4867/2
Subject: Androscoggin River, Maine and New Hampshire - Flood Control.

2nd Ind.

The Board of Engineers for Rivers and Harbors, Washington, D. C., January 20, 1938 - To the Chief of Engineers, U. S. Army.

1. The Board concurs with the division engineer in recommending a survey to determine the advisability and cost of improvement and the local cooperation required.

For the Board:

H. A. Wheeler,
Lieutenant Colonel, Corps of Engineers,
Resident Member.

F.D. 7402(Androscoggin River, Maine)15,
15/1 and Ser. 17 accompg.

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E.D. 7402(Androscoggin River, Maine)15,
15/1 and Ser. 17 accompg.

WAR DEPARTMENT
Office of Division Engineer
North Atlantic Division
14th Floor - Maritime Exchange Bldg.
80 Broad Street
New York, N. Y.

Androscoggin R. 2/3.7 August 25, 1937.

Subject: Review Report - Androscoggin River, Maine.

To: The Chief of Engineers, U. S. Army.

## SYLLABUS

The Division Engineer finds that no revision is required of the conclusions and recommendations contained in House Document No. 646, Seventy-first Congress, 3d session. Improvement of the Androscoggin River for navigation is unwarranted. Irrigation is unnecessary. The river is well adapted to power production. Existing power development is extensive and ample for present needs. The control of floods by reservoirs, local protection and channel improvements is possible, but not economically justified at the present time. Reservoir studies indicate the advantage of a four-reservoir system for combined flood control and power purposes. The future economic justification of this plan is possible.

- - - - - - - - - -

1. AUTHORITY - This report is submitted pursuant to the following authority:

(a) "RESOLVED, By the Committee on Flood Control of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors, created under section 3 of the river and harbor act, approved June 13, 1902, be, and is hereby requested to report to this Committee at the earliest practicable date, the results of the additional studies and investigations made on the Androscoggin River, to take into account important changes in economic factors, additional stream flow records, or factual data developed as a result of the recent severe flood, with a view to revising the report on this river printed as House Document No. 646, Seventy-first Congress, 3d session;" (adopted March 27, 1936).

(b) "RESOLVED BY THE COMMITTEE ON COMMERCE OF THE UNITED STATES SENATE, That the Board of Engineers for Rivers and Harbors created under section 3 of the River and Harbor Act approved June 13, 1902, be and is hereby requested to review the report on Androscoggin River, Maine, submitted in House Document No. 646, Seventy-first Congress, 3d session, with a view to determining whether any modification of the recommendations contained therein is deemed advisable as a result of the recent severe floods;" (adopted March 28, 1936).

2. PRIOR REPORT - The report under review on the Androscoggin River, submitted under the provisions of House Document No. 308, Sixty-ninth Congress, 1st session, was published as House Document No. 646, Seventy-first Congress, 3d session. This report considered navigation, flood control, power development, and irrigation. It concluded that no development for these purposes was economically advisable, and recommended that there be no Federal participation in any works of improvement with a view to modifying the existing conditions.

3. PROJECTS - There have been no previous projects and there are no existing Federal projects on the Androscoggin River.

4. DESCRIPTION - The watershed of the Androscoggin River lies principally in western Maine with part of the headwater area, comprising about 20 per cent of the total, lying in New Hampshire. The basin has a length of 110 miles, maximum width of 55 miles, and a total area of 3,470 square miles.

5. The river rises at the Canadian border near the boundary between the states of Maine and New Hampshire, flows in a southerly direction for about 75 miles, then flows east for about 70 miles into the State of Maine, then flows generally south for 60 miles to tidewater at Brunswick, Maine. The mouth of the river is its outlet into the west end of Merrymeeting Bay, a tidal basin through the eastern portion of which the Kennebec River flows. The total length of the river is about 200 miles.

6. The principal tributaries of the Androscoggin River are the Magalloway, Swift, Webb, Dead, Nezinscot, and Little Androscoggin Rivers. The largest of these is the Magalloway which has a drainage area of 500 square miles.

7. A total of 143 square miles of the drainage area is occupied by lakes and ponds which exercise complete or partial control over approximately 1,400 square miles, or 40 per cent of the entire basin area.

8. In general elevation, the Androscoggin watershed is higher than that of any other eastern river in the United States. In the 167 miles from Umbagog Lake, which is 1,244 feet above sea level, to tidewater the fall averages nearly 7.5 feet per mile. The maximum fall is more than 100 feet per mile in a reach 1.7 miles long at Rumford, Maine.

9. The upper portions of the basin are mountainous, almost entirely covered by forests, and contain comparatively few settlements, most of which are located close to the streams. Along the lower portion of the river there is a considerable volume of manufacturing of cotton goods, pulp, and paper. The lower portion of the basin is, however, mainly hilly and wooded with some cultivated areas.

