REPORT ON THE WATER-POWER

OF THE STREAMS OF

EASTERN NEW ENGLAND,

BY

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LETTER OF TRANSMITTAL.

BOSTON, MASS., *April* 30, 1883.

Professor W. P. TROWBRIDGE,

Chief Special Agent, Tenth Census, Columbia College, New York, N. Y.

SIR: I have the honor to submit herewith a report upon the water-power of eastern New England, giving the results of investigations carried on under your direction during the summer of 1882. This completes the series of reports intrusted to my care, and, as in those previously completed, the aim has been to give a reliable account of the great powers in the region considered, as well as a general discussion of its water-power in general. The suspension of field operations in the summer of 1881, and the limited time at my disposal after their renewal in 1882, rendered impossible a personal examination of the state of Maine, and a hurried visit to a few of its great powers was all that could be attempted in that state. Fortunately, however, the water-power of Maine has been ably and exhaustively treated in a report by Mr. Walter Wells, made in 1869, by the use of which, as well as by extensive correspondence, the data given have, it is hoped, been made reasonably accurate.

My thanks are due to many gentlemen who have assisted me in my work, and who are referred to in the body of the report.

Very respectfully, your obedient servant,

GEORGE F. SWAIN.

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WATER-POWER OF EASTERN NEW ENGLAND.

I.—INTRODUCTION.

The territory to be covered by the present report comprises that part of New England draining into the Atlantic ocean east of the Thames river, Connecticut. Before proceeding to discuss the various streams draining this district, its general characteristics should first be given; and the following brief *résumé* of the principles or circumstances upon which the value of powers depend will aid in forming a just estimate of the water-power of New England.

GENERAL CONSIDERATIONS.

A water-power is produced when a certain quantity of water falls through a certain distance. The greater the fall, and the greater the quantity of water, the greater the power; but if the quantity of water varies from day to day, that which flows in the period of minimum flow is all that is permanently available, while at other times there will be large amounts in excess. A good power, then, supposes a good fall, a considerable quantity of water, and a small variation in that quantity. Let us take up these three points in succession. What conditions, then, are favorable to the existence of large falls on rivers? In general, the streams must have a considerable declivity. If a stream has an average fall which is large, we may, in general, conclude that it possesses considerable power. Theoretically the power which it possesses depends upon the average quantity of water which it discharges from source to mouth, and the total fall between those two points. But there may be great differences in regard to the availability of this power. If the stream possesses natural falls of considerable magnitude in short distances, then by diverting the waters, and carrying them in canals past the falls, powers may be rendered available; but if there are no concentrated falls, and only a uniform declivity, then, in order to produce a power, a dam must be erected which shall raise the level of the water for some distance and produce a sudden fall. The erection of a dam, however, is often accompanied by the overflowing of considerable areas of valuable land above, depending on the character of the banks of the stream; and there is often danger of the breaking away of the dam in times of freshet, if it is not founded on solid material. In addition to a great declivity, then, it is necessary that a stream should possess concentrated falls and rapids, and it is, moreover, desirable that its banks shall be high and firm, affording good foundations for building, and not comprising much low land which would be liable to overflow were the water-level raised a few feet. The formation of a large pond by the erection of a dam, however, if not attended with too much expense, is an extremely favorable circumstance, as, if large enough, it allows of the storage of the water during the night, and the utilization during twelve hours, or less, of the entire flow in twenty-four. Falls and rapids generally occur when a stream crosses ledges of rock. It is therefore important that a stream shall have cut down its bed to the underlying rock, and that its drainage basin shall be underlaid with rocks at a moderate depth. If a fall or rapid is to be permanent, the rocks which cause it must be hard and impervious, otherwise they will be gradually worn away and the fall obliterated. If a stream flows at right angles across the upturned edges of a series of rock strata, the falls are apt to be greater and more numerous than if the stream runs parallel to the rock strata; it is hence a favorable circumstance if the strike of the rock strata is at right angles to the general course of the streams. A swampy country is, of course, not favorable to the existence of falls, neither is a country deeply overlaid with drift. In such cases, and generally in cases where the declivity is gradual, the bed is apt to be of movable material and the construction of a dam attended with some uncertainty.

Upon what circumstances, again, does a large average flow depend? By average flow we mean the average quantity of water discharged during a year; and, inasmuch as all the water flowing in a stream is derived from the rainfall, it is at once evident that a first requisite is a large annual rainfall. Further, the rainfall must be so

distributed through the year that there shall be the least loss by evaporation; hence in winter, when the evaporation is least, the rainfall must be largest. Again, the smaller the evaporation the less the loss from that source; hence a low annual temperature, and especially a low summer temperature, is a favorable circumstance. A pervious soil, which shall absorb the water rapidly, removing it from the action of the sun's rays, is also favorable.

But the most important requisite in regard to flow is that it be uniform, for it is only the lowest flow that is permanently available. A large number of circumstances affect the distribution of the flow through the year. First, there is the question of storage. If the surplus waters which flow in wet seasons and in freshets can be stored up and held until dry seasons, then a tolerably uniform flow may be secured; but the amount of storage capacity available must be greater, as the natural variability of the flow is greater. The presence of lakes and of facilities for artificial storage is therefore a most favorable circumstance, especially if they are deep, for then they expose less surface to the influence of evaporation. But it is evident that for uniform flow the rainfall should be greatest in summer, when the loss by evaporation is greatest; and this distribution is unfavorable to a large average flow. If large storage capacity is available, a small summer rainfall is not detrimental; but in a region without lakes it is, no doubt, a great factor contributing to a variable flow. A deep and pervious soil is a favorable factor, as it serves as a sort of reservoir, absorbing the rain which falls, and giving it out gradually by springs. This element, however, is less important in a country where there are numerous lakes, and where the rainfall is favorably distributed for uniform flow; in other cases it is very important. A low summer temperature is favorable here, as well as in regard to average flow, diminishing the evaporation when it is greatest. Extensive forests have a very great effect in regulating flow, by diminishing the amount of water flowing directly from the surface and increasing the amount percolating, to be given out elsewhere by springs. As regards topography, the most favorable condition is one which neither allows of a rapid discharge of the water falling on the surface, occasioning sudden freshets, nor of a very slow discharge and long exposure to the influence of evaporation. A mountainous country generally favors rapid discharge of storm waters, especially if the slopes are steep, rocky, and not wooded; hence streams in mountain regions are seldom of any value for manufacturing. A very flat country, on the other hand, allows of a very large evaporation, and consequently of a small average flow of the streams, and such a topography is not favorable to the existence of abrupt falls. A country which is moderately hilly is in general the most favorable. The shape of the drainage basins of the streams has also an effect. We shall meet with numerous examples of the fact that where a stream cuts across a series of parallel ranges, so that its tributaries have long and narrow basins, draining the parallel valleys between the ridges, a variable flow is to be expected, especially if the slopes are steep and the ridges high, for the rain is very apt to fall in such cases on one or a few slopes, or over several adjacent drainage basins, suddenly swelling enormously a few tributaries and the main stream. If mountains are arranged in well-defined ridges one slope is apt to have a greater rainfall than another, while if they are irregularly arranged in clusters a more uniform distribution of the rainfall is the result, and hence a more uniform flow of the streams. Again, the greater the area of the drainage basins the more uniform will be the flow, because the effect of sudden rains is comparatively smaller. The state of cultivation has also an effect on the average flow as well as on its distribution, for from cultivated ground the rain will not be shed so rapidly as from uncultivated ground; hence the flow will be more uniform in the former case, but the average flow less.

Finally, it is important to notice that one other important element of a good water-power is accessibility either by sea or by land; and, consequently, that a topography which is favorable to the location of railways along the rivers, and not along the divides, is favorable as regards water-power. In this respect high banks, with few extensive bottom-lands subject to overflow, are essential.

We proceed now to describe the general characteristics of eastern New England in the light of what has preceded, and to study the general effects of these circumstances on its water-power.

1.—Area and form.

The region to be considered embraces a land area of about 41,000 square miles, distributed as follows among the different states:

	Square miles.
Maine	29,895
New Hampshire	6,276
Massachusetts	3,750
Rhode Island	1,035
Connecticut	164
Total land area	41,120

This area forms a strip extending along the Atlantic between the parallels of about 41⅓° and 47½° north latitude. It is narrowest at the south, measuring 75 or 80 miles in width, and widest at the north, where it is about 200 miles wide. Its greatest length is about 480 miles. The coast-line runs in a southwesterly direction at the north, then south, and finally west in the southerly part of the region.

2.—Geographical and continental position.

The district considered, being situated at the northeasterly corner of the United States, bounded on the east and south by the ocean, has an exposure which is maritime to an unusual degree. Not only are the winds maritime from the south, southwest, east, and northeast, but also those from the north and northwest are far from bearing the character of land winds, having passed over considerable areas of water in the more northerly part of the continent. We may say, therefore, that only the winds from southwest to northwest are distinctly land winds, arid, and unfavorable to the amount and constancy of water-power. The winds from about two-thirds of the compass are more or less maritime. The ocean exposure of the district on the south, and the greater proportion of oceanic winds, are especially favorable, contrasted with the conditions found in the middle states. The prevalent winds through both regions are from the west or southwest, but it is the winds from the south and southwest which bring the moisture. In New England these winds come directly from the ocean, and are charged with vapor; in the middle states they have been in great part robbed of their moisture in their passage over the southern states, so that this region obtains most of its rain from the easterly and southeasterly winds, which are neither so frequent nor so warm, and hence not such good carriers of moisture as those from the south and southwest. The rainfall over New England is therefore larger in amount and more uniform in its distribution through the year than that in the middle states, and by far more uniform than that in the southern states. The continental and geographical position of the district to be considered is therefore more favorable to the existence of fine water-powers than that of any other region on the Atlantic slope, and probably more than that of any other region in America.

3.—Topography.

Topographically, the region lies entirely on the eastern slope of the Appalachian mountain system, and in a part of that system where the development of parallel ranges is but slightly pronounced. Unlike the streams of the middle states, which take their rise on the western side of the mountains, on an elevated plateau, and flow across the mountains, their tributaries draining a series of parallel and narrow valleys, the streams we are to consider, like those of the southern Atlantic states, rise on the eastern flank of the mountain system and are confined entirely to the Atlantic plain, flowing in a general southeasterly direction, excepting the streams in the north of Maine, which flow first in a northeasterly direction, bending afterward and flowing southeast. The western water-shed, or divide, of the district, starting from Long Island sound, at the ocean-level, pursues a northerly course through Connecticut, Massachusetts, and New Hampshire for about 200 miles, when it bends slightly toward the east and continues for about 280 miles, corresponding for a short distance with the boundary between Maine and Canada, and finally passing into the province of Quebec. In its course through Connecticut its elevation above the sea is small, but it gradually rises in Massachusetts and New Hampshire, till in the latter state it reaches its greatest elevation on the White mountains, beyond which it gradually falls. From this main divide a secondary one branches off toward the east, extending almost entirely across the state of Maine, from the sources of the Penobscot, and dividing the surface of that state into two slopes, a southern and a northern. In all the region except the northern slope of Maine the general course of the streams is south or southeast, this region forming the true Atlantic slope. In the northern slope of Maine, which comprises an area of about 7,400 square miles, their course is east-northeast.

Of the three parts into which we may divide the Atlantic plain in the case of the middle and southern states, viz, the eastern, the middle, and the western or mountainous, the eastern well-nigh disappears in New England, being scarcely found except in eastern Massachusetts and in Rhode Island. The *fall-line*, which bounds that region on the west, and which marks the division between the area of metamorphic rocks and that of the flat and low Tertiary and post-Tertiary deposits, runs in New England close to the coast. Granite is found within sight and sound of the sea, and the tidal and navigable portions of the rivers are of short length. The head of tide is always the head of navigation, and at this point there is generally a fall, often a large and important one. The mountain division, unlike that of the middle states, is likewise of small importance, partly because it is not of large extent, and partly because the streams within it are generally small. It is confined to the middle and northern parts of New Hampshire and a triangular portion of Maine, comprising the central portion of the state, with its greatest breadth on the west, and forming the divide between the northern and the southern slopes. In this region there are no parallel valleys, no considerable streams running for long distances without any large affluents, and consequently less severe and sudden freshets than on the streams of the middle and southern states, though this is due in great measure to other causes, which will be referred to in the proper places. The arrangement of the mountains in clusters and irregular ranges, instead of in long and parallel ridges, is favorable to a uniform distribution of the rainfall and to its gradual discharge. The mountain region is here neither so high nor so extensive as in the southern states, but is higher, though much less extensive, than in the middle states. Its effect upon the water-power of the streams is not to injure it particularly, which is more than can be said in regard to many states farther south. The favorable effect of the small extent of the eastern or tidal division in bringing the water-powers within easy reach of the sea-board, and thus facilitating transportation, need not be dwelt upon.

The greater part of the region is occupied by the true Atlantic plain, or middle division, comprising the southern slope, and extending from the coast to the foot of the mountains, averaging about 50 miles in breadth. It comprises nearly all of Rhode Island, Connecticut, and Massachusetts, the southern part of New Hampshire, and the greater part of Maine. Its elevation at the foot of the mountains varies from about 300 to 500 feet, being greatest near the elevated mountain region of New Hampshire; and its slope toward the sea is, on the whole, uniform, extending across the whole breadth of the region, and quite to tide-water. It contains almost all the water-powers of importance, which are equally abundant in all parts, existing even at the very mouths of the rivers, where they are largest. When this peculiarity is contrasted with the condition of things in the southern Atlantic states, where the streams are navigable for over 100 miles from their mouths, the advantage possessed by the New England streams will be manifest, in regard to both the magnitude of the powers and their accessibility. This southern slope, which possesses all the great water-powers of the region, is singularly well adapted for their utilization. The streams have a rapid fall, those having their sources near the elevated region in New Hampshire being the most favored in this respect. Their beds are generally of rock at the places where falls occur, with drift deposits in the intermediate distances, and their banks are uniformly high and firm. Unlike the southern streams, there are no swamps or meadow-lands of importance along their courses, so that even in high freshets very little land is overflowed. Dam succeeding dam, almost the whole fall of many of these streams may be economically utilized. The country is moderately hilly, a fact already referred to as favorable. The river valleys and the streams also are narrow at the places where falls occur, so that often only short dams are necessary. The streams are not navigable on account of their many rapids, and consequently are principally used for power.

The slope of northern Maine is gradual, and the streams in that region are sluggish; and the general slope of the entire region toward the east is so small that the current of the Saint John river, which drains it, is very moderate. On this slope there are large areas permanently swampy, rapids and falls are not numerous, and no large powers are known. The divide separating it from the southern slope is not high and sharp, but in places is very flat and swampy. The waters of the southwest branch of the Saint John and those of the northwest branch of the Penobscot come in part from the same swamps, a phenomenon which also occurs in other places.

The most important point connected with the topography of the region we are considering, as regards its influence on water-power, is the large number of lakes and ponds which exist, and the enormous facilities for storage. The beneficial effects of lakes are well known, and have already been briefly referred to. Not only do they serve as reservoirs to receive the waters tributary to them and give them out gradually, thus lessening the violence and the suddenness of freshets, and increasing very greatly the flow in dry seasons of the stream below, but they also, when deep, serve to lessen the loss by evaporation by exposing a smaller surface to the rays of the sun, and, moreover, serve to keep the water warm beneath the covering of ice which forms early in the winter, and in this way contribute to lessen the trouble experienced below with ice-jams, floating ice, or anchor-ice. Not only is little ice carried down the rivers from the ponds, but a much smaller quantity is formed below. This element is especially important in a region like New England, where the winters are severe and interruptions due to ice sometimes occur. It is therefore very important to observe that the number of lakes in this district is very large indeed. Wells states that there are connected with the rivers of Maine alone, not counting small ponds and a large number of ponds in the forest region of the state not represented on any map, over 1,620 lakes, covering together, probably, at least 2,300 square miles in area. Of this number, 1,568 are in the state of Maine, covering a total surface of 2,200 square miles, there being one lake to every 20 square miles of territory, and one square mile of lake surface to every 14.3 square miles of territory. In New Hampshire and Massachusetts lakes are not so numerous, but still sufficient in number to be of very great benefit. It is in New Hampshire, in fact, that the lakes are used to the best advantage, as we shall have occasion to show. In the part of this territory not including Maine we may count upon the map several hundred lakes and ponds, covering probably not less than 150 square miles. In regard to these lakes it is important to notice that the larger ones are generally situated near the headwaters of the rivers, at a considerable elevation above the sea. Were there only a few lakes, and near the headwaters of the large rivers, those rivers near their mouths would be subject to quite heavy freshets, for the lakes would only regulate the stream flowing directly from them; but as almost every tributary of the large rivers, from source to mouth, is also provided with lakes, the effect of the large number and elevated position of the lakes is to render the flow of almost all the streams comparatively constant. Not only are there these natural reservoirs, but there are, through all the region considered, excellent facilities for artificial storage. The lakes may, in most cases, easily be converted into storage reservoirs, as is, in fact, generally done for log-driving purposes, and, in addition, artificial ponds may be formed in many places. Wells gives the average depth which can be controlled in the lakes of Maine as not less than 8 feet. The following table, taken principally from his report, will show the elevations above tide of some of the principal lakes in the district treated in this report:

Elevation of a few of the largest lakes.

	Feet.		Feet.
Moosehead	1,023	Merrymeeting	589
Wood	1,094	Richardson	1,456
Attean	1,094	Moosehemaguntic	1,486
Long pond	1,094	Rangeley	1,511
Schoodic (about)	300	Mattagamon (about)	850
Sebec (about)	375	Chamberlain	926
Baskahegan (about)	400	Pongoewahem and Churchill	914
Pamedumcook, the Twins, and Millinoket (about)	500	Allaguash (about)	950
Ripogenus	878	Eagle	579
Chesuncook	900	Square and Cross	587
Caugnomgomoc (about)	930	Long	603
Squawpan (about)	580	Portage (about)	625
Sebago	247	Fish river (about)	660
Umbagog	1,256	Chiputneticook	382
Winnipiseogee	501	Chiputneticook Grand	449
Squam	510	Great East pond	499
Newfound	597	Ossipee lake	408

In order to give an idea of the value of this elevation, we may mention that lake Itasca, at the headwaters of the Mississippi, is only about 1,575 feet above the sea, which is over a thousand miles distant; and that lake Superior is at a height of only 630 feet, though 1,800 miles from the sea. No other district of equal size in the Union, it may be safely asserted, contains so many lakes at such high elevations, the fall to the ocean taking place within its limits. These lakes being large, as well as the streams flowing from them, their effect is to increase very greatly the theoretically available power of the latter.

If we were to sum up in a few words the effect of the topography of this district on the water-power, we should say that it is favorable in every respect, contributing not only to constant flow, but affording numberless falls easily utilized.

4.—Geology, soils, and forests.

Geologically, this district belongs almost entirely in the region of metamorphic rocks. A large part of it is underlaid with granite and allied rocks, which occupy, according to Wells, an area of 13,500 square miles in Maine, comprising the whole region west of the Kennebec, 3,400 square miles being almost exclusively underlaid with granite. In New Hampshire the entire valley of the Merrimack, as well as that of the Saco, is granitic, and large areas in Massachusetts are also underlaid with the same rock. A belt of it extends along the coast of Maine in its whole extent, and large quantities are shipped to other parts of the country. That part of the region not underlaid with granitic rock is underlaid with hard slates and schists, with their strike nearly at right angles to the general course of the rivers, so that the latter tumble over the upturned edges of those strata, and often form falls of considerable magnitude. The most important fact connected with the rocks as regards water-power is their great hardness and their disposition on the southern slopes, where the water-power is for other reasons most favorable. As the streams cross their upturned edges, ledge after ledge, numerous falls, rapids, and cascades are formed in all parts of the region, from the mountains to the sea. These falls are permanent, which would not be the case were the rocks soft, disintegrable sandstone or limestone. Further, not only are good building materials everywhere abundant, but the facilities for the location of mills on solid foundations are unsurpassed.

The soil through the whole of New England is comparatively shallow, and is generally clayey or sandy in character. The rock is much exposed over the whole region, and there is little alluvial soil. Were the rainfall very unevenly distributed through the year, and were there no facilities for storage, this shallowness of the soil would be very unfavorable, and the water would be rapidly shed from the rock surfaces, rendering the streams very variable in flow. But we shall see that the rainfall is very uniformly distributed through the year, though in a way favorable to constancy of flow, and this renders the shallowness of the soil of less detriment. Considerable beds of drift exist in places, but there are few sand-hill streams like those on the coast of New Jersey or in the southern states, there being few or none in Maine and New Hampshire, and only a few small ones in Massachusetts and Rhode Island.

The forests are very extensive in the region we are considering. It is estimated that in Maine there are 19,300 square miles of wilderness, and perhaps 21,200 square miles of woods in all. In New Hampshire the mountains are densely wooded around their bases, though the ridges, and especially the summits, are often bare. In Massachusetts and Rhode Island the woods are less extensive. These woods are located very favorably where they are likely to be long permanent, and being principally evergreen, they shade the ground at all seasons, thus checking evaporation, lessening the violence of winds, and so increasing the amount of water discharged by the streams. For a statement of the effects of forests, reference may be made to the introduction to the Report on the Southern Atlantic Water-shed. Their favorable influence is generally recognized, yet it must be remarked that their destruction would be much less detrimental here than in regions where there are no lakes, where the rainfall is

very unevenly distributed, where the temperature is high, or where the country is more mountainous. Most dense at the foot of the mountains, the woods of New England operate to check the torrents rushing from their rocky sides, and hence to mitigate very essentially their unfavorable effects.

5.—Tidal water-power.

The economical use of tidal water-power requires not only a sufficient rise and fall of the tides, but also a topography along the coast favorable for the location of buildings and for the construction of basins in which to store the water at high tide. In all these respects the coast of New England is more favorable than any other part of the Atlantic coast. The rise of the tide varies from 5.1 feet at Providence to 10 feet at Boston, 8.6 feet at Portsmouth, and 18.1 feet at Eastport, thus increasing quite regularly from south to north, and averaging 11.6 feet on the coast of Maine. South of Maine the average rise for the whole Atlantic coast is only 5.2 feet. Moreover, the coast of New England, especially in Maine, is rock-bound, so that there is no trouble with regard to proper foundations; and finally, the coast-line being very irregular and indented with numberless bays and inlets, there are no difficulties as regards storing the water in sufficient quantity.(*a*) Tidal power is used at a few places in Massachusetts, but principally in Maine, and it is in that state that the conditions are most favorable. It can be used there for sixteen hours out of twenty-four, and is used principally for saw-, grist-, and plaster-mills. There is no trouble with ice, and the facilities for transportation by sea or land are of the best.

6.—Climate.

The principal climatic conditions of the region under discussion, in so far as they affect the water-power, will be briefly given.

(*a*) Coast-line and ocean-currents.—The coast-line, which measures nearly 450 miles, following its general course, is so indented as to make its real length perhaps ten times as large. It is washed by the cold polar current which flows between the coast and the warm waters of the Gulf stream, so that the winds from the east and northeast, though maritime, are cool, while those from the south and southwest are much warmer.

(*b*) Winds.—The winds are variable, rarely blowing from one direction for more than a few days. The prevailing winds, however, are from the west, southwest, or northwest, in all parts of the region. In summer, winds from the southwest are most frequent; in winter, those from the northwest, while winds from between south and east are least frequent of all, occurring principally in summer. The resultant wind for the year, which shows the general direction of the motion of the atmosphere, is always from a point between north and west. In summer the resultant is from south of west, and in winter from north of west.

(*c*) Temperature.—The mean summer, winter, and annual temperatures are quite different in different parts of the region we are considering. The mean annual temperature varies from 40° in the north to 48° or 50° in the south; the mean summer temperature from about 62° in the north to 68° in the south; and the mean winter temperature from 12° or 14° in the north to 28° or 30° in the south. As compared with the middle and southern states, the mean annual temperature is, speaking roughly, from 8° to 15° lower, while the mean summer temperature is from 5° to 10°, and the mean winter temperature 12° to 20° lower. For more extended data we must refer to the Report on the Southern Atlantic Water-shed and the publications of the Smithsonian Institution. The most important point to be noticed is the fact that although the mean annual temperature is considerably lower than that in the middle and southern states, this is due not so much to a lower summer temperature as to a lower winter temperature. The table of extreme observed temperatures which will be given in the Report on the Southern Atlantic Water-shed shows that the highest observed temperatures in Maine and in Alabama are almost the same; and the table of average temperatures of hottest and coldest months, also given in the same report, shows very clearly that there is much greater difference between the coldest months in New England and those in the southern states than there is between the hottest months in those localities. On account of the cold current flowing along the coast of New England the temperature of that region is lower in summer than that of the regions farther inland, while its mean winter temperature is higher, so that the yearly fluctuation is less, as would naturally be expected from its position on the coast. The isothermals run generally parallel to the parallels of latitude, the mean annual temperature decreasing from south to north. Compared with other parts of the country, the annual fluctuation of temperature is greater in New England than in the southern sea-board states, but less than in the inland states. Regarding the winter temperature, the principal point to be noticed is that it is below the freezing point. The severity of the winter in New England is productive of some difficulty in keeping the wheels and canals clear of ice, but this trouble is generally considered to be greater than it really is by those in states more favored in this respect. Indeed, the trouble carries with it its own corrective. Before the lakes and ponds freeze over in the winter some trouble is experienced from floating ice and from anchor-ice, but as soon as they freeze over permanently this trouble ceases, the covering of ice keeping the water warm beneath it. Floating ice may be kept out of the canals by suitable

a The coast-line of Maine, which is 226 miles long in a direct line, measures, with all its indentations, from 2,000 to 3,000 miles.—Wells: *Water-power of Maine*, p. 34.

fenders, but at night it sometimes forms in them, and has to be run out in the morning if it is thick enough to diminish too greatly the capacity of the canals. Anchor-ice, which forms at the bottom of the canals in small particles and rises to the top, filling the races, racks, and flumes with a mass of slush, is sometimes very troublesome, but rarely after the ponds freeze over. On the whole, the interruption due to ice does not generally extend over more than a few days in the year, and in the case of some of the large powers, where pains are taken to prevent it, no trouble at all is experienced in running the machinery all the time. The low annual temperature is favorable in increasing the rainfall and diminishing the evaporation, and so contributing to the flow of the streams, without impairing the habitability of the region. This effect would be greater were the summer temperature lower.

(*d*) RAINFALL.—We have to do here with a part of the country falling under type I, according to the classification followed in the Smithsonian tables of rainfall (*Smithsonian Contributions to Knowledge*, 353, second edition, 1881). The characteristics of this type are the following: "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 stations from which this type is constructed are 18 in number, extending from Portland to Washington, and are mostly near the coast. The monthly rainfall varies from 0.84 of the mean in February to 1.22 of the mean in August, the fluctuation being, therefore, 38 per cent. of the mean monthly rainfall. In New England alone the fluctuation is rather smaller, or about 34 per cent., the monthly rainfall varying from 0.85 to 1.19 of the mean. In the Hudson River valley it is 60 per cent., in the upper Mississippi valley 105, on the southern Atlantic coast 140, and on the Pacific coast 232 per cent. From the fluctuation alone, however, no conclusions can be reached regarding the flow of the streams, for this depends upon the season when the rainfall is greatest, as has already been indicated. It is important to notice, however, that the fluctuation in New England is less than in any other part of the country, or that the rainfall is more uniformly distributed through the year. The fluctuation seems to increase a little as we go north in New England, and also as we recede from the coast, being, in some places distant from the coast, nearly or quite twice as great as given above; still, it is nevertheless true that in no part of the country is the rainfall so uniformly distributed through the year as in that with which we have now to do.

As regards absolute amount, the mean annual rainfall varies from between 44 and 50 inches along the coast and over almost the whole of Connecticut, Rhode Island, and Massachusetts, to 38 inches in the north of Maine and New Hampshire, diminishing as the coast is receded from. The rainfall averages, speaking roughly, about 11 inches in spring, 11 in summer, 12 in autumn, and 10 in winter, except near the coast, where it is more uniform.

The annual rainfall is subject to an extreme fluctuation of about 50 per cent. of its mean value, this being about as small as in any other part of the country. Very dry or very wet years are therefore not to be often looked for. We see, therefore, that both from year to year and from month to month the rainfall is about as evenly distributed in this district as in any other part of the United States. The small excess in summer and autumn is favorable to a constant flow of the streams, and would be very important, in view of the shallow soil, were there no facilities for storage.

Snow falls to a considerable depth over the whole region in question, and in the mountains does not disappear till late in the spring, remaining on the ground even all the year in some parts of New Hampshire. The mean annual depth of snow at seven stations in Maine has been found to be about 83 inches, but in the other states it is less. *The fact that in winter nearly all the precipitation is in the shape of snow has an important effect on the flow* of the streams. When the ground freezes it becomes nearly impervious to moisture, so that during the winter almost all the water reaching the streams is that derived from springs, fed by rains of the earlier months, and that due to the melting of the snow, which runs directly from the ground. If the snow stays on the ground all winter, with no warm periods sufficient to melt much of it, the streams are apt to run very low. If, on the other hand, the snows are liable to be carried off suddenly by short periods of warm weather, the streams will be subject to severe freshets. In this district, and especially in the northern part of it, the snows remain on the ground all winter, and, protected by the forests, they often are dissolved very gradually before the approaching heat of summer, and disappear much less suddenly than in the middle states. Though the rivers in both regions are subject to spring freshets when the snow goes off, those in this district are in general less sudden and severe than those on streams farther south, and they are less liable to be accompanied by ice-jams, because the ice on the lakes does not go out until it has become melted to such an extent as to be rotten and of little danger, while the streams below them, as has been remarked, are not so liable to have large masses of floating ice. Though the streams are subject to a winter drought, that drought is, in general, not so severe as that which occurs in summer, and is therefore not detrimental to the use of power. The fact that the freshets and ice-jams are not so severe here as in the states farther south is one of great importance. Rises of 60 feet, such as occur on some of the western and southern streams, are unknown here, and even the greatest recorded rise of the Connecticut at Hartford (29½ feet) has not often been reached on any of the streams we are to consider.

Another favorable feature of the district is the prevalence of fogs, which are particularly frequent in Maine. The dense fogs formed off the banks of Newfoundland are brought in by the northeast winds, and often involve, for weeks at a time, a considerable portion of the state, especially during the latter part of summer. Fogs, in fact, are generally associated with rain in Maine, the latter falling generally quite gradually, and not so much in sudden

showers as in the states farther south. These facts are important, because where rain falls gradually it is not shed from the surface so rapidly, but has more chance to be retained in the ground and discharged gradually; and where fogs prevail evaporation is diminished, because the air is cool and moist, and the rays of the sun are intercepted. This is especially important, as the fogs prevail in summer.

7.—Flow of streams.

We have discussed already the general principles governing the flow of streams, and also the effect exerted on the flow by the various general circumstances connected with the district. It is, therefore, only necessary here to show how the estimates given in the following pages have been made.

In the Report on the Southern Atlantic Water-shed reference is made to the fact—which follows clearly enough from what has been said already in this report—that it is not correct to assume any fixed proportion of the annual rainfall as discharged by the streams. In the following report estimates are given of the following four quantities regarding flow:

1. The absolute minimum flow.
2. The minimum low-season flow.
3. The maximum flow with storage.
4. The low-season flow in dry years, but not the driest.

The absolute minimum flow can only be estimated by comparison with results of gaugings on other streams, a number of which are given in the table on page 9. In estimating it, it is best to assume the number of cubic feet per second per square mile of water-shed, and all the circumstances detailed as affecting the distribution of flow have to be taken into account. The minimum flow is of course all that can be depended upon permanently, but it occurs at such rare intervals that it is generally advisable to utilize a larger amount, even if there is a deficiency at times.

The low-season flow in any year is the flow during the period, of from three to eight weeks, when the stream is lowest. This flow is different in different years, and its minimum value occurs only at intervals of a number of years. In ordinary years the flow will at all times be greater than the minimum low-season flow, except, perhaps, for a day or two; in very dry years it may be less than the minimum low-season flow for several weeks at a time. The minimum low-season flow has been estimated in the following way: It has been found by the experience of cities in regard to their water-supply, and by continued gaugings of streams, that in very dry years, in this climate, the total amount of rainfall discharged by streams falls as low as from 12 to 15 inches over the entire drainage basin. In ordinary years a larger quantity is discharged, but at intervals of from five to ten years a very dry year occurs, when the total flow does not exceed 12 or 15 inches over the water-shed. Having assumed an annual flow of from 12 to 15 inches, then, by dividing it by 12, we obtain the average flow per month, in inches on the water-shed. Now, 1 inch on a square mile, flowing off in a month, would give an average flow of 0.884 cubic feet per second, so that by multiplying by 0.884 the average flow in inches per month, we have the average flow, in a very dry year, in cubic feet per second per square mile.

It is now necessary to have some data regarding the way in which the flow varies from month to month, and in regard to this some figures are collected and shown in the table on page 10. By multiplying the average flow obtained above, by the ratio which the flow in any month bears to the mean—that ratio being reached by a study of the last-mentioned table, bearing in mind all the local circumstances—we obtain the flow in that month in the year in question. The minimum low-season flow, though not to be depended upon permanently, may be rendered so by a small amount of artificial storage. It is generally advisable to utilize a larger flow, even though there may be a deficiency at intervals.

The minimum low-season flow occurs in the driest year, but not necessarily the year of least rainfall, because it is not the amount of rainfall alone that affects the flow. Assuming, however, as close enough for practical purposes, that the amount of flow in a year will vary directly with the rainfall, and that the year of the minimum low-season flow will be the year of minimum rainfall, we may estimate the low-season flow in other years by proportioning it to the rainfall. The Smithsonian tables show that the minimum annual rainfall is about 0.7 of the mean, and the maximum about 1.3 of the mean; and, further, that the rainfall in ordinarily dry years, but not the driest, is about 0.8 of the mean. Having found, therefore, the minimum low-season flow, we may approximate to the low-season flow in ordinarily dry years by taking eight-sevenths of it, and to that in ordinary years by taking ten-sevenths of it. Further, these remarks, in connection with the table of monthly distribution of flow, will enable any one to estimate the flow during any number of months in any year. The local circumstances, however, must be carefully studied, and upon the judgment shown in taking them into account will depend the accuracy of the estimates.

If sufficient storage is available the average amount of water discharged in any year may be utilized, the quantity in excess of the average being stored up and delivered in times when the natural flow is less than the average. The quantity which can be depended upon permanently, however, is evidently that which flows off during the driest year, or the smallest quantity which flows off in a year; *i. e.*, 12 or 15 inches, according to what has been said above. By building storage reservoirs of sufficient capacity, then, we may utilize permanently a quantity equal

to 12 or 15 inches in a year over the whole drainage area, flowing off uniformly. By dividing this by 12 and multiplying by 0.884 we obtain the number of cubic feet per second per square mile of water-shed. The amount of storage necessary to render this quantity available has been found by experience to be 3 or 4 inches in depth over the entire water-shed. With small drainage areas the maximum with storage may be utilized, but with drainage areas over a few hundred square miles in area the storage necessary is so large that unless specially favorable circumstances are present, such as lakes which may easily be converted into artificial reservoirs, the storage necessary could not be economically provided for. In the case of large streams, then, the maximum with storage is of small importance. In many cases the flow can be materially regulated, but not to such an extent as to render the absolute maximum available.

I will recapitulate here briefly the meaning of the four quantities estimated:

1. ABSOLUTE MINIMUM FLOW: May be depended upon always, without storage; occurs only at rare periods; generally a large excess.

2. MINIMUM LOW-SEASON FLOW: Flow in the low season of driest year; may be depended upon, without storage, at all times except for a few days in the dry season of each year, when there may be a deficiency; with small storage, may be depended upon all the time.

3. MAXIMUM FLOW WITH STORAGE: Mean flow in driest years; storage already discussed; with larger storage, more could be utilized for several years, but not permanently.

4. LOW-SEASON FLOW IN ORDINARY DRY YEARS, without storage: May be depended upon except in the dry season of each year, when for a few days, perhaps weeks, there may be a deficiency; may be rendered permanently available by storage. This last quantity is the most important of the four, yet in each particular case it is a special problem to decide how much power may be economically utilized.

The following are the tables referred to:

Extremes of flow for some American streams.

River.	Place.	Drainage area, square miles.	Mean rainfall, inches.					Remarks on character of drainage basin.	Extremes of flow.			Minimum, cubic feet per second per square mile.	Ordinary low-water flow, cubic feet per second per square mile.	Authority and remarks.
			Spring.	Summer.	Autumn.	Winter.	Year.		Maximum, cubic feet per second.	Minimum, cubic feet per second.	Ratio.			
Merrimack	Lowell	4,085	10	11	13	9	43	Lakes and artificial reservoirs. Wooded.	81,000	1,275	64	0.31	.....	
Merrimack	Lawrence	4,500	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.	.....	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	a0.510	.....	T. G. Ellis.
Connecticut	Dartmouth	3,287	10	12	12	10	44	....do	.....	1,006	.....	0.306	.....	C. Herschel.
Housatonic	.....	790	12	12	12	10	46	.....	.....	130	.....	0.165	.....	H. Loomis, Report New York Committee Public Works, 1879.
Croton	.....	338.82	12	13	13	10	48	.....	25,367	50.80	500	0.150	.....	J. J. R. Croes and G. W. Howell.
Croton, West branch.	.....	20.37	12	13	13	10	48	Very broken and undulatory. Hills steep and rocky. Largely wooded. Little cultivated.	1,109	0.407	2,722	0.020	.....	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	10,944	225.00	88	0.023	.....	Do.
Delaware	Lambertville	6,500±	11	13	11	9	44	Hilly and rolling. Many lakes. Well wooded.	350,000	2,000	175	0.300	.....	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.

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, on good authority.

Extremes of flow for some American streams—Continued.

River.	Place.	Drainage area, square miles.	Mean rainfall, inches.					Remarks on character of drainage basin.	Extremes of flow.			Minimum, cubic feet per second per square mile.	Ordinary low-water flow, cubic feet per second per square mile.	Authority and remarks.
			Spring.	Summer.	Autumn.	Winter.	Year.		Maximum, cubic feet per second.	Minimum, cubic feet per second.	Ratio.			
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	11,470	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	.....	0.120	.....	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.	.....	.....	.....	.....	0.193	W. C. Kerr. Low-water.

Monthly distribution of flow.

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	330	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	[illegible]
Concord	361	0.25	0.32	0.36	0.43	0.54	0.68	0.85	1.07	1.36	1.76	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	[illegible]
Merrimack	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	[illegible]
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	[illegible]
Schuylkill (a)	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	1.5[illegible]	[illegible]
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	[illegible]
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	[illegible]
Merrimack	4,599	0.77	0.88	1.06	1.26	1.52	1.80	2.12	2.49	3.03	3.73	4.03	6.56	29.85	0.31	0.36	0.43	0.51	0.61	0.72	0.85	1.06	1.22	1.50	1.86	[illegible]
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	[illegible]
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	[illegible]
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	[illegible]
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	1.29	1.60	2.01	[illegible]
Passaic headwaters	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	1.90	[illegible]

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

9.—RÉSUMÉ.

Reviewing what has been written in the previous pages, the topography and the geology of the region, affording a rapid declivity from the mountains to the sea, broken by sudden falls over ledges of hard rock; the favorable character of the bed and banks as regards foundations and freedom from overflow; the favorable arrangement and small extent of the mountain region; the low temperature, causing a large rainfall and a small evaporation; the favorable distribution of the rainfall through the year; the immense facilities for storage; the extensive forests; the absence of very destructive freshets and ice-jams; the rock-bound coast, affording facilities for utilizing the large rise of the tide; the prevailing fogs; and the accessibility of the region, together constitute an array of favorable circumstances which may well entitle New England to the first rank as a water-power district, as the detailed account of the different streams will show.

