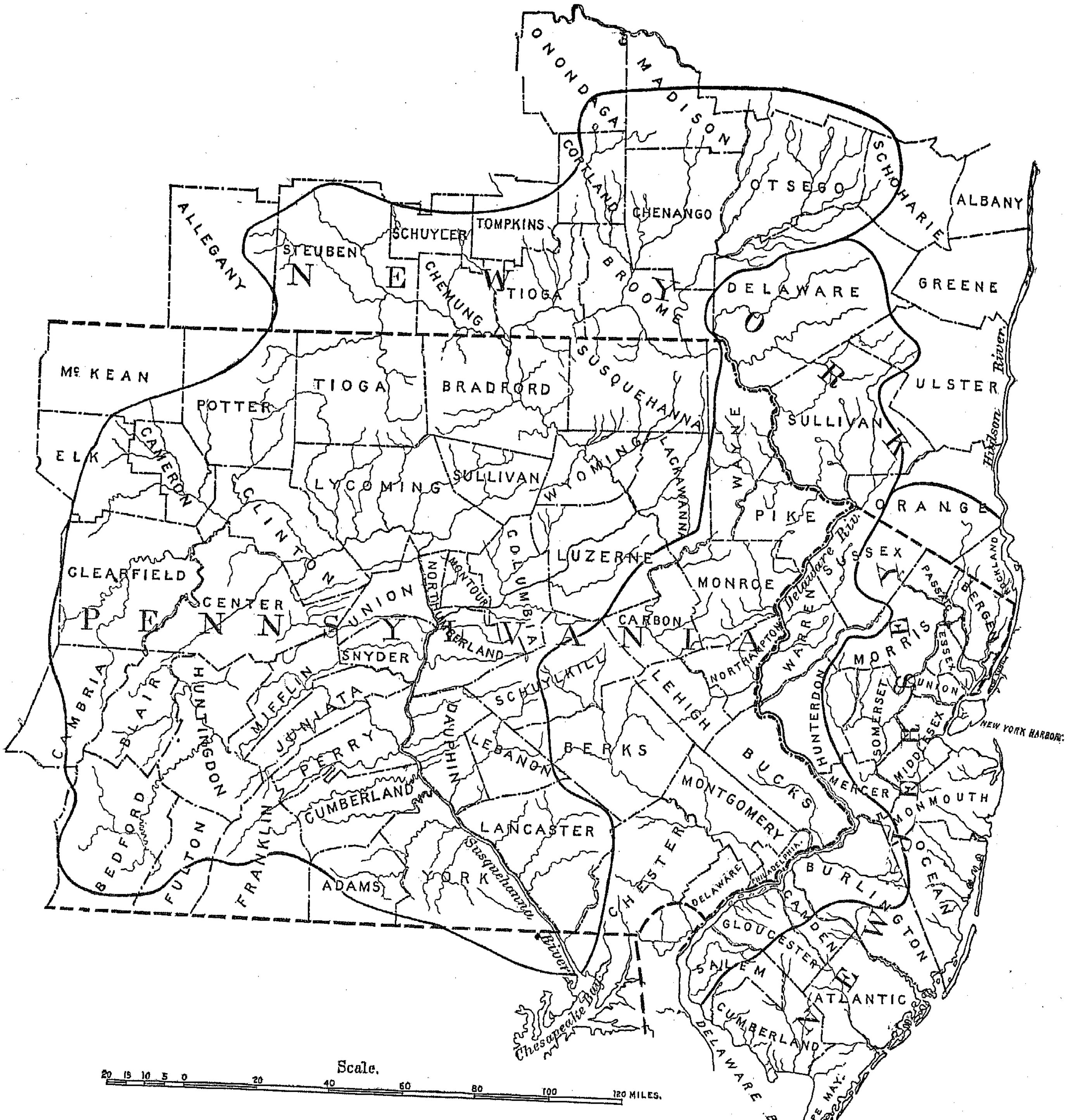
Big Elk creek, which drains 76 square miles, having its sources in Chester county, Pennsylvania, is similar in character to those already described, and is utilized for cotton-, woolen-, grist-, saw-, and paper-mills, and iron-works. At the works of the McCullough Iron Company, near Elkton, a fall of 20 feet is used, with a dam 16 feet high, and about 65 horse-power is obtained during ten months or thereabout, probably by drawing down the water in the pond, which is large. There are three unimproved sites on the stream where power could be obtained by damming, but no abrupt falls. At these places powers of from 20 to 40 horse-power could probably be developed during the greater part of the year.

Little Elk creek, which joins the Big Elk to form Elk river, drains only about 34 square miles. It is quite extensively used for flour-, paper-, and saw mills, and its fall is estimated at nearly 200 feet in its course through Cecil county, Maryland. There are several unimproved sites having quite large falls, viz, one near tide-water, said to have a fall of 24 feet; one just above Harlan's paper-mill, said to have over 30 feet fall in less than a mile; and smaller ones above.

The following table gives statistics regarding the utilized power on the streams we have been considering:

