REPORT

OF

SENATORS PAUL O. HUSTING

AND

HENRY KRUMREY

Members of Special Legislative Committee appointed to investigate and to recommend legislation relating to

Water Powers, Forestry and Drainage

Made to the Governor January 24, 1910.

MADISON, WIS.
DEMOCRAT PRINTING COMPANY, STATE PRINTER
1910

"EXHIBIT 28."

THE INTIMATE RELATION OF FOREST COVER TO STREAM FLOW.

BY E. M. GRIFFITH, STATE FORESTER.

1910.

One of the most valuable of Wisconsin's resources is her water powers. As the state has no deposits of coal, the great source of energy for manufacturers, for transportation, for light and heat is in the many water powers that are well distributed over the state. It is of the greatest importance to the industrial interests of Wisconsin that these water powers be developed and utilized to their highest capacity and protected by the counstruction of reserviors and the maintainance of a forest cover on all watersheds.

A uniform stream flow is of the utmost importance to the proper utilization of water powers, as the usefulness of a power must be measured largely by its head at low water flow.

It has been a common experience in Wisconsin for many years past, following upon the large lumbering operations in the state, that the thaws of spring have brought on more or less heavy floods and an enormous volume of water has been discharged through our steam channels within a comparatively short period of time and beside the inordinate waste of power and loss of water, a great deal of damage was done by erosion of the banks. By summer the same streams are reduced to a mere trickle and even our largest rivers but thinly cover their erosion-widened channels, while great clogging shoals of sand appear above the surface of the water. The great problem is to save the damaging flood waters of spring to supplement the summer flow.

A great deal can be accomplished by the operation of artificial

reservoirs but the maintainance of a forest cover upon the upper watersheds is necessary, even with artificial reservoirs; and with an adequate area under forest cover, artificial reservoirs might be dispensed with.

Many people do not understand just how forests affect the regimen of streams. A comparison of conditions in the forest and in the open will make this clearer. In the spring the snow in the open is melted rapidly by the sun and wasted rapidly by the winds, although much of the moisture is dissipated by evaporation and the water is formed very rapidly by the melting snow and flows off all slopes without hindrance because the frozen ground has a hard impermeable surface. Even in summer there may be similar conditions in the open. The rain will flow quickly over the sunbaked ground, rushing into whatever natural channels are available, not finding permeable soil.

In the forest on the contrary, and especially in the pine forest, the snow is sheltered from the sun's rays and protected from the sweep of drying winds. It melts very slowly and gradually. In the cedar swamps the Indians find snow or ice for their sick far into the summer season. The water formed by the melting snow does not flow off over the surface. It is held by the thick layer of leaves and twigs that forms the forest floor and sinks gradually into the soil underneath which is not only very permeable but contains an intricate network of rootlets and roots along which the water finds its way downward deep into the earth, whence it reappears long afterward through underground streams and springs, forming the small streams that feed our rivers. The summer rains also reach the forest soil gradually through the dense mid-season foliage, which drips water for hours after a rain, and are received into the soil, which yields them up gradually to the stream channels, as they are needed. In the open, the rains flow off rapidly over the ground surface and hard rains on bare ground beat the soil and wash it away, forming little gullies and then larger ones, and clogging the stream channels with detritus. The difference in the same soil in the open and under forest cover can be seen by examining an unsheltered road through a forest and the soil on either side. After a rain the road will be muddy but no matter how saturated the forest soil, it will be porous and grainy and one can walk over it without getting his shoes muddy.

Wisconsin has no mountains and therefore has no need to guard against sudden mountain torrents, with the accompanying loss of surface soil and the burying of fertile valleys under sand and gravel; but the configuration of the state is sufficiently varied to conduce to the production of floods and very serious ones, and the creation of innumerable reservoirs alone could never prevent certain serious evils. Much water might be stored and saved, but reservoirs could never prevent the sudden melting of snow on frozen ground, nor the washing away of soil and the clogging of both stream channels and reservoirs with sand and detritus.