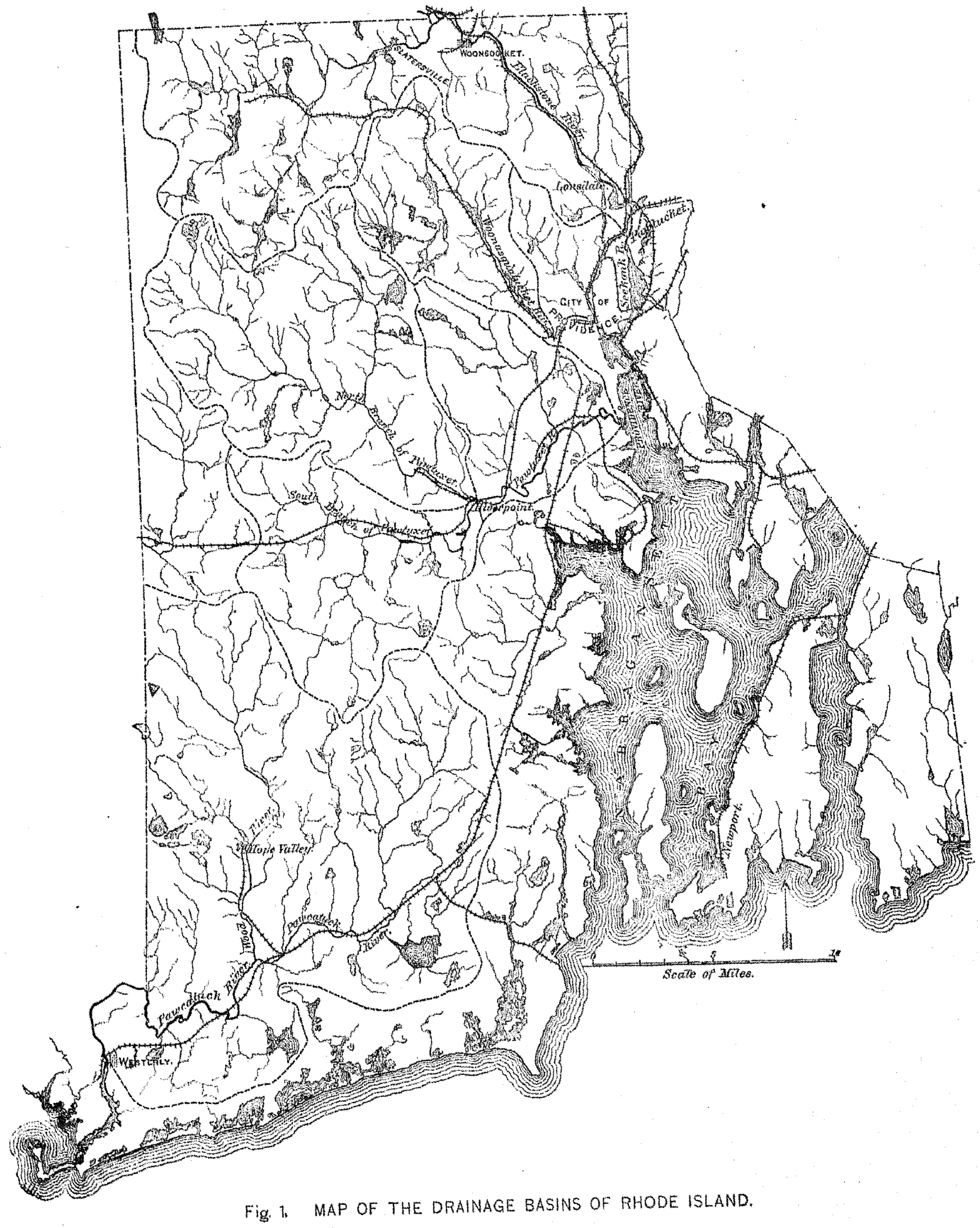


Fig. 1. MAP OF THE DRAINAGE BASINS OF RHODE ISLAND.

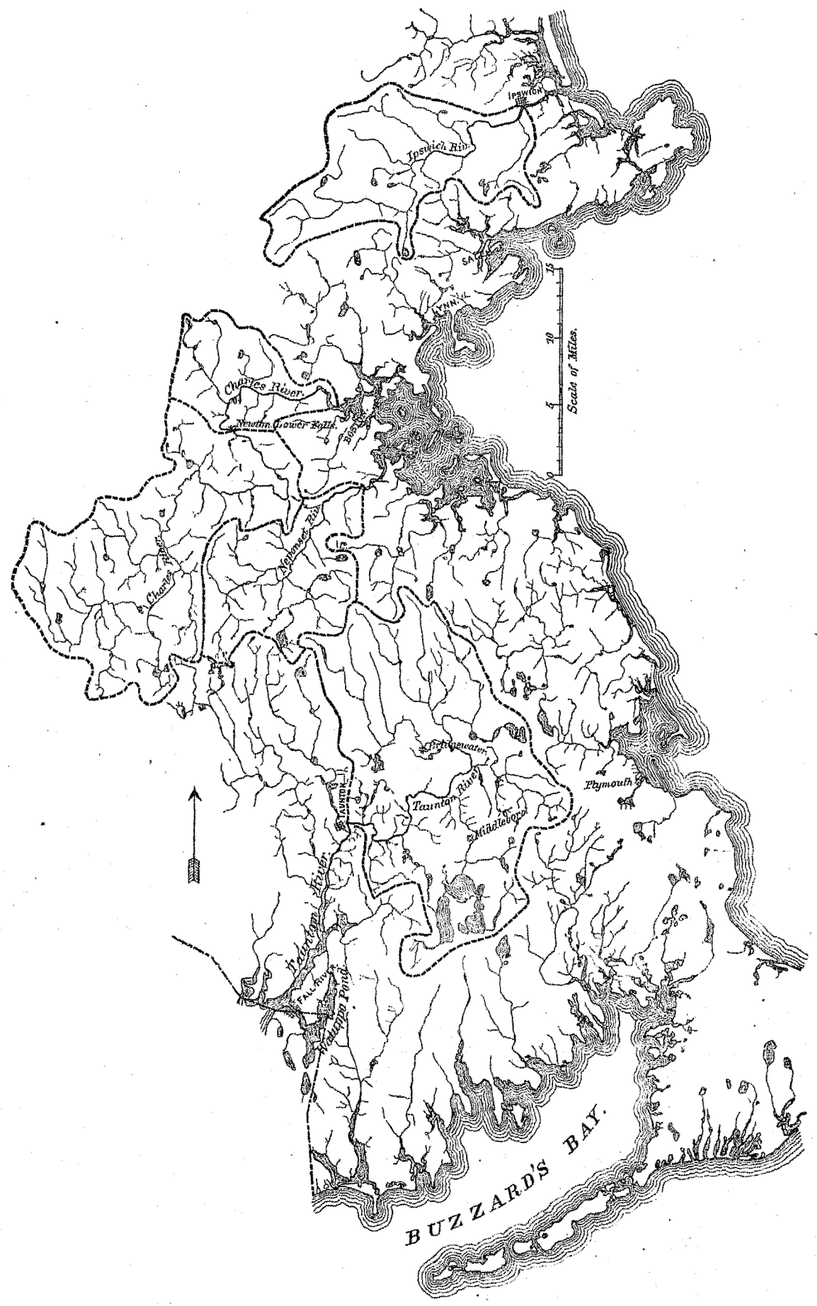


Fig. 2. MAP OF THE DRAINAGE BASINS OF EASTERN MASSACHUSETTS.

II.—THE COAST STREAMS SOUTH OF THE MERRIMACK.

The streams flowing into the Atlantic between the Merrimack and the Connecticut possess no true mountain district, but are confined entirely to the middle division, or Atlantic plain, which covers Rhode Island and eastern Massachusetts. Nevertheless, their fall is quite rapid, and lying, as they do, close to the most populous cities of the region and within easy reach of railroad communication, they have been utilized for power for many years, and privilege after privilege has been improved, until scarcely any are left idle. By a system of reservoirs their flow has been rendered in many cases much more uniform than it otherwise would be, so that some of them afford a large number of excellent powers. The rainfall over the whole region is about 45 inches, very evenly distributed through the year, nearly the same amount falling in each season.

We will describe the streams in order, commencing at the south. Passing over the Mystic river and several other small streams not worthy of a description, the first stream which is to be noticed is,

THE PAWCATUCK RIVER.

This stream takes its rise in the southern part of Kent county, Rhode Island, and pursues first a southerly course, for a distance of about 12 miles, in a straight line, under the names of Queen's and Usquebaug rivers. Turning to the west, it then pursues a tortuous course in a general southwesterly direction for about the same distance, when it reaches tide-water, at Westerly, Rhode Island, about 5 miles from Long Island sound. The stream is small, draining only about 286 square miles, comprising a considerable extent of flat and swampy country, while the rest is hilly and rolling. The only town of much importance through which it flows is Westerly, the head of navigation. The drainage area is not well wooded, and there are few lakes. Some artificial reservoirs, however, together with the swamps, serve to restrain the violence of the floods, and suffice, with the mill-ponds, to regulate the flow to some extent, making the stream quite a good one for manufacturing. Its bed and banks are in places rocky, but are generally of sand or gravel, the stream, in fact, partaking to some extent of the character of a sand-hill stream. Its fall is not large, but is completely utilized. It is not subject to severe freshets, and little ground, outside of the swamps, is overflowed, a rise of 3 feet being seldom exceeded. The character of the drainage basin is not such as to favor the rapid discharge of storm waters, and the regulating effect of the swamps and mill-ponds is considerable.

The first power on the stream is at Westerly, where the rise and fall of the tide is about 4 feet, and up to which place boats drawing nearly 7 feet ascend. A wooden dam 5½ feet high ponds the water half a mile, affording at low tide a fall of 5½ feet. Power is used on both banks, on the left by the Stillman Manufacturing Company's woolen-mill, with 50 or 60 horse-power during about eight months, while at other times the power is almost nothing; and on the right bank by the Carmichael Manufacturing Company (machine-shop and woolen-mill), using about 100 horse-power during about six months. The mills have steam in reserve.

Above Westerly there are a number of woolen- and cotton-mills on the stream, all the sites of importance being occupied. Reliable data regarding the power of these mills are not at hand. The power used, however, is much in excess of that afforded during the low season, so that generally steam-power is in reserve, and water-power alone is not depended upon. The mill-ponds suffice to store the water at night in dry seasons, but the swamps, not being controlled, are not very efficient as regulators of flow during the year, except in diminishing the violence of freshets. Full capacity is not generally secured for over nine or ten months.

Of the tributaries of the stream only one is worthy of remark. Wood river, which has its sources in Kent county, flows nearly south through a distance of about 15 miles, joining the Pawcatuck at Plainville. It drains about 83 square miles, and resembles the main river in all essential respects. Like it, it is utilized by various mills, but in dry weather the power is very small, and the mills have to use steam or stop running. The stream has a few unutilized privileges, but none of much value.

Of the lakes and ponds connected with the Pawcatuck none are dammed and used for storage except some on Wood river. Wordin's pond, which comes in above Holberton hill, is the largest sheet of water, and is connected with swamps of considerable size. In addition to this, Pasqueset, Watchaug, and School-house ponds, and two near Kingston, are not used. Connected with Wood river are some small ponds used as reservoirs, of which a few may be mentioned: Yawcoog pond covers from 500 to 550 acres when full, and can be drawn down about 16 feet, containing sufficient water to run a mill below for some three months; and Wincheck pond, just below, but above the mill, is said to cover some 400 acres, and can be drawn down 5½ or 6 feet. Both of these ponds are controlled by the mill at Rockville. Blue pond, on another branch, covers some 200 acres, and Long pond is smaller; besides which there are other and still smaller ponds. In addition, there are some small ponds on a small stream joining the Pawcatuck at Laureldale. The only sites not used are a few small ones on some of the tributaries of the main stream.

THE PAWTUXET RIVER.

This stream has two branches, the North and the South, the latter of which rises in the western part of Kent county, and pursues a generally easterly course for about 10 miles, to Riverpoint, where it meets the North branch, which has its sources in Providence county, and pursues a southeasterly course, draining a basin about 16 miles long. From Riverpoint the main stream pursues a northeasterly course for about 8 miles, emptying into the Providence river at the village of Pawtuxet, or about 5 miles below Providence. The area drained by the North branch is about 108 square miles; by the South branch, about 71 square miles; by the main stream at its mouth, about 229 square miles. The drainage basin is undulating or hilly, the fall of the stream considerable, the bed and banks are gravel, rock, and sand, the banks not often subject to overflow, and the storage facilities good. The entire fall is utilized, principally by cotton-mills, there being no unimproved sites of importance on either branch. The flow of the stream is variable, yet not to a great extent. Indeed, the stream is called one of the most permanent in Rhode Island, and there is no trouble whatever with freshets. Numbers of artificial reservoirs are connected with the stream, and are used for the benefit of the mills. The following is the information I have been able to collect regarding them:

1. Almy reservoir, Simmons' upper and lower reservoirs, connected with Pochasset river, a tributary of the main river. These are small ponds, and no further data are at hand regarding them.

2. Connected with the South branch:

a. Tioga reservoir, in the southeastern part of the town of Coventry, emptying into the South branch between Washington and Anthony. This reservoir covers about 200 acres and can be drawn down 14 feet, but is not used for power. It is opened every morning and shut every evening.

b. Carr pond, in the town of West Greenwich, joining the South branch between Washington and Coventry Center, covers about 100 acres, and can be drawn down 8 feet; allowed to flow continually.

c. Flat River reservoir, on the South branch, between Washington and Coventry Center, covers 1,000 acres, and can be drawn down 12 feet; opened every morning (except Sunday).

d. Coventry Center reservoir, above Coventry Center, covers about 300 acres; can be drawn down 8 feet. Average depth, about 6 feet.

e. Quidnick reservoir, in the town of Coventry, at the head of the stream, covers some 980 acres, (*a*) and can be drawn down 15 feet. Estimated capacity, 288,159,400 cubic feet; built in 1872 and 1873.

3. Connected with the North branch:

a. Westeonnaug reservoir, in the town of Foster, covers about 150 acres; can be drawn 13 feet; comes into Ponaganset river between Richmond and Ponaganset.

b. Ponaganset reservoir, at head of Ponaganset river, in the town of Gloucester, covers 225 acres; can be drawn down 25 feet (?).

c. Moswansicut pond, in the towns of Scituate and Johnston, on the Scituate river, covers about 550 acres; can be drawn down 8 feet.

These reservoirs have increased the low-water flow of the stream by a very large proportion. It is proposed to build a new one on the Ponaganset, in the town of Scituate, where it is estimated that a dam 14 feet high could be erected.

The first power on the Pawtuxet river is within half a mile of its mouth, or about 24 miles from the sea. The power, however, is very small. Above it there are two cotton-mills below the junction of the two branches, using a total fall of 25 feet. The mill at Pontiac has a fall of only 5 or 6 feet, while that at Natick has a fall of 20 feet and 700 horse-power. Both mills, however, have engines in reserve.

On the South branch there are some eight cotton-mills, with a total fall of 142 feet, and, in all, nearly 2,500 horse-power. The lowest mills are two of the Green Manufacturing Company, using, respectively, 8 feet fall and 100 horse-power, and 20 feet fall and 125 horse-power. These mills use no steam-power, and are therefore sometimes obliged to stop on account of low water, being only able to run at full capacity about ten months, with no waste at night. The mills above generally have steam-power in reserve. The water is well husbanded, there being no waste for months at a time in dry weather. No trouble is experienced with ice or freshets, 4 feet being a large rise. There are two small powers on this branch said to be not in use at present, though improved.

The North branch resembles the South branch, and, like it, is utilized almost completely, principally by cotton-mills, of which there are a large number on the stream and its various tributaries. The bed and banks are generally rocky where there is any fall. On the upper part of the stream and on its tributaries there are several small powers not used, but none of consequence. The flow of the stream is tolerably uniform, 4 feet being a very large rise in a freshet, as on the South branch; still, the latter is said to be more regular. From the Ponaganset reservoir to tide the fall is said to be 240 feet. Some idea of the capacity of the stream may be obtained from the following data: At the Clyde print-works, the lowest power on the stream, a wooden dam 7 feet high, with a canal of 800 feet, affords a fall of 14 feet, and 240 horse-power are obtained during nine or ten (?) months, there being no waste at night. Steam-power is in reserve, as is the case with almost all the mills on the stream.

a According to another statement, this pond is "a mile long by five-eighths of a mile wide".

At the cotton-mill of the Lippitt Company, the next above, the fall is 14½ feet, although the available fall between its dam and that below is said to be 17 feet. A power of 150 or 200 horse-power is obtained during about eight months, steam being in reserve. In dry weather there is no waste, and the power runs down to 50 or 75 horse-power.

The Pawtuxet river is one of the best utilized and improved streams in this district. From a comparatively small stream, by judicious reservoiring, a large amount of power is obtained.

THE WOONASQUATUCKET RIVER.

The Woonasquatucket is a small stream, its most distant sources lying in Providence county, about 12 miles northwest of the city of Providence, and its drainage area measuring only about 72 square miles. Its general course is southeast, and it empties into the Providence river at the city of Providence, through which it flows. It drains a hilly and rolling country, and its fall is very large. Notwithstanding its small size, it is of considerable importance as a manufacturing stream, principally on account of the large reservoirs near the headwaters, which are controlled in the interests of the mills below, and regarding which the following facts have been obtained:

1. The Waterman reservoir, covering 318 acres when full, has an average depth of about 9 feet, all of which may be drawn off. It was built nearly fifty years ago, and is controlled by the Woonasquatucket Reservoir Company, consisting of the mill-owners below.

2. The Slack reservoir, emptying below the Waterman, covers 153 acres, with an average depth of about 10 feet. It was built about sixty years ago, and is controlled by the Bernon Manufacturing Company.

3. The Sprague reservoir, controlled by private parties, covers 95 acres, with an average depth of 9 or 10 feet.

4. The Hawkins reservoir, on a tributary, and controlled by private parties, covers 30 acres, with an average depth of 10 feet.

5. The Georgiaville reservoir, or pond of the Georgiaville mills, covers some 130 acres, and is drawn down several feet. It is said that these reservoirs hold about three months' supply for the mills below. By means of them this comparatively insignificant stream has been transformed into an excellent source of power, and almost its entire fall is now utilized, principally by cotton- and woolen-mills, there being no good sites not used. According to the census returns there are, in all, 12 mills on the stream, using a total fall of 204 feet and a total power of 1,374 horse-power. The fall of the stream below the Waterman reservoir is probably not less than about 15 feet per mile. The bed and banks of the stream are generally gravelly, but sometimes rocky, and the freshets very slight, the flow being comparatively constant for so small a stream. Nevertheless, most of the mills have steam-power in reserve, for use in dry seasons. The stream is one of the best examples of what may be accomplished by a system of reservoirs, although, being so small, its flow in very dry seasons is almost nothing.

THE BLACKSTONE RIVER.

This stream, the most important one south of the Merrimack, has always been renowned as a source of power, and it probably turns more spindles than any other stream of equal size in New England. Rising in Worcester county, Massachusetts, near the city of Worcester, it pursues a course southward and eastward, passing into Rhode Island, and emptying into the Providence river at Providence. In the lower few miles of its course, below Pawtucket, it is known as the Seekonk river. It passes in its course the towns of Millbury, Uxbridge, Blackstone, and others in Massachusetts, and Woonsocket, Lonsdale, Pawtucket, and others in Rhode Island, the latter being at the head of tide and of navigation. The length of the stream from its source to Pawtucket, measured in a straight line, is about 38 miles, and its drainage area above that point measures about 458 square miles, comprising a hilly and rolling country, not very well wooded, and with good facilities for storage. Though there are no large lakes in the basin, there are numerous small ponds and reservoirs used for storage, so that the stream may be said to be very well reservoired, and its flow is much more constant than it otherwise would be. The freshets are never severe enough to do any damage, and the low-water flow is very large for a stream of its size. The bed and banks are in every way favorable for power, being often rocky, and there being few low grounds subject to inundation. The valley is entirely free from limestone, the rocks being almost wholly granitic, particularly about the headwaters. The fall of the stream is considerable, and there are a number of natural falls, but every available site has long been utilized; and although at first water-power was depended on, the mills have gradually increased the amount of power used, until now they are obliged to use considerable steam in the dry season, and in some cases all the time. The large number of ponds and reservoirs and the great number of mill-ponds enable the entire flow of the stream during the dry season to be utilized during working hours. The mills are principally woolen- and cotton-mills, and the stream is closely followed for its entire length by a railroad, so that every point is easily accessible. At the mouth of Mill brook, at the city of Worcester, the river has an elevation above tide of 438 feet, and its course below that point measures about 42 or 43 miles, so that its fall is not less than 10 feet to the mile, which is very considerable.

Commencing at the mouth, the various powers on the stream will now be considered.

The first is at Pawtucket, Rhode Island, where there are two dams. The lower one is 6 feet high, or less, and affords a fall of about 18 feet. The power afforded is used on both sides of the stream, half being owned on each side. On the east side is D. Goff & Sons' braid-mill, with $\frac{42}{64}$ of the power, or from 200 to 250 horse-power, and the Bridge Mill Paper Company, with $\frac{22}{64}$, or about 100 horse-power. On the west bank there are no large concerns, but a number of small ones, the power being rented. No pains are taken to divide the water accurately, but full capacity can generally be obtained. The second dam, only a few hundred feet above the lower one, is 7 feet high, and ponds the water for three-quarters of a mile. It is used on the east bank by the Dexter Yarn Company, owning $\frac{16}{64}$ of the entire power, and the "White mill", let to various tenants, with $\frac{13}{64}$ of the entire power. On the west bank are the "old Slater mill", a yarn-mill, the upper floor being let to small establishments at about $100 per horse-power, and the total power being $\frac{15}{64}$ of the entire power; a second mill, let to different tenants, owning $\frac{10}{64}$ of the whole; and Littlefield Brothers' thread- and yarn-mill, with $\frac{10}{64}$ of the whole power. The fall at all the mills is 82 inches, and the distribution of the water is effected by proportioning the apertures to the quantity owned. The mills run eleven hours daily, and can generally run all the year. In addition to the mills mentioned, two other mills on the west bank obtain water from the upper dam, taking their water, of which they are entitled to 23 cubic feet per second, through a separate canal 500 feet long. The first mill is let for various purposes, and uses a fall of 8 feet, the second taking the same water and discharging it below the lower dam. The power at Pawtucket is so divided up among a number of small establishments that no accurate statement of the power used can be made.

The next power is at Central Falls, where power is used on the west bank, with a fall of 10 feet, there being the following privileges: Stafford Manufacturing Company, cotton mill, owning $\frac{112}{288}$ of whole power, or about 240 horse-power; a privilege belonging to the Andrew Jenks estate, not occupied, owning $\frac{24}{288}$; Thurber, Horton & Wood's cotton-mill, with $\frac{56}{288}$; Central Falls woolen-mill, with $\frac{36}{288}$, and the Pawtucket Haircloth Company, with $\frac{60}{288}$ of the whole. The total power used is stated at 450 horse-power, and the distribution of power is effected by regulating the sizes of the apertures. Full capacity can only be obtained during ten months or so, and some steam is in reserve. (*a*)

The next power is that at Valley Falls, where there is a cotton-mill on each side of the river. The dam is of stone, 9 feet high; the fall used, 13 feet, and the power, about 600 horse-power, during nearly the whole year. Next comes the large power at Lonsdale, where the fall is about 12 feet, and both steam- and water-power are used; then the mill at Ashton, 3 miles above, belonging to the same company, with about the same fall. Part of the water from the Ashton pond is carried by a canal on the west bank of the river down to Lonsdale, and used there with a fall of about 23 feet. The cotton-mill at Albion has a fall of about 14 feet, with 560 horse-power used, and rather more available at almost all times. At Manville a large cotton-mill uses a fall of 18½ feet, with 1,750 horse-power during nine months. The Hamlet mills, next above, use about 10 feet. At Woonsocket is one of the most important privileges on the river. There are two dams. The upper one, called the Globe dam, is of stone, founded on ledge, about 210 feet long, and supplies mills on both sides of the river, as follows:

On the right bank:

1. Globe cotton-mills; 18.5 feet fall; 200 horse-power (owning $\frac{51}{288}$ of total available power).

On the left bank:

2. George C. Ballou & Son's cotton-mill; 18.5 feet fall; 150 horse-power (owning $\frac{39}{288}$ of total).
3. Harris' mill No. 1; not running; 17 feet fall; 40 horse-power (owning $\frac{9}{288}$ of total.)
4. Mowry's grist-mill; 17 feet fall; 30 or 40 horse-power (owning $\frac{9}{288}$ of total).
5. Lyman cotton-mill; 17 feet fall; 70 horse-power (owning $\frac{18}{288}$ of total).
6. Bartlett cotton-mill; 17 feet fall; 70 horse-power (owning $\frac{18}{288}$ of total).
7. Lippitt woolen-mill; 15 feet fall; 150 horse-power (owning $\frac{36}{288}$ of total).
8. Harris' cotton-mill No. 5; 15 feet fall; 70 horse-power.
9. Harris' woolen-mills, Nos. 2, 3, and 4; 15 feet fall; 170 horse-power (Nos. 8 and 9 together owning $\frac{72}{288}$ of total).
10. American Worsted Company; 16 feet fall; 150 or 200 horse-power (owning $\frac{36}{288}$ of total).

Of these mills, Nos. 2, 3, 4, and 5 discharge their water direct to the river. No. 6 discharges into a race leading to No. 11, viz:

11. Pond's mill; 8½ feet fall; 25 horse-power, discharging the water into the river below the lower dam.

Nos. 7, 8, 9, and 10 discharge their water into a race or pond leading to Nos. 12 and 13, viz:

12. Groton cotton-mills; 14½ feet fall; 200 horse-power.
13. Clinton cotton-mill; 14½ feet fall; 300 horse-power.

Nos. 12 and 13 both discharge the water into the river below the lower dam.

The capacity of the stream in dry seasons is insufficient to run the mills above mentioned, and almost all have steam-power in reserve, in some cases enough to drive the entire machinery. During three months of the

a The power given as owned by these mills does not correspond with the figures in the census returns. The proportions are correct, and the discrepancy in the number of horse-power is due to some inaccuracy in the returns, or to the fact that some of the mills do not use all the power to which they are entitled.

year steam is the chief dependence, and during six there is often a lack of water. In dry seasons there is no waste at any time of the day. The water is distributed to the different mills, according to the amounts owned, in the following manner: In the flumes leading from the canal to the mills were placed weirs, whose lengths were proportional to the amounts owned, the whole river being at first considered equivalent to a weir 96 feet long. These weirs are not all on the same level, but are lower at the lower end of the canal, to allow for the fall of the water surface, the intention being to have the water flow over all weirs at the same depth, at average stages of the water. In order to allow greater capacity at high water, all weirs were subsequently lengthened by one-half. The proportions of the entire power of the stream owned by the different mills are inclosed in parentheses in the list already given. Nos. 12 and 13 have half the river, and of this No. 12 owns two-fifths, and No. 13 three-fifths.

The lower dam at Woonsocket, which receives $\frac{124}{288}$ of the entire flow of the stream, supplies the cotton-mill of the Woonsocket Manufacturing Company, the fall being 15 or 16 feet.

Above Woonsocket the Blackstone is literally lined with mills. At Waterford a woolen-mill uses a fall of about 11 feet. At Blackstone the mills of the Blackstone Manufacturing Company use, in all—with a dam 15 feet high, a canal half a mile long, and a fall of 32 feet—a power of 1,000 horse-power during eight months. Above this, the total fall used on the main river below Worcester is about 200 feet, which, added to that below and including Blackstone, makes a total of nearly 400 feet; and as the elevation at Worcester is only 438 feet, it is evident that about all the fall is utilized. It would be hard, in fact, to find another stream in the country so completely utilized. A few unutilized falls are sometimes mentioned, but they are all small, and probably of no value. The reservoirs connected with the stream will be mentioned under the head of its tributaries.

THE TRIBUTARIES OF THE BLACKSTONE.

The first of these to be mentioned is Ten-Mile river, which empties into the Seekonk from the east, opposite the city of Providence, after draining an area of about 51 miles, principally in Massachusetts. Within a few miles of its mouth there are said to be three powers not used, the sites of the Cove mill, Hunt's mill, and the Central mill, with, in all, considerable fall. These mills were burned, and the powers have not since been used. The principal mills in operation on the stream are at Hebronville, where the fall is 9 feet, and the power 150 horse-power during part of the year, and scarcely any during three months; Dodgeville, where the fall is 12 feet, and Attleboro', where, at the Mechanics' mill, the fall is 9½ feet, with 80 horse-power during eight months. The stream is very small and unreliable, and the mills depend on steam, for, notwithstanding one reservoir used for regulating, the flow is almost nothing in summer. On the upper parts of the stream and its tributaries are some large falls but small powers.

Almost all of the small tributaries of the Blackstone below Woonsocket afford some small powers. Mill river, emptying just below the town, runs two large mills, but steam is depended upon. The most important tributary in Rhode Island is the Branch river, which has its sources in Burrillville and Gloucester, in Providence county, Rhode Island, and partly in Massachusetts, and flows in an easterly direction, draining a total area of about 100 square miles, and entering the Blackstone below the dam at Blackstone. Being fed by a number of ponds and reservoirs, it is an excellent stream for power, and is utilized to a considerable extent. The first mill as the stream is ascended is near the mouth, and is owned by the Blackstone Manufacturing Company. Between it and the mouth of the stream some fall which is not used is said to exist. At the cotton-mill of the Forestdale Manufacturing Company, just above, the fall is 16 feet, and 250 horse-power are used during about nine months, with steam for dry seasons. At Slatersville considerable power is used by John W. Slater's cotton-mills. There are three dams; from the upper one, 15 feet high, a race a mile long affords a fall of 18 feet at mill No. 2, which uses 220 horse-power all the year, and discharges the water to the lower level; the second, which is 21 feet high from the bed of the stream, serves as a reservoir dam, and only gets the waste over the upper one, the water being drawn from it into the pond below and then into the lower level, and conducted to mills Nos. 1 and 3, which use 20-feet fall and about 250 and 130 horse-power respectively. It is said that full capacity can generally be obtained nearly all the time, and that the upper dam could be raised, and an additional power thus obtained. Above this point there are four woolen-mills below the junction of the two headwaters of the river—Clear and Chepachet rivers. On the Chepachet river there are a number of mills, principally woolen, and the stream is fed by the following reservoirs: Keech pond, at the head, covering about 280 acres, with a range of about 8 feet, and Smith and Sayles' reservoir, covering 150 acres, with a range of 6 feet. These ponds are controlled by the mill-owners below. On Clear river and its branches there are likewise a number of woolen-mills, running quite constantly, on account of the reservoirs which feed the stream, of which there are the following: Pascoag reservoir, area about 550 acres, range about 16 feet, and Burlingame reservoir, about 100 acres, range 8 feet, both on the Pascoag river; Wallum pond, 800 acres, range 13 feet, and Wilson reservoir, 250 acres, range 11 feet, both on Clear river; and Herring pond, a natural pond covering 100 acres.

The Mumford river, which enters the Blackstone just below Uxbridge and drains an area of about 54 square miles, is fed by a number of reservoirs, and is well utilized. Its flow is very constant considering its size. At its mouth its capacity seems to be 150 horse-power during working hours, with a fall of 15 feet almost all the year. It is utilized within 4 miles of its mouth by six mills, with a total fall of 77 feet. Then comes a reservoir of 200

acres, averaging 4 feet deep, used only for regulating. Above this are numerous mills of various kinds, and several other reservoirs of sufficient capacity to increase the low-water flow very greatly. In fact, it is said no water is wasted during over six months of the year.

The upper tributaries of the Blackstone are in general excellent streams for power, their fall being rapid and their flow often regulated by reservoirs. Of these reservoirs the principal one is lake Quinsigamond, covering about 544 acres, and capable of being drawn down 6½ feet, its capacity being 154,000,000 cubic feet. It lies at an elevation above the sea of 358 feet, and its outlet falls 63 feet before it reaches the Blackstone, the distance being a little over 3 miles. The whole of this fall is utilized, there being at New England Village, near the outlet of the lake, a descent of 54 feet in a short distance, used on four falls. Above this point there are, besides Quinsigamond pond, two other reservoirs, the three aggregating an area of 956 acres. The power of the stream, though small, is therefore remarkably constant.

The other reservoirs on the tributary streams are too small to require special mention, covering, generally, less than 150 acres. As showing the large fall on some of the small tributaries, however, it may be mentioned that on Kettle brook, a stream not over 10 miles long, the total fall is about 360 feet, of which 306 are used. Other streams near the headwaters of the Blackstone are similar in character.

THE TAUNTON RIVER AND TRIBUTARIES.

The Taunton river, the most considerable stream of southeastern Massachusetts, is formed in Plymouth county, in the town of Bridgewater, by the junction of the Satucket and Matfield rivers, whence the stream pursues a general course toward the south and west, for a distance of about 24 miles in a straight line flowing by the city of Taunton and emptying into Mount Hope bay, near the Rhode Island line. It is navigable to the head of tide-water, at East Taunton, about 15 miles from the bay in a straight line, and above this point the area drained by the stream measures about 277 square miles, comprising a hilly and rolling country not well wooded. The stream has a small fall and a gradual declivity, with bed and banks of sand and gravel, and considerable areas of lowland along its course subject to overflow. Its flow is variable, yet much more constant than that of other streams of equal size along the coast, such as the Charles, Neponset, Ipswich, Exeter, etc. This is probably due to the lakes and ponds by which the flow is regulated, of which there are a number, though none of large capacity. There are only two powers on the stream, one at East Taunton, with a fall of 9 feet at low tide, and one near Bridgewater, with a fall of 8 feet. The former is utilized by the Old Colony Iron Company, and is at the head of navigation. The pond extends quite up to the upper power, there being no other fall on the stream. The power used was stated at 326 horse-power in 1880, and full capacity could be secured during from six to nine months, the power being very small during the rest of the time. The power near Bridgewater is used by a paper-mill, with about 100 horse-power during seven months, while during the rest of the year steam is depended upon. The drainage area above this place measures about 129 square miles. It is evident that the power of the Taunton river is not of much value, as to either amount or reliability. The tributaries are, in general, better sources of power, their fall being greater and their flow in some cases much more constant. The Satucket and Matfield rivers are utilized by small mills of various kinds, and the former has several artificial reservoirs. Town river, which joins the main stream at Bridgewater, runs the Bridgewater iron-works, but steam is depended upon. The Namasket river is the most constant stream in the drainage basin, being fed by a number of ponds, among which may be mentioned Assawompset (1,195 acres), Long (1,804 acres), Great Quittacus (1,110 acres), Little Quittacus (392 acres), and various others, aggregating nearly 7,000 acres in area. The stream flows from Assawompset pond in a northerly direction, and is only 5 or 6 miles long, emptying into the Taunton near the town of Middleboro', and draining a total area of about 63 square miles. Assawompset pond is not dammed, nor will the lowness of the country permit it to be; but its flow and level are controlled to some extent by flash-boards on the next dam below, so that its level varies to the extent of about 2½ feet. The other ponds are tributary to the Assawompset, and are not dammed. The stream is utilized by a box factory, with a fall of 10 feet, and a woolen-mill, with the same fall, and below the latter are two sites not in use, the upper known as the Muttock privilege, with a fall of 10 feet, formerly used by a grist-mill, the dam being still there, and the lower with a fall of about 6 feet. The woolen-mill uses 100 horse-power during about eight months, and at times not over 30 or 40.

Mill river, a small tributary running through Taunton, affords water-power to a number of mills during a few months of the year, but is reduced to almost nothing in summer, so that steam is relied upon. The same may be said of Three-Mile river, a tributary below Taunton.

THE POWER AT FALL RIVER, MASSACHUSETTS.

The power at Fall River, to which, perhaps, are principally due the growth and importance of the city as a manufacturing place, is remarkable in some respects. The water is derived from Watuppa pond, situated about 2 miles east of the city, with its high-water mark at an elevation above mean high tide of 129.01 feet, and covering

an area of about 5.39 square miles at high-water mark, and of 4.68 square miles at 5 feet below. The pond consists of the North and South ponds, connected by the "narrows", to which two other but smaller ponds, Sandy and Stafford's, are tributary. The total length of the lake is 7.67 miles, and its greatest width about 1.5 mile. Its drainage basin, including its own area, measures about 31.25 square miles, and comprises a hilly and rolling country, with a sandy, gravelly, and loamy soil, underlaid with granite rock. From this lake the Quequechan river, its outlet, flows westward through the city, falling rapidly over the ledges of solid rock on which the city is built, and reaching tide-water at Mount Hope bay after a course of 2 miles. The total fall of 129 feet is used by the following mills, in order:

Name of corporation.	Fall in feet as claimed by Watuppa Reservoir Company.	Number of horse power.
Troy Cotton and Woolen Manufacturing Company	15.48	150.6
Pocasset Manufacturing Company (cotton)	21.67 21.00	443.8
Watuppa Manufacturing Company (cotton)	15.38	160.0
Fall River Print-Works	10.00	104.0
Fall River Manufactory (cotton)	14.46	150.4
Annawan Manufactory (cotton)	14.73	153.2
Metacomet Mills (cotton)	16.00±	148.2
Total	128.72±	1,310.2

The fall at the Metacomet mills varies with the tide, and is probably about 16 or 17 feet at high tide. The fall at the Troy mills varies with the level of the water in the river, from 15½ feet to less than 10 feet, averaging, it is said, about 13¼ feet. It will be seen that the entire fall of the stream is utilized. The flow of water from the lake is controlled by a corporation known as the Watuppa Reservoir Company, representing all the mills below, and it is commonly stated that the amount of water used during working hours is 122.1 cubic feet per second, corresponding to 10.4 net horse-power per foot fall. On this basis, the power used by the various mills is as given in the third column of the above table. All of the mills, however, except the Annawan, have considerable steam-power in use all the time, the Annawan depending principally upon water-power, with steam only for dry seasons. The full capacity of 122 cubic feet per second cannot be obtained all the time, there being a deficiency during several months of the year, while at other times water runs to waste. When the lake is higher than 35 inches below high-water mark it is assumed that the flow is nearly constant, and as above stated, though in reality it varies; when the lake is below that point the flow is less, and when at the lowest point has been stated to vary in different years between 22 and 86 per cent. of the full discharge referred to, falling, therefore, as low as 26 or 27 cubic feet per second at times. In some years the full capacity is obtained all the time, but it would seem that not over 40 per cent. of that amount can be safely calculated upon as permanently available.

The drainage area of the lake being about 31 square miles, and the rainfall about 48 inches, then if 50 per cent. of the rainfall is collected, over, say, 30 square miles, the mean annual yield of the lake will be at the rate of about 53 cubic feet per second uniformly, or during the ten working hours about 127 cubic feet per second—a calculation showing that the yield to be expected would be somewhere near 122 cubic feet per second, as stated above. The level of the lake has been known to fall to 64 inches below high water; taking the range as 5 feet, and the mean area as 5 square miles, the storage capacity is found to be, in round numbers, about 700,000,000 cubic feet, or between five and six months' supply. The stream flows for the most part under the mills, being scarcely visible except in the mill-yards, and the dams are small affairs with no ponds of consequence.

It is to be mentioned that the water-supply of the city of Fall River, amounting to 150,000,000 gallons daily, is obtained from Watuppa pond, and that thereby the water-power of the outlet has been reduced by a small amount; to just what extent has been for some time under discussion.

Stafford's pond, covering an area of one-third of a square mile, lies at an elevation of 73.87 feet above high water of Watuppa lake, to which it is tributary, and drains an area of about 1.56 square miles, excluding its own surface.

THE MASSACHUSETTS STREAMS SOUTH OF THE CHARLES.

The streams coming under this head are of very little importance. From Fall River around to Plymouth county none are worth naming. In the latter county some possess the characteristics of sand-hill streams, and are fed by ponds sufficient to regulate their flow, but they are all small. Their beds are gravel and sand; they offer no abrupt falls, and are utilized principally by box factories. They often flow through meadow-lands and swamps, and their flow is comparatively constant. In Norfolk county there are a few larger streams, such as the Monataquot and the Neponset, but even they are of small importance, their flow being so variable, notwithstanding several artificial reservoirs by which they are fed, that the mills are obliged to depend upon steam for constant power.

THE CHARLES RIVER.

The Charles river takes its rise in the southern part of Massachusetts, near the corner of Norfolk, Worcester, and Middlesex counties. From this point its course, though very circuitous, is in general northeast, and the distance from source to mouth is about 25 miles in a straight line, though considerably farther by the river. Flowing partly in Norfolk and Middlesex counties, and partly between the two, the stream empties into the Atlantic at Boston, after passing the towns of Medway, Dedham, Newton, Waltham, Watertown, and others. The stream is tidal and navigable as far as the town of Watertown, about 6 miles from its mouth. About that point it drains an area of about 275 square miles, comprising an undulating country, with considerable low and flat ground and some swamps. No lakes of importance and no artificial reservoirs are connected with the river, so that its flow varies greatly, being reduced to almost nothing at some stages. Its fall is moderate as a whole, but in some places quite rapid, so that a number of powers are produced. The bed is generally gravel and mud, and the banks are often low. At one or two places, however, such as Newton Upper and Lower Falls, the bed is ledge, the banks are high, and the fall is precipitous. The freshets on the stream are not very severe, because the banks and meadow-lands are overflowed on the upper parts of the river, thereby restraining the floods. The stream is utilized for power to a considerable extent, there being no sites not occupied. The first power is at Watertown, where there are several mills, the fall being about 6 feet at low tide. The power is small when at its minimum, as the lowest flow affords only about 8 horse-power (gross) per foot continuously. Above Watertown we come to the Etna woolen-mills, with a small fall, then to mills at Waltham, and then to those at Newton Lower Falls. At this place there are three dams within half a mile or less, with, in all, 23 feet fall, and running a number of mills of various kinds. At Newton Upper Falls there are two dams, with a total fall of 23 feet, from which a paper-mill and a cotton-mill are run. Above this point the stream is very flat for a long distance, and almost connects with Mother brook, a tributary of the Neponset. A number of years ago one of the mill-owners on Mother brook dug a channel connecting the two streams, so that part of the water of the Charles has for years flowed into the Neponset. The case has come before the courts, and it has been decided that one-third of the water of the Charles is to go into the Neponset; and to regulate this amount, sills are made and placed at the same level across the Charles and across the channel to Mother brook, their lengths being as 2 to 1, so that the proper division of water is supposed to be effected. Above this point are several small powers, but none of consequence.