Table of utilized power on small tributaries of Chesapeake bay.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
Tributaries to	Chesapeake bay	Maryland	Worcester	Flour and grist	2	15	22
Do	do	do	Somerset	do	1	3	12
Do	do	do	Wicomico	do	17	107	238
Do	do	do	do	Saw	21	122	287
Do	do	do	Dorchester	do	10	90	112
Do	do	do	do	Flour and grist	8	75	96
Do	do	do	Talbot	do	5	68	99
Do	do	do	Caroline	do	16	182	281
Do	do	do	do	Saw	10	....	120
Do	do	do	Queen Anne	Flour and grist	8	115	205
Do	do	do	do	Woolen	1	13	50
Do	do	do	Kent	Flour and grist	8	88	174
Do	do	do	Cecil	do	20	280	393
Do	do	do	do	Furnace	1	38	50
Do	do	do	do	Saw	7	103	154
Do	do	do	do	Agricultural implements	1	10	6
Do	do	do	do	Paper	3	52	160
Do	do	do	do	Cotton	1	10	40
Do	do	do	do	Iron-works	3	74	450
Do	do	do	do	Woolen	2	....	15
Patuxent river	do	do	Anne Arundel	Flour and grist	2	20	65
Do	do	do	Prince George's	Cotton	1	30	200
Do	do	do	Montgomery	Flour and grist	3	62	128
Do	do	do	Howard	do	2	20	46
Do	do	do	do	Cotton	1	14	50
Do	do	do	do	Saw	1	8	14
Tributaries of	Patuxent river	do	Calvert	Flour and grist	2	21	16
Do	do	do	do	Saw	1	8	20
Do	do	do	Anne Arundel	do	1	6	10
Do	do	do	do	Flour and grist	3	54	37
Do	do	do	do	Cotton	1	55	250
Do	do	do	Prince George's	Saw	1	10	15
Do	do	do	do	Flour and grist	3	49	82
Do	do	do	Montgomery	do	5	111	71
Do	do	do	do	Saw	2	38	35
Do	do	do	do	Agricultural implements	1	18	20
Do	do	do	Howard	Flour and grist	1	12	30
Patapsco river	Chesapeake bay	do	Baltimore	Cotton	1	10	....
Do	do	do	do	do	1	9	75
Do	do	do	do	do	1	30	810
Do	do	do	do	Flour and grist	1	12	250
Do	do	do	do	do	1	12	250
Do	do	do	Howard	do	1	8	100
Do	do	do	do	Cotton	1	19	430
Tributaries of	Patapsco river	do	Baltimore	Flour and grist	16	301	468
Do	do	do	do	Saw	3	49	28
Do	do	do	do	Cotton	1	22	75
Do	do	do	do	Needles and pins	1	7	30
Do	do	do	do	Woolen	2	50	150
Do	do	do	do	Dyeing and cleaning	1	10	14
Do	do	do	Howard	Flour and grist	11	106	143
Do	do	do	do	Saw	5	74	55
Do	do	do	do	Agricultural implements	1	17	12
Do	do	do	do	Paper	1	20	100
Do	do	do	Carroll	Flour and grist	27	425	419
Do	do	do	do	Saw	13	203	153
Do	do	do	do	Paper	3	40	94



Drainage basins of the Susquehanna and Delaware rivers and of the Coast streams of New Jersey.

Table of utilized power on small tributaries of Chesapeake bay—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
Tributaries of	Patapsco river	Maryland	Carroll	Woolen	1	9	28
Do	...do	...do	...do	Leather	1	12	....
Do	...do	...do	Anne Arundel	Flour and grist	1	12	30
Other tributaries of	Chesapeake bay	...do	Baltimore	Copper-rolling	1	....	....
Do	...do	...do	...do	Flour and grist	27	641	561
Do	...do	...do	...do	Saw	22	398	274
Do	...do	...do	...do	Cotton	1	14	175
Do	...do	...do	...do	...do	1	25	160
Do	...do	...do	...do	Blast-furnace	1	8	60
Do	...do	...do	...do	Paper	15	245	596
Do	...do	...do	...do	Woolen	2	73	162
Do	...do	...do	Carroll	Flour and grist	5	....	64
Do	...do	...do	...do	Paper	1	18	75
Do	...do	...do	Harford	Flour and grist	18	280	429
Do	...do	...do	...do	Saw	4	57	62
Do	...do	...do	...do	Fertilizers	1	15	25
Do	...do	...do	...do	Carriage and wagon materials.	1	19	22
Do	...do	Delaware	Sussex	Flour and grist	11	80	283
Do	...do	...do	...do	Saw	10	95	258
Do	...do	Pennsylvania	Chester	Agricultural implements	1	12	10
Do	...do	...do	...do	Fertilizers	1	26	25
Do	...do	...do	...do	Flour and grist	19	351	285
Do	...do	...do	...do	Saw	9	109	126
Do	...do	...do	...do	Paper	4	67	146

VI.—THE SUSQUEHANNA RIVER AND TRIBUTARIES.

THE SUSQUEHANNA RIVER.

The Susquehanna, the largest stream on the Atlantic slope of the United States, though by no means the most important as regards water-power, has its sources entirely beyond the region of corrugations composing the eastern part of the Appalachian mountain system, on the elevated plateau which bounds that system toward the west and north, forming the water-shed between the waters flowing north and west into the Saint Lawrence, the Mississippi, and the great lakes, and those flowing into the Atlantic streams of this country. The river rises in Otsego lake, in Otsego county, New York, at an elevation above the sea of about 1,193 feet.(*a*) Its course lies first in a southwesterly and westerly direction, through Otsego, Chenango, Broome, and Tioga counties, New York, and with a portion of its course in Susquehanna county, Pennsylvania, and its volume is rapidly swelled by large tributaries, until, when it finally leaves New York in Tioga county, bending to the south to pursue a southerly course through Pennsylvania, its drainage area, just below the mouth of the Chemung, measures 7,463 square miles. In its course through Pennsylvania the stream passes through Bradford, Wyoming, Luzerne, Columbia, Montour, and Northumberland counties, to its junction with its West branch, whence it flows nearly south between Northumberland Dauphin, and Lancaster counties on the east, and Snyder, Juniata, Perry, Cumberland, and York counties on the west, passing then into Maryland, flowing between Cecil county on the east and Harford county on the west, and emptying into Chesapeake bay at its northern extremity. The total drainage area of the stream, which measures not less than 26,233 square miles, is divided as follows between the three states through which it flows: New York, 6,267; Pennsylvania, 19,711; Maryland, 255 square miles.(*b*) The principal large tributaries of the stream drain the following areas:

	Square miles.
Chenango river	1,540
Chemung river	2,518
West branch of the Susquehanna river	6,466
Juniata river	3,223

a *Geological Survey of New York*, Part III, p. 238 (1842).

b These are from my own measurements. It is to be mentioned, however, that Mr. Gannett, the geographer of the census, gives the drainage area of the Susquehanna as 27,655 square miles.

The river flows by a number of important cities and towns, among which may be mentioned the following: Binghamton, New York, at the mouth of the Chenango; Owego, New York, at the mouth of Owego creek; Athens, Pennsylvania, near the mouth of the Chemung, really on the latter stream; Towanda, Tunkhannock, Pittston, Wilkesbarre, Berwick, Bloomsburg, Danville, Northumberland (at the mouth of the West branch), Sunbury, Dauphin, Harrisburg, Marietta, Middletown, and Columbia, Pennsylvania; Port Deposit and Havre de Grace, Maryland. It is not navigable above its crossing with the fall-line, very near its mouth, but a canal extends along the stream as far up as Wilkesbarre, the river being navigated to some extent in the pools of the canal dams. When we add that the stream is closely followed for almost its entire length by railroads, it will be evident that the facilities for transportation leave nothing to be desired.