10. According to the census of 1930, the total population of the basin was nearly 150,000, approximately 124,000 in Maine and 26,000 in New Hampshire. The largest cities in the Maine portion of the watershed are Lewiston, Auburn, Rumford, Brunswick, and Lisbon, with a total population of 73,842. The largest is Lewiston with a population of 34,939. The principal city in the New Hampshire portion of the watershed is Berlin with a population of 20,018.

11. HYDROLOGY - The Androscoggin watershed is characterized by frequent, but short, periods of heavy precipitation rather uniformly distributed throughout the year. The probability of torrential rains is somewhat higher for the month of September, coinciding with the season of coastwise hurricanes from the tropics. The mean annual temperature is about 42.7 degrees Fahrenheit. A heavy annual snowfall, varying from about 77 inches on the coast to about 130 inches on the northern headwaters, results from the sustained low winter temperatures. The average annual precipitation, including water equivalent of the snowfall, is about 39.4 inches. Mean annual run-off is about 22.65 inches, or about 58 per cent of the precipitation.

12. Floods on the Androscoggin may be the result of heavy precipitation from extratropical cyclones. These may pass over the watershed at any time of the year. Floods also may result from the rapid run-off from snow melted by sudden increases in temperature or by heavy rainfall. Tropical cyclones, or hurricanes, may also reach the watershed and bring intense rainfall. These storms occur only in the summer and early fall. At this time ground conditions are usually such that much of the rainfall is absorbed and large floods do not often result.

13. Studies show that rare floods may have peak discharges approaching 90,000 c.f.s. at Rumford. The flood of March, 1936, the greatest of record on the Androscoggin River, reached a peak discharge of 74,000 c.f.s. at Rumford and 135,000 at Auburn, Maine. This flood resulted from a favorable combination of thawing temperatures, more than average depth of snow cover, and heavy precipitation. During the preceding three-month period, snowfall had exceeded the average and temperatures had been less than normal so that by March the watershed was under a deep snow cover which had not been appreciably depleted before the March storms. These storms came from the Gulf of Mexico and passed up the Atlantic seaboard with a northward movement of tropical air masses. The cooling of this moist air mass by the snow-covered surface of the watershed resulted in heavy precipitation and rapid melting of snow cover. These conditions caused a large volume of run-off.

14. NAVIGATION - No improvement of the Androscoggin River in the interests of navigation has ever been undertaken by the United States. Present depths in the tidal portion of the river are not known, but it is probable however that the controlling depth to Brunswick is not greater than the three feet indicated by a survey in 1881. The conclusions of the report under review were that any extension of navigation through or above tidewater would not be economically advisable. New developments which would require revision of these conclusions have not taken place, nor is there any reason or demand for improving the tidal portion of the river below Brunswick. Navigation could be extended above Brunswick only at high cost by means of locks and dams where necessary. Above Lewiston and Auburn there are no towns of commercial importance to be benefited if navigation were extended, and the tributary districts are largely undeveloped. Transportation by railroad and highway is adequate for the present needs.

15. IRRIGATION - The cultivated areas in the valley are small and the rainfall varies from 44 inches near the coast to 33 inches in the northern portion of the basin. This rainfall is ample for existing and prospective agricultural needs, and irrigation is unnecessary.

16. POWER DEVELOPMENT - The Androscoggin River is highly developed for power generation. With a total drainage area equal to 10.5 per cent of the area of the State of Maine, the installed generating capacity is 45 per cent of the total for the entire state. There are within the basin 53 water power develop-

ments of more than 100 horsepower each, which have a total installed generating capacity of nearly 248,000 horsepower. This is considerably in excess of present requirements, and most of the plants have the equipment and water available to furnish a large additional amount of electric power at little increase in operating costs. If this surplus power could be sold, it would materially reduce the unit cost of production.

17. INCIDENTAL FLOOD CONTROL FROM EXISTING POWER STORAGE RESERVOIRS - The total existing storage in the basin amounts to 738,000 acre-feet, equivalent to 213 acre-feet per square mile of drainage area. This storage exercises a degree of control over 1,400 square miles or 40 per cent of the entire drainage basin. It consists largely of natural lakes at the outlets of which control works have been built. These are under the jurisdiction of the power interests and are operated to impound spring run-off for release later during the low flow periods. These lakes are situated principally in the upper portion of the basin and while they ameliorate flood flows, their effect is insufficient to prevent damaging floods in the more populous lower reaches of the basin.

18. FLOOD LOSSES - The amount of damages caused by the flood of 1936 was found by census of the individual sufferers to be about $3,574,000, of which $2,756,000 represents the loss due to direct damage and $818,000 to indirect damage. Of the total loss that suffered in the Maine portion of the watershed amounted to about $3,419,000, and that in the New Hampshire portion to about $155,000. In order to take into account the indirect damages unreported but known to exist, the reported amount of indirect damages ($818,000) was doubled in computing flood control benefits. The average annual damage computed from stage versus frequency curves and stage versus damage curves was found to be $453,500.