The water-power of the Charles will be seen to be of little value. On account of the variable flow of the stream, all the mills are obliged to depend upon steam-power in the summer, being generally provided with sufficient to run their entire machinery.

THE STREAMS BETWEEN THE CHARLES AND THE MERRIMACK.

The streams included under this head are of little importance as sources of power, being very variable in flow, and all small. The first north of the Charles is the Mystic, which, with its tributaries, is utilized to a considerable extent by small mills of various kinds. The next is the Saugus, a similar stream, draining an area of about 27 square miles, and also utilized. It is fed by several ponds, and is probably as good a stream as any in this section, its fall being considerable. To give an idea of its capacity, it may be mentioned that at Scott's woolen-mill, near the mouth, where the fall is 13 feet, five sets of machinery are run, by a breast-wheel, during about eight months of the year; but during the rest of the time the power is almost nothing, and steam-power is used. There is one unutilized privilege on the stream, with a fall of 8 feet.

The largest stream to be here mentioned is the Ipswich river, which drains an area of about 136 square miles above the head of tide-water, at Ipswich. The stream rises in Middlesex county, near the town of Wilmington, and flows in a general northeasterly direction, for a distance of 22 or 23 miles in a straight line, to tide-water, draining a rolling country, with no reservoirs, and only a few small ponds tributary to it. Its fall is small and its current generally sluggish. Its flow is very variable, being almost nothing in the summer, so that the stream is a poor one for power, resembling the Exeter and others in New Hampshire. At its mouth the Ipswich cotton-mills, with a fall of about 10 feet, use about 30 horse-power during seven months, but depend upon steam. There are some small mills above, but none of the powers are of consequence.

Table of drainage areas of the streams between the Mystic and the Merrimack.

Name of stream.	Above what point.	Drainage area.	Name of stream.	Above what point.	Drainage area.
		Sq. m.			*Sq. m.*
Mystic river	Mystic	20±	Three-Mile river	Mouth	76
Pawcatuck river	Westerly	286	Ten-Mile river	do	51
Do	Mouth of Wood river	111	Do	Dodgeville	23
Wood river	Mouth	83	Quequechan river	Outlet of lake Watuppa	*a* 27
Pawtuxet river	do	229	Taunton river	Lower Taunton	337
North branch of the Pawtuxet river	Junction with South branch	108	Do	East Taunton	277
South branch of the Pawtuxet river	Junction with North branch	71	Do	Paper-mill	129
North branch of the Pawtuxet river	Hope	98	Mill river	Mouth	44
Woonasquatucket river	Olneyville	48	Assawompset river	do	63
Do	Mouth	72	Winetuxet river	do	36
Blackstone river	Pawtucket	458	Satucket river	do	32
Do	Lonsdale	438	Matfield river	do	39
Do	Manville	413	Nippenicket river	do	56
Do	Woonsocket	350	Neponset river	Milton Lower Mills	101
Do	Blackstone	248	Charles river	Brookline	281
Branch river	Mouth	100	Do	Newton Lower Falls	218
Do	Slatersville	95	Saugus river	Mouth	27
Munford river	Mouth	54	Ipswich river	Ipswich	136
Quinsigamond river	do	35			

a By measurements of the writer.

Table of power utilized on the coast streams south of the Merrimack.

Name of 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	Long Island sound	Connecticut	New London	Flour and grist	5	64	79
Do	do	do	do	Saw	4		75
Do	do	do	do	Plaster	1		15
Do	do	do	do	Paper	2	50	180
Pawcatuck river	do	do	do	Sash, door, and blind	1	3	10
Do	do	do	do	Machinery and woolen	1	5	100
Tributaries of	Pawcatuck river	do	do	Woolen	2	37	55
Do	do	do	do	Carriage and wagon	1	12	18
Pawcatuck river and tributaries	Long Island sound	Rhode Island	Washington	Woolen	12	96+	590+
Do	do	do	do	Cotton	18	323	1,479
Do	do	do	do	Agricultural implements	1	10	6
Do	do	do	do	Carriage and wagon	1		2
Do	do	do	do	Twine	2	15	22
Do	do	do	do	Machinery	2	24	55
Do	do	do	do	Sash, door, and blind	1	22	4
Do	do	do	do	Shoddy	2	24	40
Do	do	do	do	Wheelwrighting	2		7
Do	do	do	do	Flour and grist	7	123	424
Do	do	do	do	Saw	13	155+	180
Do	do	do	Kent	do	7	113	257
Do	do	do	do	Flour and grist	1	11	28
Pawtuxet river	do	do	do	Cotton	2	25	1,100
South branch of the Pawtuxet river	Pawtuxet river	do	do	do	8	142	2,480
Do	do	do	do	Woolen	1	16	60
Do	do	do	do	Flour and grist	2	23	73
North branch of the Pawtuxet river	do	do	do	Cotton	4	97	1,000
Do	do	do	Providence	do	2	29	90
Do	do	do	do	Drugs and chemicals	1	27	30
Other tributaries of the	do	do	Kent	Saw	1	8	4
Do	do	do	do	Flour and grist	6	87	128
Do	do	do	do	Machinery	1	7	40
Do	do	do	do	Blacksmithing	1	16	12
Do	do	do	do	Woolen	4	118	155
Do	do	do	do	Cotton	6	183	325
Do	do	do	Providence	do	7	188+	770
Do	do	do	do	Wheelwrighting	1	8	8

Table of power utilized on the coast streams south of the Merrimack—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.
						Feet.	
Other tributaries of the	Pawtuxet river	Rhode Island	Providence	Shoe-laces	1	14	110
Do	do	do	do	Saw	3	40	49
Woonasquatucket river	Providence river	do	do	Flour and grist	1	14	95
Do	do	do	do	Woolen	2	39	215
Do	do	do	do	Cotton	9	151	1,061
Tributaries of	Woonasquatucket river	do	do	do	1	16	10
Do	do	do	do	Machinery	1	35	8
Do	do	do	do	Dyewoods, etc	1	8	60
Blackstone river	Providence river	do	do	Flour and grist	3	43	240
Do	do	do	do	Woolen	5	72	737
Do	do	do	do	Cotton	21	271	0,415
Do	do	do	do	Paper	1	18	100
Do	do	do	do	Worsted	1	10	200
Do	do	Massachusetts	Worcester	Woolen	6	60	670
Do	do	do	do	Rolling	1	10	150
Do	do	do	do	Cotton	9	130	2,240
Do	do	do	do	Blacksmithing	1	6	8
Do	do	do	do	Flour and grist	3	30	125
Do	do	do	do	Sash, door, and blind	1	8	50
Do	do	do	do	Felt	1	15	180
Tributaries of the	Blackstone river	Rhode Island	Providence	Woolen	12	201	1,100
Do	do	do	do	Worsted	2	50	115
Do	do	do	do	Cotton	13	220+	1,600
Do	do	do	do	Wood-turning	1	6	20
Do	do	do	do	Wire-works	1	.....	10
Do	do	do	do	Agricultural implements	1	14	30
Do	do	do	do	Blacksmithing	1	8	2
Do	do	do	do	Bread and crackers	1	.....	2
Do	do	do	do	Carpentering	1	14	16
Do	do	do	do	Flour and grist	5	95	95
Do	do	do	do	Saw	11	194	315
Do	do	do	do	Machinery	2	20	50
Do	do	do	do	Shoddy	1	18	20
Do	do	Massachusetts	Worcester	Hosiery	1	.....	60
Do	do	do	do	Worsted	2	18	104
Do	do	do	do	Cotton	9	220	1,513
Do	do	do	do	Woolen	20	350	1,102
Do	do	do	do	Wire	1	17	20
Do	do	do	do	Tools	2	44	170
Do	do	do	do	Shoddy	8	182	348
Do	do	do	do	Sash, door, and blind	1	8	20
Do	do	do	do	Machinery	6	80+	295
Do	do	do	do	Saw	10	134	177
Do	do	do	do	Leather	1	7	16
Do	do	do	do	Wooden handles	2	22	33
Do	do	do	do	Flour and grist	12	105	200
Do	do	do	do	Boxes	2	.....	35
Do	do	do	do	Cutlery	2	61	411
Do	do	do	do	Bluing	1	.....	30
Do	do	do	Bristol	Flour and grist	1	7	20
Do	do	do	do	Foundery	1	8	50
Do	do	do	do	Jewelry	1	8	30
Do	do	do	do	Wood-turning	1	6	15
Do	do	do	do	Machinery	1	15	35
Do	do	do	do	Worsted	1	32	97
Do	do	do	do	Cotton	4	51	371
Do	do	do	Norfolk	Woolen	1	23	40
Do	do	do	do	Jewelry	3	20+	43
Other streams	Atlantic ocean	Rhode Island	Washington	Woolen	5	58	264
Do	do	do	do	Cotton	5	70+	200
Do	do	do	do	Flour and grist	7	98	116
Do	do	do	do	Saw	1	13	13
Do	do	do	do	Locksmithing	1	.....	3
Do	do	do	do	Printing	2	.....	4
Do	do	do	Newport	Flour and grist	2	18	44
Taunton river and tributaries	Narragansett bay	Massachusetts	Bristol	Rolling	1	10	326

Table of power utilized on the coast streams south of the Merrimack—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.
						Feet.	
Taunton river and tributaries	Narragansett bay	Massachusetts	Bristol	Cotton	6	51	860
Do	do	do	do	Agricultural implements	1	80	175
Do	do	do	do	Boxes	1	13	50
Do	do	do	do	Boots and shoes	1	13	10
Do	do	do	do	Brass and copper rolling	2	43	300
Do	do	do	do	Coffins	1	12	28
Do	do	do	do	Comb	1	14	20
Do	do	do	do	Cotton-waste	1	8	20
Do	do	do	do	Tools	2	13	10
Do	do	do	do	Cutlery	2	21	40
Do	do	do	do	Plated ware	1	7	120
Do	do	do	do	Drugs	1	12	10
Do	do	do	do	Flour and grist	4	62	113
Do	do	do	do	Nail	2	19	80
Do	do	do	do	Paper	1	8	64
Do	do	do	do	Jewelry	1	12	20
Do	do	do	do	Toys	1	6	12
Do	do	do	do	Saw	20	210	571
Do	do	do	do	Machinery	1	11	23
Do	do	do	Plymouth	Cotton	1	14	52
Do	do	do	do	Woolen	1	10	107
Do	do	do	do	Forges	1	6	20
Do	do	do	do	Rolling	2	34	170
Do	do	do	do	Boots and shoes	2	11	27
Do	do	do	do	Boxes	10	121	214
Do	do	do	do	Flour and grist	5	35	91
Do	do	do	do	Nail	8	87	60
Do	do	do	do	Saw	15	163	277
Do	do	do	do	Machinery	4	42	66
Do	do	do	do	Paper	1	8	100
Do	do	do	Norfolk	Glue	1	13	25
Do	do	do	do	Hosiery	1	20	30
Neponset river and tributaries	Atlantic ocean	do	do	Brass and copper rolling	1	10	225
Do	do	do	do	Chocolate	1	6	60
Do	do	do	do	Emery	1	13	25
Do	do	do	do	Ink	1	6	35
Do	do	do	do	Flour and grist	3	32	140
Do	do	do	do	Machinery	2	36	55
Do	do	do	do	Rolling	1	12	107
Do	do	do	do	Leather-board	2	30	55
Do	do	do	do	Tannery	1	12	27
Do	do	do	do	Saw	3	36	70
Do	do	do	do	Paper	3	42	510
Do	do	do	do	Screws	1	11	8
Do	do	do	do	Hosiery	1	12	10
Do	do	do	do	Sporting goods	1	6	10
Do	do	do	do	Tools	1	10	6
Do	do	do	do	Cotton	8	120	407
Do	do	do	do	Woolen	4	54	315
Do	do	do	do	Silk	1	13	30
Do	do	do	Suffolk	Chocolate	1	7	175
Charles river and tributaries	do	do	Norfolk	Hosiery	1	6	45
Do	do	do	do	Felt	3	42	300
Do	do	do	do	Woolen	3	24	220
Do	do	do	do	Boxes	1	6	10
Do	do	do	do	Cooperage	1	16	12
Do	do	do	do	Twine	1	9	100
Do	do	do	do	Flour and grist	1	9	10
Do	do	do	do	Machinery	1	10	10
Do	do	do	do	Saw	7	59	175
Do	do	do	do	Paints	1	12	40
Do	do	do	do	Paper	5	52	313
Do	do	do	do	Shoddy	4	63	275
Do	do	do	Worcester	Flour and grist	1	21	56
Do	do	do	Middlesex	Wheelwrighting	1	9	10
Do	do	do	do	Woolen	1	4½	125

Table of power utilized on the coast streams south of the Merrimack—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.
						Feet.	
Charles river and tributaries	Atlantic ocean	Massachusetts	Middlesex	Hardware	1	22	6
Do	do	do	do	Shoddy	1	9	40
Do	do	do	do	Cotton	2	26	820
Do	do	do	do	Furniture	1	27	10
Do	do	do	do	Steam-fitting apparatus	1	6	25
Do	do	do	do	Carpentering	1		30
Do	do	do	do	Flour and grist	6	61	198
Do	do	do	do	Nails	1		45
Do	do	do	do	Saw	1	12	20
Do	do	do	do	Saws	1		15
Do	do	do	do	Machinery	1	18	6
Do	do	do	do	Watch and clock materials	1		1
Do	do	do	do	Leather-board	1	8	100
Do	do	do	do	Paper	4	48	314
Do	do	do	do	Sash, door, and blind	1	5	8
Do	do	do	do	Sewing-machines	1	14	23
Ipswich river and tributaries	do	do	do	Saw	1	7	10
Do	do	do	Essex	Flour and grist	8	29	115
Do	do	do	do	Saw	6	76	141
Do	do	do	do	Paper	1	10	100
Do	do	do	do	Woolen	1	8	65
Do	do	do	do	Hosiery	1	7	40
Do	do	do	do	Matches	1	12	50
Do	do	do	Middlesex	Flour and grist	1	8	25
Other streams	do	do	Bristol	Cotton	7	109	1,785
Do	do	do	do	Boxes	1	12	15
Do	do	do	do	Flour and grist	10	118	284
Do	do	do	do	Saw	14	143	372
Do	do	do	do	Wheelwrighting	1	7	8
Do	do	do	Barnstable	Cutlery	1	8	15
Do	do	do	do	Foundery	2	35	55
Do	do	do	do	Shoddy	1	10	67
Do	do	do	do	Tar and turpentine	1	8	15
Do	do	do	do	Wheelwrighting	1	7	7
Do	do	do	do	Flour and grist	2	10	33
Do	do	do	do	Woolen	1	11	27
Do	do	do	Plymouth	Rolling	3	56	625
Do	do	do	do	Cotton	3	53	120
Do	do	do	do	Boxes	5	45	73
Do	do	do	do	Carriage and wagon materials	1	10	15
Do	do	do	do	Twine	1	18	20
Do	do	do	do	Cutlery	2	33	52
Do	do	do	do	Flour and grist	11	95	225
Do	do	do	do	Bolts, nuts, etc	2	28	60
Do	do	do	do	Forgings	2		70
Do	do	do	do	Foundery	2	14	12
Do	do	do	do	Nails	8	108	143
Do	do	do	do	Saw	64	641	1,623
Do	do	do	do	Musical instruments	1	8	9
Do	do	do	do	Rubber goods	1	12	80
Do	do	do	do	Wheelwrighting	1	8	5
Do	do	do	do	Zinc	2	22	75
Do	do	do	Suffolk	Flour and grist	2	15	90
Do	do	do	Norfolk	Woolen	2	17	125
Do	do	do	do	Rolling	1	6	294
Do	do	do	do	Boxes	2	16+	110
Do	do	do	do	Boot and shoe findings	1	12	12
Do	do	do	do	Flour and grist	1	11	40
Do	do	do	do	Nails	1	10	16
Do	do	do	do	Isinglass	1	18	60
Do	do	do	do	Lasts	1	11	15
Do	do	do	do	Saw	2	25	62
Do	do	do	do	Paper	1	13	62
Do	do	do	Middlesex	Fur-dressing	1	14	35
Do	do	do	do	Jewelry	1		3
Do	do	do	do	Tannery	1	12	25

FIG. 8 - MAP OF THE CHARLES RIVER OF THE MASSACHUSETTS BASIN

Table of power utilized on the coast streams south of the Merrimack—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.
						Feet.	
Other streams	Atlantic ocean	Massachusetts	Middlesex	Saw	4	28+	145
Do	do	do	do	Machinery	1	6	5
Do	do	do	do	Musical instruments	3	.....	65
Do	do	do	do	Printing and publishing	2	.....	2
Do	do	do	do	Cutlery and edge-tools	1	.....	16
Do	do	do	do	Wheelwrighting	1	.....	2
Do	do	do	do	Watch and clock materials	1	9	2
Do	do	do	Essex	Woolen	2	30	95
Do	do	do	do	Carriage materials	1	27	55
Do	do	do	do	Flour and grist	12	111	752+
Do	do	do	do	Furniture	1	7	10
Do	do	do	do	Saw	3	40	44
Do	do	do	do	Paint	1	5	40
Do	do	do	do	Tobacco	4	38	110
Do	do	do	do	Upholstering materials	1	18	25
Do	do	do	do	Vinegar	1	26	25
Do	do	do	do	Blacksmithing	1	12	25

III.—THE MERRIMACK RIVER AND TRIBUTARIES.

THE MERRIMACK RIVER.

The Merrimack river, the most noted water-power stream of the world, and on which, with its tributaries, there is probably more power utilized than in any other drainage basin of equal size in America, merits a particular description and a careful study. The sources of the stream lie in Grafton, Carroll, and Belknap counties, New Hampshire, but the main stream is formed at the town of Franklin, on the line of Belknap and Merrimack counties, by the junction of the Pemigewasset and the Winnipiseogee rivers, the former of which takes its rise in the heart of the White mountains, while the latter has its source in the lake of the same name, the largest single sheet of water in the state. These two headwaters will be discussed in detail further on. From their junction the main stream pursues a course a few degrees east of south, passing through Merrimack and Hillsborough counties, and then into Middlesex county, Massachusetts, where it bends abruptly toward the east, and flows in a direction north of east through Essex county to the sea. The total length of the stream, from its origin, at Franklin, to its mouth, at Newburyport, is in the neighborhood of 110 miles, and the total area drained is about 4,916 square miles, of which about 3,780 square miles lie in New Hampshire and about 1,136 square miles in Massachusetts. The table on page 56 gives the drainage areas of the principal tributaries, and of the main stream, above various points. The drainage basin is well populated, and the course of the stream lies by the important and populous cities of Concord and Manchester, New Hampshire, and Lowell, Lawrence, Haverhill, and Newburyport, Massachusetts. The head of tide, and of navigation for coasting vessels, is a few miles above Haverhill, but small river boats can ascend as far as Lawrence. Above that point there is no navigation on the river, although there are long stretches of still water behind the various dams supplying water-power; and although the idea of rendering the stream navigable even to Manchester has been broached, the cost of the undertaking has prevented any steps being taken to carry it out.

The physical character of the area drained by the stream varies greatly. In the upper part it is mountainous, rugged, and rocky, the streams flowing down from the steep slopes, and winding along through the intervale or alluvial lands to the lower or hill country, where the slopes are more gradual and the country only gently rolling. Toward the lower part of the stream the country becomes quite flat, and some of the tributaries, like the Concord river, drain considerable areas of low swampy country.

The comparatively small extent of the lower or eastern division, and the presence of the first fall at the head of tide-water, are facts which have received notice in the introduction. The drainage basin has been deprived of its forests to a considerable extent, and, except in the uppermost portions, scarcely any part of the basin can be called thickly wooded. The flow of the stream has in consequence no doubt diminished in constancy. As regards natural reservoirs, however, the Merrimack is favored to an unusual degree, there being, on the upper waters, about 100 square miles of reservoir area now under control, and managed by manufacturing and water-power corporations

lower down on the stream. On page 29 will be found a full list of these reservoirs, and subsequent pages give other information regarding them. Their importance in adding to the low-water flow of the river can hardly be overestimated, and although there are other streams possessing equal or greater advantages as regards storage, there are probably none in which those advantages have been so extensively and systematically improved.

The bed and banks of the Merrimack are in every way favorable for the development of power. The stream flows generally over ledges of rock at the places where power is available or utilized, while the banks are, as a rule, at those places high and firm. In places there are quite extensive tracts of bottom-land subject to overflow, but they generally occur in localities where no power is available. Between the ledges and rapids the bed of the stream is composed of gravel, sand, and bowlders, and the fall is sometimes very small. The declivity of the stream is shown approximately by the following table:

Declivity of the Merrimack river.

Place.	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			
			21.5	0	0
Mitchell's falls	21.5	0			
			5	10	2
Foot of locks at Lawrence	26.5	10			
			1	32	32
Top of Lawrence dam	27.5	39			
Top of flash-boards	27.5	42			
			9	0+	0.0+
Foot of Hunt's falls	36.5	42			
			1	11	11
Head of Hunt's falls	37.5	53			
			2	36	18
Top of Pawtucket dam, Lowell	39.5	87			
Top of flash-boards	39.5	89			
State line	48.7	90			
			17.7	4	0.23
Mouth of Nashua river	53.0	93			
Foot of Cromwell's falls	57.2	93			
			6.8	19	1.7
Foot of Goff's falls	64.0	112			
			0.6	5	8.3
Head of Goff's falls	64.6	117			
			3.4	9	2.7
Manchester, below falls	68.0	126			
			1	54	54
Top of Manchester dam	69.0	178			
Top of flash-boards	69.0	180			
			8.7	1	0.11
Hooksett, below falls	77.7	181			
			0.1	16	160
Hooksett, top of dam	77.8	197			
			4.7	2	0.43
Foot of Garvin's falls	82.5	199			
			0.23	28	123
Head of Garvin's falls	82.7	227			
			10.3	2	0.2
Foot of Sewell's falls	93 ±	229			
			1.75	19	10.86
Head of Sewell's falls	95 ±	248			
			1.2	1	0.8
Mouth of Contoocook	96.2	249			
			13.8	20	1.4
Franklin, head of river	110.1	269			

The average fall of the stream is 2.45 feet per mile. Though this is not a large fall, the greater part of it occurs in short distances, at six places, giving rise to the noted and remarkable powers for which the river is renowned. The map prefixed to this report shows the general shape of the basin and the course of the river, and the profile (Fig. 4) shows graphically the declivity of the stream.

The flow of the stream, naturally not very variable, is rendered comparatively constant by the control exercised over the large reservoirs in New Hampshire. Daily gaugings of the stream are being made at Lawrence, Massachusetts, and when sufficient data shall have been accumulated the records which have been kept by the water-power company there during the past thirty-five years will enable one to form an accurate estimate of the flow at any time during that period. Nothing has yet been given to the public, however, and the tables on pages 9 and 10 give all the data regarding flow that can now be presented. The freshets on the stream are not by any means violent, as compared with those on western and southern rivers. At the lower locks in Lawrence, where continuous records of the height of the water have been kept for over thirty-five years, the extreme range is 26½ feet. The ordinary yearly range is from 10 to 15 feet, and there are generally several freshets every year in which the water rises to 10 or 12 feet above low water. The stream is generally lowest in the summer, though sometimes nearly as low during the winter. The freshets are irregular in their occurrence, but generally take place in the spring with the greatest violence.

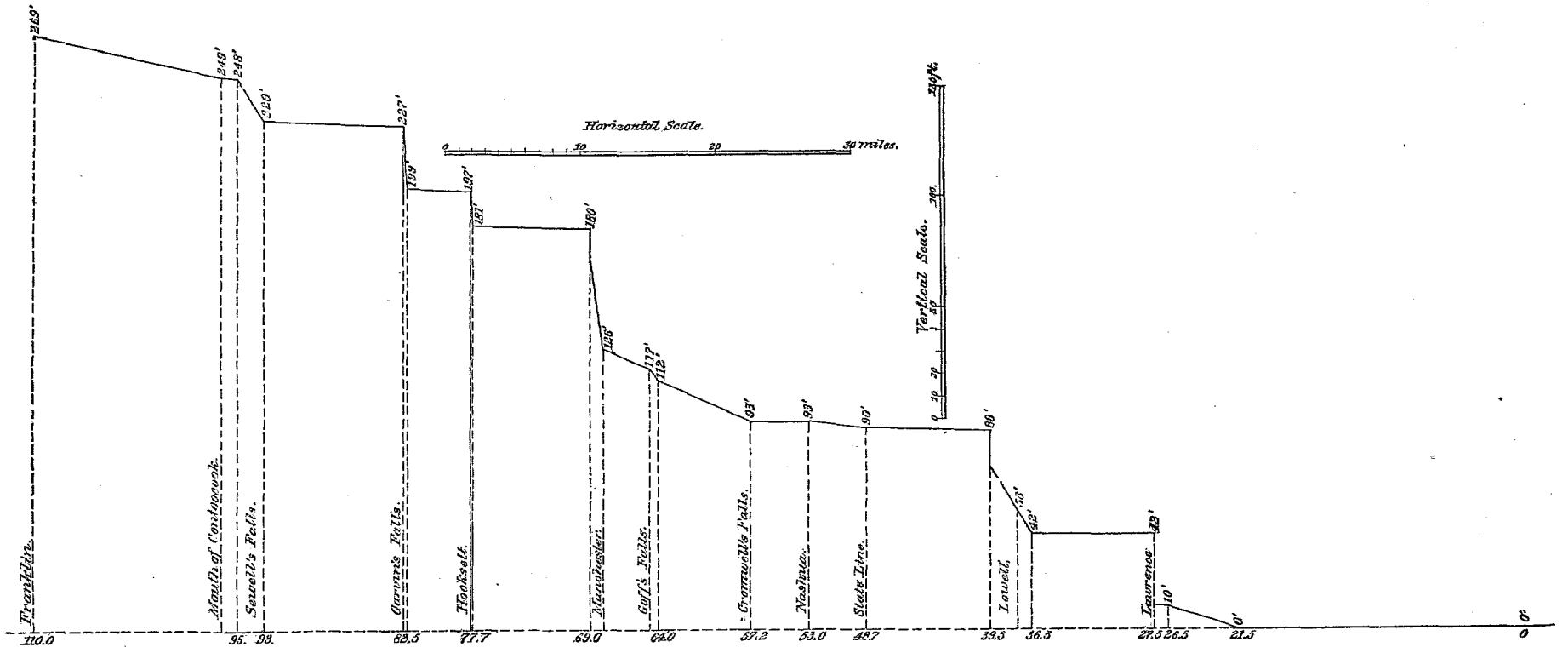


Fig. 4. PROFILE OF THE MERRIMACK RIVER.

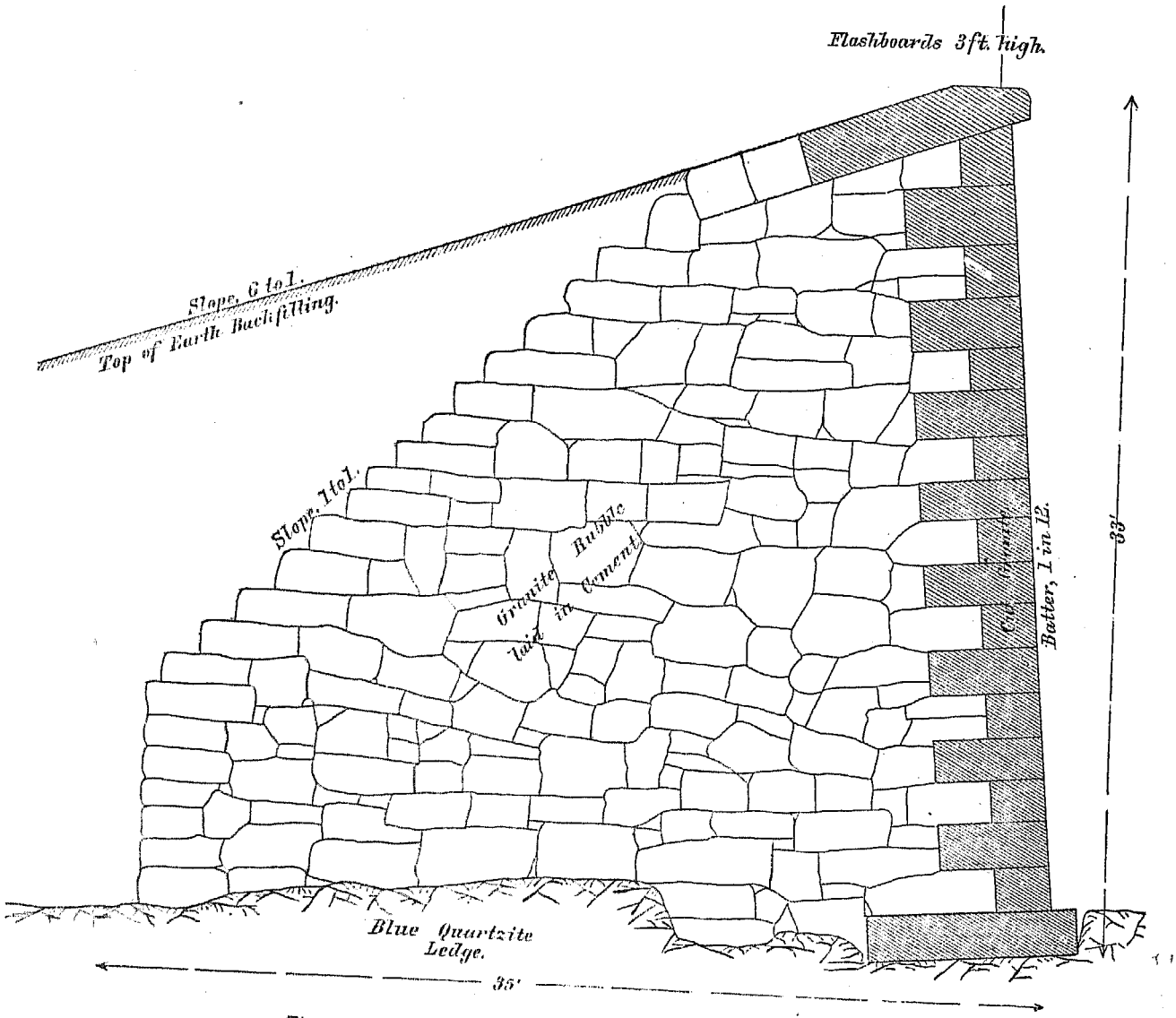
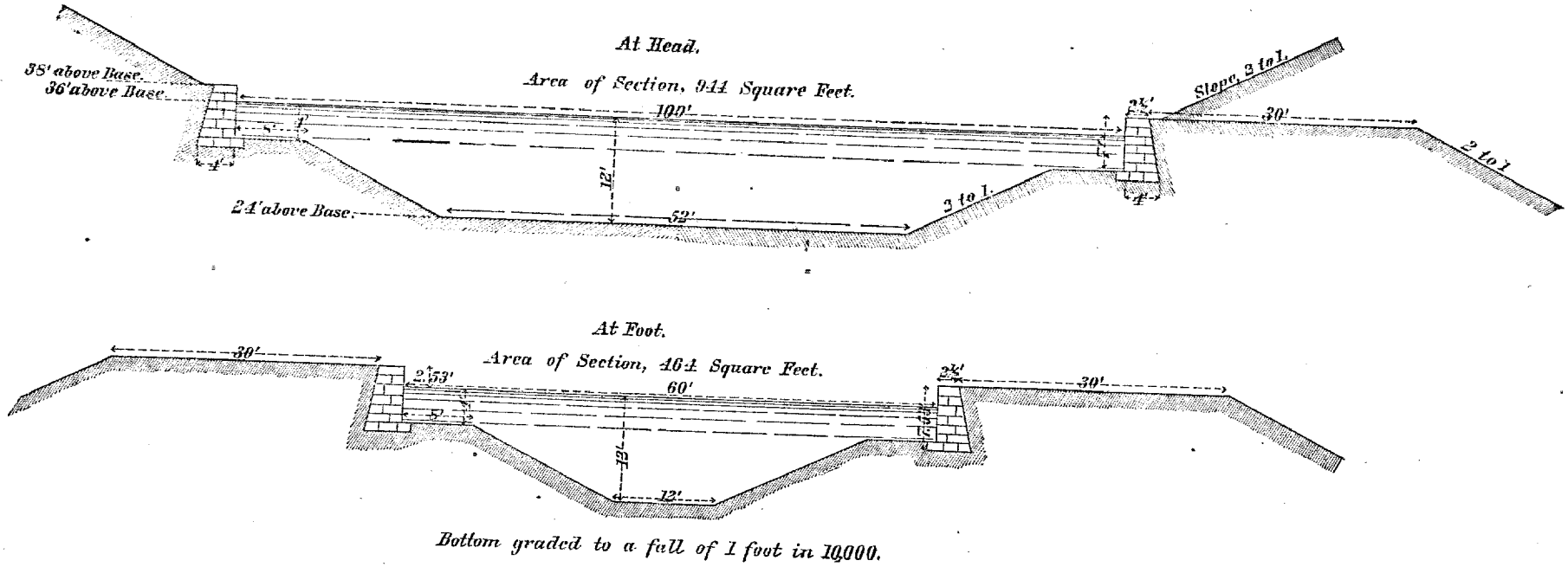


Fig. 5. SECTION OF DAM AT LAWRENCE, MASS.



Bottom graded to a fall of 1 foot in 10,000.

Fig. 6. SECTIONS OF NORTH CANAL AT LAWRENCE, MASS.

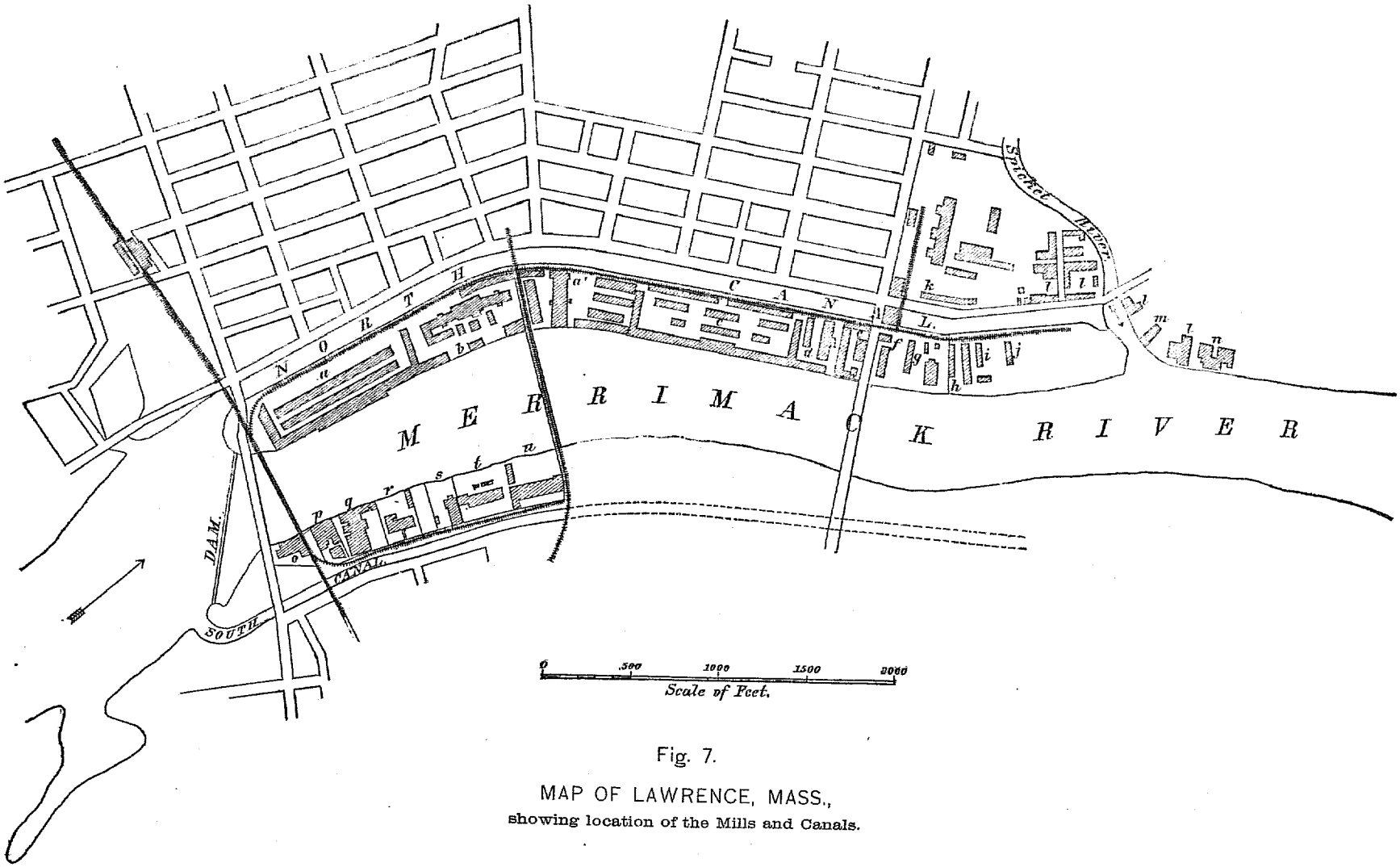


Fig. 7.

MAP OF LAWRENCE, MASS.,

showing location of the Mills and Canals.

The mean annual rainfall over the basin of the Merrimack is, according to the Smithsonian charts, about 43 inches, of which 10 fall in spring, 11 in summer, 13 in autumn, and 9 in winter. This distribution is evidently very favorable for a constant flow.

As regards accessibility, it is sufficient to refer to the map, which shows that the stream is followed closely by a railroad for its entire length. No river can be more favorably situated in this respect.

We proceed to describe the water-powers in their order as the stream is ascended:

From the mouth of the river to Haverhill bridge, a distance of 17½ miles, there is a navigable depth of 12 feet at ordinary high water. Thence to the head of Mitchell's falls, a distance of 4 miles, there is a depth of 4½ feet in ordinary stages of the river, with the mill-water at Lawrence running. Above these falls the effect of the tide is not noticeable. Mitchell's falls are of no value for water-power, the fall varying with the tide, and only amounting to 6 or 8 feet even at low water.

The first water-power on the river, and one of the most important and carefully managed in the United States, is that at Lawrence, Massachusetts.

THE WATER-POWER AT LAWRENCE, MASSACHUSETTS.

The development of the water-power at this place dates from the year 1845, when the owners of the land and the water-power were incorporated as the Essex Company, with a capital of $1,000,000. Steps were at once taken toward the utilization of the power, and on July 5, 1845, the contract was concluded for the building of the substantial dam which still holds back the waters of the river and diverts them into the channels of industry. The structure is built in a curve, the chord being 900 feet, and the center ordinate 14.97 feet. Its maximum height is 40½ feet, and its average height about 32 feet, the breadth at the base being about 35 feet. The front face has a batter of 1 in 12, the top or capping is level for 3 feet from the face, then slopes back or up-stream 1 foot in 3 feet, for 12 feet beyond which the back is stepped off at a slope of 45 degrees. Its section is shown in Fig. 5. It is composed entirely of solid stone masonry, resting on a rock foundation, which is stepped off to receive it, the front of the dam being secured by blasting out a trench in the rock, along the entire length, in which the first course of granite masonry is laid, all the stones being headers, and the next course above being all stretchers, doweled to the foundation course. The face of the dam is all of dressed stone, the headers and stretchers of each course being dovetailed together, and the capping stones being doweled to each other and to the next facing course below. The remainder of the dam is of rough stone, laid in cement, with a back-filling of earth, sloping 6 to 1. The level of the water may be raised 3 feet above the crest of the dam, by means of flash-boards, in lengths of 16 feet, resting against 1¼-inch iron bolts inserted at intervals of 20 inches in holes drilled in the capping stones. The top of the dam is at 34.12 feet on the company's scale. At the south end of the dam is a substantial wooden fishway. The excavation for the dam was begun August 1, 1845, the first stone laid September 19 of the same year, and the structure completed in 1848, its construction having occupied almost exactly three years. The rock excavation in preparing the foundation amounted to 1,700 cubic yards; the quantity of masonry laid in cement was 29,000 cubic yards, and the surface of hammered granite was 148,000 square feet. The cost of the dam, including coffer-dam and all incidentals, was $250,000. The agent and engineer of the Essex Company was Charles S. Storrow, who designed the dam and canals and the general development of the water-power, and he was efficiently assisted in carrying out the work after April, 1846, till its completion, by Captain Charles H. Bigelow, as engineer in charge of construction.