The drainage basin of the stream is very varied in character, embracing as it does such a large area. In the state of New York the stream, with its tributaries, flows through a rolling and sometimes rather broken country, forming the plateau bounding the mountain region on the north. Its declivity in this part of its course is very uniform, its bed gravel or sand, with seldom a rock ledge, and its banks moderately high, shelving, and not very extensively subject to overflow. It flows over beds of drift and offers little power. Passing into Pennsylvania, it enters the mountain region, and its course is in places very tortuous as it winds among the parallel ranges of hills. Its fall is gradual, as before, and its bed generally drift materials—gravel, sand, and bowlders. The banks are generally high, and there are few bottoms subject to extended overflow, although the river is subject to rises of 30 feet or thereabout. Below the mouth of the West branch the fall of the stream becomes rather more irregular, and at several places there are rapids where the stream flows over a rock bottom. In the lower part of its course, from Marietta to Havre de Grace, the stream "occupies a deep broad valley, varying in width from a few hundred feet to more than a mile, and on either shore it is for the most part bounded by rocky bluffs supporting table-lands at an elevation of from 100 to 500 feet above its waters".(*a*) The fall in this part of its course is quite rapid, the stream is often very wide, and the channel is dotted with islands and rocks. For a more detailed description of the river I can not do better than quote that given by Professor H. D. Rogers, in his *Geology of Pennsylvania*:

That portion of the Susquehanna river which flows near the northern boundary of the state passes from its sharp elbow, called the "Great Bend", to the mouth of its affluent, the Chemung river, through a charming broad valley, bounded by soft slopes terminating in wide table-shaped hills. It is a fertile and very beautiful district; and with its westward extension, the plain of the Chemung river is rapidly becoming one of the most attractive agricultural districts of New York. From the mouth of the Chemung river to Pittston, where the river suddenly turns at a right angle on entering the Wyoming coal-field, it flows, with many bendings, along a deep and picturesque valley, almost identical in its features with that of the corresponding stretch of the Delaware, the main difference being that the bed of the valley is wider and the hill-sides confining it less mountainous. From the mouth of the Lackawanna at Pittston, where it enters, to Nanticoke, where it leaves the beautiful Wyoming valley, the scenery along the river is wholly different. It flows through a broad and almost perfectly level, smooth plain—the Wyoming and Kingston flats—composed of a deep bed of diluvium or drift. On either side of this plain rise the rolling hills of the coal-basin, and behind these the long gentle slopes of the high mountain barriers which frame in the whole scene. At Nanticoke the river turns abruptly northward out of the coal-basin, through its steep barrier, by a highly picturesque pass, and then sweeps again as suddenly westward, to run for several miles in a closely-confined trench between the outer and the inner ridges of the basin. It does not, however, run round the western end of this, but at the ravine of the Shickshinny turns suddenly southward, and cuts across its point, leaving a high insulated hill of the coal strata on its western or right-hand side. Disengaging itself by a fine pass from the southern barrier of the coal-basin, it passes out into an open valley and makes another rectangular bend, to run once more toward the west, parallel with the Nescopeck mountain, which it follows to the neighborhood of Catawissa. Beyond this point it maintains its general course westward, somewhat south, parallel with the southern base of Montour's ridge, all the way to Northumberland, where it is joined by its great tributary, the West branch. In some portions of this long reach of the river the scenery adjoining it is uncommonly rich and pleasing. A remarkably fine view up the river is presented from the hills on its west bank, a little below the mouth of Fishing creek.

Between Northumberland and the Kittatinny valley the river leads us through many striking scenes. It is studded with many little islands, most of which are covered with trees or bushes to the water's edge, and it is here a wide and majestic river, flowing alternately, for long reaches, across highly-cultivated belts of country, and past the ends of steep and rugged mountains. Passing out from the mountains, it traverses a beautiful country in the Kittatinny valley, dividing Dauphin from Cumberland county. Quitting the limestone valley, the river next traverses the red-shale belt, between the villages of Highspire and Bainbridge, crossing a rather monotonous country, except at the Conewago falls, or rapids, where numerous hard trap-dikes impede its course, and cause it to rush in wild tumult, by deep and dangerous sluices, for a long distance between black and jutting reefs. At Chicques ridge, one mile above Columbia, the river leaves the smoother country, and passes between a range of high and picturesque crags. With two or three intermissions, caused by the softer limestone valleys which it next crosses, it runs the whole way thence to the vicinity of Port Deposit, or nearly to the head of Chesapeake bay, between steep naked and half-naked hill-sides, rising from 200 to 400 feet above its channel. In some parts of this long reach, as at the mouth of the Conestoga, the river is greatly dilated, and is filled with rocky islands and projecting reefs. In other localities its rugged banks approach, and the river rushes with tremendous force, especially during freshets, through these deeper gorges. The traveler, who finds only a rough and very toilsome path along its eastern shore from Turkey Hill to Port Deposit, a distance of more than 30 miles, will choose to descend it by its right bank along the tow-path of the canal. He will pass an almost unbroken succession of interesting rocky scenes, affording much geological instruction; and he will witness many beautiful bits of river perspective, but he will find himself pent in all the way between the bold river hills.

a Rogers' *Geology of Pennsylvania*, p. 184.

The declivity of the river is shown in the following table:

Locality.	Distance from mouth.	Elevation above mean tide.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Mouth	0.0	0	12	69	5.75
State line	12.0	69			
Crossing of Peachbottom railroad (*a*)	17.5	86			
Mouth of Fishing creek	20.0	100	31	155	5.0
Mouth of Muddy creek	22.0	119			
Columbia dam, water below	43.0	224			
Columbia dam, crest	43.0	231	14	23	1.6
Below Conewago falls	57.0	254	2±	19	9.5±
Above Conewago falls	59.0	273	10	25	2.5
Harrisburg (*b*)	69.0	298			
Rockville, crossing of Pennsylvania railroad (*c*)	75.0	305	15	38	2.5
Clark's Ferry dam, water below	84.0	336			
Clark's Ferry dam, crest	84.0	343			
Liverpool	99.0	378	38	79	2.1
Seelin's Grove	116.0	421			
Sunbury dam, water below	122.0	422			
Sunbury dam, crest	122.0	429	52	80	1.5
Nanticoke dam, water below	174.0	509			
Nanticoke dam, crest	174.0	515			
Wilkesbarre	183.0	521			
Mouth of Lackawanna river (*d*)	190.0	536			
Mouth of Tunkhannock creek (*d*)	211.0	581			
Mouth of Mehoopany creek (*d*)	223.0	604	104	229	2.2
Mouth of Wyalusing creek (*d*)	244.0	646			
Mouth of Wysox creek (*d*)	257.5	687			
Towanda (*d*)	262.0	700			
Athens, on Chemung river (*d*)	278.0	744	144	449	3.1
Lake Otsego, source of river	422.0	1,193			

a This elevation is given by Mr. S. M. Mansfield, superintendent.

b This elevation is a mean between those furnished by Chauncey Ives, esq., assistant engineer of the Cumberland Valley railroad, and Alfred Walter, esq., assistant engineer of the Northern Central railroad.

c For this elevation I am indebted to Mr. William H. Brown, chief engineer.

d For these elevations I have to thank Robert H. Sayre, esq., superintendent and engineer of the Lehigh Valley railroad. The remainder of the elevations are to be found in the volume *Tide Levels*, published by the Pennsylvania geological survey.