19. POSSIBLE METHODS OF FLOOD CONTROL - It was found that some degree of reduction of flood losses may be effected by removal of artificial obstructions such as dams, bridges, and buildings. In no instance was it found that the lessening of flood damages was sufficient to warrant removal for flood control purposes alone. State authority could eliminate these flood hazards at some future date when replacement becomes necessary as a result of the natural course of events.

20. The control of floods at the principal damage centers by means of levees and river walls was studied. This method of protection is positive up to the height of levee or river wall provided. Its influence is entirely local and provides no incidental benefits such as would result from control by reservoirs. No instance was found where full protection by levees was economically justified. Under a coordinated flood control plan some local protection would be involved after the reduction in flood heights effected by the extent of reservoir control adopted.

21. Control of floods on the Androscoggin River by means of reservoirs was indicated as the most desirable method. Study was made to locate all sites suitable for construction of dams of sufficient height to control a flood run-off equal in volume to that of the 1936 flood. Eliminations were made on the basis of size of drainage area controlled, characteristics of run-off from the area, location with respect to flood damage centers, cost of construction, and value of benefits accruing from the measure of flood control afforded.

22. PRACTICABILITY OF PROVIDING FLOOD CONTROL WORKS -

In the following economic discussion, interest rates of 5 per cent on non-Federal investments and 4 per cent on Federal investments have been used in computing the annual costs of the proposed works.

a. Local protection from floods can be accomplished by specific treatment at the various localities. The result of investigation shows however that the ratio of benefits to costs varies from 0.037 to 0.590 depending upon the locality. It was concluded that this method of protection is not economically advisable at the present time.

b. General control of floods by means of a system of four reservoirs, or a lesser number selected therefrom, was found to be uneconomical. The most advantageous reservoir plan is composed of Rumford on the main stream, Dixfield on the Webb River, Buckfield on the Nezinscot River, and Oxford on the Little Androscoggin River. Considered on a basis of benefits to flood control only, this reservoir combination has annual benefits of $374,100. The annual carrying charges are $1,000,000 and the ratio of benefits to charges is 0.37. The total first cost of this four-reservoir combination is $17,795,000. They would provide 468,300 acre-feet of storage, and would control 2,602 square miles of drainage area or 74 per cent of the entire basin. This includes the 1,100 square miles upstream from the proposed Rumford reservoir which are partially controlled by 688,000 acre-feet of existing power storage.

c. A three-reservoir system of the reservoirs at Rumford, Dixfield, and Buckfield shows annual benefits to flood control of $359,200. The first cost for this system is $14,101,000 for which the annual carrying charges are $793,000. Ratio of annual benefits to annual charges is computed as 0.45. This system would provide 396,300 acre-feet of storage and control 2,371 square miles, including 1,100 square miles partially controlled by existing storage.

d. The Rumford reservoir alone, estimated to have a first cost of $11,162,000, shows annual flood control benefits of $322,700 and annual carrying charges of $626,000, a ratio of benefits to charges of 0.52. This reservoir would provide 295,000 acre-feet and control 2,090 square miles, inclusive of 1,100 square miles now largely controlled by power storage.

23. The Rumford reservoir is the only one which shows economic possibilities for a development to provide combined storage for flood control and power. Assuming that there existed a demand sufficient to absorb the power that could be generated at existing and potential downstream plants from the increased flow, the value of combined benefits to flood control and power resulting from operation of Rumford reservoir was found to be $862,700. The first cost of the combined flood control and power reservoir is estimated at $16,063,000, and carrying charges are computed to be $1,124,000. The ratio of annual benefits to annual charges is 0.77.

24. VIEWS AND RECOMMENDATION OF THE DISTRICT ENGINEER - In connection with the review of the "308" Report under consideration, the District Engineer states that extension of navigation through or above tidewater would not be economically advisable at the present time. Irrigation is not necessary. The supply of power is ample for present demand, and further development of hydro-electric power is improbable in the immediate future. Additional reservoirs of large capacity for flood control alone or for the combined development of flood control and power do not appear to be economically justified at present. At some future time the economic justification of one or more of the proposed reservoirs may result because of increased demand for power. The future justification of flood control reservoirs alone cannot be foreseen. Additional power conservation storage, of sufficient capacity to impound the large spring floods, to produce power at the site, and to involve operation to supply incidental benefits to downstream power developments during the off-flood-peak seasons, would increase the measure of incidental flood control already existing.