The water that issues from forested watersheds and that flows in forest streams, is remarkably clear. The forest soil is not only porous but it is bound together by the root of trees and undergrowth and the water filters through it instead of beating upon it and carrying portions of it away. Of course the erosive power of water charged with sand and gravel, is very much greater than that of clear water. The Mississippi river is a tragic example of the evils of deforestation, and the United States government has recognized the source of the evil in granting the forestry departments of both Minnesota and Wisconsin a tract of 20,000 acres, so as to bring the upper headwaters of the river under forest cover. No amount of dredging will make a permanent deep water channel. The planting of trees has held the banks intact on limited areas, but with the varying flow, sands are continually shifting, channels widening, and the level of the stream-bed rising, while tons of soil are continually carried out through the mouth of the river.

Our water power resources are not only incalculably benefited by a uniform stream flow, but they become of little value with a widely fluctuating flow and all its accompanying evils, and although the operation of reservoirs will mitigate the evils, it will not cure them. The almost immediate and always disastrous effect upon stream flow when forests upon the headwaters of rivers are destroyed, has long been recognized in all parts of the world where forestry is practiced, but as this beneficial effect of the forest has been denied by certain interests in Wisconsin, the following authorities are quoted and a few examples of the many which might be given.

The theory of the relation of forest cover to stream flow and soil stability is as follows:

Gifford Pinchot says: "Both wide experience and scientific investigation have shown that there are two functions exercised by the forest in relation to stream flow.

1. Its tendency to reduce the difference between high and low water, an influence which is of the utmost importance in the distribution of flood crests, and in maintaining a steady flow of water during the different seasons of the year and during cycles of dry and wet years.

2. Its value as a surface protection against soil erosion, thus reducing the solid burden of storm waters, and decreasing the deposits of sand and silt, which are the causes of shallow and changing channels.

These two functions follow from the very nature of the forest as a soil cover. The roots of trees penetrate through the soil to the underlying rock, where they fix themselves in the crevices, and in this way hold in place the loose soil and prevent slipping and washing. The crowns of the trees break the force of the rain and also protect the soil from being carried away to the lower valleys during heavy storms. The leaves and the branches allow the rain to reach the ground but gradually; after a rain, water continues to drip from the crown for several hours, and the soil is thus enabled to absorb the greater part of it. Screened from the rays of the sun and covered with a surface milch of fallen leaves and humus, the soil remains loose and granular in structure and is therefore capable of imbibing and retaining water with spongelike capacity. It is strewn with fallen leaves, branches and trunks, and traversed by a network of dead and live roots which impede the superficial run off of water after heavy storms. This retardation of the superficial run-off allows more of it to sink into the ground through the many channels left in the soil by decayed roots. Surface run-off of rain water is wasteful and destructive, and unless artificially controlled serves as a rule no useful purpose and may inflict great loss. Sub-surface drainage makes the best use of the total precipitation that reaches the ground. It serves both for the sustenance of plant life and for the flow of streams. Accordingly the agency of the forest cover in increasing the seepage run-off at the expense of the surface run-off is the most important function which the forest performs in relation to the water supply.

A common conception of the effect of forest destruction upon climate is that it reduces the amount of rainfall. Because springs become dry and streams shrink in a deforested region, it is assumed that less rain must fall. Whether or not there be any truth in this assumption (I believe there is), it is certian that the main cause of the observed facts is the profound effect which forest destruction has upon the course which the water takes after it reaches the ground. The greatest influence of the forest is not upon the amount of rain that falls, but on what becomes of the rain after it falls. The water that sinks into the ground passes for greatly varying distances beneath the surface before reappearing, and is thus drawn off gradually from the forested watershed and supplies the brooks with pure water relatively free from detritus."