There is some discrepancy in regard to the *datum planes* used in different cases, hence the above heights are subject to some error; but as the length of the stream between the points mentioned was determined only by measurement from a map, this error is unimportant.

The flow of the stream is regulated to some extent by a number of lakes in its basin, but they are so small that their effect is hardly perceptible, so that the river is subject to considerable variations in volume. The freshets rise in places to a height of 30 feet, and the minimum flow would probably be quite low were it not for the very large area drained by the stream. No gaugings of the flow could be obtained, so that I am obliged to depend entirely upon estimates. The facilities for storage may be called good, and there are numerous sites where storage reservoirs might be constructed; but although by their means the flow of the small tributaries of the stream might easily be regulated so that the maximum flow available might be utilized, it would be a stupendous undertaking to endeavor to do this for large areas like those drained by either fork of the stream. The power estimated as the "maximum with storage" must therefore be looked upon as practically altogether unavailable.

A large portion of the drainage basin of the river, namely, that part in the central and western parts of Pennsylvania, is very well wooded, and lumbering is carried on very extensively; other parts of the basin are almost cleared of forests over considerable areas.

The mean annual rainfall over the basin is about 39 or 40 inches, of which 10 fall in spring, 12 in summer, 9 or 10 in autumn, and 8 in winter—a distribution quite favorable for constancy of flow.

As the river is descended from its source in lake Otsego, no important water-powers are met for many miles. I did not personally examine the stream above the town of Susquehanna, having been told by every one whom I questioned that there were no powers of note above that place. In cases where a stream flows with a uniform declivity, and with no large utilized powers, it was of course impossible for me to obtain much information; for the rule is that in such cases, if the fall is great enough, power can be obtained by damming wherever the banks are good and where there would be no difficulty on account of flowage. The returns of the enumerators show that the stream is well utilized in the part of its course referred to, but the powers and the falls also are generally small. I heard of no special sites not used, and therefore did not visit this part of the river. The dams, I was told, are generally primitive brush or crib dams, and many of the mills have falls of only 3 or 4 feet.

At Susquehanna there are two powers, the upper one, a grist- and planing-mill, using a fall of 3 feet, and the lower one, a grist-mill, with a fall of 4 feet.

The first important power on the river is at Binghamton, New York. A dam, built of crib-work, 450 feet long and 5½ feet high above low water, extends entirely across the stream, ponding the water for about 2 miles, with an average width of perhaps 500 feet. A race 500 feet long supplies power to the following mills:

1. Saw- and planing-mill, cabinet- and box-shop; 2. Doolittle's grist-mill; 3. Machine-shop, wood-working machinery, wool cards; 4. Tannery; 5. Factory of children's sleds, carriages, etc.

The power is owned jointly by the owners of these different establishments, and the method of distributing the water is not very clear. Full capacity can be obtained during about ten months, and it sinks during the low season as low as one-half. All the mills use a fall of about 5½ feet, and a total power of something like 250 or 300 horse-power. In the low season no water runs over the dam in the day-time, but the pond is not large enough to store all the flow during the night. The race is about 80 feet wide, and 6 feet deep at its head.

The drainage area of the stream above Binghamton measures no less than 2,279 square miles. The volume of water must therefore be considerable—perhaps, when at its minimum, about 340 cubic feet per second, affording a gross power, with a fall of 5½ feet, of about 215 horse-power.

Below Binghamton there is no power of importance on the river for a very long distance. Above the Pennsylvania line there are some ripples or rapids, and several small mills, with falls of a few feet. Such mills are, of course, "drowned out" in times of high water. The stream in this part of its course is from 500 to 1,000 feet wide.

The stream has been surveyed from the state line to Nanticoke dam, below Wilkesbarre, by the United States Engineers, under the direction of Colonel J. N. Macomb, whose report is to be found in the *Annual Report of the Chief of Engineers* for 1880, Appendix F, page 594. Between the mouth of the Chemung, just below Athens, and Towanda there have been three mills, no longer in existence, but the falls were small and the power unimportant. In fact, we may say that there is no power on the river from the New York line to Nanticoke, and as the table of declivity shows, the fall of the river in this part of its course is scarcely over 2 feet to the mile. The ripples separating the long and navigable ponds are very short, and have falls generally of but a few inches, "not often reaching 2 feet, and seldom exceeding it". There are places where, by building a dam which would pond the water for several miles, falls of 5 and even 10 feet could be obtained, and there are a few mills on the river now. For instance, beginning about a mile below Ulster there is a fall of 6 feet or so in a little over 2 miles; a few miles below Mehoopany, at Horse Race falls and below, there is a fall of 8 feet or so in about a mile; and there are a few small mills on the river in the distance referred to, with falls of not over 7 feet. Although power could no doubt be developed by building dams, and although the volume of water is large, yet it is clear that on account of the considerable width of the river and the small falls obtainable, the facilities for water-power are decidedly poor, especially when we consider the heavy freshets, and particularly the ice-jams, to which the river is subject. It is found much more economical to utilize the small tributaries instead of the river itself.

It should be mentioned here that there was at one time a canal along the Chemung and the Susquehanna, above Wilkesbarre, and that there were several canal dams on both streams, now destroyed. It is said that they averaged 8 or 10 feet in height, but I was not able to determine this point definitely.

The Nanticoke dam, which backs the water half way up to Wilkesbarre, or a distance of about 4 miles, is the first dam below Binghamton extending quite across the river. It is a crib-dam, 900 feet long, and 6 feet high above low water, and its pool is used for navigation for several miles. A certain amount of power is available at the dam, but the fall is so small that there would probably be frequent interruptions on account of high water. The quantity of water diverted for the purpose of feeding the canal could not be accurately ascertained, but it is no doubt very small compared with even the low-water flow of the river. I should estimate the volume of water in the stream during the low season of dry years at about 3,300 cubic feet per second, which would correspond to about 375 gross horse-power per foot fall. The drainage area above this point is about 9,850 square miles, and the rainfall 39 inches—10 in spring, 11 in summer, 10 in autumn, and 8 in winter. As this site, however, is situated in the coal region, where fuel is cheap, and as the location otherwise is said to be unfavorable, it is not an important available power.