The dam crosses the stream in an oblique direction, and on each side there are extensive wing-walls, that on the south side being 324 feet long, and that on the north side 405 feet, making, with the overfall, a total length of 1,629 feet. There is a canal on each side of the river. That on the north side, which is the principal one, is 5,330 feet long, 100 feet wide at the upper end, and 60 at the lower end. Its section is shown in Fig. 6. Its depth is 12 feet in the middle and 4 feet at the side walls, and the bottom is graded to a fall of 1 foot in 10,000, or 0.53 foot in the length of the canal. The head-gates are 24 in number, arranged in six sets of 4 each, or closing six sluice-ways between piers, 12 feet deep and 9 feet wide, so that each gate is 3 feet high and 9 feet long. They are operated by hand. At the head of the canal there is also a lock; and at the foot there are three locks, descending into the river, together with a waste-way by which the canal may be emptied into the Spicket river, which joins the Merrimack just at the foot of the canal. Between the canal and the river are situated the principal mills, as the map (Fig. 7) shows; and at a distance of about 80 feet from the canal a line of sheet-piling extends parallel to it for nearly half its length, to prevent percolation, the bank being to a considerable extent artificial. The cost of this canal, with the structures connected with it, was about $250,000, and the excavation amounted to 266,000 cubic yards.

The south canal was built in 1866, and carried for a distance of 2,000 feet, with a rectangular section 60 feet wide and 10 feet deep. It is expected to continue it some 1,500 feet farther, beyond which an iron penstock will be laid. The head-gates are 16 in number, in four sets, and are operated by hand. This canal has cost about $150,000.

The Essex Company's dam crosses the river near the foot of what were known as Bodwell's falls, over which it backs the water, deadening the current for a distance of 9 miles, to the foot of Hunt's falls, with an average width of perhaps 600 feet, giving a pond area of about 29,000,000 square feet, or not far from a square mile. This area, in connection with the large ponds on the stream, above, is sufficient to prevent any waste of water in a dry

season; and it sometimes occurs that there is scarcely any waste of water over the dam for weeks at a time, though at such times, even, the mills are using considerable surplus water (see page 27). The water has been drawn nearly 2 feet below the top of the flash-boards in very dry seasons, owing to the large quantity of water used at night, when none is allowed to pass the Lowell dam.

The fall at the mill-wheels in Lawrence is, during ten months of the year, from 26 to 30 feet. During the spring and autumn freshets it is often reduced to 20 feet for a few days, and on one occasion, in April, 1852, it was reduced to 7 feet for a few hours. This was the greatest freshet known in one hundred years. There is a difference in fall of only 0.3 or 0.4 feet between the head and the foot of the canal. The table on page 27 gives the mills using power.

The Essex Company sells power at Lawrence by the "mill-power", which is defined as follows:

Each mill-power is declared to be the right to draw from the nearest canal or water-course of the grantors, and through the land to be granted, so much water as shall give a power of 30 cubic feet of water per second, when the head and fall is 25 feet; and no more is to be drawn in any one second, nor is the same to be drawn more than 16 hours in each day of twenty-four hours—and in order to prevent disputes as to the power of each mill-privilege in the variations of the height of water from changes in the season or other causes, it is understood and declared that the quantity of water shall be varied in proportion to the variation of the height, 1 foot being allowed and deducted from the height of the actual head and fall, and also from that with which it is compared before computing the proportion between them: thus on a head and fall of 30 feet the quantity of water to be used would be $24\frac{24}{29}$ cubic feet per second; and the respective parties, where either has any lawful interest therein, may at all reasonable times, in a peaceable manner, and after due notice to the principal steward or agent then on duty at any mill, enter the raceway thereof to measure and compare the quantity of water used with the quantity granted, and in the measurement all wastage shall be included.

To express in other words the method of determining the quantity of water, instead of dividing 750 (the product of 25 and 30) by the fall, 720 is divided by the fall minus one foot. Tables are used in the office, giving quantity of water per mill-power corresponding to fall. The Essex Company is to maintain the same and principal canals; the raceways and flumes of the mills are property of the grantees. I quote further from the "proposals", as follows:

In order to continue in the grantors an interest in common with the grantees for the preservation and support of the mill-powers which may be granted, and to secure a fund to indemnify the grantees for expenses which may be incurred by them for making repairs, if the grantors should improperly neglect to make them, it is proposed that part of the consideration of every sale, and all that is to be allowed the grantors for the repairs, etc., by them assumed, should be paid or secured to them in the form of a reservation of rent. *It is therefore declared* that each mill-power with the land to which it is annexed shall forever be subject to a perpetual annual rent of at least two hundred and sixty ounces, troy weight, of silver of the present standard fineness of the silver coin of the United States, (*a*) or an equivalent in gold, at the option of the grantee at the time of payment.

The following additional quotations from the "proposals" need no elucidation:

If any grantee shall sustain any injury from deficiency of water happening from any cause whatever, other than his own neglect or misconduct, his rent may cease during the time such deficiency may continue, but no longer. Provided, that where more than one mill-power shall be granted, the grantee shall pay rent for so many mill-powers as shall remain * * *; and if such deficiency should happen through the misconduct or willful neglect of the grantors, the grantees shall have a right to recover damages in an action at law against the grantors, in addition to the rent to be withheld as aforesaid.

If any grantee shall suffer damage from want of water from causes not arising from his own neglect or misconduct, and which may be removed or remedied, and the grantors shall, after due notice for that purpose, unreasonably fail to remove the obstructions or remedy the mischief, the grantees injured * * * may * * * remove or remedy the causes of injury; and to pay and indemnify them for the expense and charge thereby incurred, such grantees shall, after the expiration of thirty days from the time the amount of such expense shall have been adjusted * * * have a lien upon all the rents which may have been reserved to the grantors upon the sale of any mill-power, and which may become payable after the expiration of said thirty days, and may * * * demand, sue for, and receive the same until they shall be fully reimbursed as aforesaid.

The grantees are not to use more water than is granted, nor waste it, nor permit it to be wasted, for want of repairs or through the deficiency of their works or otherwise; and if so wasted, or more be used than is granted, the grantors may stop the water from entering their flumes by closing the gates across them, or by any other method, until such waste or excessive use be guarded against; and may also at the same time have their action at law for damages; and other grantees who shall suffer thereby may also have their action at law for damages.

Under these proposals the Essex Company has sold 128 mill-powers, or (as a mill-power is equivalent to a gross power of 85.23 horse-power) 10,909 horse-power. A mill-power was originally valued at about $15,000, and all the original grantees, including all the large corporations on the north side, paid about $10,000 down, and continue to pay an annual interest on the remainder of about 6 per cent., or $300 per annum per mill-power, defined in weight of silver. Of late years, however, the company has leased power for annual payment in currency, without an original cash payment, and all the newer mills, including those on the south side, pay an annual rent of $1,200 per mill-power. This rate is equivalent to $14 08 per gross horse-power per annum.

The following table gives a list of the mills now operated, the power owned by each, and other items of interest, with references to Fig. 7:

a Two hundred and sixty ounces of silver, as above defined, are equivalent in value to about $300.

Table giving details regarding the mills and power at Lawrence, Massachusetts.

Name of corporation or firm.	Designation on map.	Goods manufactured, or kind of mill.	Number of spindles. (a)	Number of looms. (a)	Water taken, from which canal.	Head and fall.	POWER OWNED. Mill-powers.	POWER OWNED. Horse-powers (gross).	Steam-power in horse-powers. (a)	Quantity of water in cubic feet, per second. (b)
						Feet.				
Pacific Mills { Main Pacific / Central Pacific }	{ a / a' }	Cotton, woolen, worsted, etc.	160, 500	4, 500	North	28±	{ 25 / 11	2, 131 / 938	2, 400	{ 666. 67 / 293. 33
Atlantic Cotton Mills	b	Cotton	87, 888	1, 805	do	28±	22	1, 875	500	586. 66
Washington Mills	c	Woolen and cotton	15, 000	1, 404	do	28±	17	1, 449	1, 000	453. 33
Pemberton Mills	d	do	28, 000	669	do	28±	12½	1, 065	300	393. 33
Lawrence Duck Company	e	Duck, felt, and twines	8, 000	140	do	28±	5	426		133. 33
Everett Mills	k	Cotton and duck	32, 096	1, 000	do	28±	10	852	200	266. 67
Lawrence Woolen Company	f	Woolen	3, 280	50	do	28±	1½	128		40
George E. Davis & Son	g	Foundery and grist-mill			do	28±	⅔	57		17. 77
Wright Manufacturing Company	h	Braid			do	28±	½	43		13. 33
Lawrence Spindle and Flier Works	i	Spindles, fliers, and machine-shop			do	28±	10/12	71		22. 22
Dawson & Dustin	j	Leather-board and machine-shop			do	28±	⅓	43		13. 33
Russell Paper Company	l	Paper			do	28±	6½	540		168. 87
William McAllister	m	Shoddy			do	28±	⅙	14		4. 44
Jerome A. Bacon	n	Paper			do	28±	2	170		53. 33
Total from north canal			334, 764	9, 568			115	9, 802	4, 200	3, 066. 67
Davis & Taylor	o	Flour and grain			South	28±	2	170		53. 33
Munroe Felt and Paper Company	p	Paper			do	28±	3	256		80
Merrimack Paper Company	q	do			do	28±	3	256		80
Butler & Robinson	r	Worsted yarn			do	28±	2	170		53. 33
Clegg & Fisher	s	Leather-board			do	28±	2	170		53. 33
Union Mill	t				do	28±				
N. W. Farwell & Son	u	Bleachery			do	28±	1	85		26. 67
Total from south canal							13	1, 108		346. 66
Total on both sides of the river			334, 764	9, 568			128	10, 910	4, 200	3, 413. 33

a These data are taken from the "Annual" for 1882, published by the *Lawrence American*.
b The quantity of water is calculated for a fall of 28 feet, at the rate of 26⅔ cubic feet per second per mill-power.

The Union mill, on the south canal, belongs to the Essex Company, which owns the wheel and rents room with power to the Lawrence Line Company, Messrs. Stedman & Smith, machinists, and the Lawrence Electric-Light Company. About two mill-powers are used in this mill.

In addition to the power owned and utilized as above described, a considerable amount of surplus power is utilized by a number of the mills, in accordance with regulations from which the following extracts are made:

I. The use of such surplus water-power shall be permitted to a party desiring to use the same, only on the express condition that it shall furnish the engineer of the Essex Company with all reasonable facilities for ascertaining the quantities used by it, and that it shall comply with such reasonable requirements as he may from time to time make in relation thereto, and with such limitations as to the amount of surplus water-power which it may use, as he, having in view the supply of water in the river, and the respective wants of the different parties using, may deem it expedient from time to time to prescribe; but the limitation so to be prescribed by him shall not restrict a party without its assent to a less quantity of water than would be allowed to it under the general limitation provided for in Article III.

* * * * * * * * *

III. The Essex Company, whenever in their opinion the supply of water renders it expedient as a matter of necessity or precaution, may limit the use of surplus water-power to a certain percentage of the aggregate amount then granted by indenture as aforesaid, but such limitation shall be uniform in its application to all those grantees who shall then have agreed for the use of surplus water-power under these regulations, and shall be in proportion to the number of mill-powers owned by them respectively.

The prices paid for surplus power are as follows, for each day upon which such power is used, viz: For each surplus mill-power or part thereof not exceeding 20 per cent. of the amount owned by the party, at the rate of $4 per mill-power; for each surplus mill-power or part thereof in excess of such 20 per cent., but less than 50 per cent. of the amount owned, at the rate of $8 per mill-power; for each surplus mill-power or part thereof in excess of such 50 per cent., at the rate of $4 per mill-power.

The amount of surplus power used varies with the season. In a dry time its use is sometimes restricted and divided according to Article III, given above. Since the Essex Company has leased power the use of surplus has been limited upon forty days, thirty-four of which were in the fall of 1880 and six in January, 1883. Upon two days only the limitation was as low as 25 per cent., all lessees being then allowed to draw 125 per cent. of the amount of power held by them. Upon the other days the limitation was such as to allow the lessees to draw 140, 150, or 175 per cent. of the amount of power leased. Some of the lessees draw no surplus power, while others draw an amount equal to over 100 per cent. of their regular power. The smallest number of surplus mill-powers used, on the average, during the driest week of the extreme drought of 1880 was 27 (making the total power used

155 mill-powers); and the smallest number used, on the average, during any month has been 35 (making the total power used 163 mill-powers), during working hours. Hence we may take the minimum power of the stream during working hours as 155 mill-powers, or 13,160 gross horse-power. (*a*) The company can still lease a considerable amount of power, but the total low-water power of the stream is now utilized, though to some extent as surplus power. Some mills use steam-power all the time, while others use it only at high water, on account of insufficient wheel-capacity when the fall is diminished. The paper-mills run continuously except Sunday, but in low water are sometimes required to stop during the night; the other mills run sixty hours a week, or about eleven hours on every day except Saturday, in summer, and 10¼ in winter. The mills experience little trouble with ice. The canal often freezes over at night, but is cleared out in the morning before the mills start. The large mills never have to stop for this cause, but some of the small mills at the lower end of the north canal are sometimes obliged to stop for an hour or so.

In the methods adopted in Lawrence for measuring the quantity of water drawn by the different mills, the principle followed is to gauge the quantity every day, some time during ordinary working hours. Accordingly, each mill is visited every day by an inspector, who observes and records the following data: (1) The height of water in the canal at or near the head of the penstock; (2) the height of water in the river; (3) the height of water in the penstock, a short distance above the wheel, read by means of a tube screwed at right angles into the outside of the penstock, and connecting above with a glass tube placed against a scale-board; (4) height of water in the wheel-pit; and (5) height of the speed-gate, all the wheels used being turbines. In order to be sure of the correctness of these readings, the canal and penstock gauges, as well as the pit and river gauges, are periodically compared when the mills are not running, and if the two readings do not agree the error is noted. It may be remarked here that all gauges are intended to be set at the same datum, so that their readings may be strictly comparable without any reduction. In order to be sure that the penstock-gauge tube is freely open, it is periodically tested when the water is drawn out of the canal by pouring water into it.

The difference between 1 and 2 gives the total fall; and for this fall the quantity of water to which the mill is entitled is found in the table giving "quantity of water per mill-power corresponding to fall". If a corporation does not utilize nearly the whole of this fall it is its own fault. The difference between 3 and 4 gives the fall acting on the wheel, and this, together with the height of the speed-gate, affords a means of determining the quantity of water actually used, by comparison with diagrams prepared for the purpose, in a way described below, and which give, for any fall and gate-opening, the quantity passing, there being a diagram for each wheel. The quantity used each day being compared with that to which the mill is entitled, the excess is found and the price for the surplus water determined according to rules already given. The quantities are worked up systematically and with great care.

The diagrams referred to are prepared by making measurements of the quantity of water drawn by each wheel under different heads and at different heights of gate, when the wheels are known to be in good condition, horizontal distances representing quantities of water, and vertical distances heights of gate. In constructing the curves for different heights of fall, due account is taken of the variation of the quantity with the fall and with the relative velocity of the wheel and the issuing water, as well as of the way in which the wheel is set. These measurements are repeated at short intervals of time, to determine if any change has occurred in the amount discharged by the wheels. Such change may be produced by leaves and sticks piling upon the guides, as of the Boyden turbine, or by blocks or bits of coal obstructing the outlets, or by increased leakage between the wheel and its gate or case, or by breakage and loss of a bucket, or by the gate-hoisting apparatus being out of order, or by the wheel-step wearing down. These frequent measurements are also necessary to determine the amount wasted by wheels not in use, and any leakage from the flumes, and the water used for washing and other purposes which does not pass through the wheels. The differences between the results of these measurements and those given by the diagrams is noticed and allowed for in subsequent use of the latter.

Five different methods of making these measurements are or have been in use in Lawrence, which will be considered in order. They all consist in gauging the quantity of water used, the speed-gates being observed at the same time, as well as the height of the water in the penstock and the pit.

1. *Weir measurements.*—In the case of certain mills, weirs are placed on the tail-races, and by observing the height of water on the crest, the discharge is obtained, with due reference to the cirumstances of the case, according to methods which need not be further discussed here.

2. *Flume measurements.*—These, like the weir measurements, are made in the tail-races, and are used for some of the large mills. The velocity at numerous points is obtained by means of loaded poles, the results of the measurements in the flumes being plotted and reduced by methods well known to engineers. (*b*)

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a Since the above was written (February, 1883) the Merrimack river has experienced an unprecedented drought, that of September, 1883, at which time additional limitations were enforced at Lawrence. The flow of the stream averaged at the lowest period about 1,390 cubic feet per second for twenty-four hours of the six working days, being but little in excess of the quantity leased if drawn regularly ten hours a day. The minimum power of the stream during working hours should therefore be now placed at but little over 128 mill-powers, or about 10,867 gross horse-power.

b See Francis: *Lowell Hydraulic Experiments.*

3. *Measurements with the differential tube.*—This instrument is in principle what has been known as Darcy's tube, although some modifications have been introduced in Lawrence. It consists of two small brass tubes, open at the bottom, which are inserted in the current, the lower end of one being turned up stream and that of the other down stream. The tubes connect above with glass tubes fixed on a scale-board, there being diaphragms and stop-cocks between the glass and brass tubes, the former to hinder oscillations of the column, the latter to shut off the columns in the glass tubes and prevent oscillations entirely. The water will stand at different heights in the two tubes, and from the difference of the two the velocity may be determined, if the instrument has been tested beforehand, so that the relation between the velocity and the difference in height is known. The two glass tubes are connected at the top, and an air-pump is used to exhaust the air, so that the water will rise to a convenient height for measurement. The instrument is used by raising or lowering it so as to get the velocity at different depths in a vertical line, the depth of the water being also observed, and then shifting it horizontally so as to get the velocities in different verticals across the current. The mean velocity and the discharge are deduced in a manner similar to that used in flume measurements. When time is not available for a complete series of measurements, the velocity is taken at one point, generally in the center of the section, the ratio of the velocity at that point to the mean velocity in the section being known from previous experiments.

4. Instruments have been devised by Mr. Mills, the engineer of the company, by which he is enabled to observe the velocity simultaneously at twenty-five or thirty points in a cross-section of an open or closed conduit, and they are used in many of the large penstocks for determining the quantity of water flowing; but Mr. Mills wishes still further to perfect these instruments before presenting them to the public.

5. When little water was drawn from the south canal, it was measured by shutting the head-gates of the canal and observing continuously at two points the heights of the surface every half minute for fifteen or twenty minutes, as the wheels drew the water from the canal, thus using the canal as a measuring basin.

From the above description of the methods of conducting the measurements in Lawrence it is evident that the power is one of the most carefully managed in this country. The chief engineer of the company is Hiram F. Mills, to whose unvarying kindness, as well as to that of his assistants, the above information is due.

The drainage area of the Merrimack above Lawrence is about 4,599 square miles, according to my measurements. (*a*)

The Merrimack river is supplied with storage reservoirs in New Hampshire, of considerable size, so that in dry weather the natural flow of the stream may be increased to a considerable extent by drawing on these reservoirs. At the time of the extreme drought of September, 1883, however, no water was being drawn on orders from these sources, although a certain very considerable quantity is always allowed to flow from them, as will hereafter be seen. As these reservoirs are partially controlled in Lawrence, they may be described here.

The Essex Company and the Proprietors of Locks and Canals on the Merrimack river (at Lowell) form together the Lake Winnipiseogee Cotton and Woolen Manufacturing Company, a corporation chartered in 1831, and controlling to a certain extent the storage on a number of lakes in the state of New Hampshire, as shown by the following table:

Storage reservoirs of the Lake Company.

Name.	Area.	Estimated depth that may be drawn.	Remarks.
	Sq. miles.	*Feet.*	
Lake Winnipiseogee and Long bay	71.75	2.5	
Smith's pond and Crooked pond	4.85	4.0	Tributary to lake Winnipiseogee.
Great bay	7.33	2.0	Below lake Winnipiseogee.
Great and Little Squam lakes	11.75	3.5	
New Found lake	7.80	3.0	
Total	103.48		

These reservoirs, being drawn upon during the dry season, contribute greatly to the improvement of all the water-powers below them. They are not drawn upon regularly, and generally water is not drawn upon order during as much as three months of the year, though, at times, several hundred cubic feet per second are drawn. At the time of minimum flow, as remarked above, no water was being drawn.

The lakes named in the above table are shown on the maps of the Winnipiseogee and Pemigewasset rivers. There are dams as follows: At the outlets of New Found and Squam lakes and Smith's pond, at Lake Village (below Long bay), and at Union bridge (below Great bay). At all of these places, excepting at Smith's pond, the company is obliged to allow a certain minimum quantity of water to flow at all times past the dam, so that it is unable to utilize the storage to quite so good advantage as it otherwise might. Some further data regarding the reservoirs will be given hereafter. The following figures, however, have a value in this connection. The reservoirs are drawn from at all times of the year, and during the five years from 1873 to 1878 the total number of days on which water

a Mr. Mills states the drainage area as 4,553 square miles, a result agreeing with mine within the reasonable limits of error.

was drawn from lake Winnipiseogee on orders from Lowell or Lawrence was 226, or an average of 45 days per year. The total depth of water thus drawn was 2.30 feet, or an average yearly depth of 0.46 feet, the maximum in any one year being 0.71 feet, part of which was drawn in January and February, and part in September and October. This shows that the quantity drawn on orders is small, and that if the lake is drawn down 4 feet, as is sometimes stated, it is not all on orders, but part is evaporated, and part goes to supply the mills on the streams below, which must be supplied continuously.

In connection with the flow of the river, reference has already been made to the fact that measurements are being carried on at Lawrence, which will in time afford data for a most valuable history of the flow of the stream. The amount of water flowing over the dam every day is determined by frequent readings of the gauges in the pond, and the profile of the top of the flash-boards, in case such are used, is found by leveling. The greatest depth of water yet observed on the dam is about 10 feet.

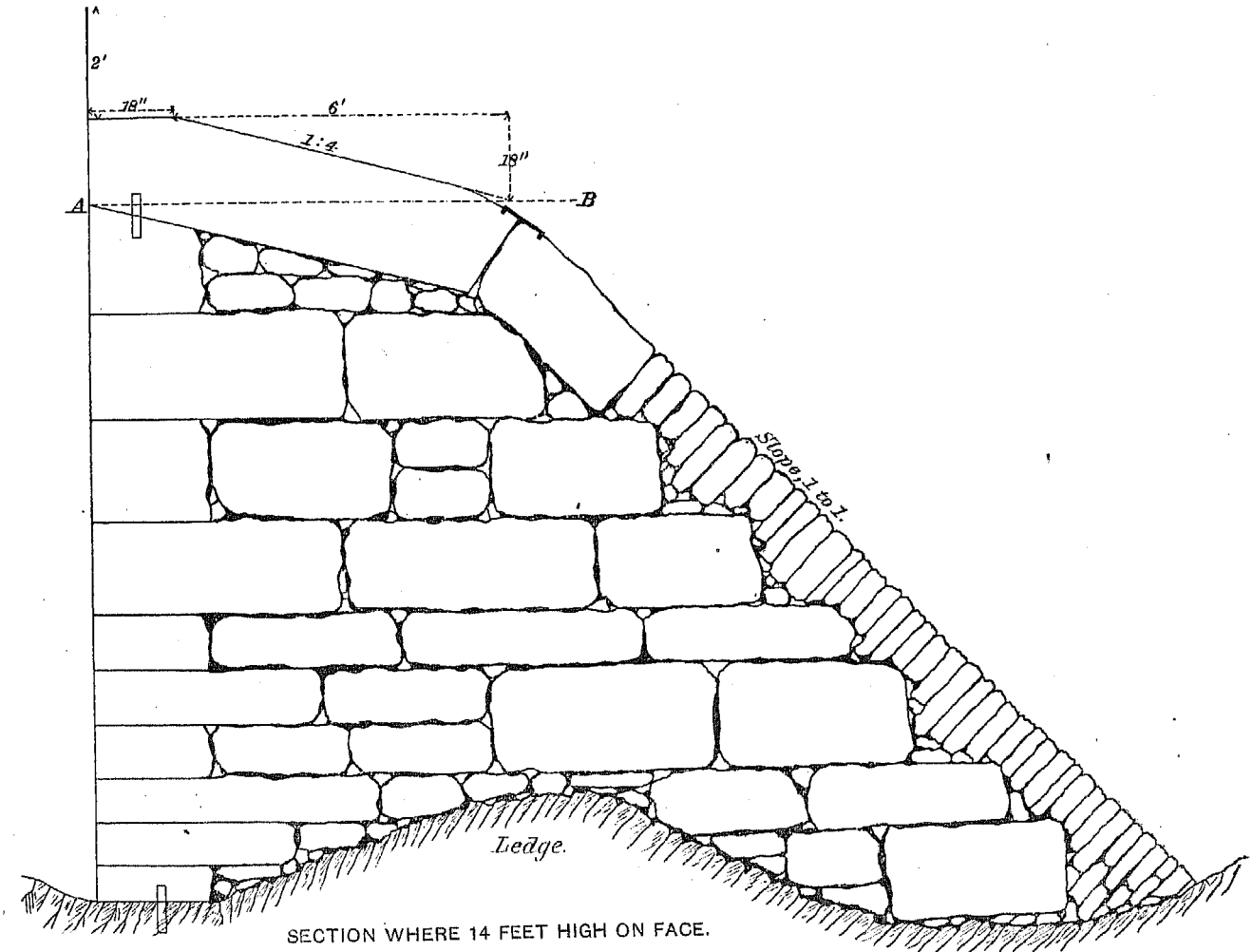
From the top of the Lawrence dam to the top of the Pawtucket dam at Lowell, a distance of about 12 miles, the fall of the river is about 48 feet. Of this fall about 11 feet occurs at Hunt's falls, 9 miles above the Lawrence dam, in a distance of 5,700 feet. This fall is owned by the corporations in Lowell, and will probably never be improved, inasmuch as the construction of a dam there would reduce the fall at the mills above in medium and high stages of the water. The fall is thus of no value as a source of power.

We come, therefore, to the second great power on the Merrimack river, that at Lowell.

THE WATER-POWER AT LOWELL, MASSACHUSETTS.

This power was one of the first of the large powers in this country which was systematically brought into use, and it has been developed and controlled in so admirable a manner that it has long served as a model for other works in various parts of the land. The first step toward the construction of any hydraulic works on the river was taken June 27, 1792, on which date a corporation known as the "Proprietors of the Locks and Canals on Merrimack River" was chartered for the purpose of improving the navigation of the river, and rendering it navigable by boats from tide-water to the New Hampshire line. No dam was built; in fact, the original charter prohibited the building of dams; but the canal known as the Pawtucket canal was built before the year 1800, having been opened in 1796. In 1801 a petition to erect a dam not over 2 feet high was sent to the legislature, but was probably not granted. It would seem, however, that at that time a similar dam was in existence, though only an incomplete structure extending partly across the river. In 1822 the Merrimack Manufacturing Company was incorporated, having purchased a number of farms near the falls. This company, in the same year, enlarged the Pawtucket canal; and although the records are not very clear as to when or by whom it was constructed, it appears that in 1821 there was a wing-dam at the head of the falls, together with a saw- and grist-mill. This dam extended to what is known as Great Rock, and its top was several feet below the top of the present dam. In 1825 there was a temporary dam across the river, and in 1826 the Merrimack Manufacturing Company appears to have made a beginning on a new dam; but in the same year this company transferred all its real estate to the Proprietors of Locks and Canals, who completed the dam in 1830 to 2 feet below its present height (or to 30 feet on the Locks and Canals scale). It was raised 2 feet in 1833 by putting on two courses of granite stone, and its expense up to February, 1833, was about $10,000. As originally constructed, it was built of wooden cribs filled with stone, and with some stone laid as paving below the dam, to prevent its being undermined where it was not built on rock. All of the original stone work, however, was laid without cement, and the gravel filling washed out with every freshet, so that in 1839 the dam had to be tightened by laying a course of masonry in cement at the back of the capping. Flash-boards were used, and in 1840 it was found that the leakage of the dam and flash-boards was 93 cubic feet per second. In 1847 that part of the dam between Great Rock and the gate-house was rebuilt in its present position to conform to the entrance to the northern canal, which was built during that and the previous year (1846). Its top was level, and at a height of 32 feet on the Locks and Canals scale; and its section is similar to that in Fig. 8. The lowest course in the face is doweled to the foundation, which is solid rock, and the capping-stones are doweled together and to the course below. The capping-stones and the slope-stones behind them are clamped together. The ashler work and granite backing were laid without cement—the mortar-stone backing and leveling in cement; the joints in the capping were filled with sulphur. In 1869 the directors considered the propriety of rebuilding the remainder of the dam, from Great Rock to the north side of the river, but it was not decided to commence the work till February, 1875. The new dam was built on nearly the same site as the old one, and its section is shown in Fig. 8. The rock foundation is stepped off to receive the ashler work, and the stones were laid at first without cement in beds or joints, and then grouted, course by course, with pure Portland cement. The backing is laid in a mortar consisting of equal parts by measure of the Newark Lime and Cement Company's cement, and clean, sharp sand. This was done to provide for possible disintegration and loss of cement, at and near the face of the dam, from the action of water and frost. As it is, the bearings will not be affected by the failure of the cement. In the portion of the dam built in 1847 the ashler was laid without cement in any form, with the same object; but some of the stretchers have worked out, to prevent which occurrence the new dam was grouted. The bed and joints of the capping, up to the level A B, were grouted with Portland cement in the same

Fig. 8. SECTION OF DAM AT LOWELL, MASS.



SECTION WHERE 14 FEET HIGH ON FACE.

Where the dam is more than 14 feet high, the part below 14 feet from the top is 20 feet thick, except at the "deep place."

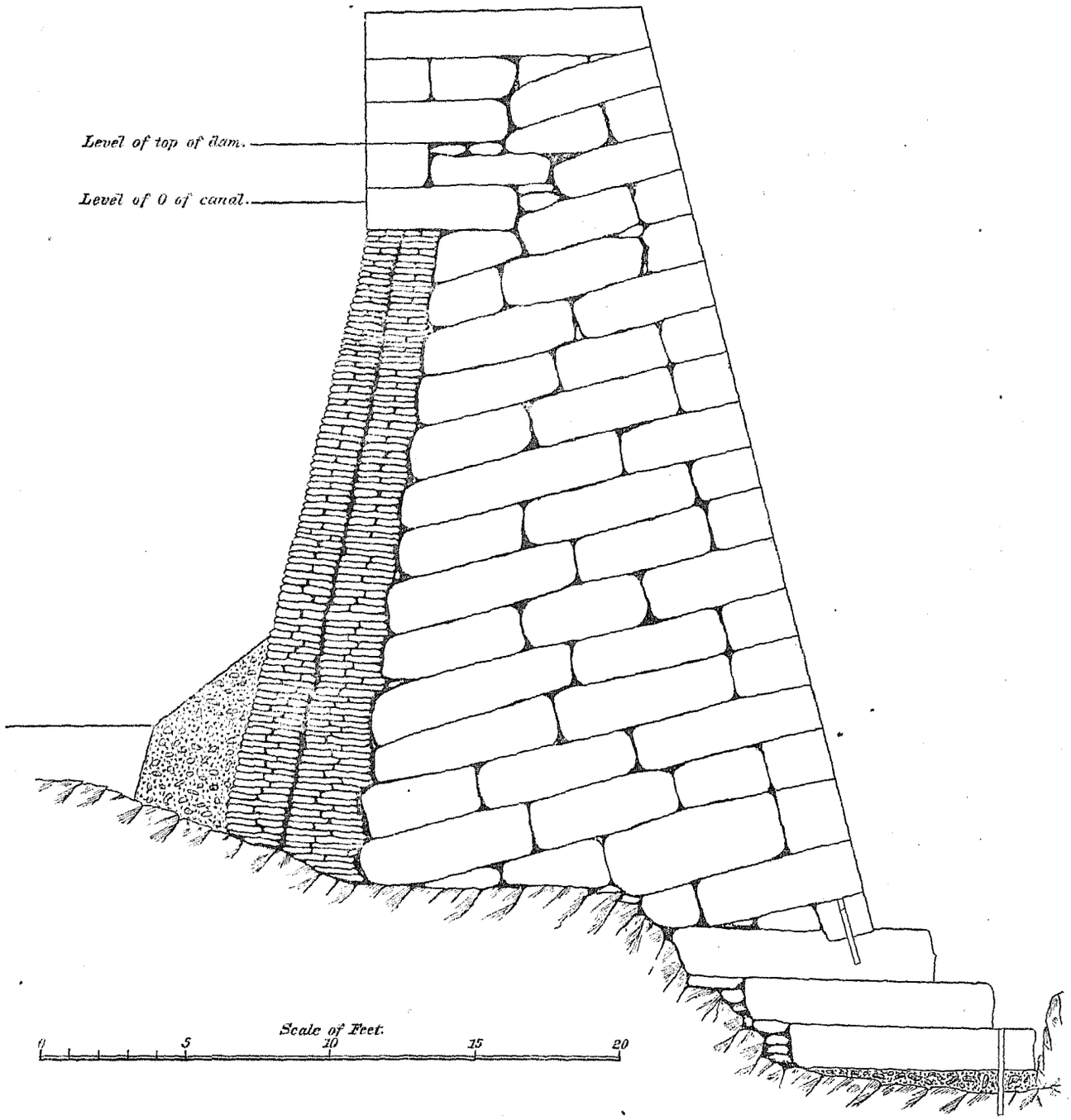


Fig. 9.

SECTION OF GREAT RIVER WALL AT LOWELL, MASS.

1326 feet from north side of Pawtucket Bridge.

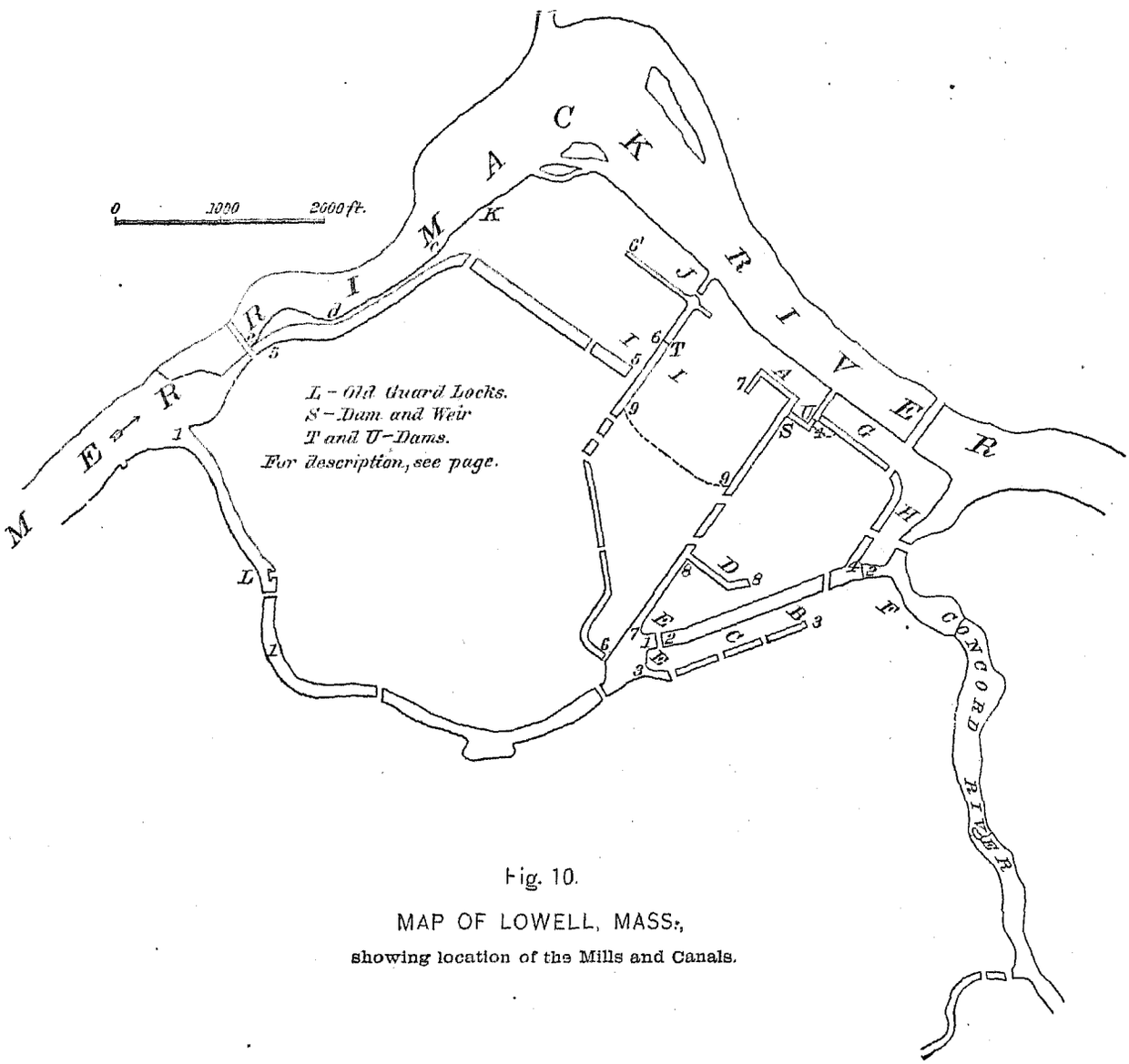


Fig. 10.

MAP OF LOWELL, MASS.,

showing location of the Mills and Canals.

manner; above A B the joints and the 1¾-inch iron dowels of the capping were filled with melted sulphur. The crest of the dam (18 inches wide) is fine-hammered, and designed to be at the exact mean height of the dam of 1847; above this, as in the old dam, there are flash-boards 2 feet high. In what is called "the deep place", at the lowest point of which the bed is 38.3 feet below the top of the dam, the foundation was prepared for the ashler work, for a distance of 100 feet, by leveling up with rubble masonry in cement to a height of 20.66 feet below the top of the dam. Great Rock was cut down and capped with granite in 1875, and First and Second rocks in 1876. The total length of the dam is 1,093.5 feet, its height varying from 2 feet or so, on the north side of the river, to 16 feet, excluding "the deep place". Its crest is at 32 feet, and the top of the flash-boards at 34 feet, on the company's scale. It extends in a very broken line up stream, often quite in the direction of the current, its south end being 700 or 800 feet below its north end. The total cost of rebuilding the dam in 1875 and 1876 was $104,056 75; that of building the dam of 1847 was about $10,000, making the total cost of the dam about $114,000. The works were carried out under the supervision of Mr. J. B. Francis, the present agent and engineer of the company, whose connection with the company commenced November 22, 1834, and has since been uninterrupted. (*a*)

The dam deadens the current, in the ordinary state of the river, for about 18 miles, forming, in low water, a reservoir of about 1,120 acres, which is sufficient to store the low-water flow of the river during the night-time, allowing the entire daily flow of the stream, during the dry season, to be utilized during ordinary working hours, as at Lawrence. The dam is situated at the head of what are known as Pawtucket falls, and for a distance of half a mile below the gate-house the bed of the stream is solid rock, the fall rapid, and the banks high and rocky. Two canals lead the water from above the dam, the original Pawtucket canal, enlarged in 1822 and 1823, and the northern canal (see map), both on the south side of the river. Various other canals intersect these two, all of which are shown on the accompanying map of Lowell (Fig. 10), and regarding which data are also given in the following table:

Canals at Lowell, Massachusetts. (*a*)

Name.	Designation on map.	Section.	Length (approximate).	Depth (approximate).	Width (approximate).	On what level.
Pawtucket:			*Feet.*	*Feet.*	*Feet.*	
Upper level	1–1	Irregular	6,500	10	Irregular.	Upper.
Lower level	2–2	Rectangular	2,200	7	100	Lower.
Hamilton	3–3	do	1,600	10	50	Upper.
Eastern	4–4	do	2,000	8	42 to 66	Lower.
Northern	5–5	do	4,100	16 to 21	100	Upper.
Western	6–6	do	3,500	10	15 to 115	Do.
Do	6–6′	do	1,000	8	30 to 80	Lower.
Merrimack	7–7	Rectangular and irregular	3,400	10	50	Upper.
Lowell	8–8	Rectangular	500	10	30	Do.
Moody-street feeder	9–9	Rectangular and arched over.	1,390	*b* 10	30	Do.

a Total length of canals, about 5 miles. Bottom of lower level, at about 9 feet on scale. River behind mills, at low water, at about 2 feet on scale. Water surface, lower level, at about 17 feet on scale. Bottom of upper level, at about 22 feet on scale. Water surface, upper level, at about 32 feet on scale.

b In middle of arches.

These canals are in many respects extremely interesting from an engineering point of view. With the exception of the Moody-street feeder, they are all open, and generally rectangular in section, only the upper level of the Pawtucket canal and the Merrimack canal being irregular in places. The Moody-street feeder, which was built through Moody street to connect the western and the Merrimack canals, is an underground conduit, divided into three parts by two longitudinal walls, forming the piers for three arches, which close the conduit on top. It is 1,390 feet long, and each of the three sections is 10 feet wide in the clear, and 7 feet high from the floor to the springing of the arches. The latter are of brick, 1 foot thick, and segmental, the radius being 5 feet 8 inches and the rise 3 feet. The side walls are 2½ feet thick, and the piers 15½ inches at top, spreading to 23 inches at the bottom. The feeder cost $86,131 81, or about $62 per running foot. The northern canal was built at great cost, being separated from the river, for a distance of about a quarter of a mile, between *c* and *d* on the map (Fig. 10), by a great river-wall of masonry, in places 36 feet high, and a section of which is shown in Fig. 9. This wall is founded on ledge, and is provided with four large and two small sluice-openings, for emptying the canal, together with an overflow. Between *d* and *e* on the map the canal is excavated, but a wall is carried down to the ledge, on the river side. The total cost of the northern canal was $551,584 70. The head-gates of the northern and the Pawtucket canals are all worked by hydraulic power. Those of the former are ten in number, each 8 feet wide, and filling an entire opening between piers. The lift is 15 feet, making the area of gate-opening 1,200 square feet, and they are raised by means of a small turbine wheel which drives a line of shafting, from which, by means

a It is a pleasure to acknowledge here my great indebtedness to Mr. Francis and his assistants for the information contained in these pages, and for revision of the manuscript.

of belts, the hoisting apparatus is driven. At the Pawtucket canal the gates are five in number, 9 feet long and with a lift of 10 feet, making the area of gate-opening 450 square feet. They are raised by being attached directly to a piston, which is raised by hydraulic pressure obtained from the water-pipes from the company's private reservoir. The details of these gates are worthy of careful study.