B. E. Fernow in "Economics of Forestry" says:

"The philosophy of the influence on waterflow rests mainly upon the recognition that the rain and snow waters penetrate more reaily a forest-covered soil than one that is bared of this protective cover. The action here is of a threefold nature; first, the mechanical obstruction which the foliage offers reduces the amount of the water which reaches the soil and lengthens the time during which it can do so; the foliage, together with the loose litter of the forest floor, also reduces the compacting effect of the raindrops and the drying effect of sun and wind, and keeps the soil granular, so that the water can easily percolate; then the mechanical obstruction which the litter, underbrush, and trunks, and possibly here and there moss, offer to the rapid surface drainage of waters, lengthens the time during which this percolation may take place; and thirdly, the network of deeply penetrating roots, live and decayed, offers additional channels for a change of surface drainage into subdrainage. * * * Particular interest in this connection attaches to the influence of forest cover on the melting of snow masses, which gives rise to spring floods. In the dense forest, the snow in usually less deep, a part being intercepted by the crowns of trees and evaporated, and lies more uniformly, owing to the absence of drifting winds. It is a well-noted experience that it will lie in the shade of the woods from one to two weeks longer, i. e. melt so much more slowly. These elements of distribution in space and time must have an influence upon the

rapidity of surface flow, and it the soil is not frozen, time is given for precolation and gradual removal. * * * This forest effect on the run-off of terrestrial waters is naturally greatest and most important in mountainous regions, where the water has the tendency to collect quickly, and to be carried off rapidly, but it also exists in the level plain, where it has the tendency to elevate the general ground-water level and thereby make a reserve available during times of drouth."

The few following examples are given as showing the effect of forest cover on stream flow:

"Mr. W. B. Greeley of the U. S. Forest Service made a careful investigation of two streams in the Catskills. One, Esopus Creek, was well timbered, having not more than 15 per cent of cleared land upon its basin. The Walkill has 85 per cent. of cleared land and the remaining forest cover was confined to small scattered wood lots, but its topography was such that there could be water storage by natural reservoirs. The difference in the two streams were as follows:

1. The slope of the Esopus basins are twice as steep as those of the Walkill.

2. The fall of the Esopus is six times as rapid as that of the Walkill.

3. The topography of the Esopus basin is much more simple and direct than that of the Walkill.

4. The Esopus has no natural reservoirs, whereas a relatively large percentage of the Walkill basin consists of swamps and ponds.

The question was whether forest cover on the one hand or moderate topography, extensive natural reservoirs, and favorable geological conditions on the other exert the greatest relative influence in storing precipation and equalizing stream discharge.

It was fould that the combined influence of the moderate topography, natural reservoirs, and favorable geological conditions of the Walkill is somewhat stronger in promoting evenness of stream flow than the compact forest cover of the Esopus basin.

At the same time the margin of difference between the regularity of the two streams is so small as to establish beyond doubt that the forest cover of the Esopus does exert a strong

conserving and regulating influence upon the flow of that stream. This is especially true when we recall how unfavorable the other factors of topography and geology upon that catchment area are to equable stream flow. The forest cover of the Esopus thus appears to overcome to a large degree the unfavorable effects of steep topography, hard and dense surface rocks, and marked deficiency in natural storage facilities. It reduces the flow of that mountain stream to a regularity almost equal to that of a lowland type of stream where exactly opposite topography conditions prevail."

Mr. C. C. Vermeule in the report of the State Geologist for New Jersey for 1895 says:

"It is a matter of common observation that at such times rivers continue to flow when rainfall is very much less than the evaporation, and indeed, for long periods when there is no rainfall at all. Anything which tends to increase this amount of water held in the ground, and to regulate its discharge into the streams, tends to give a larger flow, and to shorten the periods of very low water in the streams during droughts, and with this increased capacity of the ground to absorb rain comes also less frequent floods. The more water that is drained out from the soil the more can be absorbed when the heavy rains come at the end of the droughts. Humus in the forest forms a great sponge, and of itself holds a large amount of water, while it and the inequalities caused by tree roots, etc., tend to prevent the water flowing over the surface and the roots of the trees provide channels by which the water percolates into the sub-soil readily. In this way the forest will easily absorb a larger amount of water than open lands. A high state of cultivation also has a tendency to increase the capacity of the ground to absorb water because of constant loosening of the surface and the facilities provided for ready drainage. In this way cultivation, like forests, tends to render floods less frequent, but the effect of the drainage of the soil is that the ground water absorbed is fed out more rapidly to the streams during the early months of a dry period than is the case in forests; consequently, the ground water is sooner exhausted, and the duration of the low stages of the rivers during protracted droughts is thereby lengthened. Barren watersheds offer much less capacity for absorption of rainfall.