25. VIEWS OF THE DIVISION ENGINEER - The Division Engineer concurs with the views and recommendations of the report under review, which are substantially repeated in the views and recommendations of the District Engineer in the preceding paragraph. The Androscoggin basin suffered serious damage during the unprecedented flood of March 1936. The existing storage of 738,000 acre-feet exercises a degree of control over 1,400 square miles or 40 per cent

of the basin, resulting in considerable reduction of flood stages. Annual benefits, resulting from the proposed additional flood control plan, do not warrant Federal participation in such improvement at the present time under existing law. Future justification of the additional flood control plan is possible.

26. CONCLUSION -

a. No improvement of the Androscoggin River for navigation, power development, flood control, or irrigation is economically advisable at the present time.

b. It is recommended that this report be not published at this time due to investigations under the Flood Control Act of 1936 which are now under way.

E. L. DALEY,
Colonel, Corps of Engineers,
Division Engineer.

Incl. accpg.:
2/3.4, in tripl.

COPY of 1/258 Androscoggin

WAR DEPARTMENT
Office of Division Engineer
North Atlantic Division
14th Floor - Maritime Exchange Bldg.
80 Broad Street
New York, N. Y.

Androscoggin R. 2/3.7 August 25, 1937.

Subject: Review Report - Androscoggin River, Maine.

To: The Chief of Engineers, U. S. Army.

## SYLLABUS

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1. AUTHORITY - This report is submitted pursuant to the following authority:

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23. The Rumford reservoir is the only one which shows economic possibilities for a development to provide combined storage for flood control and power. Assuming that there existed a demand sufficient to absorb the power that could be generated at existing and potential downstream plants from the increased flow, the value of combined benefits to flood control and power resulting from operation of Rumford reservoir was found to be $862,700. The first cost of the combined flood control and power reservoir is estimated at $16,063,000, and carrying charges are computed to be $1,124,000. The ratio of annual benefits to annual charges is 0.77.

24. VIEWS AND RECOMMENDATION OF THE DISTRICT ENGINEER - In connection with the review of the "308" Report under consideration, the District Engineer states that extension of navigation through or above tidewater would not be economically advisable at the present time. Irrigation is not necessary. The supply of power is ample for present demand, and further development of hydro-electric power is improbable in the immediate future. Additional reservoirs of large capacity for flood control alone or for the combined development of flood control and power do not appear to be economically justified at present. At some future time the economic justification of one or more of the proposed reservoirs may result because of increased demand for power. The future justification of flood control reservoirs alone cannot be foreseen. Additional power conservation storage, of sufficient capacity to impound the large spring floods, to produce power at the site, and to involve operation to supply incidental benefits to downstream power developments during the off-flood-peak seasons, would increase the measure of incidental flood control already existing.

25. VIEWS OF THE DIVISION ENGINEER - The Division Engineer concurs with the views and recommendations of the report under review, which are substantially repeated in the views and recommendations of the District Engineer in the preceding paragraph. The Androscoggin basin suffered serious damage during the unprecedented flood of March 1936. The existing storage of 738,000 acre-feet exercises a degree of control over 1,400 square miles or 40 per cent

of the basin, resulting in considerable reduction of flood stages. Annual benefits, resulting from the proposed additional flood control plan, do not warrant Federal participation in such improvement at the present time under existing law. Future justification of the additional flood control plan is possible.

26. CONCLUSION -

a. No improvement of the Androscoggin River for navigation, power development, flood control, or irrigation is economically advisable at the present time.

b. It is recommended that this report be not published at this time due to investigations under the Flood Control Act of 1936 which are now under way.

E. L. DALEY,
Colonel, Corps of Engineers,
Division Engineer.

Incl. accpg.:
2/3.4, in tripl.

WAR DEPARTMENT
Office of Division Engineer
North Atlantic Division
14th Floor - Maritime Exchange Bldg.
80 Broad Street
New York, N. Y.

Androscoggin R. 2/3.7 August 25, 1937.

Subject: Review Report - Androscoggin River, Maine.

To: The Chief of Engineers, U. S. Army.

## SYLLABUS

The Division Engineer finds that no revision is required of the conclusions and recommendations contained in House Document No. 646, Seventy-first Congress, 3d session. Improvement of the Androscoggin River for navigation is unwarranted. Irrigation is unnecessary. The river is well adapted to power production. Existing power development is extensive and ample for present needs. The control of floods by reservoirs, local protection and channel improvements is possible, but not economically justified at the present time. Reservoir studies indicate the advantage of a four-reservoir system for combined flood control and power purposes. The future economic justification of this plan is possible.

- - - - - - - - - - -

1. AUTHORITY - This report is submitted pursuant to the following authority:

(a) "RESOLVED, By the Committee on Flood Control of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors, created under section 3 of the river and harbor act, approved June 13, 1902, be, and is hereby requested to report to this Committee at the earliest practicable date, the results of the additional studies and investigations made on the Androscoggin River, to take into account important changes in economic factors, additional stream flow records, or factual data developed as a result of the recent severe flood, with a view to revising the report on this river printed as House Document No. 646, Seventy-first Congress, 3d session;" (adopted March 27, 1936).