From Nanticoke to the mouth of the West branch there is no power of importance on the stream. There are a few small ripples where, by building dams, falls of from 5 to 10 feet could perhaps be obtained, but none of them are of any value, not even Berwick falls, the most important, where the fall is about 3 feet in 200 yards, over some rock ledges.

It may be as well to mention here the fact that at various points along the Pennsylvania canal, which extends not only along the main Susquehanna from Columbia to Wilkesbarre, but also along the West branch and the Juniata river, power is utilized from the canal to a small extent, the water being either discharged into the river or around the locks to lower levels. The amount of power thus utilized is at present very small, and there is a quite large traffic on the canal, so that the question of water-power is of minor importance. It is said, however, that considerable power could be utilized at the locks, where water is continually wasting to the levels below. The company has hitherto been disinclined to lease water for power, and the few leases that they have granted are mere sufferances. The company guarantees nothing, and simply allows the mills to use the surplus water, subject to interruption at any time, according to the pleasure of the company. The mills pay an annual rent, varying according to the fall, the size of the mill, the ultimate disposition of the water, and other circumstances, and averaging, perhaps, $100; and as they use generally powers of from 20 to 60 horse-power or thereabout, the price may be considered as from $2 to $5 per horse-power. These figures, however, are very rough, no measurements of the water ever having been made. An additional charge is made if the water is allowed to remain in the canal during the winter, as it is usually drawn off at that season of the year.

On the North branch there are three of these mills using water from the canal, viz, a grist-mill at Beach Haven, using the fall of a lock (9.75 feet), a keg factory at Rupert, with a fall of 10 feet, and the pumping machinery at Berwick, which supplies the town with water, with a fall of 7 feet. The water is generally drawn off during the winter. Some data regarding the power available from the canal will be found on page 64.

Just below the junction of the North and West branches of the river is the second canal dam, at Sunbury. It is 2,600 feet long and 7.5 feet high above low water, and its pond is used for navigation for 2½ miles. It supplies no power, though a considerable amount could be used, subject, however, to frequent interruptions. The site is not a very favorable one, on that account, although the volume of water is very large—being, according to my estimates, not less than 4,350 cubic feet per second when at its minimum, and 6,100 during the low season of dry years. The former quantity would correspond to nearly 500 gross horse-power per foot, and the latter to nearly 700. The drainage area above this place is over 17,000 square miles.

There is no power on the river between this dam and the next canal dam, at Clark's Ferry, just above the mouth of the Juniata. This dam is 1,955 feet long and 7 feet high, and backs the water 2 miles. In its pond boats cross the river. The fall could no doubt be used for power, and theoretically a very large amount would be available, the drainage area being about 18,829 square miles. I should judge that the flow during the low season of dry years would be not less than 6,600 cubic feet per second, affording 750 gross horse-power per foot. There would of course be trouble with backwater, and it would probably not be economical to use much power.

Two saw-mills use power from the canal between Sunbury and Clark's Ferry, one at Trevorton locks, using a fall of 8 feet, and one at Liverpool lock with a fall of 7 feet.

The next power as the stream is descended is at Conewango (or Conewago) falls, just below the mouth of Conewago creek, and about 5 miles below Middletown. These falls are the most important on the river above Columbia. According to measurements with a pocket-level, the fall amounts to 7 or 8 feet in less than a mile, and I think it probable that by means of a dam a fall of 10 or 12 feet could be utilized at this place. The width of the stream is nearly a quarter of a mile at the head of the falls, and from 800 to 1,000 feet at the foot. The bed is rocky and the banks covered with rocks and bowlders. The facilities for building are not very good on the east side, on account of the canal and the railroad, which follow the bank quite closely, leaving little or no room in times of high water; still the power might be utilized on this side, and, in fact, there was once a canal cut there, serving to let rafts pass the falls, and at the same time supplying power, it is said, to a small saw-mill. No water runs in this canal now, and it is entirely filled with *débris* and the alluvium deposited by the river. The water was turned into it by a short dam at its head, extending across to an island, and not over 300 feet long. By means of several islands in the stream, a large amount of water could easily be turned to either bank without a dam entirely across the river. On the west side there is also a canal, formerly used to supply power to two mills at the lower end and to carry boats by the falls. The fall used was about 8 feet. There was one guard and one outlet lock, and a wing, dam at the head of the canal, now in bad condition, though not entirely carried away. This canal could be cleaned out without much difficulty, and the fall utilized at the lower end; and on the whole the building facilities are better on this side than on the other. The river seldom rises over 8 feet here, it is said, and never runs over into the canal just described. The Northern Central railroad runs close by the bank of the river, so that the facilities for transportation by rail are equally good on either side of the river.

The next power is at Columbia, where we come to the lowest canal dam on the river. The structure is 6,800 feet long and 7½ feet high. Power is available only on the eastern shore, where a small amount is already used for a saw-mill. The power theoretically available is estimated on page 64.

Between Clark's Ferry and Columbia there are a few small mills using power from the canal; one, a saw-mill, just below Clark's Ferry, takes water from the river and uses a fall of from 6 to 8 feet; a grist-mill at Harrisburg uses a fall of 15 feet, feeding to the river; and the canal company has some shops at Harrisburg, with a fall of 11 feet, feeding to the canal.

From Columbia to the mouth of the river there is, according to what has been said on pages 60 and 61, a large amount of power, the fall being large. There are numerous rapids, and numerous places where small mills might be located, but it would seem that the banks are not very favorable for the development of large powers, while the width and swiftness of the river would no doubt render dams very expensive. Besides, the canal on the west and the railroad on the east, both following the river pretty closely, might interfere with the development of some sites. Perhaps the best opportunity for the utilization of power within this distance is afforded at the lower part near the mouth of the river, where there is a canal 9 miles long, extending from Peach Bottom to a point a mile above Port Deposit, and originally constructed, many years ago, for purposes of navigation, as well as with the object of supplying a certain amount of power. A wing-dam was built at its head, but it is no longer in existence, and the canal is much filled up. The total fall is stated at 80 feet, and there were locks as follows: At the head, a guard-lock with a lift of a few feet; at Conewingo, 3 miles below the head, locks with a total lift of 20 feet; at Octarara, 22 feet; at the "burnt mill", 24 feet; and an outlet-lock, 12 feet. It was intended to use considerable power at each lock, excepting the guard- and outlet-locks, and several small mills were built, but they have not been in operation for many years. The old locks are all gone; but if it were desired to develop power in this vicinity I think that a large amount could easily be rendered available here. It is no doubt the best site in the vicinity for a large power, and in fact the best site on the river. The canal could be made to intercept the waters of a number of streams which now flow into the river, viz, Octarara, Conewingo, and Fishing creeks.