The fall at Lowell, at ordinary low water, is about 35 feet, of which about 2 feet is lost in consequence of the descent in the canals, leaving a net fall of about 33 feet. In severe freshets, however, the water below the mills rises 10 or 12 feet, and it has been (in 1852) 13 feet 7 inches deep on the dam; the fall, therefore, varies between about 33 and 20 feet. About one-sixth of the water is used on the entire fall, and the remainder is used twice over, on falls of about 14 and 19 feet, respectively. The lower fall, however, was reduced to 3 feet in 1852, the water rising in the river to 14 feet on the scale; and in 1878 the water rose to 10 feet, the fall being only 7 feet. Such cases, however, are, of course, extremely rare.

The water-power of the Merrimack at Lowell is owned, as has already been stated, by the Proprietors of Locks and Canals on Merrimack River, what is called the "permanent power" being held by the manufacturing companies under perpetual leases. The capital stock of the Proprietors of Locks and Canals is held entirely by the ten large manufacturing corporations using the power, in proportion to the permanent power held by them, respectively. The power, therefore, unlike that at many other places, is controlled by the very parties who use it, and by no others, and is not leased or sold by other and different parties, though managed by a quite distinct corporation. It may be expected, therefore, that the price of water-power in Lowell should be very low, and this will be seen to be the case. The water-power has been granted by the Proprietors of Locks and Canals in definite quantities, called mill-powers, as in Lawrence, but in this case a mill-power is defined to be

> The right to draw from the nearest canal of the said Proprietors so much water as, during fifteen hours in every day of twenty-four hours, shall give a power equal to 25 cubic feet per second at the great fall when the head and fall there is 30 feet, to 45.5 cubic feet per second at the lower fall when the head and fall there is 17 feet, and to 60.5 cubic feet per second at the middle fall when the head and fall there is 13 feet. And in order to prevent disputes as to the power of each mill-privilege in the variations of the height of water from changes of the season or other causes, it is understood and declared that the quantity of water shall be increased in proportion to the *reduction* of the height, * * * one foot being allowed and deducted from the height of the actual head and fall, and also from that with which it is compared before computing the proportion between them.

This method of determining the quantity of water is similar to that used in Lawrence; thus, when the head and fall (from canal to river) is 29 feet at the great fall, the quantity of water is $\frac{30}{29}$ of 25 cubic feet per second, the quantity of water being increased on account of the smaller fall, not in the proportion of 30 to 29, but in that of 29 to 28. We may also find the quantity by dividing 725 by the fall minus 1 foot. It is important to notice, however, that if the falls are more than those stated in the quotation above (*i. e.*, 30 feet on the total fall—13 feet on the upper level, and 17 feet on the lower level), no change is made in the quantity of water allowed, so that the mills obtain gratis the benefit of any additional fall. Now, although at the time the leases were made the fall from the upper level to the lower, and that from the lower level to the river, were respectively 13 and 17 feet, the canal walls have been raised since that time, so that the actual falls now are 14 and 19 feet. In the table on page 33, the smaller falls, which may be called the nominal falls, are given, while the actual falls are added in parentheses. Tables are prepared, as in Lawrence, giving the quantity of water per mill-power corresponding to fall. The Proprietors are to maintain the dam and canals, while the flumes and raceways are to be kept in order by the corporations. The Proprietors are not bound to furnish power between the hours of 8 p. m. and 5 a. m. The lease contains various other stipulations, regarding injury from lack of water, rights of the Proprietors to measure the quantity of water used, liability of either party to damages under certain circumstances, etc., which, however, are so nearly like those which have been already quoted as being in use in Lawrence, that it is not necessary to give them in detail. The permanent power, as already stated, is held under permanent leases, but with a reserved rent, as at Lawrence, the object of which is to provide for the management of the same and the maintenance of the works. This reserved rent for the permanent power is fixed at $300 per mill-power per annum, or (as a mill-power is equal to about 85 gross horse-power) at $3 53 per gross horse-power per annum, which is only sufficient to cover the necessary expenses of maintaining the power. Cash payments were made when leases were given, averaging about $10,000 per mill-power.

The following list gives the names of the corporations now owning power, as well as the amount owned by each, together with various other details:

Table giving details regarding the mills and power at Lowell, Massachusetts.

Name of corporation.	Designation on map.	Goods manufactured.	Number of spindles. (a)	Number of looms. (a)	Water taken from—	Water discharged into—	Head and fall in feet. (b)	POWER OWNED. Mill-powers.	POWER OWNED. Gross horse-power.	Steam-power in horse-power. (a)	Quantity of water in cubic feet per second.	No. shares in Proprietors of Locks and Canals.
Merrimack Manufacturing Company.	A.	Cotton.....	153,552	4,267	Merrimack canal	Merrimack river....	30 (33.5).	$24\frac{23}{35}$	2,097	6,000	616.667	740
Hamilton Manufacturing Company.	B.	....do	59,816	1,597	Hamilton canal.....	Lower level of Pawtucket canal.	13 (14)	16	1,360	1,200	968.000	480
Appleton Company.....	C.	....do	45,000	1,228	....do	....do	13 (14)	$8\frac{13}{35}$	725	750	516.267	256
Lowell Manufacturing Company	D.	Cotton and woolen....	22,750 (worsted and wool). 2,000 (cotton).	317 (power carpet). 75 (lasting).	Merrimack canal.....	....do	13 (14)	$8\frac{13}{35}$	714	1,040	508.200	252
Lowell Machine Shop (c)...	E.	.....	.....	.....	Merrimack canal and Machine-shop basin.	....do	13 (14)	$3\frac{9}{35}$	280	375	199.650	99
Middlesex Company.....	F.	Woolen.....	18,640	250 (broad).	Lower level of Pawtucket canal.	Concord river.....	17 (17)	$5\frac{23}{35}$	490	125	262.383	173
Boott Cotton Mills.....	G.	Cotton.....	127,000	3,600	Eastern canal.....	Merrimack river....	17 (19)	$17\frac{23}{35}$	1,519	1,000	812.933	536
Massachusetts Cotton Mills	H.	....do	119,528	3,658	....do	Merrimack and Concord rivers.	17 (19)	$24\frac{18}{35}$	2,085	950	1116.267	736
Tremont and Suffolk Mills.	I.	... do	94,000	2,700	Northern canal.....	Lawrence basin.....	13 (14)	13	1,105	1,500	786.500	390
Lawrence Manufacturing Company.	J.	....do	100,000	2,360	Lawrence basin.....	Merrimack river....	17 (21)	$17\frac{9}{35}$	1,470	1,000	787,150	519
Total	....	.....	742,286	20,052	.....	.....	.....	$139\frac{11}{30}$	11,845	13,040	.....	4,181

a These data are from *Annual Statistics of Manufactures in Lowell and Neighboring Towns, January*, 1882. Published by the Lowell *Vox Populi*.
b Figures in parentheses are actual falls (see page 32).
c This establishment consumes per year 1,100 tons wrought-iron, 8,500 tons cast-iron, and 200 tons steel—in all 9,800 tons of metal.

It appears, therefore, that there are sold at Lowell, in all, $139\frac{11}{30}$ mill-powers, or 11,845 gross horse-power on the original leases. As giving a further idea of the magnitude of the mills, it may be mentioned that the total capital invested in the ten corporations named in the table is $13,950,000, and the total number of operatives employed, 16,665. The quantity of water taken from the river, when no surplus is used, is 3,595.284 cubic feet per second, during working hours, under the normal falls. Of this, 616.667 cubic feet are discharged directly into the river, 786.5 into the Lawrence basin, and the remainder, or 2,192.117 cubic feet, into the lower level of the Pawtucket canal. The quantity taken from this last canal and discharged into the river is 2,191.583 cubic feet per second, while from the Lawrence basin 781.150 cubic feet are taken. It is clear that the water is utilized almost absolutely without waste.

As in Lawrence, a large amount of surplus power is used in Lowell, in accordance with regulations, from which the following extracts are made:

1. Any company who shall use any of such surplus power, but to an extent not exceeding 40 per cent. of the whole number of permanent powers that such company is now entitled to use, shall pay therefor, as a contribution toward the annual expenditures of said Proprietors, $5 per mill-power per day for the time that each power or part thereof shall be used.

2. In order to restrain the use of such surplus power, any company that shall be found to have used more of it than 40 per cent. of the powers so held and owned by such company, shall pay for all excess over 40 per cent. thereof, and not exceeding 50 per cent. thereof, at the rate of $10 per mill-power per day; and for all excess over 50 per cent. thereof, and not exceeding 60 per cent. thereof, at the rate of $20 per mill-power per day; and when more than 60 per cent excess is used, such company shall pay for the whole amount of surplus power used by it, at the rate of $20 per mill-power per day.

As in Lawrence, the engineer of the Proprietors can make measurements of the quantity used by each mill as often as he sees fit, and can limit the amount of surplus power to be used, having in view the supply of water in the river, "such limitations to be uniform in their application to all said companies, and to be in proportion to the mill-powers owned by them respectively." If, during the time when such limitations are in force, any company shall use a quantity of water in excess of that to which it is limited, said company shall pay for the same at the rate of $75 per mill-power per day for the greatest excess used on each day. Quarterly reports are made and accounts sent in to the different companies.

6. During *backwater* a uniform rate of $1 per mill-power per day shall be paid, and it shall be considered "backwater" when the height of the water in the river at the gauge back of the mills of the Merrimack Manufacturing Company is at or above 1 foot below zero, excepting when the water is raised to that point, or above, by ice.

In dry weather little or no surplus is used, while during "backwater" large amounts are used, some companies using up to 75 per cent. of what they own. In the fall and winter of 1880 and 1881 all the mills were limited in its use, and for twenty-eight days during that period its use was prohibited. The greatest amount of surplus used when there is no backwater is about 30 or 40 per cent. of the power owned. The minimum power available during working hours is consequently entirely utilized, although during a great part of the year some water goes to waste.

As a rule, even in low water, water flows over the dam early in the morning, but sometimes there is no waste whatever. We may, therefore, take the minimum power of the stream, during working hours, as $139\frac{11}{36}$ mill-powers, for the companies have never failed to obtain, with the aid of the lakes in New Hampshire, the full power they own. (*a*) A large amount of steam-power is used, as the table shows; some all the time, some only when surplus water is too expensive. The mills run from 6.45 a. m. till noon, and from 1 till 6 p. m., stopping at 4.30 on Saturdays, making sixty hours per week, the legal limit for the employment of women and children in factories. As in Lawrence, arrangements are made for disposing of ice, and there is little interruption of work caused by it.

It remains to describe the system of measuring water used at Lowell for the purpose of determining the quantity used by each mill. The method adopted is in most essential particulars the same as that used at Lawrence, though differing in many matters of detail. The idea is to get a direct measurement of the quantity of water used by each mill during a certain period—say a week—when the rate of running remains about the same. If anything occurs to alter the quantity of water consumed a new measurement is made. But it is recognized that the quantity of water used varies continually during the period chosen, according to the hour of the day and the day of the week, being greatest on Monday morning and least on Saturday afternoon. Accordingly, during the period taken, not one measurement, but four, are usually taken; one on a Monday morning, one on an ordinary morning, one on an ordinary afternoon, and one on a Saturday afternoon. The excess or surplus used above the power owned at each of these times is calculated, the fall from canal to river having been simultaneously observed. That on Monday morning added to that on Saturday afternoon, and to five times that on ordinary mornings and afternoons, if divided by 12, gives the average surplus used, and this is taken as the surplus used during the whole period considered.

In addition to these measurements, which are made, perhaps, rather more frequently than in Lawrence, daily records are made in Lowell of the heights of water at each mill in canal, penstock, wheel-pit, and river, together with height of speed-gate; but these observations are not used in working up the daily quantity of water discharged, as they are in Lawrence, except in unusual cases. For instance, if something occurs in one of the mills which necessitates stopping one wheel for a few days and substituting another, or if in any way the regular rate of work is interrupted for a short time, during which a flume measurement cannot be made, then the daily observations are used to determine the quantity used during said time of interruption; said quantity being obtained, not from diagrams, but from tables giving similar results. These tables are computed as follows: For each wheel the area of bucket-opening and the area of guide-opening are found by measurement. The smallest of these being called A, the quantity of water discharged under a given head, h (from penstock to wheel-pit, as in Lawrence), is calculated by the following formula:

$$Q = m\,A\,Q_r\,\sqrt{2gh}$$

in which m is a coefficient known by experience, g the acceleration due to gravity (32.2 feet per second), and Q_r the ratio of the discharge at any given opening of gate to that at full gate. This ratio is found for different gate-openings by actual test of the wheel, or by comparison with results of tests on similar wheels. The table gives, therefore, the discharge for different gate-openings under a given head, h, from penstock to wheel-pit. For any other head the quantity is assumed to vary as the square root of that head.

These tables are used in the following cases:

1. When, as above noticed, the regular running is interrupted for a short time, during which a standard measurement cannot be made.

2. Whenever it is *backwater*, in which case the fall is varying continually, water is very cheap (see page 33), and great accuracy is not so essential.

3. In times of low water, when the use of power is limited, and when, in addition to the ordinary standard measurements, it is necessary to calculate the quantity at frequent intervals. In such cases observations are made several times a day and the tables used.

Just as the diagrams in Lawrence must be tested at periods by comparison with the results of measurements, so these tables must be checked at every opportunity. Before explaining how this is done, we must describe the measurements in use in Lowell. These are only of three kinds—weir, orifice, and flume. One weir and one orifice measurement only is made, in connection with the Lawrence Manufacturing Company, which uses the water from the Tremont and Suffolk mills, together with an additional quantity which is admitted to the Lawrence basin

a Since the above was written (February, 1883) the extreme drought which occurred in September of that year, and which has been already referred to in describing the power at Lawrence, has rendered it necessary to modify the above statements. During that drought, for a period of about a month, the flow of the river reached a lower point than ever known before, falling to about 1,275 or 1,300 cubic feet per second (during twenty-four hours) on the worst day, as has already been noted in the table on page 9. During this entire period no water was drawn from lake Winnipiseogee, on account of its low stage, except what is lawfully required to be allowed to run, and the use of surplus water was prohibited in Lowell for a longer period than at any previous time since the establishment of the power.

through gates which have been experimented upon, and for which the coefficients are accurately known. The quantity used by the Tremont and Suffolk mills is measured, also that which goes through the gates and that which flows over the waste-weir of the Lawrence basin. In this way the quantity used by the Lawrence Company is obtained. All the other measurements are flume measurements, made nearly as in Lawrence. An important point of difference, however, is that in Lowell there is no space behind the mills allowing the measurements to be made in the tail-races; in fact, the mills are built almost over the water, so that the measurements have to be made in the main canals. They are made at regular times, and the velocity taken every foot and a half across the flumes. Simultaneously with these measurements (except on Monday mornings and Saturday afternoons, when the fluctuations of power are great) the speed-gate gauges, and the heights of water in penstock and pit, and canal and river, are observed. We have seen that in Lawrence a diagram is obtained generally for each wheel, though this has sometimes to be done indirectly, and this diagram is tested by the periodic measurements. In Lowell, however, as the measurements are made in the canals, and not in the tail-races, the total quantity of water used by each mill is what is obtained. Each flume measurement, therefore, applies only to some particular combination of wheels which happen to be running at the time of the measurement. For every flume measurement, then, except those on Monday morning and Saturday afternoon, a coefficient or correction is found, to be applied to the wheel tables, and a large number of coefficients has been thus obtained, applicable to various combinations of wheels running; so that in any case when the wheel tables have to be used, the proper coefficient is sought out from among the most recent ones, as nearly as may be.

One other point remains to be noticed. Some of the mills use wheels which have been carefully tested under various heads, gates, and speeds. In such cases the daily observations of head and gate are probably as accurate as flume measurements would be; and the quantity of water passing such wheels is determined by observing, as in flume measurements, during the period when the power used is about constant, the quantity passing some Monday forenoon, some Saturday afternoon, and on some ordinary forenoon and afternoon.

We may sum up briefly, as follows, the principal differences between the methods of measurement in Lowell and Lawrence:

1. In Lawrence, the measurements are made in the tail-races; in Lowell, generally in the canals.

2. In Lawrence, reliance is placed on the wheel diagrams, which are checked at intervals by standard measurements, and the daily quantity is calculated; in Lowell, the wheel tables are only resorted to in exceptional cases, and reliance is placed on the mills running at a uniform rate during certain periods, during which the average quantity is calculated directly from measurements.

3. In Lawrence, flume, weir, and piezometric measurements are made; in Lowell, mainly flume and weir measurements.

The drainage basin of the Merrimack above Lowell comprises an area of about 4,085 square miles, according to my measurements, the principal tributary between Lowell and Lawrence being the Concord.

The Lowell mill-pond extends to the foot of Cromwell's falls, 4¼ miles above Nashua and 17¾ miles above the Pawtucket dam. From this point up to Manchester, New Hampshire, a distance of about 13 miles, the river rises about 33 feet. In this distance there are several descents honored by the name of falls, but none of them are of much value for water-power, and will scarcely be improved. The following table gives details regarding them: (*a*)

From—	To—	Rise.	Distance.
		Feet.	*Feet.*
Foot of Cromwell's falls	Foot of Moore's falls	5.75	28,532
Foot of Moore's falls	Foot of Little Cohass falls	8.55	12,500
Foot of Little Cohass falls	Foot of Goff's falls	4.50	5,900
Foot of Goff's falls	Foot of Short falls	5.69	4,400
Foot of Short falls	Foot of Griffin's falls	4.03	5,300
Foot of Griffin's falls	Foot of Merrill's falls	2.08	10,800
Foot of Merrill's falls	Head of Merrill's falls	2.56	1,250
Foot of Cromwell's falls	Head of Merrill's falls	33.16	68,682

THE WATER-POWER AT MANCHESTER, NEW HAMPSHIRE.

We now come to the third of the great powers on the Merrimack, and one which will hold its own with the two already described. A log dam across the river at Amoskeag falls existed prior to 1809, the power created being used for a grain- or a saw-mill. A cotton-spinning mill was built on the west side, and was also run by water from this dam. In 1825 a second mill was added to this, and a third was built on an island in the river. All these mills were run thenceforward in the manufacture of tickings until they were burned, in 1840 and 1847.

The Amoskeag Manufacturing Company was formed in 1831, and purchased these mills, the water-power, and several thousand acres of land, on which the city of Manchester has since been built. In 1837 this company

a Senate Ex. Doc. No. 45, Forty-seventh Congress, first session, p. 12.

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a Senate Ex. Doc. No. 45, Forty-seventh Congress, first session, p. 12.

replaced the log dam with a stone dam, and built about 4,000 feet of its upper canal, on which, in 1838, a cotton-mill was built. Between that time and 1845, this canal was built as it now is, and the lower canal was added. The erection of mills on these canals has continued to the present time.

The present dam, constructed in 1871, a little farther down the river than the old one, consists of two parts—the wing and the main dam. The former commences at the gates at the head of the canal, and extends up-stream nearly parallel to the east bank, ending at a large rock or ledge a little to the east of the middle of the river. It is perfectly straight. Its length is 260 feet and its average height 10.92 feet. It is founded entirely on ledge of coarse mica-schist and granite. The main dam extends from the upper side of the rock at the end of the wing, up and across the river to the gates of the small canal on the west bank. It is curved up-stream in an irregular curve, its length being 420 feet and its average height 11.85 feet. It also is founded entirely on ledge. The wing-dam was rebuilt in 1870 and the main dam in 1871, and the cost of both was $60,000. They are the same in construction, and are built of hammered granite laid in cement. Their section is shown in Fig. 11. The crest is perfectly level for a foot in width, and its height is 70 feet on the Manchester scale (for its height above tide, see page 24). It is drilled every 4 feet 8 inches for wrought-iron pins 1½ inch in diameter, for holding on flash-boards to a height of 2 feet. The face batters 2 inches to the foot, and the back 1 inch to the foot. The ledge on which the dam stands is leveled off in steps to receive it.

Canals lead from the dam on both sides of the river. That on the west side is only about 100 feet long, 20 feet wide, and 8 or 10 feet deep, supplying only the paper-mills of the P. C. Cheney Company. On the east side there are two levels. The upper canal is about a mile long, rectangular in section, varying in width from 50 to 70 feet, and in depth from 10 to 12 feet. The lower level is about 7,250 feet long, rectangular in section, its width varying from 40 feet at the head to 60 feet at the lower end, and the depth from 8 to 10 feet. The map shows these canals and the locks at the head. The head-gates are twenty-four in number, arranged, as in Lawrence, in six sets of four each. The gate-openings are each 10 feet high and 8 feet 10½ inches wide, making the total area of gate-opening 532½ square feet. The gates are raised by a turbine wheel, running a shaft from which the gates are operated by means of bevel-wheels. The Manchester dam backs the water about 8 miles up to Hooksett, the average width of the pond being about 450 feet, and its area measuring about 443 acres. This pond is sufficient in dry weather to allow of the water being stored during the night-time and the entire flow utilized during working hours, so that in very dry weather it sometimes occurs that no water flows over the dam for days at a time. Generally, however, there is some waste toward morning, and sometimes during the day-time, even during the summer. The flash-boards are kept on almost all the time, but are sometimes carried off by the ice and high water. The dam is built at the head of the Amoskeag falls, and the principal fall occurs below it. The fall from the upper to the lower canal is about 21 feet and is nearly constant; that from the lower level to the river is from 29 to 31 feet at low water near the lower end of the canal, and about 34 feet at its very foot. At ordinary high water this fall is reduced to about 25 feet. The power is controlled by the Amoskeag Manufacturing Company, which has disposed of a portion of the power in accordance with proposals from which the following extracts are made, the power being leased by the mill-power:

II. Each mill-power at the respective falls is declared to be the right to draw from the nearest canal or water-course of the grantors, * * * 38 cubic feet of water per second at the upper fall, when the head and fall there is 20 feet—or a quantity inversely proportionate to the height at the other falls—and in order to prevent disputes as to the power of each mill-privilege in the variations of the height of water from changes of the season or other causes, it is understood and declared that the quantity of water shall be increased in proportion to the reduction of the height, 1 foot being allowed and deducted from the height of the actual head and fall, and also from that with which it is compared before computing the proportion between them.

This rule is the same as dividing 722 by the fall minus 1 foot, in order to find the quantity. A mill-power is therefore equivalent to 86.36 gross horse-power. The Amoskeag Company is to maintain the dam and main canal, while the flumes and raceways are property of the parties leasing power.

V. Every purchaser is to hold his purchase subject to the right of every prior grantee in case of a deficiency of water, but the grantors warrant a sufficient water-power existing at the time of the sale to each grantee, respectively.

As at Lowell and Lawrence, the power granted is held by perpetual leases, with a reserved perpetual annual rent per mill-power, defined in this case as at least sixteen and one-eighth ounces troy weight of gold of the present standard fineness and weight of the gold coin of the United States, or an equivalent in gold, at the option of the grantee at the time of payment. This is equivalent to about $300 per annum. Other terms of the proposals resemble so closely those which are in use in Lawrence and Lowell, and which have been quoted, that it is not necessary to repeat them. It is only to be added that, excepting 35 mill-powers, granted at first by lessees, power is only to be used during sixteen hours each day, viz, from 4 o'clock a. m. until 8 o'clock p. m. It will be seen that the annual rent is nearly the same as in Lowell, and for the large mills in Lawrence, being here $3 47 per annum per gross horse-power.

Under these proposals the Amoskeag Company has disposed of its power as shown in the following table, similar to those which have been given for Lowell and Lawrence:

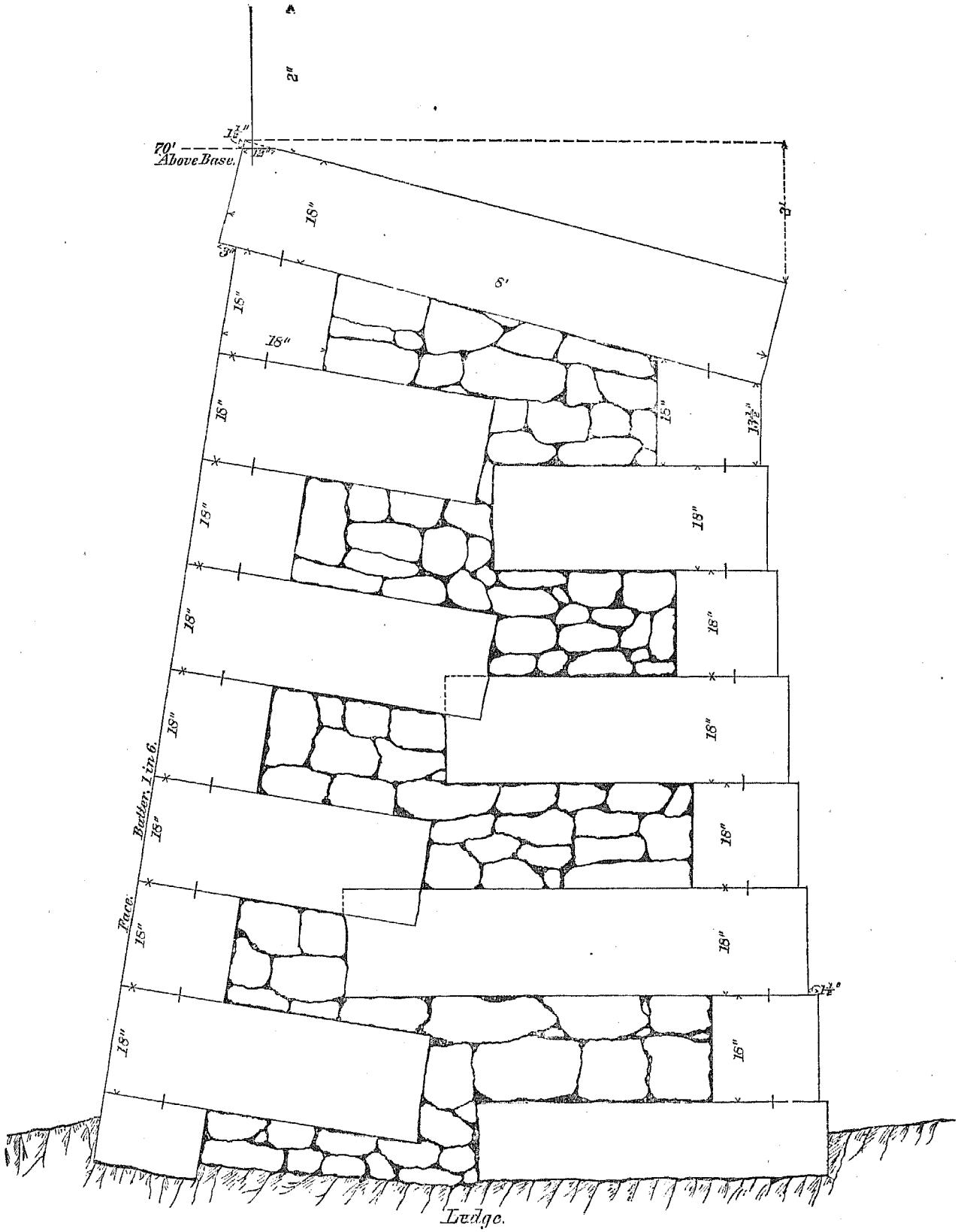

Fig. 11. SECTION OF DAM AT MANCHESTER, N. H.

Table giving details regarding the mills and power at Manchester, New Hampshire.

Name of corporation or firm.	Designation on map.	Goods manufactured.	Number of spindles.	Number of looms.	Water taken from—	Water discharged into—	Head and fall.	POWER OWNED. Mill-powers.	Horse-power, gross.	Horse-power, net. (a)	Steam-power in horse-power.	Quantity of water per second.
							Feet.					*Cu. feet.*
John Hoyt & Co. (b)	*A*	Paper			Upper canal	Lower canal	21	2	172.72	125		72.26
Langdon Manufacturing Company	*B*	Cotton	32,256	720	do	do	21	8	690.88	500		288.80
Amory Manufacturing Company	*C*	do	55,000	1,420	do	do	21	16	1,381.76	1,000		577.60
Stark Mills	*D*	do	52,000	1,400	do	do	21	20	1,727.20	1,250	500	722
Amoskeag Manufacturing Company	*E*	do	c171,096	c5,808	do	do	21	26	2,245.36	1,625	800	938.60
Amoskeag Pump House	*F*				Lower canal	River	20	1	86.36	62.5		38
Mechanics' Row	*G*	Miscellaneous			do	do	25	2	172.72	125		60.16
Olzendam's Mill	*H*	Hosiery			do	do	26	6	518.16	375		173.28
Amoskeag Electric-Light building					do	do	26					
Stark Picker House	*K*				do	do	27½	5	431.80	312.5		136.22
Amoskeag Manufacturing Company	*L*	Cotton, etc			do	do	30	56	4,836.16	3,500		1,393.84
Manchester Mills and Print-Works	*M*	Cotton & woolen	75,000	2,800	do	do	30	40	3,454.40	2,500	150	995.60
Namaske Mill (d)	*N*	Bagging			do	do	33	2	172.72	125		45.13
Total			385,352	12,148				184	15,890.24	11,500	1,450	

a The horse-powers in this column are net horse-powers, assuming a mill-power to equal 62½ net horse-power, corresponding to an efficiency of the turbine of about 73 per cent.

b Runs night and day.

c Total operated by the company.

d Owned and operated by the Amoskeag Manufacturing Company.

At the Amoskeag pump-house water is pumped from the lower level to a reservoir in the upper part of the city, to supply hydrant-water to the yards. Mechanics' Row consists of a number of small establishments for wood-working, carpentering, etc., together with a grist-mill taking water from the river by means of a small wing-dam, and using about 30 horse-power, with a fall of 12 feet. On the west side of the river are the paper-mills of the P. C. Cheney Company, using 260 horse-power on two wheels, with a fall of 40 feet, and 20 horse-power on another, with a fall of 15 feet, besides two other wheels under 40 feet head in the pulp-mills, giving 440 horse-power. This mill has the right to use water-power only when there is a surplus; at other times steam is used entirely.

It appears from the table that the amount of permanent power held by the various establishments at Manchester is 184 mill-powers, or 15,890 gross horse-power, or about 11,500 net horse-power, being thus considerably greater than that at Lowell or at Lawrence. The normal quantity of water used from the upper canal is 2,599 cubic feet per second, and from the lower canal 2,842 cubic feet per second, so that according to this there must be a waste between the two canals. The mills named in the table can obtain full capacity nearly all the time, but in very dry seasons some steam-power is used by the Amoskeag Company, thus allowing the other mills more water. The total amount of steam-power used, however, either during part of the year or continuously, is very small compared with that used at Lowell, or even at Lawrence. During part of the year there is an excess of power, and regulations have existed since January 1, 1883, similar to those at Lawrence and Lowell, regarding the use of surplus power, which can be used by paying for it at the rate of $5 per mill-power per day. The mills run from 6.30 to 12 a. m., and from 1 to 6.45 p. m., closing at 4 p. m. on Saturdays. Considerable trouble is experienced with ice before the pond freezes over, and sometimes the mills are obliged to stop on account of the filling up of the canals with anchor ice.

The amount of water used by the different mills has hitherto not been determined, as at Lowell and Lawrence, by actual and periodical gaugings. Measurements were made in August, 1879, by Mr. H. F. Mills, chief engineer of the Essex Company, of Lawrence, who, by means of flume measurements in the canals, determined how much water the mills were using, at the same time observing the fall from penstock to wheel-pit, and the height of speed-gate. At the time of my visit to Manchester it was stated that daily observations of the quantity used, by observation of the height of speed-gate and of water in penstock and pit, and comparison with Mr. Mills' measurements, were made only in dry weather, when there was danger of failure of supply. At that time, too, no regulations were in force regarding surplus water, which could be used whenever there was enough of it. Since that time, however, the regulations regarding surplus power have been established, and it may be that systematic observations are or will be enforced.

The drainage area above Manchester is about 2,839 square miles. Systematic and continued gaugings of the flow have not been made, and no data in this respect, further than the figures already adduced, can be given. (*a*)

a I am indebted to Colonel T. L. Livermore, agent, and to Mr. E. A. Hobbs, engineer, of the Amoskeag Company, for information regarding the power at Manchester.

The power at Manchester compares favorably, both as regards amount and facilities for utilization, with any in New England. Few rivers can boast three such powers as those on the Merrimack at Lawrence, Lowell, and Manchester.

THE POWER AT HOOKSETT, NEW HAMPSHIRE.

The next power above Manchester is at the head of the pond, at Hooksett, about 8 miles by the river above the Manchester dam. A canal was over fifty years ago constructed around the Hooksett falls, for purposes of navigation, for, in Tanner's *Description of the Canals and Railroads of the United States*, published in 1840, we find it mentioned, with the statement that it was 825 feet long, with three locks, and a fall of 16 feet. The power was, until 1865, controlled by the Amoskeag Company, but is now owned by the Hooksett Manufacturing Company. The present dam is built of stone, and extends nearly, but not entirely, across the river at the head of the falls, ponding the water for a distance of about 4 miles, with an average width of 300 or 400 feet. It was built in 1841, and is several hundred feet long and perhaps 3 or 4 feet high. It is founded entirely on ledge, and may be raised about a foot by means of flash-boards, which are put on during the summer months. From the dam a canal, about 300 feet long and 20 or 25 feet wide, leads to the cotton-mill of the Hooksett Company, situated on the east bank, the fall used being about 14 feet, and the power about 350 horse-power, which can of course be obtained all the time, there being about the same quantity of water here as at Manchester. No steam-power is used, and there is at all times a great waste of water over and around the dam. It is said that there have been mills at this place for over fifty years, and the dam has been several times rebuilt. The topography is very favorable for the utilization of the power, and a very large amount is still available. The drainage area above the place is about 2,791 square miles, but the power may be estimated from the figures given for Manchester, as there are no important tributaries between the two places. It is probable that for a fall of 14 feet the minimum power is not less than 1,800 gross horse-power continuously, and perhaps more. The pond, however, is probably not large enough to allow of this being concentrated entirely into working hours, though this might be done to some extent. The power is an excellent one and worthy of a place among the great powers of the Merrimack. There is no reason why the full power, of which such a very small fraction is now in use, could not profitably be utilized.

THE POWER AT GARVIN'S FALLS.

About 4 miles above Hooksett and 3 miles below Concord we come to Garvin's falls, the next power, situated just above the mouth of the Soucook river. Many years ago, long before the introduction of railroads into the state, a canal, known as the Bow canal, was built around these falls for purposes of navigation, the remains of which still exist; and the Amoskeag Company, which owns the power, has for some years maintained a dam at the head of the falls, as required by its charter, though no power has been used. Originally a stone dam existed there, but that was carried away some twenty years ago, and the present dam is of wood. It was built in 1879, cost $6,000, is about 550 feet long, and averages 8 feet in height. It backs the water several miles, with a width of some 400 feet, forming a considerable pond. Below the dam, which is founded on ledge, the fall is rapid for some distance, amounting, according to Frank Merrill, civil engineer, of Concord, to 28.4 feet in 1,200 feet. The bed is rocky, and the banks are very favorable for the utilization of the power. The canal extends along the right bank, and is about 2,000 feet long, with several locks at the foot; and although no power has yet been utilized, a pulp-mill is now being erected there, power having been leased from the Amoskeag Company. The old canal is to be used as a race, and the mill located at the foot. The drainage area above these falls measures about 2,412 square miles. The power available is very large, the quantity of water being less than that at Manchester only by that contributed by the Suncook and Soucook rivers and a few brooks. The minimum flow continuously is probably not less than 900 cubic feet per second, which would correspond, on a fall of 28 feet, to a power of nearly 3,000 gross horse-power. The pond would allow of this being increased considerably during working hours, but to what extent I am unable to state. The power is a most excellent one in every respect.

THE POWER AT SEWELL'S FALLS.

The next power above Garvin's falls (except one little rapid not worth considering), and the last on the Merrimack, is at Sewell's falls, about 4 miles above Concord. Around these falls, as around those at Hooksett and at Garvin's falls, a canal was commenced many years ago for purposes of navigation. Its length was a quarter of a mile, and it was completed in 1837; but it is said that difficulty was experienced in the construction of a dam, the bed of the stream being composed of sand and gravel, with no ledge, so that navigation around the falls was never successfully established. The total fall, at lowest water, is 19.1 feet in a distance of 1.75 mile, according to Frank Merrill, civil engineer, of Concord. The greater part of this fall, however, occurs in a distance of a mile. The power is owned by the Concord Land and Water-Power Company, and steps are being taken toward its development. The fall is situated below the mouth of the Contoocook river, and the drainage area above measures about 2,350 square miles. Estimates of the power available are omitted, at the request of the engineer of the

company, on account of the fact that the conditions which will be established regarding flowage, and the arrangements which will be made with the Lake Company regarding quantity of water, are not yet definitely decided upon. Of course, the conditions which may be established here will modify to some extent those existing at the sites lower on the river, so that the figures which have been given in previous pages as to the amount of power available are only to be considered as approximate.

Excellent building materials are found in the vicinity of Concord, the granite having a national reputation. Should this power be developed, one more will be added to the great powers on the Merrimack.

Above Sewell's falls the river has considerable fall, but no good sites for power. The fall between the head of the falls and the junction of the Winnipiseogee and Pemigewasset rivers is, according to the table on page 24, 21 feet. Two miles below Franklin, at Webster Place, a fall commences, which extends for some distance up both rivers, and is extensively utilized on the Winnipiseogee. From Webster Place up to the tail-race of the Winnipiseogee Paper Company, the lowest power on that stream, there is a fall of 14 feet, unutilized, but it is probably not of very much value. From Webster Place to the junction of the two rivers the fall is 10.84 feet at low water.

The following table gives the statistics of power utilized on the Merrimack river. All the powers above Lowell and Lawrence partake equally with those places of the advantage derived from the storage reservoirs on the upper tributaries, though none except Manchester are sufficiently developed to appreciate the benefit. The profile of the river (Fig. 4) shows graphically the abrupt descents which render the river so excellent a source of power:

Table of power utilized on the Merrimack river.

Stream.	Place.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used (gross).	Horse-power used or owned (gross).
						Feet.	
Merrimack river	Lawrence	Massachusetts	Essex	Cotton	3	84	3,153
Do	do	do	do	Woolen	2	56	298
Do	do	do	do	Cotton and woolen	3	84	5,583
Do	do	do	do	Flour and grist	2	56	199
Do	do	do	do	Foundery	1	28	28
Do	do	do	do	Leather-board	2	56	191
Do	do	do	do	Braid	1	28	43
Do	do	do	do	Shoddy	1	28	14
Do	do	do	do	Machinery, etc. (*a*)	2	56	93
Do	do	do	do	Paper	4	112	1,222
Do	do	do	do	Bleachery	1	28	85
Do	do	do	do	Electric light	1	28	.....
Do	do	do	do	Lines	1	28	.....
Do	Lowell	do	Middlesex	Cotton	7	134½	10,361
Do	do	do	do	Woolen	1	17	490
Do	do	do	do	Cotton and woolen	1	14	714
Do	do	do	do	Machinery	1	14	280
Do	Manchester	New Hampshire	Hillsborough	Paper	2	6	1,085
Do	do	do	do	Flour and grist	1	12	*b* 30
Do	do	do	do	Cotton	4	141½	11,314
Do	do	do	do	Bagging	1	33	173
Do	do	do	do	Cotton and woolen	1	30	3,454
Do	do	do	do	Pump-house	1	20	86
Do	do	do	do	Miscellaneous	.....	.....	173
Do	do	do	do	Hosiery	1	26	} 518
Do	do	do	do	Electric light	1	26	
Do	do	do	Merrimack	Cotton	1	14	1350

Total horse-power (gross) utilized in dry seasons, about 39 591.

a Besides these, four machine-shops rent power. *b* Net.

THE TRIBUTARIES OF THE MERRIMACK.

In their order, as the Merrimack is ascended, the principal tributaries are the following:

THE POWOW RIVER.