(b) "RESOLVED BY THE COMMITTEE ON COMMERCE OF THE UNITED STATES SENATE, That the Board of Engineers for Rivers and Harbors created under section 3 of the River and Harbor Act approved June 13, 1902, be and is hereby requested to review the report on Androscoggin River, Maine, submitted in House Document No. 646, Seventy-first Congress, 3d session, with a view to determining whether any modification of the recommendations contained therein is deemed advisable as a result of the recent severe floods;" (adopted March 26, 1936).

2. PRIOR REPORT - The report under review on the Androscoggin River, submitted under the provisions of House Document No. 308, Sixty-ninth Congress, 1st session, was published as House Document No. 646, Seventy-first Congress, 3d session. This report considered navigation, flood control, power development, and irrigation. It concluded that no development for these purposes was economically advisable, and recommended that there be no Federal participation in any works of improvement with a view to modifying the existing conditions.

3. PROJECTS - There have been no previous projects and there are no existing Federal projects on the Androscoggin River.

4. DESCRIPTION - The watershed of the Androscoggin River lies principally in western Maine with part of the headwater area, comprising about 20 per cent of the total, lying in New Hampshire. The basin has a length of 110 miles, maximum width of 55 miles, and a total area of 3,470 square miles.

5. The river rises at the Canadian border near the boundary between the states of Maine and New Hampshire, flows in a southerly direction for about 75 miles, then flows east for about 70 miles into the State of Maine, then flows generally south for 60 miles to tidewater at Brunswick, Maine. The mouth of the river is its outlet into the west end of Merrymeeting Bay, a tidal basin through the eastern portion of which the Kennebec River flows. The total length of the river is about 200 miles.

6. The principal tributaries of the Androscoggin River are the Magalloway, Swift, Webb, Dead, Nezinscot, and Little Androscoggin Rivers. The largest of these is the Magalloway which has a drainage area of 500 square miles.

7. A total of 143 square miles of the drainage area is occupied by lakes and ponds which exercise complete or partial control over approximately 1,400 square miles, or 40 per cent of the entire basin area.

8. In general elevation, the Androscoggin watershed is higher than that of any other eastern river in the United States. In the 167 miles from Umbagog Lake, which is 1,244 feet above sea level, to tidewater the fall averages nearly 7.5 feet per mile. The maximum fall is more than 100 feet per mile in a reach 1.7 miles long at Rumford, Maine.

9. The upper portions of the basin are mountainous, almost entirely covered by forests, and contain comparatively few settlements, most of which are located close to the streams. Along the lower portion of the river there is a considerable volume of manufacturing of cotton goods, pulp, and paper. The lower portion of the basin is, however, mainly hilly and wooded with some cultivated areas.

10. According to the census of 1930, the total population of the basin was nearly 150,000, approximately 124,000 in Maine and 26,000 in New Hampshire. The largest cities in the Maine portion of the watershed are Lewiston, Auburn, Rumford, Brunswick, and Lisbon, with a total population of 73,842. The largest is Lewiston with a population of 34,939. The principal city in the New Hampshire portion of the watershed is Berlin with a population of 20,015.

11. HYDROLOGY - The Androscoggin watershed is characterized by frequent, but short, periods of heavy precipitation rather uniformly distributed throughout the year. The probability of torrential rains is somewhat higher for the month of September, coinciding with the season of coastwise hurricanes from the tropics. The mean annual temperature is about 42.7 degrees Fahrenheit. A heavy annual snowfall, varying from about 77 inches on the coast to about 130 inches on the northern headwaters, results from the sustained low winter temperatures. The average annual precipitation, including water equivalent of the snowfall, is about 39.4 inches. Mean annual run-off is about 22.65 inches, or about 56 per cent of the precipitation.

12. Floods on the Androscoggin may be the result of heavy precipitation from extratropical cyclones. These may pass over the watershed at any time of the year. Floods also may result from the rapid run-off from snow melted by sudden increases in temperature or by heavy rainfall. Tropical cyclones, or hurricanes, may also reach the watershed and bring intense rainfall. These storms occur only in the summer and early fall. At this time ground conditions are usually such that much of the rainfall is absorbed and large floods do not often result.

13. Studies show that rare floods may have peak discharges approaching 90,000 c.f.s. at Rumford. The flood of March, 1936, the greatest of record on the Androscoggin River, reached a peak discharge of 74,000 c.f.s. at Rumford and 135,000 at Auburn, Maine. This flood resulted from a favorable combination of thawing temperatures, more than average depth of snow cover, and heavy precipitation. During the preceding three-month period, snowfall had exceeded the average and temperatures had been less than normal so that by March the watershed was under a deep snow cover which had not been appreciably depleted before the March storms. These storms came from the Gulf of Mexico and passed up the Atlantic seaboard with a northward movement of tropical air masses. The cooling of this moist air mass by the snow-covered surface of the watershed resulted in heavy precipitation and rapid melting of snow cover. These conditions caused a large volume of run-off.