The preceding pages show that the Susquehanna river offers a very small amount of power in comparison with its size, and that there are only four or five sites at all worthy of attention. Passing as it does through the coal-fields, it is not probable that much power will be used on the river for some time to come, especially so long as good small powers can be found on the tributary creeks. The expense of building the long dams which any extensive utilization of power would render necessary, and of maintaining them against the heavy freshets and ice-jams of the river, and the small fall available in all except a few places, render the stream of small value for power in comparison with its size. It is, no doubt, more suited for improvement as a channel of communication than as a source of power.

The following table gives a summary of the power available on the stream at the sites specially referred to in the preceding pages. The maximum power available with storage has not been estimated, because of its being practically unavailable. And it must be specially remarked that on account of the great size of the stream even the other powers estimated in the table are not fully available. Although power could be used at each dam, it would manifestly be impracticable to turn even the minimum flow of the stream to either side, except at Binghamton so that from a practical point of view all that can be said is that at each of the sites named above a certain small amount of power can be economically used.

Summary of power on the Susquehanna river.

Locality.	Distance from mouth.	Drainage area.	Rainfall on basin.					Total fall.		Horse-power available, gross. (a)			Remarks.
			Spring.	Summer.	Autumn.	Winter.	Year.	Length.	Height.	Minimum.	Minimum low season.	Low season, dry years.	
	Miles.	*Sq. miles.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Miles.*	*Feet.*				
Binghamton	318	2, 279	9	11	10	8	38	....	5. 5	215	300	350	Dam 5.5 feet high.
Nanticoke dam	174	9, 850	10	11	10	8	39	....	6. 0	1, 540	1, 875	2, 250	Dam 6 feet high.
Sunbury dam	122	17, 425	10	12	10	8	40	....	7. 5	3, 700	4, 450	5, 200	Dam 7.5 feet high.
Clark's Ferry dam	84	18, 829	10	12	10	8	40	....	7. 0	3, 750	4, 500	5, 250	Dam 7 feet high.
Conewago falls	57	23, 860	10	12	10	8	40	....	10. 0±	8, 100±	9, 400	10, 800	See description.
Columbia dam	43	24, 835	10	12	10	8	40	....	7. 5	6, 350	7, 400	8, 450	Dam 7.5 feet high.
Port Deposit canal	5±	26, 000	10	12	10	8	40	9	80. 0	71, 000	82, 800	94, 600	

a See pages 8 to 11. The utilized power on the stream and its tributaries is tabulated on pages 80 to 89.

In regard to the amount of power available from the Pennsylvania canal, it depends upon whether the water is discharged into the river or into a lower level. As regards the power available at the locks, the chief engineer of the canal, Mr. Thomas T. Wierman, has been to the trouble of having measurements made of the flume-water, or the water flowing around the locks in the flumes, for supplying the lower levels, and he states that on the eastern division of the canal, from Clark's Ferry dam to Columbia, there are 15 lift-locks, with an average lift of 8.6 feet each, and an average flow around the locks of 125 cubic feet per second. This would afford a theoretical or gross power of 14.2 horse-power per foot, or a total of over 1,800 gross horse power. It is said that a large proportion of this could be easily utilized.

It may be as well to give here Mr. Wierman's figures for all the remaining divisions of the canal. On the lower West Branch division, from Northumberland to Clark's Ferry dam, there are 9 lift-locks, with an average lift of 7.1 feet, and an average flow around them of 87 cubic feet per second, affording a total gross power of nearly 650 horse-power. On the Wyoming division, from Nanticoke dam to Northumberland, there are 7 lift-locks, with an average lift of 9 feet, and an average flow of 150 cubic feet per second; affording in all 1,071 gross horse-power. On the upper West Branch division, from Lock Haven to Northumberland, there are 16 locks, averaging 6 feet each, with 66 cubic feet per second, or a total power of 720 gross horse-power. On the Juniata division, from Huntington dam to the Susquehanna, there are 34 lift-locks, with an average lift of 7 feet, and 54 cubic feet per second, or, in all, 1,461 gross horse-power.

The use of these powers does not interfere with the navigation on the canal. Although at each lock the power available is small, there seems to be no reason why it could not in very many cases be easily and advantageously utilized.

TRIBUTARIES OF THE NORTH BRANCH OF THE SUSQUEHANNA RIVER.

A list of the more important tributaries above the Chemung, with their drainage areas, will be found in the table on page 78, and in the table of utilized power will be found a statement of the total power utilized on them. As a rule, they seem to be well improved, and are, doubtless, better suited for power than the main stream. They flow in beds of sand and gravel, with no natural falls; but their declivities, though generally gradual, are steeper than that of the main river, and the falls utilized at the mills are sometimes quite large, the mills being generally saw- and grist-mills, using only small amounts of power. There are lakes on some of these streams, sometimes covering sufficient area to regulate their flow to a considerable extent. Lake Otsego, at the head of the river, is about 7½ miles long, and 1½ mile wide, and Oak creek, the first tributary of any note, rises in Schuyler's lake, a sheet of water nearly 4 miles long and about a mile wide. These are the only large sheets of water, but there are numerous small ones, covering from a few acres to nearly a square mile. Estimates of the flow of these tributaries are scarcely necessary. The Chenango river, the most important of them, drains an area of 1,540 square miles, taking its rise in Madison county, and flowing south through Madison, Chenango, and Broome, and by the towns of Sherburne, Norwich, and Oxford, emptying into the Susquehanna at Binghamton. At this place there is a power which will give an idea of the water-power in the vicinity. A dam at the head of Noyes' island, 1.200 feet long and 3 feet high, built of brush and stone, turns the water to one side, and at the foot of the island, which is 1,300 feet long, a second dam 40 feet long and 5 feet high connects it with the shore, and here the mills are located, comprising a grist-mill, a comb factory, and a brush factory. The privilege is owned by E. M. & J. P. Noyes, who operate the comb factory and rent the other two mills, the fall used being 5 feet at low water. Full capacity can be obtained for about nine months of the year, the power utilized being stated as about 125 (?) horse-power. There is also occasional trouble on account of backwater, the water rising, it is said, to a height of 22 feet in extreme freshets, though not ordinarily above 12 or 14 feet. It is stated that in dry seasons the mills use all the water in the river. Three miles above Binghamton, at Port Dickinson, there is a second power, the fall being about 5 feet, with a dam 550 feet long and 4 or 5 feet high. The power is utilized by a paper-mill, a grist-mill, and a flour-mill, using together some 150 horse-power.(a) Full capacity can be obtained during only about ten months. There are numerous small saw- and grist-mills on the main stream and its tributaries, above this point, but none are of importance. The stream is bordered in many places by bottoms subject to overflow.