This stream empties from the north, taking its rise in Rockingham county, New Hampshire, in the town of Kingston, and flowing in a southeasterly direction, joining the Merrimack just above Newburyport. Its length is about 10 miles in a straight line, and it drains an area of about 50 square miles. At the head of tide-water are the towns of Amesbury and Saulsbury, where are located the principal powers on the stream. Its drainage basin is low and rather sandy, and the flow of the stream would be exceedingly variable if it were not for the reservoirs, of which there are several, controlled by the Hamilton Woolen Company. The only powers on the stream worth mentioning are those of the above named company, at Amesbury, which has five different dams within a distance of from an eighth to a quarter of a mile, the total fall being nearly 70 feet. The first or upper one is of wood, 26 feet high, the fall utilized being 26 feet, and the power 1,300 horse-power during from three to five months of the year, and sometimes almost nothing. The second dam is 18 feet high, of wood, and only receives what water runs over the one above. It supplies about 25 horse-power when there is a waste over the dam above. The third is 10½ feet high, the fall the same, and the power 75 horse-power during seven or eight months. The fourth is 16 feet high, and the power 150 horse-power, with the same fall. The fifth is 14 feet high, and the fall 14 feet at low water, affording 215 horse-power. All the mills have steam-power, generally enough to run them at full capacity, and some steam is used all the time. About three-eighths of a mile above the upper dam is lake Gardner, with a dam 18 feet high, used only as a storage reservoir and not for power. The gates are shut every night, and the flow of the river thus concentrated, almost at all seasons, into the ten working hours. Only during freshets is there great waste of water.

Several small streams join the Merrimack between Newburyport and Lawrence, but scarcely any are worthy of special mention. One which comes in at Groveland is fed by two ponds, covering, it is said, several hundred acres, so that the stream is excellent for its size, being very constant in flow. Another of the same class enters from the south just below Lawrence, rising in "Great pond" in North Andover, which covers 650 acres at high water, and lies at an elevation of about 75 or 80 feet above the mouth of the stream, which is only 2 miles distant. Almost every foot of this fall is utilized, there being five mills on the stream, with a total fall of 80 feet at low water in the Merrimack, and using together between 150 and 200 horse-power. No water is wasted, and the power of the stream is literally exhausted. Great pond is dammed, and its level can be varied by 11 feet or thereabout, so that it offers considerable storage. Few streams of such small size are better utilized or are more favorable for power than this one.

THE SHAWSHEEN RIVER.

This stream enters the Merrimack from the south, just opposite the city of Lawrence, and drains an area of about 72 square miles. Taking its rise near the town of Lexington, in Middlesex county, it flows in a general northeasterly direction, its length in a straight line being some 18 miles. The principal town on its course is Andover. Its drainage basin comprises principally a hilly and rolling country, like all of eastern Massachusetts, but along the middle part of the course of the stream there are considerable areas of swamp-land, and the stream is very sluggish. In the upper and lower parts its fall is considerable, and its bed and banks are favorable for power, but in the upper part it is too small to be valuable, so that the principal power used is below the town of Ballardvale, or within 5 miles of its mouth. Below this point the fall is rapid, and is all utilized. The flow of the stream is very variable, but no continued gaugings are on record. There is only one artificial reservoir, known as Foster's pond, which is dammed, and the expense of maintaining which is borne by the mills below Ballardvale in proportion to their fall. The exact storage capacity of this pond could not be ascertained, but is very small. Its area is about 40 acres. (*a*) The river has been sometimes proposed as a source of water-supply for the cities of Boston and Cambridge, but has not yet been so used. The following are the principal powers on the stream:

1. Woolen-mill at Ballardvale, fall 11 feet.
2. Twine-mill of Smith & Dove (upper mill) at Andover, fall 13 feet; 150 horse-power used, but during less than two months of the year; steam sufficient to run all the machinery.
3. Marland woolen-mill, at Andover, fall 12 feet; 150 horse-power during a few months; 90 horse-power steam.
4. Twine-mill of Smith & Dove (lower mill), fall 6 feet.

The stream is sometimes so low that the mills are obliged either to stop or to run entirely by steam.

a Report of Massachusetts State Board of Health, 1873, p. 126.

THE SPICKET RIVER.

This stream empties into the Merrimack at Lawrence, rising in Rockingham county, New Hampshire, and flowing south and southeast into Massachusetts, its length in a straight line being about 15 miles and its drainage area 79 square miles, of which 10 are in Massachusetts. It is not a very good stream for power, its flow being very variable. Several small ponds near the headwaters are dammed and used to regulate the flow, viz: *Policy pond*, in New Hampshire, covering about 450 acres, and with a range of 8 feet; Island pond, covering about 480 acres, and other smaller ones. In Lawrence there are three mills on the stream, the lowest with a fall of 15 feet, the next with 12 feet, and the third, the Arlington worsted-mill, with 12 feet. The power at the last is stated at 140 horse-power during part of the year. A short distance above, a fall of 39 feet is used, at the Methuen Company's cotton-mill, with 300 horse-power during eight months. In very dry seasons the flow of the stream is very small, and the mills depend upon steam.

BEAVER BROOK.

This stream, which is in all respects similar to the Spicket, rises in Rockingham county, New Hampshire, and flows south, entering the Merrimack opposite Lowell, after draining about 92 square miles. The mill nearest the mouth, that of the Merrimack Manufacturing Company (woolen), uses 175 horse-power during about eight months, with a fall of 18 feet. At times, however, the power is almost nothing, and steam has to be used. There are a few ponds connected with the stream, and used as reservoirs, but their capacity is small. A short distance above the woolen-mill referred to there is a fall, not utilized, said to amount to 12 feet. Above this there are several small mills, as shown by the table on a subsequent page.

THE CONCORD RIVER.

The Concord river is formed in the town of the same name, in Middlesex county, Massachusetts, by the union of its two headwaters, the Sudbury and the Assabet, whence it flows in a nearly northerly direction for a distance of about 12 miles in a straight line, emptying into the Merrimack at Lowell, draining a total area of about 380 square miles, according to my measurements. Its drainage basin is hilly and rolling near the mouth of the stream, and its fall is large, the bed being rocky and the banks high; but from North Billerica to the junction of the two headwaters the stream flows mostly through swamp- and meadow-land, and is exceedingly sluggish, its fall being not over 2 inches per mile, its course very circuitous, and the bed sand and mud. The Assabet, however, drains a more hilly and broken country, and has a rapid fall and high banks, while the Sudbury is for some distance flat, like the Concord. The drainage basin is not well wooded, and the reservoirs used for regulating the flow are not of large capacity, so that the flow of the stream is quite variable, notwithstanding the large areas of meadow-land subject to inundation, and in some cases permanently wet.

The most important power on the Concord is within 2 miles of its mouth, in which distance the fall is not less than 40 feet, over a rocky bed, the fall corresponding to that in the Merrimack, just opposite. The lowest dam is 7 or 8 feet high, and affords a fall of 11 or 12 feet, used on both sides of the river. On the north, the Middlesex woolen-mills use a power of nearly 200 horse-power, taking 167 or 168 cubic feet per second from the river. Full capacity cannot be secured all the year, and steam is in reserve. No water is wasted during nearly ten months of the year, it is said. The mills on the opposite side of the river can only use water when it would otherwise run over the dam. They include the Belvidere Woolen Manufacturing Company's mill, with 75 horse-power during seven months, together with several smaller mills. The power used on this side amounts to about 175 horse power, and can be obtained during six or seven months.

The second dam is a quarter of a mile above, at Massic falls; the fall is 7 or 8 feet, and the power is used by a paper-mill and a woolen-mill.

The third dam is that of the Wamesit Power Company, and is a primitive wooden dam, turning the water into a canal about 2,300 feet long, near the lower end of which are the mills, some discharging the water into Meadow brook, and others into the Concord directly, the fall being 23 or 24 feet. The power is owned by a number of parties, and the estimated flow when the water stands at the top of the dam is 288 cubic feet per second, which is owned as follows:

	Cubic feet per second.
1. L. W. Faulkner & Son (woolen-mill)	25
2. Chase woolen-mill (burned)	48
3. Stirling woolen-mill	36
4. American Bolt Company	36
5. Belvidere Woolen Company	27
6. Wamesit Power Company	68
7. Wood's grist-mill	12
8. Bleachery	36
Total	288

When the flow is less than 288 cubic feet per second, each owner is entitled to a quantity proportional to the amounts given above; thus, the Wamesit Power Company owns $\frac{48}{288}$ of the water flowing at all times. There is no way, however, of dividing the water in these proportions. Full capacity can only be obtained during about eight months, there being sometimes "but little more than enough water for the boilers", all the mills having steam-power in reserve. The Wamesit Power Company has its own wheels and engines, and leases power to a number of small establishments.

The next power on the stream is at North Billerica, where a stone dam 9 feet high affords a fall of 11 feet. Power is used on the west bank by C. P. Talbot & Co.'s mills, the woolen-mill using 400 horse-power during about eight months, and the dye-wood mills 200 horse-power almost all the time. The woolen-mill is run partly by steam (200 horse-power) during about four months. On the east bank, J. R. Faulkner & Co.'s woolen-mill uses 75 horse-power during about six months, using only the surplus water, and running entirely by steam about half the time. On account of the swamps and meadows above here, the freshets are not at all severe, the water seldom rising over 4 feet on the dam, which is 150 feet long.

Above this point the Concord is very circuitous, and is one of the most sluggish of rivers. Between North Billerica and Saxonville, on the Sudbury, a distance along the stream of 29½ miles, there is no power utilized; the course of the stream lies through a very level country, and is bordered by meadow-lands varying in width from a few rods to a mile, covering some 4,000 acres in all, large areas of which are permanently wet. At Saxonville, there are large mills, but they are run mostly by steam since the water of the upper Sudbury has been taken for the supply of Boston. There is no power on the stream between Saxonville and the Boston dam, although a small amount of water is allowed to pass continually. Above the Boston dam the drainage area is about 72 square miles, and there are a few small mills. At the head of one of the branches, in Hopkinton, is a reservoir covering about 576 acres, originally built by the city of Boston as a compensating reservoir, but now owned by private parties and used for power.

The Assabet is essentially different from the Concord and the Sudbury. With higher banks and greater fall, and with no meadows along its course, it is more affected by sudden rains, and rises and falls more quickly. On account of its greater fall it is much more extensively used for power, and a few artificial reservoirs have been built to regulate the flow. The table beyond shows the total fall and power used, and little is to be added. The drainage area is about 175 square miles, and at the American powder-works, not far from the mouth, a power of 200 horse-power is used, with a fall of 11 feet, during about six months, while during the rest of the time the power is small. Most of the mills have steam-power in reserve. Of the reservoirs on the stream we may mention the following: Boon pond, covering 100 acres; Fort Meadow reservoir, built originally by the city of Boston as a compensating reservoir, covering 250 acres, and capable of being drawn down 24 or 25 feet; Gates' pond; Magog pond, on the Nashoba brook, covering 220 acres or more; and other smaller ponds. The privileges are nearly all occupied, no large ones being still unutilized. Both the Sudbury and the Assabet have their sources in Worcester county, whence they flow into Middlesex.

STONY BROOK.

This stream takes its rise in Worcester county, Massachusetts, in Harvard township, and flows northeast into the Merrimack at North Chelmsford, its length in a straight line being about 12 miles, and its drainage area about 35 square miles. It has considerable fall, and is not bordered by meadow-lands, like the Concord, and, considering its size, is quite a good stream for power. It is reservoired to some extent, and regarding the ponds the following approximate data are given: (a) Millfield pond, near the mouth, covers about 80 acres; Nabnasset pond covers 98 acres, and can be drawn down 8 feet; Forge pond covers 143 acres, and can also be drawn down 8 feet; Spectacle pond, running into Forge pond, covers 71 acres, with a range of 4 feet. These ponds are controlled by a company representing the mill-owners below. Other ponds covering, in all, several hundred acres, are connected with the stream, but are not dammed. The stream is utilized to a considerable extent, as the table shows. At its mouth is an unutilized privilege with a fall of 6 or 8 feet, subject, however, to backwater. Just above are the mills at North Chelmsford, using a fall of 24 feet, and comprising the Chelmsford foundery, Silver & Gay's machine-shop, and a worsted-mill, the total power used being about 175 horse-power, though at times no power at all is to be had. The mills, as well as those on the upper part of the stream, are generally provided with steam-power.

THE NASHUA RIVER.

The Nashua river is formed by the union of its two branches, the North and the South, the former of which has its sources in the northern part of Worcester county, and flows southeast for a distance of about 18 miles in a straight line, while the latter rises in the central part of the same county and pursues a circuitous course toward the south, east, and north. The former branch drains about 127, the latter about 129, square miles, all comprising a country quite hilly and steep about the upper parts of the streams, while lower down there are considerable areas of low-lying land, and the slopes are very gradual. The topography is favorable to storage, but no

a *Report of Massachusetts State Board of Health*, 1873.

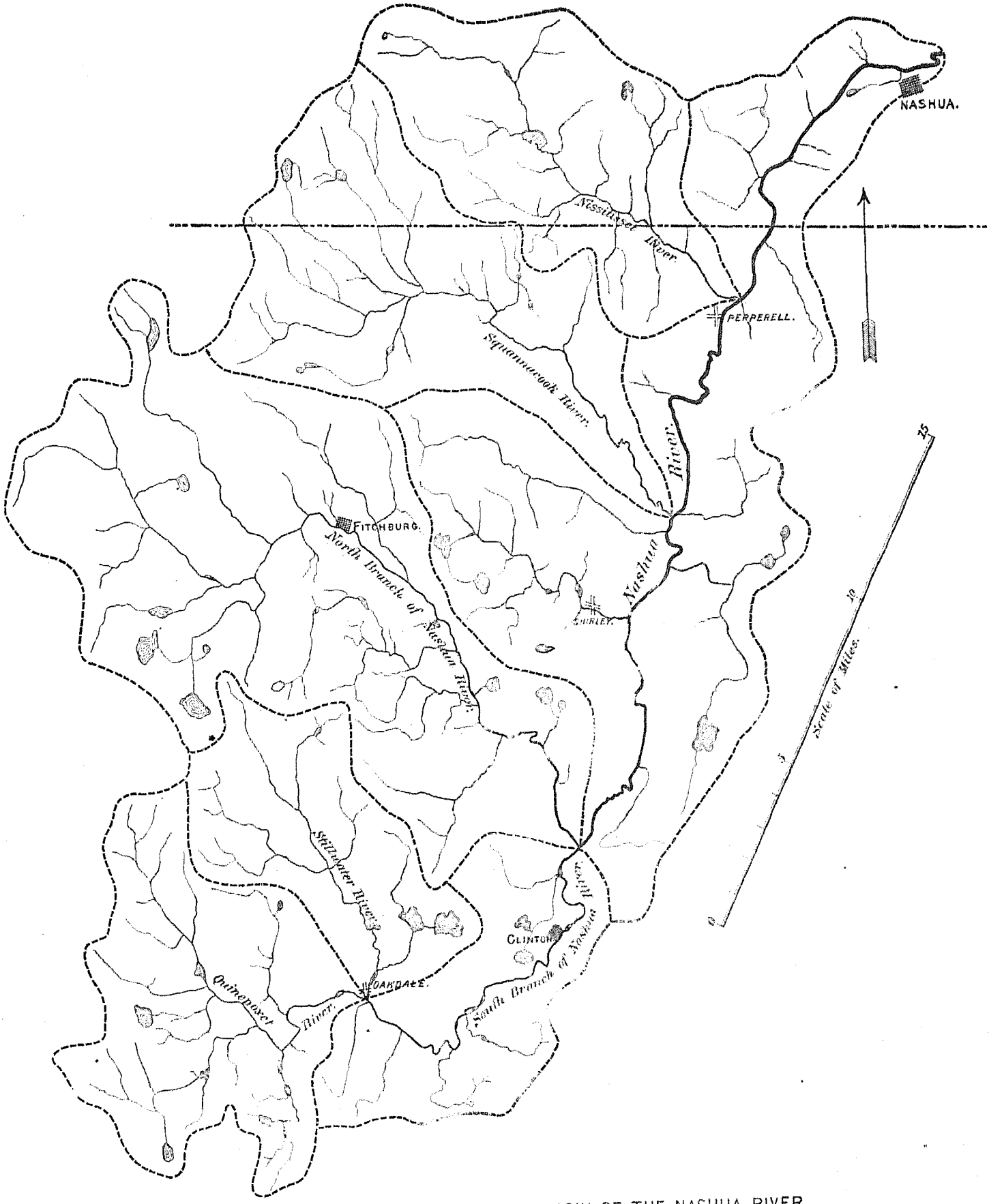

Fig. 12. MAP OF THE DRAINAGE BASIN OF THE NASHUA RIVER.

large reservoirs are in use, the only ones being a few small lakes and ponds near the headwaters of the streams, which, while sufficient to regulate, to a large extent, the flow of the small streams forming their outlets, exercise scarcely any appreciable influence on the main stream. From the junction of the two branches the Nashua pursues a northerly and easterly course, passing into Middlesex county, and then into New Hampshire, joining the Merrimack at Nashua. The length of its course, from the junction to the mouth, is about 24 miles in a straight line, and the total area drained by the stream is about 516 square miles. No important town lies on its course, except Nashua. The drainage basin, below the junction of the two branches, is largely low and level in character, especially that lying along the main stream. The areas drained by the branches which empty from the west are hilly and rolling, resembling the basins of the two headwaters. For a distance of 3 or 4 miles from its mouth the fall of the stream is rapid, the bed rocky, and the banks are high; above that point its fall is less for a distance of from 8 to 10 miles, but the banks are still high enough to confine the river, except in high freshets; but for the remainder of its length, from Groton to the junction of the branches, the stream is very sluggish, its bed and banks are sandy and gravelly, and the latter often subject to overflow, considerable areas of meadow-land which border the stream being inundated at times. The flow is naturally very variable, but is regulated somewhat, though only to a small extent, by the large number of mills on the tributaries of the stream. The rainfall over the basin is about 45 inches, of which 12 fall in spring, 11 in summer, 12 in autumn, and 10 in winter. The stream and its principal branches are easily accessible by rail at all points.

Commencing at the mouth, the first power is at Nashua, close to the Merrimack. A dam about 16 feet high and 134 feet long, with a canal of 1,000 feet, affords a fall of 20 feet at the cotton-mill of the Jackson Company (Indian Head mills). The power used is 1,100 horse-power, which can be obtained during about ten months, steam to the extent of 300 horse-power being in reserve.

About a mile above is the cotton-mill of the Nashua Manufacturing Company, where, with a dam 16 feet high and a canal 3 miles long, a fall of 36 feet is obtained, with 1,200 horse-power in use. Full capacity can generally be obtained for ten or eleven months, but a large amount of steam-power is in use.

The drainage area being 516 square miles, I should estimate the flow of the stream at this point about as follows:

Estimate of flow of Nashua river at Nashua.

State of flow (see pages 8-10).	Flow per second.	Horse-power available (gross) continuously.		
	Cubic feet.	*1 foot fall.*	*20 feet fall.*	*36 feet fall.*
Minimum	85	9.6	192	346
Minimum low season	115	13.1	262	472
Maximum, with storage	400	45.4	908	1,634
Low season, dry years	135	15.3	306	551

Five miles above Nashua, at Runnell's bridge, is an unimproved privilege, said to have a fall of 8 feet. Four miles above, at Pepperell, are the mills of the Fairchild Paper Company. A fall of 13 feet is used and 500 horse-power obtained during nine months at the upper mill, and 6½ feet with about 300 horse-power at the lower mill. A paper-mill at Groton completes the list of mills on the Nashua. Above this point the stream is sluggish, and flows through meadow-lands, up to the junction of the two branches.

Of the tributaries of the Nashua, the only ones worth mentioning below the junction of the branches are Nissittissit and Squannacook rivers, both of which enter from the west and are similar in character, rising in New Hampshire, at a considerable elevation, and draining a hilly country, with considerable fall. They seem to be very good streams for power, except that their flow is quite variable; and they are utilized by a number of mills of various kinds. At Shirley a small stream enters, which is the outlet of several ponds, covering, in all, several hundred acres, and running several cotton-mills, as well as mills of other kinds, but steam is used during part of the year.

The North branch of the Nashua has a rapid fall, is an excellent stream for power, and is well utilized. Several reservoirs on the headwaters serve to regulate the flow to some extent, and the large number of mill-ponds have a similar effect; but as no large reservoirs exist, the flow is still quite variable. Wachusett pond, on one of the branches, covers several hundred acres, and may be drawn down 16 feet; Meeting-house pond, tributary to it, covers about 172 acres, with a range of 10 feet; a third reservoir, in Gardner, can be drawn down 13 feet, but its area could not be ascertained; a fourth, in Ashburnham, covers several hundred acres, and can be drawn down about 17 feet. There are a large number of mills on the stream, as the table of utilized power shows, but steam-power is generally in reserve. Four unutilized privileges are said to exist on the stream. The first is near the mouth, and is improved, the mill being formerly occupied for the manufacture of shoe-shanks; the second is a little above, and the fall is said to be about 9 feet; the third is a short distance below Fitchburg, and the fall is said to be 22 feet; immediately above is a scythe-shop, not now running, with a fall of 14 feet. Above this point the fall of the stream and of its tributaries is very rapid, and is utilized by many mills. The tributaries, too, are rapid streams, generally almost completely utilized, though there are some unutilized sites. One little stream running through Leominster runs no fewer than ten mills, with over 130 feet fall.

The South branch of the Nashua resembles the north, and, like it, is well utilized. At Clinton the Lancaster gingham-mills use a fall of 27 feet and 700 horse-power, but only during two or three months. Sufficient steam-power is at hand to run the entire machinery. The Stillwater and Quinepoxet rivers, which form the stream, are very rapid, and in all respects favorable for power, except that their flow is very variable. Some small reservoirs serve, however, to regulate their flow to some extent, two which empty near the mouth of the Stillwater covering about 370 acres. Near Clinton several ponds, covering 235 acres and capable of being drawn down some 17 feet, serve to run several large mills.

PENNICHUCK BROOK.

This small stream empties into the Merrimack about 2 miles above the Nashua. It has considerable fall, and is utilized by a few saw-mills and by the water-works supplying Nashua. The water-works have two dams, with falls of 17 and 15 feet, respectively, and water-power is used to pump the water from the brook to a height of 132 feet, the average quantity pumped per day being 1,000,000 gallons.

THE SOUHEGAN RIVER.

The Souhegan has its sources in Worcester county, Massachusetts, and flows first in a northeasterly direction for 12 or 15 miles into Hillsborough county, New Hampshire, then turning and flowing east for about an equal distance, emptying into the Merrimack at Merrimack station, about 8 miles above Nashua. The principal towns on the course of the stream are Greenville, Wilton, and Milford. The area drained is about 224 square miles, comprising a very hilly country. The fall of the stream is very large, though no data regarding it are at hand, but its total descent from the Massachusetts line is not less than 700 feet. The bed and banks are rocky, with few low grounds subject to overflow, and the stream is quick to rise and fall. Its flow is said, in fact, to be extremely variable, and, as there are no lakes and no artificial reservoirs to regulate it, the statement is probably correct. The mills on the stream are quite numerous, but a large amount of fall is still unutilized, some sites being not very accessible, though a railroad touches the river at the mouth and at Greenville, and follows it from Milford to Wilton. The following data are very incomplete, but are all that could be obtained with the time at disposal:

At the mouth of the stream there is a fall of 25 or 30 feet over a ledge of rock, with a wooden dam about 10 feet high. The power is used by three woolen-mills and a cabinet-shop, with perhaps 100 or 125 horse-power in all; but, although the power is an excellent one, it is very badly utilized, and could be made much more valuable than it is at present. Probably the minimum power would not be less than about 3½ horse-power per foot during twenty-four hours, while, during the low season of dry years there would perhaps be 4½ or 5 horse-power continuously. The pond is said to be large enough to store the low-water flow during the night. The local conditions are favorable for the utilization of the power, and, properly developed, this would be one of the best of the small powers in the vicinity. It is within a quarter of a mile of the Concord railroad.

A short distance above is a fall known as Parker's, not improved, though said to be a fine site. The fall is said to be 23 feet. Then comes Atherton's falls, not improved, the fall being stated at 28 feet; then Nichol's falls, 10 feet; Wilkin's falls, 8 feet; Fuller's falls, 12 feet; and Field's falls, all in the town of Merrimack. (*a*)

About 3 miles above this is a small mill, beyond which there is nothing below Milford, 8 or 10 miles from the mouth. This town is quite a manufacturing center, and a number of dams cross the stream; but no details regarding the power are at hand, except the statistics given beyond. Above Milford there are several mills, and a number of sites that might be utilized. Several mills, however, have recently been built, and all the good sites will probably be soon occupied.

The Souhegan may probably be said to possess a greater proportion of unutilized water-power than any stream in the vicinity, and its resources deserve attention. Its fall is very large, and, although its flow is very variable, a systematic utilization of the power would do much to remedy this objection.

COHASS BROOK.

This is a small stream, entering the Merrimack from the east just below Manchester. It takes its rise in Massabesic lake, which lies about 4 miles east of the city, and covers about 2,400 acres, its drainage area being about 44 square miles. From this lake, which is situated at an elevation above tide of about 256 feet, Cohass brook pursues a course measuring about 5 miles in a straight line, in which distance it descends not less than 140 feet, draining a total area of about 68 square miles. Its basin is hilly, comprising little flat or meadow land, except in a few cases, below the lake, where the stream is bordered by such lands. Lake Massabesic is used as a source of water-supply for the city of Manchester, the stream being dammed a short distance below its outlet, and the water being pumped up by water-power. The dam is of stone, 100 feet long and 24 feet high, and was built in 1873. A canal and penstock 2,070 feet long afford a fall of 43 feet, and a power of 120 horse-power is used during twelve hours every day, there being seldom a lack of water. Twelve hundred thousand gallons per day are pumped to a height of 113 feet. On account of the large size of the pond no water is wasted in dry seasons, and the range of water in the pond is but 5 feet.

(*a*) *Report of the Commissioners on the Preliminary Examination of the Water-power of New Hampshire* (1870), p. 47.

Below this dam a meadow borders the stream for some distance, below which is an unutilized fall of perhaps 5 or 6 feet, once used. Then comes a saw-mill, which is at present not in operation, with a fall of 12 feet or so, and then a second fall of 8 or 10 feet, not used. At the mouth of the stream are the Derry woolen-mills, there being three dams, with falls of 14, 12, and 12 feet, respectively. About 90 horse-power are used on each fall, and full capacity is secured nearly all the time, no steam being in use. The flow of the stream is quite regular, even more so than before the water-works were built, and freshets are unknown.

Although the above are all the falls that could be learned of, there must be more fall on the stream still unutilized, in order to make up the total fall of about 140 feet, above mentioned.

THE PISCATAQUOG RIVER.

This stream has two branches, which unite in the town of Goffstown, near Parker's station, whence the stream flows in an easterly and southerly direction for a distance of about 8 miles, emptying into the Merrimack just opposite Manchester, and draining a total area of about 214 square miles. The North branch takes its rise in the town of Deering, and pursues a circuitous course eastward, draining about 77 square miles, while the South branch rises in Francestown, and drains about 100 square miles. The drainage area is hilly, and the fall of the stream is great, though not so large as that of the western tributaries of the Merrimack between this point and the state line. The bed and banks are generally rocky where the falls occur, but are often light and sandy in the intervals. The flow is quite variable, there being no lakes or artificial reservoirs of importance. Mount William pond, in Weare; Gregg's pond, in Deering; and Haunted pond, in Francestown, cover respectively about 125, 250, and 190 acres, and are the largest in the basin. Facilities for storage, however, are said to exist, and have been talked of in connection with the water-supply of Manchester.

Near the mouth of the stream is a shuttle factory, with a fall of 10½ feet, and about 60 horse-power during nine months. Two miles above is an unutilized fall known as Kelly's falls, where the fall is small, but where it is said that a dam 18 feet high could be built. At Goffstown Centre a pulp-mill uses a fall of 13 feet and 167 horse-power during about nine months, no steam being used. Between this mill and Goffstown West Village there is considerable unutilized fall. At the latter place a sash-and-blind mill uses 13 feet, and above that point there are various small mills on both branches, and several small unutilized privileges. That the fall of the stream is large is shown by the fact that its elevation at Parker's station is about 299 feet, while at its mouth it is about 121 feet, so that the slope between these points is at the rate of not less than 12 or 15 feet per mile, while above Parker's station the slope is even more rapid than below. The total fall utilized within the distance referred to being about 50 feet, there is an unutilized fall on this stream, below the junction of the two branches, of about 128 feet. No gaugings of the flow are on record, but it has been estimated at about 45 cubic feet per second, on the average, during the summer months. Its minimum flow is probably not over half this quantity. On the upper branches of the stream there is no doubt a large amount of power entirely unused.

THE SUNCOOK RIVER.

This stream, the next important tributary of the Merrimack, takes its rise at the foot of Gunstock mountain, in Belknap county, whence it pursues a course toward the south and west, entering the Merrimack in Merrimack county, about 6 miles below Concord and 2 miles above Hooksett. Its length measured in a straight line is about 27 miles, and its drainage area measures about 264 square miles, its largest tributary being the Little Suncook, which drains 44 square miles. The principal towns on the stream are Suncook, at the mouth, and Pittsfield. The drainage basin is hilly and broken, more so than that of the streams south; the bed and banks of the stream are often rock, and there are no swamps or meadow-lands of importance subject to inundation. The fall of the stream is large. Lougee pond, near its head, lies at an elevation above the sea of 622 feet, while the height of its mouth is about 198 feet, so that the total fall of the stream between these points, or about 22 miles in a straight line, is about 424 feet. Allowing for the windings of the stream, its declivity is probably not less than 12 feet to the mile.

The following table gives some additional elevations:

Declivity of the Suncook river.

Place.	Distance from mouth.	Elevation above tide.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Mouth	0	198			
			12±	138	11.5±
Mouth of Little Suncook	12±	336			
			8±	135	16.9±
Pittsfield, above dam	20±	471			
			12±	151	12.6±
Lougee pond	32±	622			

Of the total fall mentioned, only about 350 feet are utilized, so that some fall is still available. The flow of the stream is regulated to some extent by a number of ponds near the headwaters of the stream, but near the mouth their effect is small. Of these ponds we may mention the following, with their areas as given by the agent of the Pittsfield mills, Mr. G. E. Kent: Lougee pond, 627 acres, from which 5½ feet can be drawn; Upper Suncook pond, 380 acres, and Lower Suncook pond, 294 acres, from both of which 8 feet may be drawn; Place's pond, 300 acres, from which 11 feet may be drawn; Half Moon pond, 361 acres, and Brindle pond, 250 acres, not dammed; Hill's pond, 100 acres, a range of 2 feet being controlled; together with eight other ponds not dammed, with a total area of 711 acres—making in all, above Pittsfield, fifteen ponds, with a combined area of 3,023 acres. Besides these, the manufacturing companies at Suncook control two ponds, both on the Little Suncook, viz: Suncook pond, 500 acres, from which 4 feet may be drawn, and Pleasant pond, 500 acres, from which 6 feet may be drawn. Notwithstanding these regulators, the flow of the stream is quite variable, though no trouble is experienced with freshets. A railroad follows the stream as far as Pittsfield, thus rendering every important point easily accessible. The important powers on the stream are the following:

Within a mile of the mouth the fall is about 80 feet, used by three cotton-mills. At the lowest, that of the China Manufacturing Company, the fall is 35 feet, and about 1,000 (?) horse-power are used during about nine months. The dam is about 25 feet high, and the canal 1,000 feet long. Steam is in reserve to the extent of 1,000 horse-power. At the next mill, the Pembroke, a stone dam 17 feet high affords a fall of 17 feet, with 350 (?) horse-power used almost all the time, steam being only used to the extent of 75 horse-power. At the third mill, that of the Webster Manufacturing Company, a wooden dam 7 feet high, with a canal of 1,200 feet, affords a fall of 27 feet and 500 (?) horse-power, considerable steam being used all the time. At these mills there is no waste of water in a dry time.

The next mill above is a saw- and grist-mill, using but a small amount of power. The pond is used principally to regulate the flow, the dam being provided with gates which are shut every night and opened every morning. The flow at this point, which is the same as that at the mills below, might be estimated about as follows, the drainage area being about 264 square miles: Minimum, 50 cubic feet per second, or about 5.7 horse-power per foot continuously; minimum low season, 62 cubic feet per second, or about 7.1 horse-power per foot; low season, dry years, 71 cubic feet per second, or 8.1 horse-power per foot; and maximum with storage, 180 cubic feet per second, or about 20 horse-power per foot.

At Backstreet there are two dams, with a total fall of about 22 feet. At Short falls, and at various points above, there are small mills, using only small amounts of power. At Pittsfield the Pittsfield cotton-mills use a fall of 18 feet, and obtain 200 horse-power all the time, by saving the water at night during six months of the year. Between the mouth of the Little Suncook and this place there are numerous unimproved sites. Above Pittsfield there is a dam used for regulating, being shut every night, and still farther up are the ponds which have been named.

On the Little Suncook there are various small mills, supplied with very constant power. Both streams may be called excellent streams for power, and considerable additional power will no doubt some time be utilized on them. Suncook pond, at the head of the Little Suncook, has an elevation of 512 feet, while the mouth of the stream is at an elevation of 336 feet. The total fall of the Little Suncook is, therefore, 176 feet, or about 35 feet per mile.

THE SOUCOOK RIVER.

This stream, which rises in the southern part of Belknap county, pursues a southerly course almost parallel to that of the Suncook, emptying into the Merrimack about 2 miles above the mouth of the latter. Its length, in a straight line, is about 20 miles, and it drains an area of about 90 square miles. Its power seems of little importance, for not only is very little used, but the stream is said to be sluggish and unfit for power in its lower parts, while above it is too small, its flow being also very variable. It may, therefore, be dismissed without further description.

THE CONTOOCOOK RIVER.

The Contoocook, the largest tributary of the Merrimack, takes its rise in the southeastern corner of Cheshire county, very near the Massachusetts line, its sources being a number of ponds in the towns of Jaffrey and Rindge. For about 25 miles in a direct distance the course of the stream is a few degrees east of north, the river passing into Hillsborough and Merrimack counties; for the remainder of its length, or about 20 miles in a straight line, its course is northeast, till it joins the Merrimack at Fisherville, about 6 miles north of the city of Concord. Its length, measured along its course, is over 50 miles, and its total drainage area measures about 766 square miles. The principal towns on the stream are Peterborough, Bennington, Antrim, Hillsborough, Henniker, and Hopkinton. The fall of the stream is large, as the following table shows. Rising at an elevation of between 1,100 and 1,200 feet above the sea, it falls, in its course of about 55 miles, to an elevation of 249 feet, or an average of about 15.7 feet per mile. Its declivity is not gradual, however, but is broken by a number of abrupt falls, rendering a large amount of power available. The topography of the drainage area is rather peculiar. Separated on the south by a

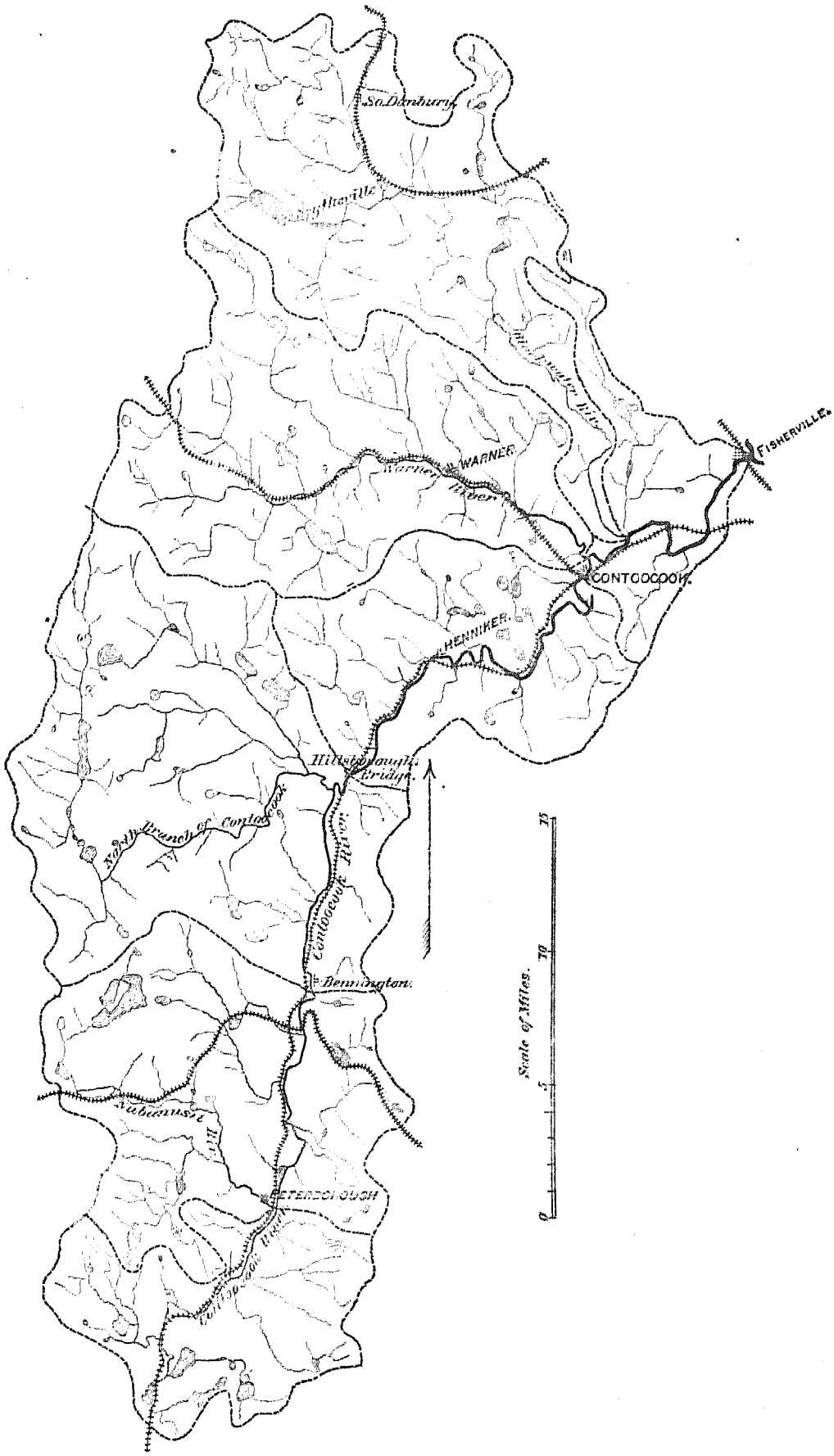

Fig. 13. MAP OF THE DRAINAGE BASIN OF THE CONTOOCOOK RIVER.

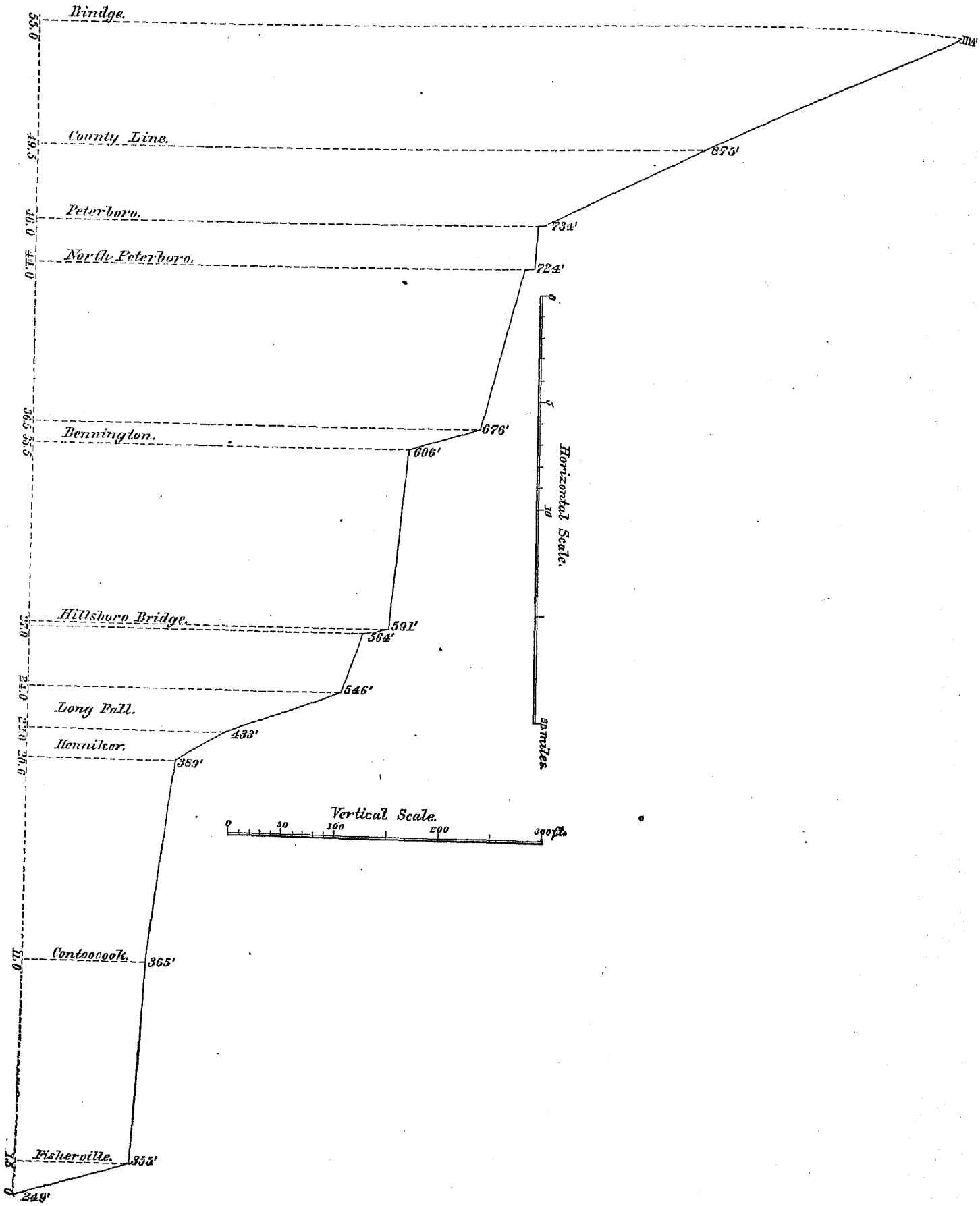

Fig. 14. PROFILE OF THE CONTOOCOOK RIVER.

range of hills from the sources of the tributaries of the Connecticut, it is bounded on the east by a range of high and irregular hills which separate it from the main valley of the Merrimack, and which increase in height toward the south. From these hills the valley spreads out toward the west, first falling suddenly, then rising gradually to the water-shed between the Contoocook and the Connecticut. It is in the extreme eastern part of the basin that the course of the stream lies, flowing at the very base of the hills separating it from the Merrimack. From the east, therefore, the stream receives no tributaries of importance, while from the west and northwest it receives important affluents. Flowing, then, in a direction almost contrary to that of the stream it seeks to join, the Contoocook finally cuts through, near Henniker, the hills separating the two, and then flows more directly toward it.