14. NAVIGATION - No improvement of the Androscoggin River in the interests of navigation has ever been undertaken by the United States. Present depths in the tidal portion of the river are not known, but it is probable however that the controlling depth to Brunswick is not greater than the three feet indicated by a survey in 1881. The conclusions of the report under review were that any extension of navigation through or above tidewater would not be economically advisable. New developments which would require revision of these conclusions have not taken place, nor is there any reason or demand for improving the tidal portion of the river below Brunswick. Navigation could be extended above Brunswick only at high cost by means of locks and dams where necessary. Above Lewiston and Auburn there are no towns of commercial importance to be benefited if navigation were extended, and the tributary districts are largely undeveloped. Transportation by railroad and highway is adequate for the present needs.

15. IRRIGATION - The cultivated areas in the valley are small and the rainfall varies from 44 inches near the coast to 33 inches in the northern portion of the basin. This rainfall is ample for existing and prospective agricultural needs, and irrigation is unnecessary.

16. POWER DEVELOPMENT - The Androscoggin River is highly developed for power generation. With a total drainage area equal to 10.5 per cent of the area of the State of Maine, the installed generating capacity is 45 per cent of the total for the entire state. There are within the basin 53 water power develop-

ments of more than 100 horsepower each, which have a total installed generating capacity of nearly 248,000 horsepower. This is considerably in excess of present requirements, and most of the plants have the equipment and water available to furnish a large additional amount of electric power at little increase in operating costs. If this surplus power could be sold, it would materially reduce the unit cost of production.

17. INCIDENTAL FLOOD CONTROL FROM EXISTING POWER STORAGE RESERVOIRS - The total existing storage in the basin amounts to 738,000 acre-feet, equivalent to 213 acre-feet per square mile of drainage area. This storage exercises a degree of control over 1,400 square miles or 40 per cent of the entire drainage basin. It consists largely of natural lakes at the outlets of which control works have been built. These are under the jurisdiction of the power interests and are operated to impound spring run-off for release later during the low flow periods. These lakes are situated principally in the upper portion of the basin and while they ameliorate flood flows, their effect is insufficient to prevent damaging floods in the more populous lower reaches of the basin.

18. FLOOD LOSSES - The amount of damages caused by the flood of 1936 was found by census of the individual sufferers to be about $3,574,000, of which $2,756,000 represents the loss due to direct damage and $818,000 to indirect damage. Of the total loss that suffered in the Maine portion of the watershed amounted to about $3,419,000, and that in the New Hampshire portion to about $155,000. In order to take into account the indirect damages unreported but known to exist, the reported amount of indirect damages ($818,000) was doubled in computing flood control benefits. The average annual damage computed from stage versus frequency curves and stage versus damage curves was found to be $453,500.

19. POSSIBLE METHODS OF FLOOD CONTROL - It was found that some degree of reduction of flood losses may be effected by removal of artificial obstructions such as dams, bridges, and buildings. In no instance was it found that the lessening of flood damages was sufficient to warrant removal for flood control purposes alone. State authority could eliminate these flood hazards at some future date when replacement becomes necessary as a result of the natural course of events.

20. The control of floods at the principal damage centers by means of levees and river walls was studied. This method of protection is positive up to the height of levee or river wall provided. Its influence is entirely local and provides no incidental benefits such as would result from control by reservoirs. No instance was found where full protection by levees was economically justified. Under a coordinated flood control plan some local protection would be involved after the reduction in flood heights effected by the extent of reservoir control adopted.

21. Control of floods on the Androscoggin River by means of reservoirs was indicated as the most desirable method. Study was made to locate all sites suitable for construction of dams of sufficient height to control a flood run-off equal in volume to that of the 1936 flood. Eliminations were made on the basis of size of drainage area controlled, characteristics of run-off from the area, location with respect to flood damage centers, cost of construction, and value of benefits accruing from the measure of flood control afforded.

22. PRACTICABILITY OF PROVIDING FLOOD CONTROL WORKS -

In the following economic discussion, interest rates of 5 per cent on non-Federal investments and 4 per cent on Federal investments have been used in computing the annual costs of the proposed works.

a. Local protection from floods can be accomplished by specific treatment at the various localities. The result of investigation shows however that the ratio of benefits to costs varies from 0.037 to 0.590 depending upon the locality. It was concluded that this method of protection is not economically advisable at the present time.