There is no humus or other matter on the surface to retain the rain, and the ground becomes hard and resists free percolation. The difference between forested and deforested watersheds is very well illustrated by the Passaic and the Raritan respectively, while some of our small red sandstone watersheds are good types of barren country.

We have, in the following table, contrasted these types, the data being obtained from the Report on Water Supply. This table shows in inches of rainfall the amount of water which would flow off to the several streams from their watersheds for each month, during a drought of such a character that all conditions from rainfall, or depletions from evaporation, to the ground water are suspended, the water here shown being entirely water of drainage.

YIELD OF SPRINGS ON VARIOUS TYPES OF WATER SHEDS DURING DROUGHT, IN INCHES OF RAINFALL.

Month	Passaic type of forest watershed	Raritan type of highly cultivated watershed	Type of barren watershed
First	1.16	1.43	.94
Second	.54	.64	.33
Third	.40	.45	.26
Fourth	.33	.35	.20
Fifth	.32	.30	.14
Sixth	.31	.27	.12
Seventh	.30	.25	.10
Eighth	.29	.23	.08
Ninth	.28	.22	.07
Total	3.93	4.14	2.29

It will be observed that while the Raritan and the Passaic show nearly the same total amount of drainage, the Raritan gives up this water faster in the early months, and therefore its springs become sooner exhausted and it runs lower toward the last of the drought. The barren ground, having absorbed much less water, has less flow from springs throughout. How important this is upon the dry season flow of these streams becomes apparent from the following table:

FLOW IN GALLONS DAILY PER SQUARE MILE DURING THE LAST EIGHT MONTHS OF THE DRIEST YEAR.

Month	Passaic forested	Raritan cultivated	Barren watershed
April	597,000	754,000	631,000
May	297,000	325,000	145,000
June	272,000	272,000	139,000
July	207,000	134,000	22,000
August	140,000	89,000	22,000
September	139,000	87,000	23,000
October	129,000	84,000	22,000
November	127,000	93,000	23,000

The conditions here shown are believed to be illustrative of the effect of forests upon stream flow, and the comparative effects of cultivation and barrenness. We have found it a rule that the heavier forested catchments furnish a steadier flow, better sustained during dry periods, and that while they are subject once in a great while to severe floods, nevertheless floods not quite so severe are less frequent than upon deforested catchments not highly cultivated. Flood-flow, it must be remembered, however, is largely a matter of topography, and while floods are heavy and frequent upon the deforested Raritan and Neshminy, the same is true of the well-forested Ramapo and Pequannock, while they are extremely light upon the lightly-wooded Pequest. The economic importance of the effect we have noted lies in the greater value of forested streams for water power, and the smaller storage reservoirs needed thereon to furnish a given daily supply of water to cities. Illustrative of this, the Passaic will furnish for 9 months of the year from 100 square miles of watershed, 45 horsepower on 10 feet fall, whereas the Raritan will furnish but 41 and the barren watershed 28 horsepower. During the other 3 months the Passaic will furnish an average of 36, the Raritan 32 and the barren watershed 20 horsepower. To collect 570,000 gallons per square mile of watershed, we shall need storage reservoirs of the following capacity: Passaic 84,000,000, Raritan 110,000,000, and the barren watersheds 126,000,000 gallons. The difference in cost of collecting a supply at the above rate per square mile,

therefore, upon the type of streams selected to represent the forested and those representing the barren conditions, would be about $8,400 per square mile. Both the Passaic and Raritan exceed 800 square miles in catchment. For this area the saving would be $6,720,000.