Declivity of the Contoocook river.

Place.	Distance from mouth.	Elevation above tide.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Mouth	0	249±			
			1.5	106	71.0
One and one-half miles above mouth	1.5	355			
			9.5	10	1.0
Just above Contoocookville	11.0	365			
			9.6	24	2.5
Just below Henniker	20.6	389			
			1.4	44	31.4
Foot of Long fall	22.0	433			
			2.0	113	56.5
Head of Long fall	24.0	546			
			2.8	18	6.4
Foot of falls at Hillsborough bridge	26.8	564			
			0.2	27	135.0
Head of falls at Hillsborough bridge	27.0	591			
			8.5	15	1.8
Foot of falls at Bennington	35.5	606			
			1.0	70	70.0
Head of falls at Bennington	36.5	676			
			7.5	38	5.1
Foot of falls at North Peterborough	44.0	714			
			0	10	.....
Head of falls at North Peterborough	44.0	724			
			2.0	3	1.5
Foot of falls at Peterborough	46.0	727			
			0	7	.....
Head of falls at Peterborough	46.0	734			
			3.5	141	40.3
Hillsborough county-line	49.5	875±			
			5.5	239	43.4
Three Ponds, in Rindge	55.0	1,114			

The bed and banks of the Contoocook are in every way favorable for power. The former is generally of rock or gravel, and no difficulty is found in building dams at the places where power is available. The banks are generally high enough to confine the stream, there being few low grounds subject to overflow except along the lower part of the stream, below West Hopkinton. The flow of the stream is quite variable, there being no large reservoirs by which it is regulated. A few small ponds and reservoirs near the headwaters and on the tributaries are utilized by the mill-owners for purposes of storage, but they exercise little effect on the main stream. The freshets, however, though quite heavy, cause little or no trouble, on account of the large fall of the stream. The basin is tolerably well wooded. No gaugings of the flow are on record, but some estimates are presented below. The rainfall over the basin averages about 44 inches, of which 11 fall in spring and in summer, 13 in autumn, and 9 in winter; a distribution favorable for constant flow. A railroad follows the river for almost its entire length, rendering every point easily accessible.

The first power on the river, as it is ascended, is at Fisherville, where the fall amounts to over 100 feet in a distance of 1½ mile. Within this distance there are a number of dams and mills of various kinds, but the power is not economically utilized, and a considerable amount is wasted. The upper dam is 1½ mile above the mouth of the stream, and is of wood, 10 feet high, ponding the water for about 6 miles. It turns the water into a partly natural channel between the shore and an island, and a fall of 7½ feet is used by a saw-mill, by means of a dam across this channel, the water being discharged into the channel below the dam. Just below, a fall of 20 feet is available, using this same water, but no power is yet used here.

The next dam below is the Penacook dam, 1 mile below, the total fall between it and the dam above being about 30 feet. This dam is about 200 feet long and 12 or 13 feet high, making a pond covering at least 520,000 square feet. A canal about 1,100 feet long affords a fall of from 12 to 15 feet, used on the right bank by the following mills: Penacook cotton-mill, 15 feet fall and about 350 horse-power; C. H. Amsden's furniture factory, with 12 feet fall and about 115 horse-power; and a table factory, with about 12 feet fall and 25 horse-power. The power is owned by the Contoocook Manufacturing Company, and power, etc., leased by those using it. Full capacity can generally be obtained by all these mills, but in dry weather there is no waste at night. The water from the last two mills passes into the pond below, the next or third dam being of wood, about 225 feet long and 8 or 9 feet high, supplying the cotton-mill of the Contoocook Manufacturing Company, on the left bank, with a fall of 15 feet and about 150 horse-power, which can always be obtained. Part of the water from the Penacook mill passes into the pond of this

dam; the rest supplies the Concord Axle Company, which uses a fall of about 7½ feet and about 60 horse-power. Between this point and the next or lowest dam some fall is not utilized. The last dam is a primitive affair, making no pond and turning the water into races on both sides of the river. On the south or right bank a canal about 400 feet long supplies C. M. & A. W. Rolfe's sash, door, and blind factory with a fall of 9 feet and about 30 horse-power, followed by Blanchard's Excelsior mill, with a fall of 17 feet, now, however, not in operation. On the north or left bank are Harris' woolen-mill, with a fall of 16 feet and about 35 horse-power, and Stratton, Merrill & Co.'s saw-mill and flour-mill, with about 90 horse-power at the latter, the fall being about 20 feet. The latter firm also leases some power to an ax-handle factory, a granite-polishing shop, and saw-works. A large amount of fall is wasted here in the races. Between the lowest mills and the river there is some fall, amounting, at low water, to 4 or 5 feet, but in high water this disappears.

It will be evident that the power at Fisherville, naturally a very fine one, is wastefully utilized and in part yet unimproved. Taking the drainage area above the uppermost dam as 760 square miles, we may estimate the available power about as follows:

Estimate of power of the Contoocook river at Fisherville.

State of flow (see pages 8-10).	Flow per second.	Horse-power available (gross) continuously.		Flow during twelve hours.	Horse-power available (gross) during twelve hours.	
	Cubic feet.	*1 foot fall.*	*100 feet fall.*	*Cu. ft.*	*1 foot fall.*	*100 feet fall.*
Minimum	150	17.0	1,700	300	34.0	3,400
Minimum low season	190	21.6	2,160	380	43.2	4,320
Maximum, with storage	450	51.1	5,110	665	75.6	7,560
Low season, dry years	220	25.0	2,500	435	50.0	5,000

According to a report by John R. Freeman, hydraulic engineer, of Lawrence, Massachusetts, the storage on the upper pond is probably sufficient to store a quantity of water which would give a flow of 215 cubic feet per second during twelve hours, thereby doubling the low-season flow during working hours. Mr. Freeman made a gauging when the river was said to be in its ordinary summer condition, and found the flow without storage to be 269 cubic feet per second. The large power at this place is thus far from completely utilized, and there is opportunity for great development. Between Fisherville and West Hopkinton the river is bordered by lowlands, while above the latter place the banks are generally high.

The next power above Fisherville is 12 miles above the upper dam, by the river, at Contoocookville. At Blackwater falls, 6 miles above the upper dam, there is a small fall, but it is destroyed by the flash-boards below, and is of no value. At Contoocookville a fall of 7 or 8 feet is used for a saw- and grist-mill and a machine-shop, with a small amount of power and a very leaky dam, though considerable power is available. At West Hopkinton, about 3½ miles above, a fall of 7 or 8 feet is used. Between this and the next power, at Henniker, there is some fall not used. At Henniker there are two dams. The lower one affords a fall of 12 feet at a small mill, and the upper one a fall of 8 feet. At West Henniker a fall of 12 feet is used at a paper-mill, using 100 horse-power, which can be obtained during about eleven months. Above the pond of this mill, which is about a quarter of a mile long, the fall is very rapid for 2 miles, amounting to 113 feet in that distance, the river winding through a narrow valley, with a rocky bed and high banks. A large portion of this fall could probably be rendered available, but none is yet utilized. The quantity of water is the same as at Hillsborough, and from the table below the power available can be seen. At Hillsborough there are two dams. The lower one is about 12 feet high, and supplies a canal on each side of the river, power being used on the south side for two knitting-mills, with about 75 horse-power, a needle-shop, and a grist-mill, with perhaps 40 horse-power; and on the north side for a saw-mill with 75 horse-power, and a silk factory with 8 horse-power. The fall is from 12 to 16 feet. In dry weather no water is wasted at night, except what leaks through the dam. The upper dam is about 11 feet high and ponds the water about 5 miles. The fall is 14 feet, used by the Hillsborough woolen-mill, with 80 or 90 horse-power. Half the river is owned on the other side, but is not used, except that gates are opened there to let water pass into the lower pond when it does not flow over the dam.

The drainage area above Hillsborough is about 359 square miles, and the power may be estimated about as follows:

Estimate of power at Hillsborough Bridge.

State of flow (see pages 8-10).	Flow per second.	Horse-power available (gross) continuously.			
	Cubic feet.	*1 foot fall.*	*12 feet fall.*	*14 feet fall.*	*113 feet fall.*
Minimum	50	6.8	82	95	768
Minimum low season	72	8.2	98	115	927
Maximum with storage	250	28.4	341	398	3,209
Low season, dry years	82	9.3	112	130	1,051

As already stated, the dry-weather flow may all be concentrated into twelve hours, and the power thus doubled.

The next power above Hillsborough bridge is at Bennington, about 9 miles distant. At this place the fall is 70 feet in about 2 miles, and is utilized at five dams. The uppermost dam, which is 7 or 8 feet high, is a mile above the station, and was formerly utilized by a powder-mill, but is now used only as a regulator. Below it is a dam about 12 feet high, affording a fall of 12 feet at a knife factory. Next below are a grist- and saw-mill and a second knife factory, the former with a fall of 12 feet, the latter with one of 7 feet, from different dams. The fifth dam supplies a paper-mill, with a fall of 18 feet, and about 120 horse-power, during part of the year.

The power at Bennington is badly utilized, and might be made much more valuable than it now is. The amount of power may be estimated as follows, the drainage area being about 194 square miles:

Estimate of power at Bennington.

State of flow (see pages 8-10).	Flow per second.	Horse-power available (gross) continuously.	
	Cubic feet.	*1 foot fall.*	*70 feet fall.*
Minimum	30	3.4	238
Minimum low season	36	4.1	287
Maximum, with storage	150	17.0	1,190
Low season, dry years	42	4.8	336

The ponds are all small, excepting the upper two, but these are large enough to allow of the power being greatly increased, and probably doubled, during working hours.

The next power above Bennington is 2 miles below Peterborough, where a fall of 10 feet is utilized. At Peterborough a grist-mill uses 7 feet, and above this place are various small mills and several unutilized privileges. Half a mile above the town is a fall of 6 or 7 feet, once utilized; then just above is the "Kimball" privilege, also unutilized, said to have a fall of 10 feet; and 2½ miles above the town is a third unutilized site, the fall being considerable for a distance of a mile or so. The upper parts of the stream are well utilized, and, on account of the ponds on the headwaters, the power is more constant than lower down. Few details could be learned regarding these ponds, except that some are dammed and used for regulating. Their effect is only felt appreciably on the upper parts of the river.

Of the tributaries of the Contoocook, the first to be mentioned is the Blackwater river, which takes its rise in Pleasant pond, in the northern part of Merrimack county, and pursues a southerly and easterly course, draining about 132 square miles, and joining the Contoocook about 6½ miles above its mouth. The privileges on the stream were named to me as follows, by those acquainted with it, in their order as one ascends: 1. An old privilege, not used, with 10 feet; 2. Jackman's mills, where the total fall is some 30 feet, 10 feet being used at present by a saw-mill; 3. Dodge's mills, a saw-mill, with 12 feet; 4. Swett's mills, a grist-mill, with 15 or 20 feet used and considerably more available; 5. Burbank's saw-mill, 10 feet. Above this are numerous small mills not worth naming. Pleasant pond is dammed to a height of about 6 feet, and used by a mill below. The stream is quite a good one for power, but its flow is very variable, and the mills sometimes have to stop.

The next tributary is Warner river, a stream very similar to the Blackwater. It rises in the western part of the county, and pursues a course a little south of east, joining the Contoocook just below Contoocookville. The powers are as follows:

1. At Davisville there is a fall of 42 feet in a quarter of a mile, with a dam of 8 or 10 feet, of which about 12 feet are used for a paper-mill, with a power of 60 horse-power continuously during about nine months, and 12 feet for a machine-shop, with about 30 horse-power. Below this, a fall of 18 feet is not used. This site is the best on the river.

2. At Warner village, a grist-mill uses 6 or 7 feet.

3. At Waterloo a fall of 15 or 20 feet is used.

4. At Roby's corner a fall of 8 feet is not used.

Above this are various small mills, and other sites not used. Several ponds feed the stream, viz: Long pond, in Webster, about 500 acres, dammed about 4 feet, and used for regulating; Bradford pond, covering 500 acres, not dammed; Long pond, in Sutton, covering 200 acres, and dammed. The stream offers considerable facilities for the development of small powers, but its flow, like that of the Blackwater, is very variable.

The North branch of the Contoocook, which joins the main stream just above Hillsborough bridge, runs a few small mills, but no details are at hand. Several ponds flow into this stream, the principal ones being Long pond, which covers about 450 acres, and can be drawn down about 5 feet; Island pond, covering about 380 acres, but said to be not regulated; Loon pond and Contention pond, each covering about 200 acres, and not regulated. The stream has a large fall, descending over 432 feet from source to mouth.

Great brook, which enters the river in Antrim, from the west, is the outlet of Gregg's pond, and falls 464 feet from the pond to the river, in a distance of only about 3 miles, running a number of mills. The power is small, but quite constant.

The only remaining tributary worth naming is Nubanusit creek, which enters from the west in Peterborough, draining about 56 square miles. It has a very rapid fall and runs a number of mills. Near the mouth is the Phenix factory, with a fall of 25 feet, and 136 horse-power during part of the year, and just above it is a pulp-mill with 26 feet, and about 200 horse-power. Within a mile of its mouth its fall is not less than 100 feet, and it extends some distance farther up the stream with almost the same slope. A fall of 14 feet, unutilized, is said to exist below the lower mill of the Union Manufacturing Company, and another, of 52 feet, above their upper mill. Above this point there are extensive meadows, which, it is said, could easily be flooded, and a reservoir formed sufficient to increase very greatly the power below; and other similar meadows exist farther up. The upper parts of the stream are well utilized, but some unutilized sites still exist—one, with 14 feet fall, just above the lower meadow, and others still above. The stream is fed by some ponds, viz, Thorndike pond, covering, it is said, 450 acres, and capable of being drawn down 6 feet, entering the main stream just above the unutilized fall of 52 feet; Spoonwood pond, the head of the stream, covering 160 acres, and capable of being drawn down 10 feet; Long pond, 800 (?) acres, with a range of 12 feet; Twichell pond, 120 acres, with a range of 4 feet; Phenix reservoir, covering several hundred acres, with a range of 6 or 7 feet, and lying at an elevation of 1,218 feet. The power of this little stream, which falls over 500 feet from Harrisville to its mouth, is excellent, though small. The mill-ponds on the lower part are small, but those above suffice to store the water at night, in dry seasons, rendering it possible to control the flow. The stream could no doubt be further improved in this direction, and there is a large amount of fall upon it still unutilized.

THE WINNIPISEOGEE RIVER.

This river, which has already been referred to as one of the headwaters of the Merrimack, is a most remarkable stream. Lake Winnipiseogee, of which it is the outlet, lies in Belknap and Carroll counties, and covers, when full, an area of 71¾ square miles, including Long bay, receiving, in addition, through its tributaries, the waters of various smaller lakes and ponds, aggregating about 11 square miles in area. From the lake the Winnipiseogee river passes first by the town of Lake Village into Round bay, which covers about 0.5 square mile, and then flows by the town of Laconia into Great bay, covering 7.33 square miles; thence it continues its course toward the southeast, widening into numerous bays, until at last it joins the Pemigewasset at Franklin, to form the Merrimack. The length of its course, in a straight line from Lake Village to Franklin, is about 12 miles, and its total drainage area measures not less than 480 square miles. Further data regarding the area drained above other points are given in the table on a subsequent page. Within this short course of 12 miles the stream descends not less than 225 feet. The following table shows its declivity more in detail, and from it Fig. 16 has been constructed. The figures are only approximate, but are not far from the truth:

Declivity of the Winnipiseogee river.

Place.	Distance from mouth.	Elevation above sea.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Lake Winnipiseogee	13.65	496-502.0			
			.....	10.0±	
Lake Village, below dam	13.65	490.0			
			0.06	2.0	
Round bay, head	13.59	488.0			
			1.25	.....	
Round bay, foot	12.34	488.0			
			0.42	0.5	
Laconia, above dam	11.92	487.5			
			.....	8.0	
Laconia, below dam	11.92	479.5			
			0.75	1.5	4.88
Great bay, head	11.17	478.0			
			3.86	.....	
Sanbornton bay, foot	7.31	478.0			
			0.62	1.5	
Union bridge, above dam	6.69	476.0			
			.....	9.5	
Union bridge, below dam	6.69	466.5			
			0.08	6.0	
Little bay, head	6.61	460.5			
			1.35	.....	
Little bay, foot	5.26	460.5			
			1.45	8.5	
Above Tilton	3.81	452.0			
			1.16	42.0	36.21
Below Tilton	2.65	410.0			
			2.15	140.0	
Below Franklin Falls	0.50	270.0			65.12
			0.50	3.0±	
Mouth of river	.....	267.0			

In the lower 2 miles of its course the stream descends like a cataract over ledges of solid rock, the banks being high, rocky, and sometimes abrupt. In the upper part of its course the bed and banks are sometimes of sand and gravel, but there are no low grounds subject to overflow, even were the stream subject to freshets. Being the outlet of the largest lake in New Hampshire, the flow from which is furthermore controlled in the interest of the

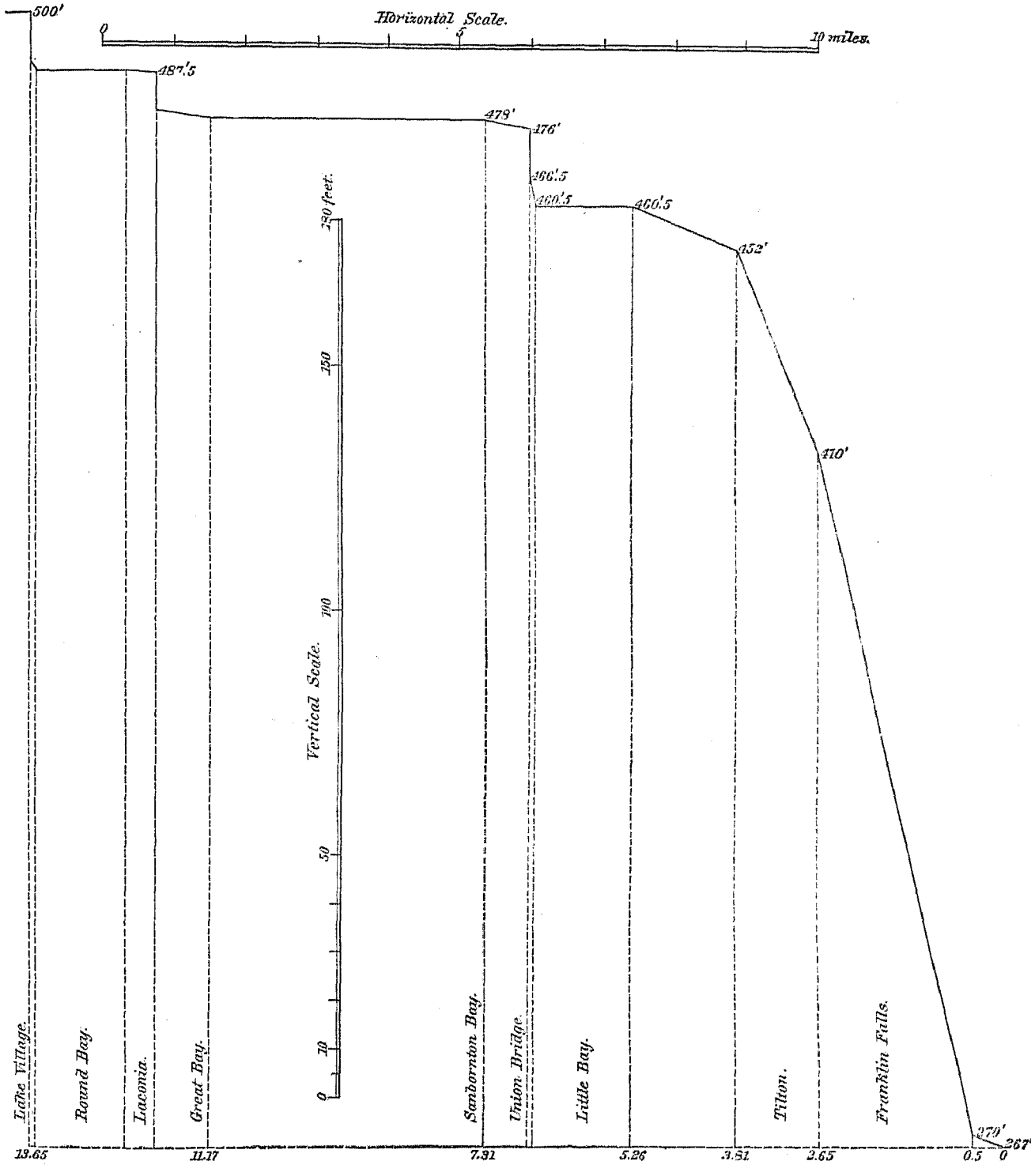

Fig. 15. PROFILE OF THE WINNIPISEOGEE RIVER.

mills lower down on the stream, the volume of water is remarkably constant. Even were the lake not controlled, *the volume of the river would be comparatively constant, but being regulated, the water-power below is considerably* improved. In the summer-time, namely, when other streams are at their lowest, the corporations at Lowell and Lawrence are drawing heavily on the lake, and there is a heavy flow on the Winnipiseogee. Were the flow of the lake under absolute control of the Lake Company, there would be times when it might desire to retain all the water, allowing none to flow down the Winnipiseogee; but in order to prevent this injury to the water-powers on the latter stream, that company is obliged to allow a very considerable quantity to flow past its dams at Lake Village and at Union bridge—continuously at Union bridge, but during the day-time at Lake Village. The minimum power of this river, then, is very considerable, and the stream is, in fact, one of the most favorable in the state or in the country as a source of power. It is astonishing to see the large quantity flowing down the Winnipiseogee in the summer-time, when other streams are almost dry. The extreme range of water on the lake is about 5½ feet, of which about 18 inches are not controlled, but goes over the dam in freshets, the lowest level being about 4 feet below the top of the dam. The river, however, scarcely knows a freshet, as it is ordinarily understood, the water *seldom rising over 3 or 4 feet. The storage capacity of the lake is probably at least great enough to store a* depth of 3 or 4 inches over the water-shed tributary to it, or a depth sufficient to render available the maximum flow possible continuously. (See pages 8–10.)

A map of the drainage basin of the Winnipiseogee river is shown in Fig. 16. It comprises a hilly country, tolerably well wooded, the rainfall over which averages about 44 inches, 11 falling in spring and in summer, 13 in autumn, and 9 in winter. The tributaries of the stream are small and unimportant. A railroad follows the river for its entire length, rendering every point easy of access.

The powers on the stream are as follows:

The large fall near the mouth, at Franklin Falls, is controlled by Franklin Falls Water Power Company, and affords a power that will bear comparison with the great powers on the Merrimack. There are six dams within a distance of 2.15 miles. The first or lowest, as the river is ascended, is of wood, 9 feet high and 60 feet long, with flash-boards 5 feet high, making the fall 14 feet, which is used on both sides of the river; on the north by the *Winnipiseogee Paper Company, using 500 horse-power;* and on the south by A. W. Sulloway's hosiery-mill, with 50 or 60 horse-power. The paper-mill runs night and day, the other only in the day-time. No steam is in use, but at times, however, there is no waste of water. One-third of the power is owned by A. W. Sulloway, and two-thirds by the paper company. The maximum power used is much in excess of that afforded by the minimum flow, because in the paper-mills extra wheels are on hand to be run when there is an abundance of water.

The second dam is about 4,200 feet above the first, but between the two there is an unimproved fall of about 19 feet, corresponding to a minimum power of several hundred horse-power. The second dam, built of wood, is 100 feet long and 14 feet high, with 18 inches of flash-boards. The fall is 14 feet, and is used on the south side by the Franklin woolen-mill, using 100 horse-power, and on the north side by the hosiery-mill of Walter Aiken, using 200 (?) horse-power. Full capacity is always obtained, and no steam is necessary.

The third dam, built of wood, is 720 feet above the second, and is about 100 feet long and 11 feet high, with 2 feet of flash-boards. The power is used on the south side by the Winnipeseogee Paper Company, with a fall of 16 *feet, and about 500 horse-power in all,* and by the Clark & Haynes machine-shop, using only a fall of 13 feet and 30 horse-power; and on the north side by Sleeper's sash-and-blind mill, with a fall of 12 feet and 32 horse-power, and by Call's grist-mill, with a fall of 12 feet and 25 horse-power.

The fourth dam is 650 feet above the third, and is of wood, 125 feet long and 20 feet high, with 2 or 3 feet of flash-boards. It supplies the pulp-mill of the paper company, where the fall is 20 feet, and the power used some 1,000 horse-power.

The fifth dam is a new dam, built in 1881, while all the others were built many years ago. It is about 1,500 feet above the fourth, and between the two there is an unimproved fall of about 16 feet, capable of affording a minimum power of several hundred gross horse-power. The fifth dam is of wood, 90 feet long and 27 feet high, affording a fall of 27 feet, which is used at a pulp-mill of the paper company, where about 1,400 horse-power are used.

The sixth dam is about 4,300 feet above the fifth, and is of wood, 100 feet long and 7½ feet high, including 2 *feet of flash-boards.* The fall is 14 feet, used by a third pulp-mill, with nearly 700 horse-power.

Almost the entire power on these falls is controlled by the Franklin Falls Water Power Company, and power is rented, with land, at special rates, according to circumstances. The Winnipiseogee Paper Company owns the controlling interest in the water-power company. The minimum power which would be afforded continuously by the total fall of 140 feet at Franklin Falls is several thousand gross horse-power. The ponds are all too small to allow of the concentration of power into the day-time, but as the principal part of the power is used by the paper-mills, which run day and night, this is not desired. Scarcely any power in New England can compare with this one for constancy of flow and for generally favorable circumstances.

The next power on the stream is at Tilton, where there is a fall of about 42 feet in a little over a mile, with four dams. The lowest affords a fall of 10½ feet, used to run a woolen-mill, with 30 or 40 horse-power. Just below this mill a fall of 7 or 8 feet is unimproved. The next dam above affords a fall of 10 or 12 feet, and is used on the

north bank by the Winnisquam cotton-mill, with 125 or 150 horse-power, and a hosiery-mill on the south bank, with 25 or 30 horse-power. The third dam is a movable "needle" dam, made by supporting vertical planks against sills above and below. The fall is 6 feet, used on both sides, by a woolen- and a grist-mill. The fourth dam affords a fall of 7½ feet, which is used on the south side by the Granite woolen-mill, with about 50 horse-power, and on the north bank by a saw-mill, leasing power of the Granite Company. The whole power at this dam is owned by the Lake Company, and a rent of $300 per annum is paid for it.

Between the last mill and Little bay is a site not used, where there was formerly a saw-mill. The fall, however, is not very large, and the power is not spoken of as a very good one.

At Union bridge, between Little and Sanbornton bays, is the dam of the Lake Company, built of stone and wood, and provided with gates for regulating the amount of water allowed to pass. The power afforded is used by a small saw- and grist-mill, discharging the water into Little bay, and using a fall of about 10 feet. There is considerable fall below the dam, which is from 7 to 10 feet high, and the total fall to Little bay from the pond above the dam is about 17 feet, which might be utilized without difficulty. At present the mill cannot be run uninterruptedly, the water being at times allowed to flow over the dam, where its quantity can be measured, instead of through the race. There seems no reason, however, why, with proper arrangements, a large power could not be used here.

The next power on the stream is at Laconia, above Great bay. The dam at this place is of wood, about 50 feet long and 6½ feet high. From it a canal extends on each side of the river, supplying the following mills, all with falls of 8 feet:

	Proportion of total power.
On the north side:	
J. W. Busiel & Co.'s hosiery-mill	$\frac{3}{24}$
L. F. Busiel's hosiery-mill	$\frac{1}{24}$
Marshall Brothers' yarn-mill	$\frac{8}{24}$
Total	$\frac{1}{2}$
On the south side:	
W. H. Abel & Co's machine-shop; William Busiel's shoddy-mill	$\frac{4}{32}$
Pitman Manufacturing Company's hosiery-mill	$\frac{5}{32}$
Laconia grist-mill	$\frac{3}{32}$
Guilford hosiery-mill	$\frac{4}{32}$
Total	$\frac{1}{2}$

This power is owned by the mill-owners in common, in the above proportions, but no measurements are made of the quantity used by each, or precautions taken to secure the proper distribution, the sizes of the wheels forming the only data. No steam-power is in use, and there is during the greater part of the time no waste of water whatever. In addition to these mills there are three others, taking water from a canal on the north side, which runs from above the dam. These mills are the Winnipiseogee hosiery-mill, with about 25 horse-power; W. S. Thomas' machine-shop, with 10 horse-power; and the Laconia car-shops, with perhaps 40 horse-power. The power on this canal is leased as it stands, with room, there being no regular rate for power.

The only remaining power on the Winnipiseogee is at Lake village. The dam at this place belongs to the Lake Company, which also owns all the water-power rights, and is of stone and wood, about 10 feet high and 250 feet long. The discharge is regulated by gates, as at Union bridge. When water is ordered from Lowell or Lawrence, the necessary quantity is allowed to pass the lower dam, the same quantity being also allowed to pass that at Lake Village, hence water is received at Lowell sooner than if the only dam were that at Lake Village, for then the intermediate bays would first have to be filled. The power at Lake Village is used on both banks. On the right are the company's grist-mill, with 30 horse-power; Bartlett's hosiery-mill; the Howard twine-mill, with 40 horse-power; and the Union Lace Company, with about 100 horse-power. On the left are the company's saw-mill, with 25 or 30 horse-power; Holt & Co.'s hosiery-mill; Brown, Wood & Kingman's hosiery-mill; the Cox Needle Company, with 8 horse-power; Cole's foundery and machine-shop, with 115 horse-power, partly sublet; and the railroad repair-shops, with 35 or 40 horse-power. In most cases the buildings are owned by the Lake Company, and the power and buildings are rented as they stand, there being no regular rate for power. In the case of the Cole Manufacturing Company and the railroad repair-shops, the power is held by a perpetual lease.

The tributaries of the Winnipiseogee river are of small importance. The only one worth mentioning—Tioga river—rises in a reservoir in Gilmanton, and enters the river between Tilton and Little bay. It affords power to a hosiery-mill at Belmont, using 96 horse-power, with a fall of 32 feet. The reservoir covers 137 acres, and can be drawn down 15 feet.

The tributaries of the lake are also not of great importance, and are all small streams, the divide between the lake and adjacent streams lying nowhere more than 7 miles from the lake. There are none on the west worth naming. Merrymeeting river, from the south, is the outlet of Merrymeeting pond, which covers about 3.7 square miles, and lies at an elevation of 87 feet above lake Winnipiseogee. Little power, however, is used on the stream.

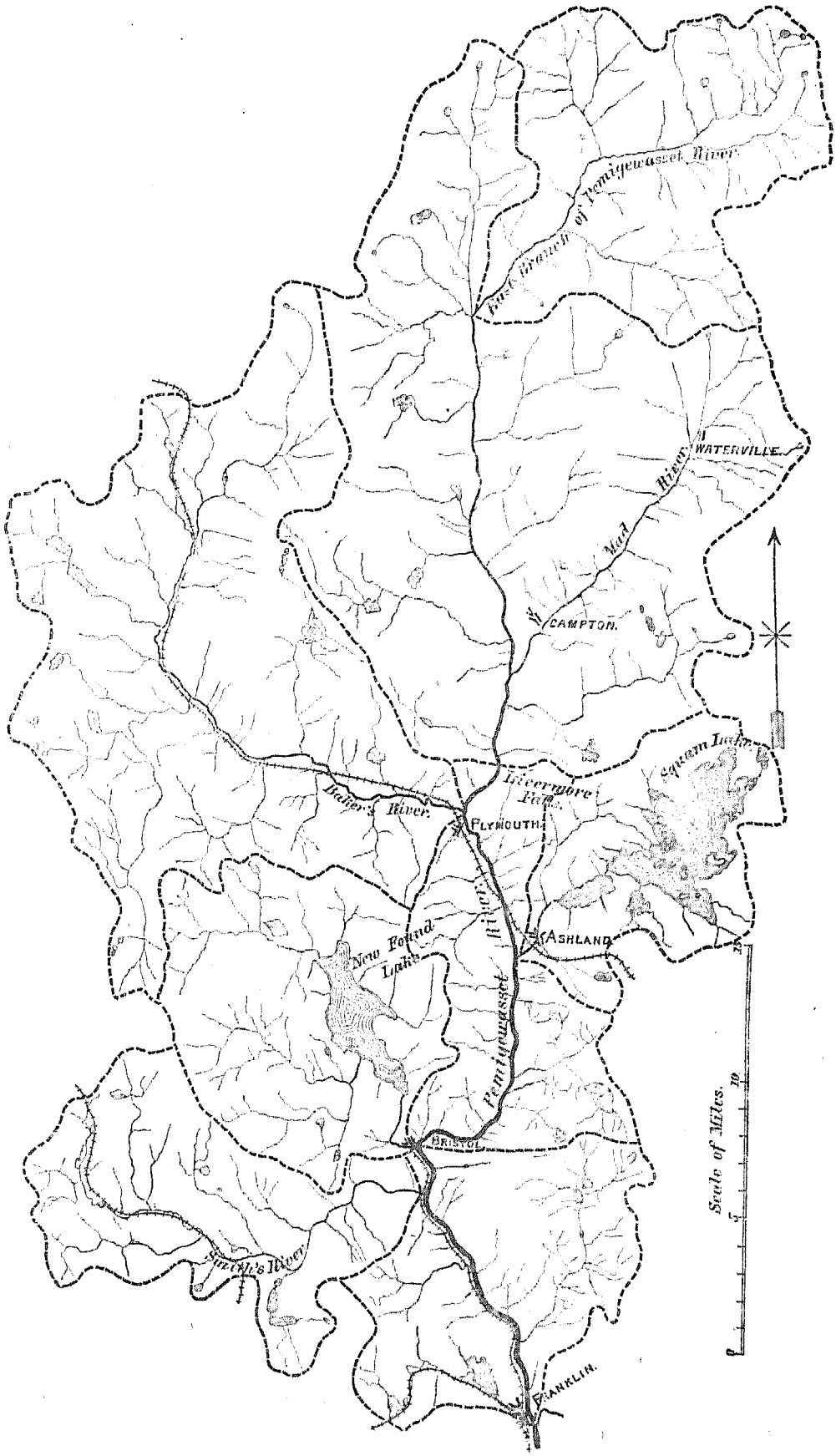

Fig. 16. MAP OF THE DRAINAGE BASIN OF THE PEMIGEWASSET RIVER.

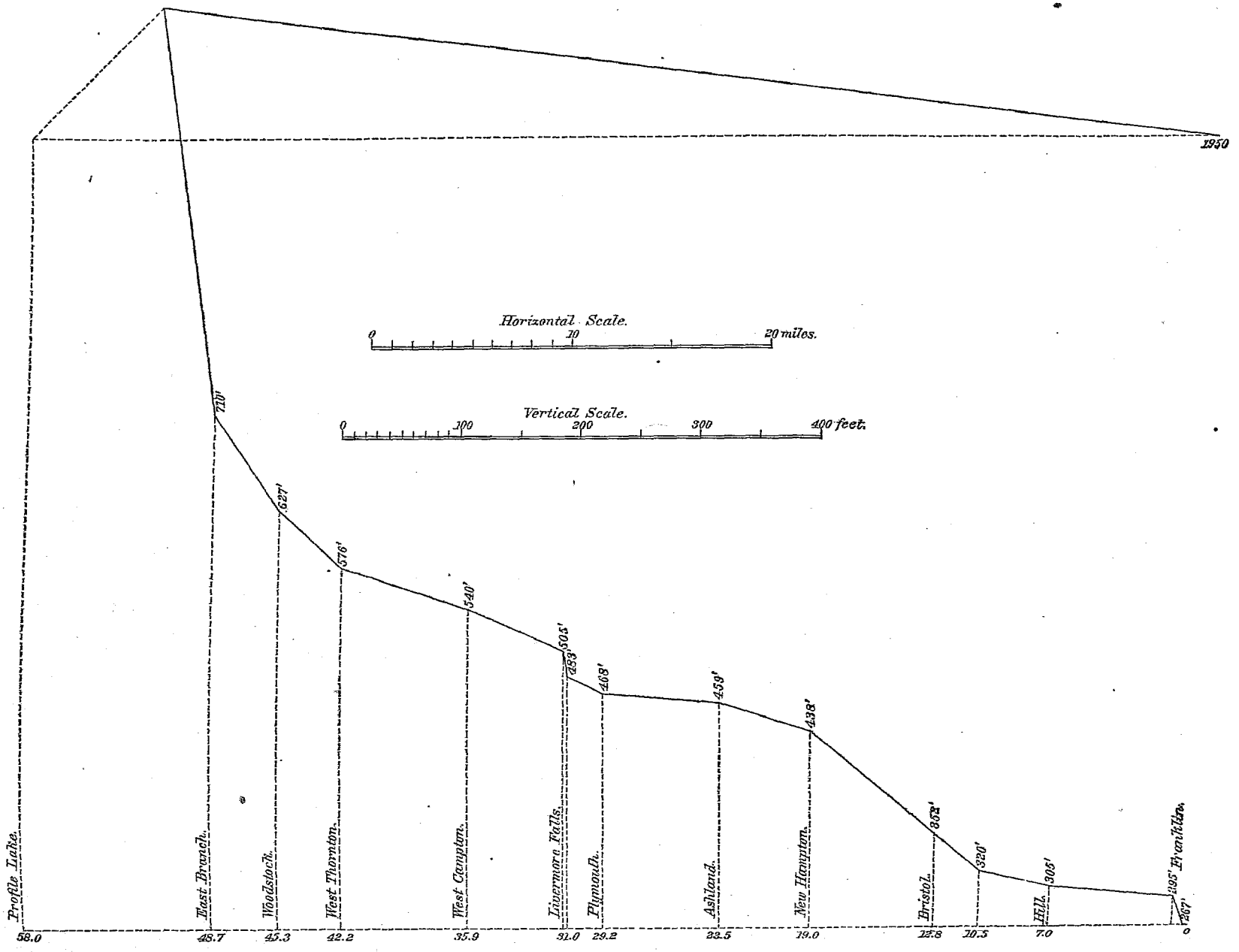

Fig. 17. PROFILE OF THE PEMIGEWASSET RIVER.

notwithstanding its considerable fall. The lake is not dammed. At Wolfeborough there are some mills on the outlet of Smith's pond, which lies at an elevation of 40 feet above the lake. The pond is dammed, and is controlled by the Lake Company, with power to shut off the flow entirely, and the mills referred to are below the company's dam, there being no power used at the latter. In Moultonborough the outlet of some small ponds runs a few small mills, but the only other stream worth naming is the Wukawan river, which empties at Meredith village. It is the outlet of lake Wukawan, covering 1 square mile, and into which flow Long pond and Hawkins pond. A dam a quarter of a mile below lake Wukawan raises the level of the latter 6½ feet, and that of Long pond 4 feet, the dam itself being about 60 feet long and 11 feet high. The fall from this point to lake Winnipiseogee, in a distance of a few hundred feet, is 42 feet when both lakes are full. The power is owned and controlled by the Meredith Mechanic Association, which owns, also, the land, buildings, machinery, etc., and leases the power as it stands. The mills supplied are the following, all with 42 feet fall: Hodgson's hosiery-mill, 60 horse-power; American Twist Drill Company, 60 horse power; Long's piano shop and Clark's box factory, 60 horse-power; grist-mill, 30 horse-power; Wadleigh Plow Company, 10 horse-power. Full capacity can always be secured, and no steam is used. In dry weather, however, there is no waste at night except from the flumes and penstocks. The power, though small, is an excellent one.