b. General control of floods by means of a system of four reservoirs, or a lesser number selected therefrom, was found to be uneconomical. The most advantageous reservoir plan is composed of Rumford on the main stream, Dixfield on the Webb River, Buckfield on the Nezinscot River, and Oxford on the Little Androscoggin River. Considered on a basis of benefits to flood control only, this reservoir combination has annual benefits of $374,100. The annual carrying charges are $1,000,000 and the ratio of benefits to charges is 0.37. The total first cost of this four-reservoir combination is $17,795,000. They would provide 488,300 acre-feet of storage, and would control 2,602 square miles of drainage area or 74 per cent of the entire basin. This includes the 1,100 square miles upstream from the proposed Rumford reservoir which are partially controlled by 688,000 acre-feet of existing power storage.

c. A three-reservoir system of the reservoirs at Rumford, Dixfield, and Buckfield shows annual benefits to flood control of $359,200. The first cost for this system is $14,101,000 for which the annual carrying charges are $793,000. Ratio of annual benefits to annual charges is computed as 0.45. This system would provide 396,300 acre-feet of storage and control 2,371 square miles, including 1,100 square miles partially controlled by existing storage.

d. The Rumford reservoir alone, estimated to have a first cost of $11,162,000, shows annual flood control benefits of $322,700 and annual carrying charges of $626,000, a ratio of benefits to charges of 0.52. This reservoir would provide 295,000 acre-feet and control 2,090 square miles, inclusive of 1,100 square miles now largely controlled by power storage.

23. The Rumford reservoir is the only one which shows economic possibilities for a development to provide combined storage for flood control and power. Assuming that there existed a demand sufficient to absorb the power that could be generated at existing and potential downstream plants from the increased flow, the value of combined benefits to flood control and power resulting from operation of Rumford reservoir was found to be $862,700. The first cost of the combined flood control and power reservoir is estimated at $16,063,000, and carrying charges are computed to be $1,124,000. The ratio of annual benefits to annual charges is 0.77.

24. VIEWS AND RECOMMENDATION OF THE DISTRICT ENGINEER - In connection with the review of the "308" Report under consideration, the District Engineer states that extension of navigation through or above tidewater would not be economically advisable at the present time. Irrigation is not necessary. The supply of power is ample for present demand, and further development of hydro-electric power is improbable in the immediate future. Additional reservoirs of large capacity for flood control alone or for the combined development of flood control and power do not appear to be economically justified at present. At some future time the economic justification of one or more of the proposed reservoirs may result because of increased demand for power. The future justification of flood control reservoirs alone cannot be foreseen. Additional power conservation storage, of sufficient capacity to impound the large spring floods, to produce power at the site, and to involve operation to supply incidental benefits to downstream power developments during the off-flood-peak seasons, would increase the measure of incidental flood control already existing.

25. VIEWS OF THE DIVISION ENGINEER - The Division Engineer concurs with the views and recommendations of the report under review, which are substantially repeated in the views and recommendations of the District Engineer in the preceding paragraph. The Androscoggin basin suffered serious damage during the unprecedented flood of March 1936. The existing storage of 738,000 acre-feet exercises a degree of control over 1,400 square miles or 40 per cent

of the basin, resulting in considerable reduction of flood stages. Annual benefits, resulting from the proposed additional flood control plan, do not warrant Federal participation in such improvement at the present time under existing law. Future justification of the additional flood control plan is possible.

26. CONCLUSION -

a. No improvement of the Androscoggin River for navigation, power development, flood control, or irrigation is economically advisable at the present time.

b. It is recommended that this report be not published at this time due to investigations under the Flood Control Act of 1936 which are now under way.

E. L. DALEY,
Colonel, Corps of Engineers,
Division Engineer.

Incl. accpg.:
2/3.4, in tripl.

PRELIMINARY EXAMINATION OF THE ANDROSCOGGIN RIVER,

MAINE AND NEW HAMPSHIRE, FOR FLOOD CONTROL

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Syllabus

The District Engineer finds that, although the Androscoggin Basin is subject to appreciable flood losses, the annual flood damage is comparatively small and complete flood protection cannot be economically provided at the present time. General flood protection by means of levees or channel improvement is not practicable and local flood protection by these means is not justified at the present time. Reservoir control is entirely practicable, however, and it is possible that partial protection by this means may be justified. It is also possible that, if further development takes place in the valley, the need and justification for flood control may increase.

The District Engineer recommends that a survey be made to determine the extent of reservoir control which may be justified.

The District Engineer further recommends that the states be encouraged to provide regulation for the elimination of channel encroachments and for the control of existing storage and also that the flood warning and flood forecasting services of all agencies be extended and correlated through the United States Weather Bureau.

War Department
United States Engineer Office
Boston, Massachusetts

October 11, 1937

Subject: Report on a Preliminary Examination of the Androscoggin River, Maine and New Hampshire, for Flood Control

To: The Division Engineer, North Atlantic Division, New York, N.Y.