Taking the same area, we find the excess of water power of the forested stream would be for 100 feet fall, 1,360 horsepower, the value of which, at a rental of $35 per horsepower per annum, would be $47,600 or the interest at 5 per cent. on $952,000.

We do not advance these figures as exact measures of the value of forests, but they may be taken as indicative of the possible financial loss which might result in stream flow alone from deforesting such of our water sheds as are not adapted for cultivation.

It will also be seen how amply this effect of forests in increasing the stream-flow for 5 or 6 months during the latter part of a dry period justifies popular opinion as to a falling off of streams when the forests are cut off. Such effect is very much more likely to impress itself upon the popular mind than increase of evaporation, for this would tend to decrease the total run-off for the year without being very apparent to ordinary observation. Being a much more enduring effect, it would also be more noticeable than any change in the very greatest or least rate of discharge.

Most of the portion of the state now in forest is not adapted to cultivation. It should remain in forest, because it will in no other way yield revenue; because it is needed to maintain the equable flow of our streams, and because it renders beautiful what would otherwise be an unsightly waste. Unless the state is prepared to assume the ownership of forest lands, the continued good condition of the forests can only be secured by instructing the owners how they can improve this condition, and, at the same time, increase their revenues. It is especially important that our highlands forests, for the future gathering grounds of our city water supply, shall continue to be preserved and improved, as they undobtedly have improved during the last quarter century."

Says Mr. Charles A. Stone, of the firm of Stone & Webster, Electrical Engineers, Boston, Mass.:

"One of the most important features in the commercial development of a waterpower enterprise is the uniformity or flow of the stream on which the development is undertaken. Where streams are subject to severe drought or great floods, commercial development is practically impossible. Nature has provided for the uniformity of flow by covering the watersheds at the headwaters of these streams with forests. * * * When these forests are cut off, conditions are entirley changed, and great freshets result."

Mr. Theophilus Parsons, a representative of the manufacturing interests of New England, says:

"New England is largely dependent upon her factories run by water power. The flow of the rivers furnishing this power is growing yearly more uncertain. Both floods and droughts are more frequent. It is plenty or famine. This situation is due to the pernicious cutting of woods along the headwaters of the New England rivers.

I have known the Connecticut for over thirty-six years. It drains an area of four thousand square miles. Until recently the wooded hills kept the flow of the river even. Now, in the spring, we have floods, while in the summer the water sometimes will not run our mills.

This is a question in which every manufacturer on the eastern coast of the United States is interested."

"Snow will lie in the forest more evenly and continuously than on the open, wind-swept areas. Thereby not only the amount finally remaining for drainage is increased, but the soil is presented from freezing, and is kept open for percolation when the snow melts. The retardation of the melting has been determined by Buhler in Switzerland to be from eight to fourteen days."

Honorable Robert M. La Follette said in his message as Governor of Wisconsin in 1905:

"Probably not more than half a dozen states in the Union, are so abundantly supplied wtih natural water power as Wisconsin, and no state in the middle west is comparable to it in this respect. More than one thousand lakes, widely distributed within its borders, form natural reservoirs, furnishing sources of supply to the streams which flow through every section of the state.

We have recently undertaken, at considerable expense, the establishment of a forestry commission with a view of preserving whatever remains of the forests upon state lands not suited to agriculture, and the reforesting of these, and such other lands as can most profitably be used for that purpose. The state forestry legislation, adopted two years ago, very defective in many respects, will, it is hoped be so amended as to establish this important work upon a permanent and efficient basis. It is referred to in this connection because the preservation of our forests and the reforesting of lands about the sources and along the headwaters of our principal streams, are absolutely essential to the preservation of Wisconsin's splendid water-powers. The restoration of our forests, and the preservation of our water powers go hand in hand."