Owego creek, which joins the Susquehanna just below Owego, draining about 391 square miles, has a number of small mills. Its power is said to be quite well utilized, and with the exception of a mill at the mouth, which has a fall of 16 feet, with a race three-quarters of a mile long, the falls are generally 6 or 8 feet.

Shepard's creek, or Cayuta creek, heading in Cayuta lake, in Schuyler county, though a small stream, draining only about 148 square miles, is utilized to a considerable extent by grist- and saw-mills, a tannery, and a paper-mill. Near the mouth there was a woolen-mill, burned several years ago, but the dam is still there, and the available fall is 12 or 13 feet, with a race half a mile long. Near the mouth is also a flour-mill, with a fall of 12.5 feet at low water, and using, in connection with a plaster-mill, some 80 or 100 horse-power, (?) and with no waste in summer. It is said that there are several unimproved sites on the stream besides that of the old woolen-mill.

The Chemung river, the most important affluent of the North branch, has its sources in Pennsylvania and New York, but the main stream is formed in Steuben county, New York, at the town of Painted Post, by the union of the Tioga and Conhocton rivers, whence it pursues a general southeasterly course, passing into Chemung county, and finally joining the Susquehanna in Bradford county, Pennsylvania, just south of the state line, after having drained a total area of some 2,500 square miles. Measured in a straight line, the length of the stream is about 35 miles, and the only towns of importance by which it flows are Corning, Elmira, and Athens. There was once a canal along the stream, and it is said that there were three canal dams on the river, one at Athens, one at Corning, and one at an intermediate point, but no traces of them are now to be seen. The character of the drainage basin of the stream, which flows with a uniform declivity over a bed of sand and gravel, with no falls and few rapids, resembles that of the Chenango. That part of it lying in Pennsylvania is perhaps rather more broken, and the elevation of the water-shed which forms its boundary is also greater than in New York, attaining to 1,650 or 1,700 feet at the head-waters of the Tioga and Genesee,(b) while the elevation of the summit between the Chemung river and Seneca lake is only 890 feet.(c) There are a few small lakes in the basin, but they are not large enough to regulate the flow to a great extent, so that the stream is subject to quite heavy freshets, and is considered more variable in flow than the Susquehanna. In March, 1865, the water rose 24 feet at Elmira, and probably higher at other places. Such freshets, together with the ice-jams

a The power used can not be stated exactly, and this figure may be considerably in error.

b Rogers' *Geology of Pennsylvania*, p. 4.

c *Geology of New York*.

which occur, would be destructive to high dams, but the existing ones, being low brush or crib-work structures, are not often injured. Sheet-piling is sometimes used in their construction, where the bed of the stream is very pervious. The power used on the river is altogether insignificant, there being no rapids with falls of over a few feet, the slope of the stream being not greater than about 4 feet per mile, and there are few available sites not used. A mile below Athens there is a grist-mill with a brush and timber dam 600 feet long and 2 feet high, with a fall of 4 or 5 feet, and utilizing from 25 to 50 horse-power. At Athens there was once a canal dam, said to have been 9 feet high, and backing the water a considerable distance. There is little natural fall in the river, and such sites might be found at a number of places, fall being obtained by backing up the water and overflowing more or less land. At Tozer's bridge, a mile and a half above Athens, there is a small fall available, and several mills were once located there. Several similar sites exist below Elmira, at which place there is a grist-mill, with a fall of 5 feet, and using about 60 horse-power; while above that point there are also a few small rapids, none of any consequence, although power could no doubt be obtained by damming.

The Conhocton river, which rises in Livingston county and flows southeast into Steuben to join the Canisteo at Painted Post, drains an area of about 600 square miles, and is said to be the best stream for power in the neighborhood. The table on page 83 will show that it is used quite extensively for small mills, the falls being generally 8 or 9 feet. Its flow is said to be more steady than that of any other large stream in the vicinity, on account of numerous springs and several small lakes, and the powers are therefore better. The declivity of the stream is uniform, and no sites not used were brought to my notice, although it is probable that some power could be developed by damming in many places. Many of the mills have to stop running during the dry season, or are obliged to run at greatly reduced capacity.

The Tioga river, and its tributary the Canisteo, are similar in general character to the Conhocton, and are utilized by small saw- and grist-mills. They offer no falls or rapids of importance. Their flow is said to be much more variable than formerly, on account of the clearing of the land. The fall of these streams is probably greater than that of the Conhocton, but their declivities are uniform. The banks are higher and the country is more broken, and the mill-ponds are therefore small, and there are no other artificial reservoirs of any kind. The freshets are said to be very violent, and the dams so subject to undermining that they are frequently built on piling. The falls vary from 5 to 10 feet, and the mills generally have from 2 to 4 pairs of stones.

It is evident from the above that the drainage basin of the upper Susquehanna is not favorable for the development of large powers, although a large number of smaller powers may be obtained artificially.

After receiving the Chemung, the Susquehanna passes from the plateau of New York into the real mountain district, and its tributaries have more fall than farther north, or at least they offer better sites for power, having more numerous rapids, and sometimes cataracts, with beds of solid rock. They are utilized to a considerable extent, generally by saw- and grist-mills, but none of them being large streams, they may be dismissed very briefly.

Sugar creek, from the west, is utilized by a number of saw- and grist-mills, the latter with from 2 to 4 pairs of stones. It has no falls, so far as I could learn.

Towanda creek, from the west, is similar, and a few small lakes are tributary to it. Some of the small tributaries of these streams have large falls.

Wysox creek, from the east, runs a few small mills; and Wyalusing creek, from the same side, has been quite well improved, but some sites formerly occupied by saw-mills have been abandoned as the country became cleared. Almost all of the mills in this vicinity are short of water during the summer. The falls average 8 or 9 feet, and the dams are generally of brush or crib-work.

Mehoopany creek, from the west, is a rapid stream, but has no falls, so far as I could learn. It is utilized by a few mills.