THE PEMIGEWASSET RIVER.

This river, which, by its union with the Winnipiseogee, forms the Merrimack, is a stream essentially different from the one just described. It has its source in the heart of the mountains, in Grafton county, being the outlet of Profile lake, in Franconia, which lies at an elevation of about 1,950 feet above the sea. From this small sheet of water the river descends very rapidly, pursuing a very straight course almost due south for a distance of nearly 40 miles. It then bends and flows west for about 6 miles, turning again at Bristol and flowing nearly south to join the Winnipiseogee. For the lower 23 miles of its course it forms the boundary between Belknap county on the east and Grafton and Merrimack counties on the west. Its total length along its course is about 58 miles; its drainage area measures about 1,013 square miles; and the principal towns on its course are Franklin, Hill, Bristol, New Hampton, Ashland, and Plymouth. Its drainage area is mountainous and hilly, and in the upper part is quite thickly covered with woods, probably nine-tenths of the area above Plymouth (*a*) and two-thirds of that southward being covered with forests. The fall of the stream is rapid, as the following table shows, but is for the most part gradual, except in the upper part. The bed and banks in the lower part are mostly of gravel and sand, and the stream is bordered in places by alluvial lands from half a mile to a mile in width, which, however, are seldom overflowed:

Declivity of the Pemigewasset river.

Place.	Distance from mouth.	Elevation above tide.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Profile lake, source of river	58.0	1,950			
			9.3	1,240	133.33
Mouth of East branch	48.7	710			
			3.4	83	24.41
Woodstock	45.3	627			
			3.1	51	16.45
West Thornton	42.2	576			
			6.3	36	5.71
West Compton	35.9	540			
			4.7	35	7.45
Livermore falls (above)	31.2	505			
			0.2	22	110
Livermore falls (below)	31.0	483			
			1.8	15	8.33
Plymouth	29.2	468			
			5.7	9	1.58
Ashland	23.5	459			
			4.5	21	4.67
New Hampton	19.0	438			
			6.2	86	13.87
Bristol	12.8	352			
			2.3	32	13.91
Mouth of Smith's river	10.5	320			
			3.5	15	4.29
Hill	7.0	305			
			6.2	10	1.61
Franklin (above falls)	0.8	295			
			0.6	26	43.33
Franklin (below falls)	0.2	269			
			0.2	2	10
Mouth		267			

NOTE.—These figures are taken from the *Geology of New Hampshire*, Vol. III.

In the upper part, above Thornton and Compton, the river valley is narrow and closely bordered on both sides by mountain ranges, the bed and banks being rocky and the falls abrupt. Draining, as it does, a mountain region,

a *Geology of New Hampshire*, Vol. I, p. 306.

the flow of the stream is very variable, especially as there are no large lakes to render it constant. Only on two of its tributaries is artificial storage made use of to any extent, and these join the river in the lower part of its course. A few estimates of the flow are presented in the following pages. The rainfall over the basin is about the same as over that of the Winnipiseogee, or about 44 inches, of which 11 fall in spring and in summer, 14 in autumn, and 8 in winter. The stream is accessible by rail between Franklin and Bristol and between Ashland and Plymouth, and a new railroad is now being built above Plymouth, rendering the upper parts easier of access.

Notwithstanding the great fall of the river, its water-power is almost unimproved. Not a mill occurs on the lower 31 miles of its course, and above that point it is so small and so variable as to be of little value. Several falls occur, however, within this distance which deserve mention. The first is at Franklin, being really a continuation of the fall on the Merrimack just below the junction of the two headwaters. The principal part of the fall, however, occurs just above the town, where within a distance of less than three-quarters of a mile the stream descends 26 feet. In the upper part the fall is about 15 or 20 feet in a quarter of a mile, over a bed of rock and bowlders, with high banks. The general location would admit of the utilization of the power, though it has never been attempted. The drainage area being about 994 square miles, I should make an estimate of the power about as follows:

Estimate of power of the Pemigewasset river at Franklin.

State of flow (see pages 8–10).	Drainage area.	Flow per second.	Horse-power available (gross) continuously.		
	Sq. miles.	*Cubic feet.*	*1 foot fall.*	*15 feet fall.*	*26 feet fall.*
Minimum	994	200	22.7	340	590
Minimum low season		250	28.4	426	738
Maximum, with storage		600	68.2	723	1,773
Low season, dry years		290	33.0	495	858

There is no fall of importance between this point and the mouth of Smith's river, a small fall at Hill being valueless. From the mouth of Smith's river the fall is rapid all the way to New Hampton, but the greater part, known as Bristol falls, occurs in about a mile, near the town. The bed is of gravel and bowlders, and the banks are tolerably high. This site has never been used. An estimate of the power available might be given somewhat as follows:

Estimate of power at Bristol.

State of flow (see pages 8–10).	Drainage area.	Flow per second.	Horse-power available (gross) continuously.
	Sq. miles.	*Cubic feet.*	*1 foot fall.*
Minimum	754	125	14.2
Minimum low season		150	17.0
Maximum, with storage		450	51.1
Low season, dry years		176	20.0

Of the total fall referred to it is said that 14 feet could be utilized without a dam, and with a canal 2,800 feet long.

Between New Hampton and Ashland there is a site formerly used, but not of much importance. The stream is rocky and the banks are high all the way between Bristol and New Hampton, but above that point, and especially above Ashland, the valley opens out, the fall is less, and the bed and banks are often sand. Two more small falls, of 4 or 5 feet, occur between New Hampton and Ashland. Thence up to Plymouth, and above, the stream is very flat and the banks sandy, the river frequently changing its channel. The principal fall in this part of the river occurs at Livermore falls, 2 miles above Plymouth. A wooden dam 28 feet high, on a ledge of rock, ponds the water only a few hundred feet, but the fall used is only 18 feet, the rest being wasted. The power is used for an excelsior-mill and a tannery. The fall is rapid above this place, and numerous sites could be found where power might be developed, but no mills are now running. The quantity of water is very small in the summer, and the power is therefore exceedingly unreliable.

It would seem, then, that various causes have combined to prevent the utilization of the power of the Pemigewasset, namely, the fact that the smaller tributaries have generally sufficed for the small mills seeking power in this vicinity, and the variability of flow of the main river, together with the greater difficulty and cost of utilizing it, especially as the bed and banks are generally gravel or sand. The tributaries of the Pemigewasset are, therefore, of greater importance than the main stream as sources of power.

TRIBUTARIES OF THE PEMIGEWASSET RIVER.—At Franklin a small stream enters from the west, the outlet of Webster pond, affording small but constant power. Its fall is very large, and is all utilized.

Smith's river, from the west, emptying about 2 miles below Bristol, drains about 80 square miles. Its fall is rapid for several miles from its mouth, amounting, it is said, to several hundred feet in that distance, of which, however, only about 25 or 30 feet are utilized. Within half a mile of the mouth the fall is said to be nearly 100 feet. Above Danbury the river has little fall. Its flow is exceedingly variable, there being no lakes of importance tributary to it, and in the summer it is almost dry. Had it equally large reservoirs it might be as valuable a stream as New Found or Squam rivers, described below.

New Found river, which joins the Pemigewasset at Bristol, is a stream similar to the Winnipiseogee, though much smaller. It is the outlet of New Found lake, a sheet of water covering about 7.8 square miles, and lying at an elevation of about 597 feet above the sea. (*a*) The stream is only between 2 and 3 miles in length, but its descent in that distance is about 238 feet, the greater part of this fall occurring at the lower end, where it pours in successive cataracts over ledges of rock. The total drainage area of the stream is about 95 square miles; that of the lake is almost as large. The lake is one of the reservoirs of the Lake Company, and its level has been raised about 7 or 8 feet by a dam, affording a large storage capacity, probably sufficient to store a depth of 3 or 4 inches on the entire drainage area, or enough to render available the maximum flow possible continuously. (See pages 8–10.) We have here, then, as in the case of the Winnipiseogee, an example of a stream reservoired to its full capacity, so that no additional reservoirs could render permanently available during a number of years a greater flow than would now be afforded were the discharge made uniform. As in the case of the Winnipiseogee, the flow is partially controlled by the Lake Company, and there is generally most water flowing in the summer, when other streams are suffering from lack of water. The powers on the stream are the following: At the outlet of the lake a saw-mill belonging to the Lake Company, runs part of the year; within the next half-mile there is an unutilized fall of between 10 and 20 feet; then comes a woolen-mill, with a fall of 6 or 7 feet, now not running; then a saw-mill, with a fall of 12 feet; then Mason, Perkins & Co.'s paper-mill, with a fall of 22½ feet, and about 200 horse-power, running day and night; then a grist-mill, with 13 feet fall; then the New Hampshire Chemical Pulp and Paper Company, with about 15 feet; then Holden's woolen-mill, with 16 feet, and not over 30 horse-power; then Mason, Perkins & Co.'s straw-board mill and a tannery, with 13 feet. This brings us to the bridge at Bristol, 900 feet from the mouth of the river. Between this point and the lake the utilized fall is therefore about 110 feet, and the fall still unutilized about 25 feet. In the last 900 feet of its course the river falls 103½ feet, and the power is used in a very complicated and wasteful manner by a large number of mills, which it is not necessary to describe. The water is distributed in a crude and unscientific manner, but the mills generally can run almost all the time, and no trouble ensues.

The next stream of importance is *Squam river*, a stream similar to that just described, being the outlet of Great and Little Squam lakes, which cover together about 11.75 square miles, and lie at an elevation of about 510 feet above the sea. It is about 2½ miles long, falling 111 feet, and entering the Pemigewasset at Ashland. It drains a total area of about 67 square miles, and the lakes but little less. The latter are controlled by the Lake Company, and a dam about 15 feet high, near the outlet of Little Squam lake, raises the level of both lakes some 4 or 5 feet, affording probably sufficient storage capacity to render available the maximum flow permanently possible, so that we have here a third example of a stream reservoired to its full capacity. The Lake Company allows a considerable quantity of water to flow continuously past its dam, thus affording excellent powers on the stream below, the fall being utilized by a number of mills, as follows:

At the upper dam a saw-mill is operated by the Lake Company, running part of the year; next below is a grist-mill, also owned by the company; then comes a woolen-mill, with 15 feet and about 50 horse-power, and a leather-board mill, with 40 horse-power; below is a new hosiery-mill and a straw-board mill, neither in operation, with a fall of 16 feet; then a paper-mill, with 15½ feet and about 60 horse-power; then a tannery, with 14 feet and 45 horse-power; then a paper-mill, with 17½ feet and 150 horse-power; and, finally, within a mile of the mouth of the stream, a leather-board mill, with 11 feet. There is little fall not used on the stream, except at the unutilized site mentioned above.

The remaining tributaries of the Pemigewasset are of small importance, draining a mountainous country, and with very variable flow, though with large fall. *Baker's river*, which empties from the west, just above Plymouth, drains about 220 square miles, but in the lower part of its course is bordered by alluvial lands, and has little power, while on its upper parts a few small saw-mills run part of the year. The bed and banks on the lower parts are sandy and gravelly, and subject to considerable changes in freshets. *Mad river*, which enters from the east, a little farther up, has considerable fall, deriving its name from its rapid current, and is utilized at Compton and other places by mills of various kinds. The *East branch* of the Pemigewasset drains a wholly uninhabited region of some 115 square miles. On these upper tributaries many cataracts are to be found, but they are of no value for power.

(*a*) *Geology of New Hampshire*, Vol. I, p. 308.

The following tables give the drainage areas of the tributaries of the Merrimack, and the power utilized on them. In glancing over the figures one will observe the enormous power which this drainage basin affords. The total net horse-power utilized is, in round numbers, 78,600 on the main stream and its branches, or about 16 horse-power per square mile of area:

Table of drainage areas of the Merrimack river and tributaries.

Stream.	Tributary to what.	Above what point.	Drainage area.	Stream.	Tributary to what.	Above what point.	Drainage area.
			Sq. miles.				*Sq. miles.*
Merrimack river	Atlantic ocean	Franklin	1,493	Suncook river	Merrimack river	Mouth of Little Suncook	108
Do	do	Sewell's falls	2,350	Do	do	Short falls	220
Do	do	Garvin's falls	2,412	Do	do	Mouth	264
Do	do	Hooksett	2,791	Little Suncook river	Suncook river	do	44
Do	do	Manchester	2,839	Soucook river	Merrimack river	do	90
Do	do	Lowell	4,085	Contoocook river	do	Peterborough	68
Do	do	Lawrence	4,599	Do	do	Bennington	194
Do	do	Newburyport	4,916	Do	do	Hillsborough	359
Powow river	Merrimack river	Mouth	50	Do	do	Henniker	388
Shawsheen river	do	do	72	Do	do	West Hopkinton	423
Spicket river	do	do	79	Do	do	Contoocook	593
Beaver brook	do	do	92	Do	do	Mouth	766
Sudbury river	Concord	do	150	Nubanusit river	Contoocook	do	56
Assabet river	do	do	175	North branch of	do	do	127
Concord river	Merrimack river	North Billerica	355	Warner river	do	do	149
Do	do	Mouth of Meadow brook	361	Blackstone river	do	Cilleyville	67
Do	do	Mouth	380	Do	do	Mouth	132
Stony brook	do	do	35	Winnipiseogee river	Merrimack	Outlet of lake	348
Nashua river	do	Junction of two branches	256	Do	do	Lake Village	357
Do	do	Mouth	516	Do	do	Laconia	367
North branch of	Nashua river	do	127	Do	do	East Tilton	423
South branch of	do	do	129	Do	do	Tilton	466
Squanacook river	do	do	70	Do	do	Mouth	480
Nissitissit river	do	do	54	Merrymeeting river	Lake Winnipiseogee	do	37
Stillwater river	South branch of the Nashua river.	do	37	Pemigewasset river	Merrimack river	Livermore falls	398
Quinepoxet river	do	do	54	Do	do	Bristol falls	754
Souhegan river	Merrimack river	Wilton	67	Do	do	Franklin falls	994
Do	do	Mouth	224	Do	do	Mouth	1,013
Stony brook	Souhegan river	do	30	Smith's river	Pemigewasset river	do	80
Baboosic brook	do	do	51	New Found river	do	do	95
Cohass brook	Merrimack river	do	68	Baker's river	do	do	220
Piscataquog river	do	do	214	Squam river	do	do	67
South branch of	Piscataquog river	do	100	Mad river	do	do	66
North branch of	do	do	77	North branch of	do	do	28
Suncook river	Merrimack river	Pittsfield	133	East branch of	do	do	115

Table of power utilized on the tributaries of the Merrimack river.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
Powow river	Merrimack river	Massachusetts	Essex	Woolen	1	66	1,765
Do	do	New Hampshire	Rockingham	Flour and grist	1	7	30
Do	do	do	do	Saw	2	18	55
Shawsheen river	do	Massachusetts	Essex	Twine	2	19	225
Do	do	do	do	Woolen	2	23	275
Do	do	do	do	Saw	1	13	5
Do	do	do	Middlesex	Flour and grist	1	12	20
Do	do	do	do	Saw	1	12	20
Do	do	do	do	Wooden-ware	1	8	100
Spicket river	do	do	Essex	Bagging	1	40	62
Do	do	do	do		1	15	.....
Do	do	do	do	Woolen	1	12	80
Do	do	do	do	Cotton	1	39	300
Do	do	do	do	Worsted	1	12	140
Do	do	New Hampshire	Rockingham	Hosiery	1	10	40
Do	do	do	do	Woolen	1	15	75

Table of power utilized on the tributaries of the Merrimack river—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
Spicket river	Merrimack river	New Hampshire	Rockingham	Box	1	8	30
Do	do	do	do	Saw	2	30	92
Beaver brook	do	do	do	Box	1	12	8
Do	do	do	do	Carriage materials	1	10	50
Do	do	do	do	Cutlery	1	12	15
Do	do	do	do	Flour and grist	2	29	80
Do	do	do	do	Saw	3	39	110
Do	do	do	do	Musical instruments	1	6	6
Do	do	do	Hillsborough	Flour and grist	1	11	30
Do	do	do	do	Saw	1	7	12
Do	do	do	do	Woolen	1	7	20
Do	do	Massachusetts	Middlesex	do	2	34	290
Do	do	do	do	Flour and grist	1	9	20
Do	do	do	do	Paper	1	10	46
Concord river	do	do	do	Dye-woods, etc	1	11	200
Do	do	do	do	Flour and grist	1	.....	30
Do	do	do	do	Bolts, nuts, etc	1	22	50
Do	do	do	do	Tannery	1	.....	12
Do	do	do	do	Mattresses, etc	1	.....	40
Do	do	do	do	Machinery	2	18	35
Do	do	do	do	Paper	1	7	42
Do	do	do	do	Worsted	1	10	40
Do	do	do	do	Woolen	8	122	860
Sudbury river	Concord river	do	do	do	2	50	(?)600
Do	do	do	do	Boots and shoes	1	8	5
Do	do	do	do	Boxes	1	4	20
Do	do	do	do	Saw	2	18	16
Do	do	do	Worcester	Woolen	1	24	115
Do	do	do	do	Carriage and wagon materials	1	16	15
Do	do	do	do	Flour and grist	2	34	59
Assabet river	do	do	Middlesex	Boots and shoes	1	10	45
Do	do	do	do	Flour and grist	1	12	20
Do	do	do	do	Gunpowder	1	11	200
Do	do	do	do	Paper	1	10	75
Do	do	do	do	Woolen	3	48	640
Do	do	do	do	Cotton	1	8	40
Do	do	do	Worcester	Woolen	2	29	178
Do	do	do	do	Fertilizers	1	8	30
Do	do	do	Worcester	Flour and grist	2	29	70
Do	do	do	do	Ivory and bone work	2	17	30
Do	do	do	do	Saw	4	45	192
Do	do	do	do	Wood-turning	1	9	12
Other tributaries of the	do	do	Middlesex	Cotton	1	16	25
Do	do	do	do	Cooperage	2	16	14
Do	do	do	do	Flour and grist	11	135	447
Do	do	do	do	Fertilizers	1	15	25
Do	do	do	do	Saw	7	95	205
Do	do	do	do	Machinery	3	.....	44
Do	do	do	do	Musical instruments	1	8	20
Do	do	do	do	Pencil lead	1	11	20
Do	do	do	do	Shoddy	1	16	40
Do	do	do	do	Wheelwrighting	2	22	7
Do	do	do	do	Tools	1	11	25
Do	do	do	do	Vinegar	1	10	7
Do	do	do	Worcester	Boots and shoes	1	7	6
Do	do	do	do	Combs	1	12	10
Do	do	do	do	Flour and grist	7	83	207
Do	do	do	do	Saw	3	36	87
Do	do	do	do	Rubber goods	1	22	50
Do	do	do	do	Vinegar	1	16	40
Do	do	do	do	Wheelwrighting	1	8	12
Stony brook	Merrimack river	do	Middlesex	Hosiery	1	.....	150
Do	do	do	do	Worsted	3	52	380
Do	do	do	do	Woolen	1	16	101
Do	do	do	do	Saw	1	7	30
Do	do	do	do	Flour and grist	1	7	33
							105

Table of power utilized on the tributaries of the Merrimack river—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
Stony brook	Merrimack river	Massachusetts	Middlesex	Machinery	2	48	95
Do	do	do	do	Shoddy	1	7	60
Do	do	do	Worcester	Leather-board (?)	1	20	55
Nashua river	do	New Hampshire	Hillsborough	Cotton	2	56	2,300
Do	do	Massachusetts	Middlesex	Paper	2	27	418
Do	do	do	do	Saw	1	8	60
North branch of the	Nashua river	do	do	Agricultural implements	1	12	40
Do	do	do	do	Woolen	1	11	40
Do	do	do	do	Blacksmithing	1	7	4
Do	do	do	do	Carpentering	1	10	20
Do	do	do	do	Flour and grist	4	52	240
Do	do	do	do	Flax and linen	1	8	60
Do	do	do	do	Furniture	5	81	90
Do	do	do	do	Leather-dressing	1	9	15
Do	do	do	do	Leather-board (?)	1	9	100
Do	do	do	do	Saw	3	34	110
Do	do	do	do	Shoddy	1	.....	32
Do	do	do	do	Machinery	3	.....	78
Do	do	do	do	Paper	2	28	235
Do	do	do	do	Printing and publishing	1	.....	2
Do	do	do	do	Sash, doors, and blinds	1	11	25
Do	do	do	do	Wood-pulp	1	10	75
Do	do	do	do	Wood-turning	4	.....	28
Do	do	do	do	Wooden-ware	1	6	20
Tributaries of the North branch of the	do	do	do	Cotton	2	21	160
Do	do	do	do	Buttons	2	28	40
Do	do	do	do	Jewelry	1	30	20
Do	do	do	do	Cutlery and edge-tools	1	15	30
Do	do	do	do	Machinery	2	10	31
Do	do	do	do	Carriages and wagons	1	25	115
Do	do	do	do	Wagon materials	1	11	20
Do	do	do	do	Combs	5	62	49
Do	do	do	do	Saw	5	64	110
Do	do	do	do	Flour and grist	3	41	66
Do	do	do	do	Furniture	5	60	151
Do	do	do	do	Paper	.....	.....	1,039
Do	do	do	do	Woolen	3	50	145
Do	do	do	do	Cotton	2	33	158
South branch of the	do	do	do	Musical instruments	1	14	64
Do	do	do	Worcester	Cotton	2	42	886
Do	do	do	do	Comb	1	6	70
Do	do	do	do	Flour and grist	2	10	112
Do	do	do	do	Furniture	1	17	22
Do	do	do	do	Tannery	1	14	25
Tributaries of the South branch of the	do	do	do	Saw (?)	1	9	30
Do	do	do	do	Cotton	10	205	948
Do	do	do	do	Carpet	1	30	30
Do	do	do	do	Woolen	6	142	586
Do	do	do	do	Flour and grist	7	126	303
Do	do	do	do	Saw	7	132	165
Do	do	do	do	Shoddy	3	65	70
Do	do	do	do	Stone- and earthen-ware	1	12	16
Other tributaries of the	do	do	do	Wood-turning	1	18	6
Do	do	do	do	Cotton	3	47	290
Do	do	do	Middlesex	Baskets, etc	1	15	10
Do	do	do	do	Machinery	1	8	10
Do	do	do	do	Blacksmithing	1	10	6
Do	do	do	do	Leather-board	6	77	395
Do	do	do	do	Cutlery	1	12	10
Do	do	do	do	Paper	2	24	210
Do	do	do	do	Flour and grist	8	102	169
Do	do	do	do	Wooden-ware	2	.....	44
Do	do	do	do	Furnishing goods	1	14	90
Do	do	do	do	Saw	13	192	414
Do	do	do	Worcester	Wheelwrighting	1	16	16
				Saw	7	50+	157

Table of power utilized on the tributaries of the Merrimack river—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
Other tributaries of the	Nashua river	New Hampshire	Hillsborough	Furniture	1	12	43
Do	do	do	do	Wheelwrighting	1	10	16
Do	do	do	do	Saw	8	128	418
Do	do	do	do	Silk	1	8	10
Do	Merrimack river	Massachusetts	Essex	Woolen	5	70+	295
Do	do	do	do	Carriages and wagons	1	25	10
Do	do	do	do	Flour and grist	1	13	10
Do	do	do	do	Tannery	1	8	8
Do	do	do	do	Saw	2	29	55
Do	do	do	do	Machinery	1	16	60
Do	do	do	Suffolk	Foundery	1	24	15
Do	do	do	Middlesex	Box	2	31	60
Do	do	do	do	Brooms and brushes	1	8	5
Do	do	do	do	Carpentering	2	24	22
Do	do	do	do	Flour and grist	4	47	100
Do	do	do	do	Saw	4	53	105
Do	do	do	do	Shoddy	1	19	15
Souhegan river	do	do	do	Flour and grain	1	11	10
Do	do	do	do	Saw	4	48	54
Do	do	do	Worcester	do	1	9	20
Do	do	New Hampshire	Hillsborough	Woolen	1	20	65
Do	do	do	do	Cotton	3	22+	734
Do	do	do	do	Worsted	1	32	165
Do	do	do	do	Agricultural implements	2	24	64
Do	do	do	do	Flour and grist	3	39	155
Do	do	do	do	Toys and games	1	18	90
Do	do	do	do	Furniture	3	64	153
Do	do	do	do	Looking-glass	1	9	25
Do	do	do	do	Saw	4	38	180
Do	do	do	do	Shoddy	1	17	20
Tributaries of the	Souhegan river	do	do	Flour and grist	6	84	199
Do	do	do	do	Wood-turning	3	34	31
Do	do	do	do	Furniture	1	12	6
Do	do	do	do	Planing	1	10	35
Do	do	do	do	Saw	14	174	415
Do	do	do	do	Wooden-ware	1	10	10
Do	do	do	do	Stone- and earthen-ware	1	40	20
Cohass river	Merrimack river	do	do	Woolen	1	42	170
Piscataquog river and tributaries	do	do	do	Cotton	1	16	66
Do	do	do	do	Boxes	1	10	15
Do	do	do	do	Cooperage	1	8	22
Do	do	do	do	Flour and grist	5	50	272
Do	do	do	do	Furniture	1	7	6
Do	do	do	do	Planing	1	9	6
Do	do	do	do	Machinery	1	6	3
Do	do	do	do	Saw	24	250	495
Do	do	do	do	Sash, doors, and blinds	1	13	10
Do	do	do	do	Toys and games	2	19	26
Do	do	do	do	Wood-pulp	1	13	167
Do	do	do	do	Wood-turning	1	10	8
Do	do	do	do	Shuttle	1	10	60
Suncook river	do	do	Merrimack	Cotton	5	105	2,000±
Do	do	do	do	Boots and shoes	1	10	20
Do	do	do	do	Cordage	1	8	20
Do	do	do	do	Flour and grist	5	51	152
Do	do	do	do	Saw	9	81	208
Do	do	do	do	Planing	1	10	20
Do	do	do	Belknap	Woolen	1	7	20
Do	do	do	do	Agricultural implements	1	10	46
Do	do	do	do	Boots and shoes	1	5	10
Do	do	do	do	Flour and grist	3	25	98
Do	do	do	do	Saw	3	32	106
Little Suncook river	Suncook river	do	Merrimack	Flour and grist	2	20	102
Do	do	do	do	Saw	1	11	50
Do	do	do	Strafford	do	1	38	20
Soucook river	Merrimack river	do	Merrimack	Washing-machines	1	.....	47
Do	do	do	do	Wheelwrighting	1	12	25
						107	

Table of power utilized on the tributaries of the Merrimack river—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
Contoocook river	Merrimack river	New Hampshire	Merrimack	Cotton	2	31	500
Do	do	do	do	Furniture	1	12	115
Do	do	do	do	Table	1	12	25
Do	do	do	do	Axles	1	7	60
Do	do	do	do	Sash, door, and blind	1	9	30
Do	do	do	do	Excelsior	1	17	.....
Do	do	do	do	Woolen	1	16	35
Do	do	do	do	Saw	5	74	225
Do	do	do	do	Flour and grist	3	42	260
Do	do	do	do	Ax-handles	1	20	.....
Do	do	do	do	Saw-works	1	20	.....
Do	do	do	do	Granite-polishing	1	20	.....
Do	do	do	do	Cooperage	2	20	75
Do	do	do	do	Machinery	1	7	10
Do	do	do	do	Paper	1	12	100
Do	do	do	Hillsborough	Hosiery	1	15	80
Do	do	do	do	Woolen	1	14	90
Do	do	do	do	Needles	1	15	5
Do	do	do	do	Silk	1	15	8(?)
Do	do	do	do	Paper	1	18	120
Do	do	do	do	Agricultural implements	1	10	5
Do	do	do	do	Cutlery	2	19	.....
Do	do	do	do	Flour and grist	3	20+	200
Do	do	do	do	Scientific instruments	2	10	58
Do	do	do	do	Saw	5	53+	125
Do	do	do	do	Surgical appliances	1	8	20
Do	do	do	do	Wooden-ware	1	7	40
Do	do	do	Cheshire	Flour and grist	1	12	25
Do	do	do	do	Saw	4	66	185
Do	do	do	do	Cutlery	1	6	20
Do	do	do	do	Wood-pulp	1	18	100
Do	do	do	do	Wooden-ware	2	22	65
Do	do	do	do	Cotton	1	21	125
Blackwater river	Contoocook river	do	Merrimack	Hosiery	1	11	25
Do	do	do	do	Tannery	1	12	32
Do	do	do	do	Wheelwrighting	1	13	15
Do	do	do	do	Saw	6	69	270
Do	do	do	do	Blacksmithing	1	8	8
Do	do	do	do	Leather-board	1	15	70
Do	do	do	do	Flour and grist	3	33	121
Warner river	do	do	do	Carpentering	1	12	25
Do	do	do	do	Paper	1	12	60
Do	do	do	do	Carriage materials	2	19	70
Do	do	do	do	Excelsior	1	22	60
Do	do	do	do	Furniture	1	10	12
Do	do	do	do	Flour and grist	2	16	75
Do	do	do	do	Saw	4	39	151
Nubanusit river	do	do	Hillsborough	Cotton	2	72	288
Do	do	do	do	Baskets, etc	1	12	15
Do	do	do	do	Blacksmithing	1	9	12
Do	do	do	do	Carpentering	1	11	20
Do	do	do	do	Furniture	1	9	50
Do	do	do	do	Foundery	1	.....	3
Do	do	do	do	Saw	1	9	50
Do	do	do	do	Paper	2	34	110
Do	do	do	do	Woolen	1	25	25
Do	do	do	do	Wood-pulp	1	26	200
Other tributaries of the	do	do	do	Blacksmithing	2	30	18
Do	do	do	do	Cutlery	1	30	45
Do	do	do	do	Excelsior	1	16	12
Do	do	do	do	Flour and grist	1	.....	6
Do	do	do	do	Wire-work	1	14	40
Do	do	do	do	Furniture	3	.....	40
Do	do	do	do	Saw	6	108	251
Do	do	do	do	Wheelwrighting	1	.....	8
Do	do	do	do	Wood-turning	1	20	16

Table of power utilized on the tributaries of the Merrimack river—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall used.	Total horse-power used, net.
						Feet.	
Other tributaries of the	Contoocook river	New Hampshire	Cheshire	Saw	6	76	281
Do	do	do	do	Wooden-ware	6	87	321
Do	do	do	Merrimack	Agricultural implements	1	12	50
Do	do	do	do	Excelsior	1	13	50
Do	do	do	do	Saddlery and harness	1	19	40
Do	do	do	do	Sash, door, and blind	1	12	32
Do	do	do	do	Spools and bobbins	1	11	10
Do	do	do	do	Wheelwrighting	2	16	82
Do	do	do	do	Wooden-ware	2	42	75
Do	do	do	do	Tannery	1	8	12
Do	do	do	do	Flour and grist	2	29	115
Do	do	do	do	Saw	13	212	363
Do	do	do	do	Planing	1	.....	16
Do	Merrimack	do	Hillsborough	Cotton	1	26	150
Do	do	do	do	Silk	1	8	10
Do	do	do	do	Carriage and wagon materials	1	.....	10
Do	do	do	do	Cutlery	1	22	185
Do	do	do	do	Drugs and chemicals	1	15	25
Do	do	do	do	Files	2	.....	28
Do	do	do	do	Flour and grist	2	17	58
Do	do	do	do	Saw	16	238	440
Do	do	do	do	Sash, door, and blind	1	12	35
Do	do	do	do	Wheelwrighting	4	33+	49
Do	do	do	do	Wood-turning	2	.....	50
Do	do	do	do	Tannery	1	28	16
Do	do	do	Rockingham	Cooperage	1	12	10
Do	do	do	do	Flour and grist	4	34	115
Do	do	do	do	Saw	20	240	491
Do	do	do	Merrimack	Woolen	1	63	100
Do	do	do	do	Brick and tile	1	16	10
Do	do	do	do	Blacksmithing	2	.....	9
Do	do	do	do	Carpentering	1	12	20
Do	do	do	do	Cooperage	1	36	40
Do	do	do	do	Dentistry (?)	2	220	2
Do	do	do	do	Furniture	1	.....	10
Do	do	do	do	Flour and grist	5	89	301
Do	do	do	do	Printing and publishing	3	330	12
Do	do	do	do	Saw	10	125+	258
Do	do	do	do	Marble work	1	14	20
Do	do	do	do	Machinery	1	12	150
Do	do	do	Belknap	Watch and clock	1	30	4
Do	do	do	do	Saw	4	50	120
Winnipiseogee river	do	do	Merrimack	Woolen	3	27	180
Do	do	do	do	Paper	1	91	4,100(?)
Do	do	do	do	Sash, door, and blind	1	12	32
Do	do	do	do	Saws	1	13	10
Do	do	do	do	Flour and grist	1	12	25
Do	do	do	do	Machinery	1	13	20
Do	do	do	do	Hosiery	3	38	280
Do	do	do	Belknap	Flour and grist	4	38	175
Do	do	do	do	Car-repairing	2	18	70(?)
Do	do	do	do	Yarn	1	8	.....
Do	do	do	do	Woolen	1	10	40
Do	do	do	do	Needles	2	.....	18
Do	do	do	do	Cotton	1	10	120
Do	do	do	do	Twine	1	8	40
Do	do	do	do	Lace	1	10	100
Do	do	do	do	Hosiery	8	75	425±
Do	do	do	do	Shoddy	1	8	.....
Do	do	do	do	Machinery	3	26	.....
Do	do	do	do	Saw	2	19	135
Tributaries of the	Winnipiseogee river	do	do	Cotton	1	32	96
Do	do	do	do	Shoddy	1	28	20
Do	do	do	do	Saw	1	.....	6
Do	Lake Winnipiseogee	do	do	Agricultural implements	2	40+	23
Do	do	do	do	Hosiery	1	42	60

Total power utilized on the tributaries of the Merrimack river—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 the	Lake Winnipiscogee	New Hampshire	Belknap	Carpentering	1	42	30
Do	do	do	do	Tannery	1	16	20
Do	do	do	do	Musical instruments	1	42	30
Do	do	do	do	Flour and grist	2	52	60
Do	do	do	do	Saw	3	54	99
Do	do	do	Carroll	Furniture	1	14	40
Do	do	do	do	Flour and grist	2	32	100
Do	do	do	do	Saw	5	59	218
Do	do	do	do	Woolen	1	25½	36
Pemigewasset river	Merrimack river	do	Grafton	Excelsior	1	18	50
Do	do	do	do	Tannery	1	18	.....
Smith's river	Pemigewasset river	do	Merrimack	Flour and grist	1	10	24
Do	do	do	do	Saw	3	34	120
Do	do	do	Grafton	do	3	101	85
Other tributaries of the	do	do	Merrimack	Surgical appliances	1	10	8
Do	do	do	do	Carriages and wagons	1	15	10
Do	do	do	do	Foundery	1	20	20
Do	do	do	do	Flour and grist	3	61	64
Do	do	do	do	Tannery	1	12	9
Do	do	do	do	Saw	5	61	185
Do	do	do	do	Needles and pins	1	15	6
Do	do	do	do	Hosiery	2	21	35
Do	do	do	Grafton	Clothing	1	16	5
Do	do	do	do	Wheelwrighting	1	11	11
New Found river	do	do	do	Woolen	1	16	30
Do	do	do	do	Paper	3	46	207
Do	do	do	do	Carpentering	2	.....	30
Do	do	do	do	Flour and grist	3	30	130
Do	do	do	do	Blacksmithing	1	12	15
Do	do	do	do	Wood-turning	1	16	86
Do	do	do	do	Carriages and wagons	1	12	50
Do	do	do	do	Gloves	1	18	76
Do	do	do	do	Tanneries	2	38	150
Do	do	do	do	Machinery	1	8	2
Do	do	do	do	Straw-board	1	13	.....
Do	do	do	do	Wood-pulp	1	22	200
Do	do	do	do	Saw	1	12	50
Squam river	do	do	do	Machinery	1	12	60
Do	do	do	do	Paper	2	33	210
Do	do	do	do	Flour and grist	1	13	40
Do	do	do	do	Tannery	1	14	45
Do	do	do	do	Leather-board	2	26	80
Do	do	do	do	Woolen	1	15	50
Do	do	do	do	Saw	1	15	.....
Mad river	do	do	do	Blacksmithing	1	9	35
Do	do	do	do	Furniture	1	14	40
Do	do	do	do	Woolen	1	11	34
Do	do	do	do	Sash, door, and blind	1	14	65
Do	do	do	do	Wood-turning	1	14	40
Do	do	do	do	Saw	1	11	30
Do	do	do	do	Flour and grist	1	14	40
Baker's river	do	do	do	Planing	1	8	20
Do	do	do	do	Saw	3	42	173
Do	do	do	do	Flour and grist	1	18	60
Other tributaries of the	do	do	do	Carpentering	1	10	20
Do	do	do	do	Gloves and mittens	3	27	55
Do	do	do	do	Wooden handles	2	25	45
Do	do	do	do	Saw	92	575	910
Do	do	do	do	Veneering	1	18	20
Do	do	do	do	Tanneries	3	30+	49
Do	do	do	do	Flour and grist	6	115	185
Do	do	do	Carroll	Saw	2	26	50
Do	do	do	do	Flour and grist	1	30	40

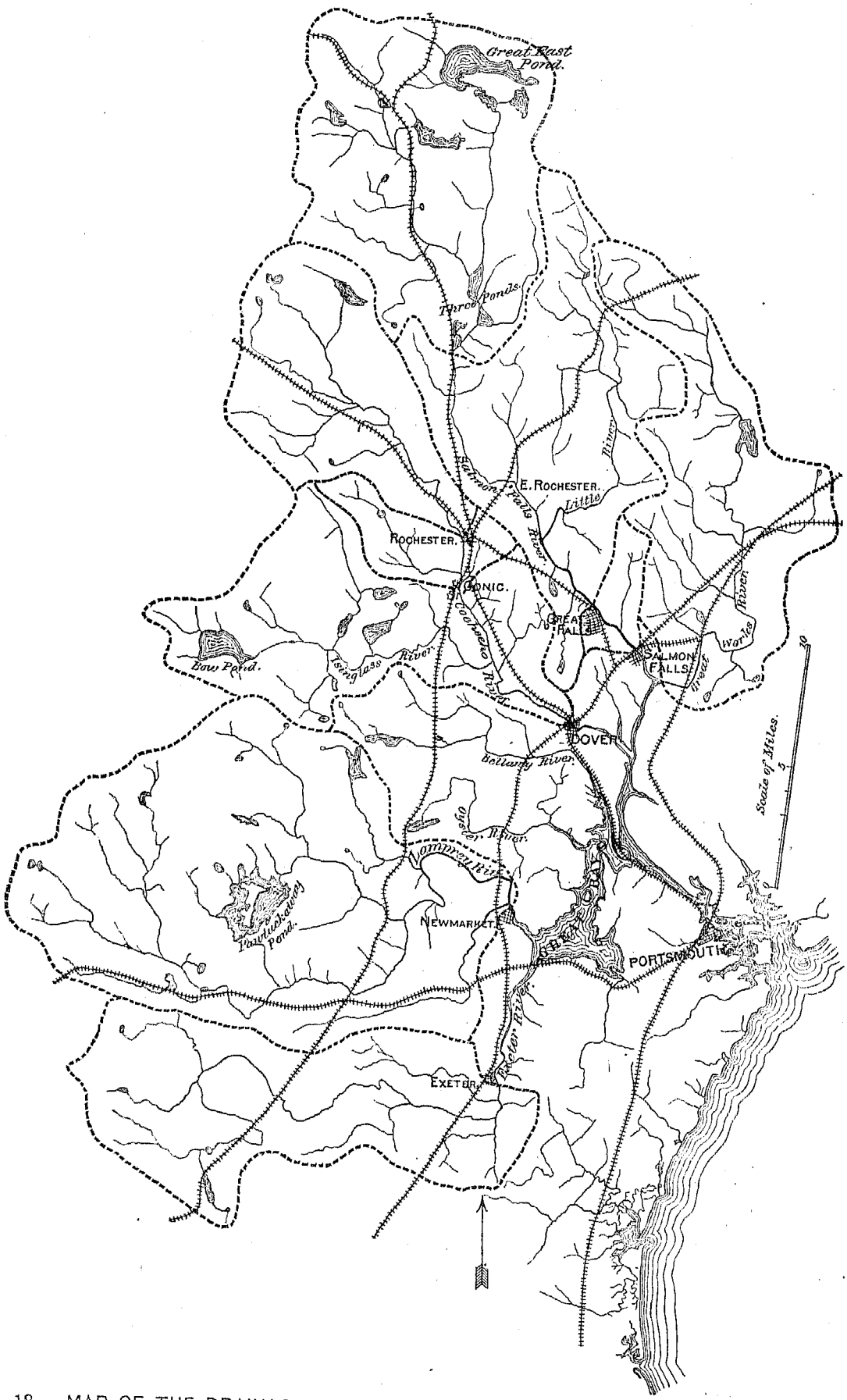

Fig. 18. MAP OF THE DRAINAGE BASINS OF THE COAST STREAMS OF NEW HAMPSHIRE.