Governor James O. Davidson in his message in 1909, said:

"Our forest reserve now comprises 300,000 acres of land, situated in seventeen counties of the state. During the past two years the state has purchased, through the department, about 34,000 acres of cut-over lands, an addition to the reserves in Iron, Vilas and Onedia counties, and has entered into a contract to purchase 1,400 more acres in Vilas county. These lands, will, in time, be of great value to the state in timber produce, but their greatest value is in protecting the water powers thereon. The lands preserved by the state are not of value for agricultural purposes and have been purchased at a small outlay. The acquiring of other lands for forestry purposes, especially on or near the head waters of our streams, should be encouraged."

The governors of all the states at the White House Conference in May, 1908, adopted the following declaration of principles:

"We urge the continuation and extension of forest policies adapted to secure the husbanding and renewal of our diminishing timber supply, the prevention of soil erosion, the protection of headwaters, and the maintenance of the purity and navigability of our streams. We recognize that the private ownership of forest lands entails responsibilities in the interests of the people and we favor the enactment of laws looking to the protection and replacement of privately owned forests.

We recognize in our waters a most valuable asset of the people

of the United States, and we recommend the enactment of laws looking to the conservation of water resources for irrigation, water supply, power and navigation, to the end that navigable and source streams may be brought under complete control and fully utilized for every purpose. We especially urge on the Federal Congress the immediate adoption of a wise, active, and through waterway policy, providing for the prompt improvement of our streams and the conservation of their watersheds required for the uses of commerce and the protection of the interests of our people."

The letter of President Roosevelt transmitting to Congress the report of the National Conservation Commission contained the following passage: "I especially commend to the Congress the facts presented by the Commission as to the relation between forests and stream flow in its bearing upon the importance of the forest lands in national ownership. Without an understanding of this intimate relation the conservation of both these natural resources must largely fail."

The North American Conservation Conference representing Canada, Mexico and the United States made a declaration of principles which contained the following:

"We recognize the forests as indispensable to civilization and public welfare. They furnish material for construction and manufacture, and promote the habitability of the earth. We regard the wise use, effective protection, especially from fire, and prompt renewal of the forests on land best adapted to such use, as a public necessity and hence a public duty devolving upon all forest owners alike, whether public, corporate or individual.

Forests are necessary to protect the sources of streams, moderate floods and equalize the flow of waters, temper the eliment and protect the soil; and we agree that all forests necessary for these purposes should be amply safeguarded. We affirm the absolute need of holding for forests, or reforesting, all lands supplying the headwaters of streams, and we therefore favor the control or acquisition of such lands for the public."

It is estimated that Wisconsin is blessed with approximately 1,000,000 horsepower in hundreds of water powers widely distributed over the state. Such a wealth of water powers which

in a few years will all be harnessed and made to convey energy to nearly every city and town, weans everything to the future of the state, providedthat reasonable, commonsense methods of stream conservation, which have been tried and long since proven in old countries, are adopted. The value of our streams for water power development will rest almost entirely upon the eveness and uniformity of their flow. Wisconsin is remarkably fortunate in having such a network of lakes and swamps at the head-waters of her important rivers, as these catch and hold the spring freshets and their capacity can be greatly enlarged by building dams. The lands draining into these lakes at the head-waters of the rivers should be included within the forest reserves and the forest growth protected.

Fortunately most of these lands are not as valuable for agricultural crops as for timber, and therefore it will not be necessary to keep forests on lands which should be made into farms.

"EXHIBIT 29"

STATEMENT OF

PROFESSOR D. W. MEAD, OF MADISON, WISCONSIN,

TO

COMMITTEE ON WATER POWERS, FORESTRY AND DRAINAGE,

OF THE WISCONSIN LEGISLATURE.

(Revised-1910)

Subjects:

Value of Water Powers.

Forests and Stream Flow.

Water Power Trust.

The Legal Phase.

State Regulation and Control.

Stream Flow Measurements.

Mr. Chairman and Gentlemen: I wish to offer a word of personal explanation. I come here at your request, to assist you in any way that I can, and give to you such benefit as I may of some 25 years of experience in the development of water resources in many of the United States in the lines of water supply, water power, drainage, and irrigation. In my practice, which has been principally that of a civil engineer, my connection with the University having only extended for some five years and my professional practice still continuing, I