Bowman's creek, also from the west, is said to have a fall of 15 feet about 8 miles from its mouth, utilized by a saw-mill with a total fall of 27 feet, the dam being 12 feet high. There is said to be an unimproved site 20 miles from the mouth, but the stream must be very small there. One of its tributaries, Leonard's creek, is said to have a number of natural falls, some unimproved.

Meshoppen creek, from the east, is said to have two falls within 300 feet of each other, a mile and a quarter from the mouth, each of 20 feet, and unimproved. The elevation of the stream at its mouth, according to information furnished by Mr. Robert H. Sayre, chief engineer of the Lehigh Valley railroad, is 610 feet, while at the crossing of the Montrose railroad, 12 miles above, measured on the map, it is 925 feet, according to the engineer, Mr. Ansart; so that the fall is very large within that distance. It is probable that all the streams in this neighborhood have steep declivities.

Tunkhannock creek, from the east, is the largest tributary of the North branch below the Chemung, draining over 400 square miles. Regarding its power, however, I have no particulars except what is contained in the table of utilized power. I heard of no falls on the stream, although it was stated that there were numerous rapids where power could be developed. The stream is utilized only by small mills, with 3 or 4 pairs of stones. There are several small lakes in the drainage basin, the largest being Marcy lake, covering, it is said, 200 acres, and just below the lake, on the outlet leading to the Tunkhannock, a natural fall of 30 feet is reported, not in use, while on the same stream a fall of some 20 or 25 feet is used by a toy factory, the power being very constant. The elevation of the lake is given as 957 feet by Mr. Ansart, engineer of the Montrose railroad. Fall creek, the outlet of lake Wynola (?), has also some large falls, and it is said that there is a dam at the outlet of the lake. There seem to be a number of small undeveloped powers in this vicinity, and, on account of the lakes, some of them may be valuable.

The Lackawanna river, from the east, enters the Susquehanna at Pittston and drains an area of nearly 325 square miles. Rising in Susquehanna and Wayne counties, it pursues a southerly and southwesterly course, passing into Lackawanna and Luzerne counties and draining a long and narrow basin. It has tributary to it a number of small lakes. Like the other tributaries which have been mentioned, it has some falls and rapids, with a rock bed in places, and is utilized for small mills of various kinds. During the past few years the land has been rapidly cleared in the basin, and great complaint is made that the flow of the stream is much more variable than formerly and that the water-power is of small value. The fact that fuel costs very little in this vicinity has also the effect of diminishing the value of the water-power. The stream is moreover said to be so polluted by the water pumped from the mines that no animal can live in it; and it is said to rapidly corrode cast iron, so that wheels and gates have to be replaced at short intervals. As regards shoals and mills, there is said to be a succession of rapids near the mouth of the stream, with a total fall of some 20 or 30 feet in half a mile, utilized to some extent, but not completely. At Providence, about 12 miles from the mouth, there is an ax factory, with a fall of 10 feet. Above are a number of saw- and grist-mills and a few powder-mills, and the power of the stream or its tributaries is also used to some extent for pumping out mines. Roaring brook and Spring brook, small tributaries of the Lackawanna, are utilized for saw- and grist-mills, but the powers are all small, and, although on the former there are some falls near Scranton, they are of not much value for power.

Harvey's creek, which enters the Susquehanna from the west, just above the Nanticoke dam, is the outlet of Harvey's lake, which is said to cover about a square mile, and is dammed at its outlet by a stone dam 6 feet high. The flow of the stream is thus regulated to a considerable extent, and its power is said to be the best in the vicinity, the fall being quite large and the bed often rock. It is utilized by some 10 or 12 mills, mostly saw-mills.

Hunlock's creek, emptying 4 miles below Nanticoke, from the west, has its source in a pond, partly artificial, and is similar in character to Harvey's creek, except that its flow is not so regular. Near its mouth there is said to be a natural fall of 30 or 40 feet, not utilized, and all the tributaries to the Susquehanna in this immediate neighborhood, where it leaves the Wyoming valley and cuts through the mountains, have very steep declivities, and often rapids and cataracts, over beds of solid rock. The great trouble with most of them is their variable flow. Although quite well utilized, numerous sites may be found on almost all of them.

Shickshinny creek, the next tributary from the west, is like the others, but perhaps even more variable in flow than Hunlock's creek.

Big and Little Wapwallopen creeks, from the east, enter the river below Nanticoke, and resemble the streams just described. The former is very small, and the latter is also a small stream, but has considerable utilized power. About a mile above its mouth it has a large fall, amounting to 200 feet or over in about 2 miles, which is utilized to a considerable extent by Dupont & Co.'s powder-mills. As the stream is ascended we first come to a grist-mill, with a fall of 22 feet, a race a mile long, and a dam 6 feet high; then a powder-mill, with a fall of 36 feet, a flume 300 feet long, and a dam 4 feet high; then another powder-mill, with a fall of 18 feet, a race of 500 feet, and a dam 12 feet high; then another, with a fall of 8 feet, a dam of the same height, and no race; then still others, along a race 3,200 feet long, the fall being 119 feet at its lower end, and the dam 4 feet high; then a fall of 30 feet unimproved, and not very favorable, and, finally, a number of grist- and saw-mills on the upper part of the stream. The power used at the powder-mills aggregates about 275 horse-power, but full capacity can be obtained during only six months. There are said to be few good sites not utilized.

Nescopec creek, which enters the river opposite Berwick, resembles the creek just described, but has not so much fall, though a much larger stream. I heard of no unimproved sites, and none of the mills are large.

Fishing creek, which enters from the west just below Bloomsburg, has its sources in Sullivan county, and flows south into Columbia, draining an area of at least 350 square miles. It is well utilized by grist- and saw-mills, paper-mills, and furnaces, and there are said to be some sites yet unimproved. The falls used are sometimes quite large, the greater part being obtained by damming. The stream is a good one for power, but its flow is quite variable, there being only two or three very small lakes tributary to it.

Catawissa creek, from the east, is the last tributary of the North branch which calls for remark, rising in Schuylkill county and emptying into the river at Catawissa. It has no lakes, and its fall is said to be uniform; yet its flow is said to be tolerably constant. Like the other streams in the vicinity, it is utilized by small mills of various kinds.

As regards the rainfall over the basins of these tributaries, in New York state it is about 36 or 37 inches, of which 9 fall in spring, 10 in summer and in autumn, and 8 in winter. In some parts it is smaller, even as low as 32 or 33 inches. In Pennsylvania it is about 39 or 40 inches—10 in spring, 11 in summer, 11 in autumn, and 8 in winter.