1. Authority. - This report is submitted in accordance with an Act (Public No. 512, 74th Congress) approved June 25, 1936, authorizing a "preliminary examination of the Androscoggin River, in Maine and New Hampshire, and its tributaries, with a view to control of their floods" and the Flood Control Act (Public No. 738, 74th Congress) approved June 22, 1936, which directs in part as follows:

"Section 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following-named localities, * * * * * * * * * * * Androscoggin River, Maine * * * * * * * * * * ."

2. Prior Reports. - The only prior reports made on this river pertaining to flood control are the report made under the provisions of House Document No. 308, 69th Congress, 1st Session (printed as House Document No. 646, 71st Congress, 3d Session) and the review thereof (not printed) dated December 30, 1936, which was made under the authority of resolutions of the Committee on Commerce of the United States Senate and the Committee on Flood Control of the House of Representatives.

3. Existing Project. - There are no existing or prior projects for flood control for the Androscoggin River.

4. Description of the Watershed. - The Androscoggin River Basin is located principally in western Maine, with part of the headwater area, about 20 per cent of the total, lying in New Hampshire. The basin has a length of 110 miles, a maximum width of 55 miles, and a total drainage area of 3,470 square miles. The lake and pond area, amounting to 143 square miles or 4.1 per cent of the total basin area, exercises a considerable degree of control over about 1,400 square miles, or 40 per cent of the total basin area. The topography ranges from rough and mountainous in the upper portion to broad, low hills with considerable lake and swamp area in the lower portions. The river and its tributaries follow irregular, winding courses over deep glacial overburden beneath which the pre-glacial bedrock drainage courses are completely buried. Where the bedrock is exposed or close to the surface, as it is in numerous short channel reaches in the high hills and mountains, the channel has not been incised into the rock more than 5 to 10 feet. The bedrock is predominantly granite, schist and gneiss, with occasional areas of slate and other metamorphic rock. The overburden consists mainly of gravelly, somewhat silty sands.

5. Development Within the Basin. - The total population of the basin in 1930 was about 150,000, most of which is contained in the six largest cities, all over 3,000 population, which are located on the main stream. The upper part of the basin is largely forest covered and has comparatively few settlements. In the lower half of the basin there is a large volume of manufacturing, the principal products being cotton goods, pulp and paper. The lower part of the basin has good highways and is served by the Maine Central and Grand Trunk Railroads.

6. Description of the Main River. - The Androscoggin River rises at the Canadian border near the boundary between the States of Maine and New Hampshire, in mountainous territory, at an elevation of about 2,600 to 2,900 feet above mean sea level. From Umbagog Lake, about 35 miles south of the headwaters, the river flows in a southerly direction for about 35 miles, then turns easterly into Maine for about 70 miles, and thence flows in a general southerly direction for 60 miles to tidewater at Brunswick, Maine. The main stream has an average slope over its 200-mile length of about 13 feet per mile. Much of the fall is concentrated near Berlin, New Hampshire and at Rumford, Maine. The average discharge for the 9-year period of record at Auburn, Maine, (drainage area, 3,260 square miles) is 5,420 c.f.s.; the maximum, 135,000 c.f.s.; and the minimum 465 c.f.s.

7. Tributaries. - The principal tributaries are shown in the following table:

TABLE I - TRIBUTARIES OF THE ANDROSCOGGIN RIVER

| River | Drainage Area (sq.mi.) | Location: Headwaters | Location: Mouth | Distance of Mouth from Tidewater (miles) | Discharge of Record c.f.s./sq.mi.: Max. | Min. | Mean |
|---|---|---|---|---|---|---|---|
| Magalloway | 500 | At International boundary 13 mi. W. of Big Island, Me. | Errol, N. H. | 165 | Completely regulated | | |
| Swift | 135 | 5 mi. N. of Houghton, Me. | Rumford, Me. | 82 | 136.84 | .05* | 1.87 |
| Webb | 125 | 3 mi. N.E. of Weld, Me. | Dixfield, Me. | 75 | No gaging station | | |
| Dead | 100 | 4 mi. N. of Vienna, Me. | 5 mi. N. of Leeds, Me. | 46 | No gaging station | | |
| Nezinscot | 275 | 2 mi. N.W. of Redding, Me. | 4 mi. N. E. of Turner, Me. | 38 | No gaging station | | |
| Little Androscoggin | 380 | Bryant Pond, Me. | Auburn, Me. | 24 | 46.58 | .01* | 1.83 |

* Regulated by controlled storage.

8. Development of Water Resources. - The Androscoggin River has been very highly developed for power. Of an estimated 353,000 horsepower available, 246,469 horsepower in 42 installations have been developed. Twenty-eight installations, utilizing 775 feet of head and totalling 239,873 horsepower are on the main stream and the remaining 14 installations, with 310 feet of head and totalling 6,596 horsepower, are on the tributaries. The storage capacity is equally well developed, amounting to about 740,000 acre-feet for the entire drainage area, or about 213 acre-feet per square mile. Most of this storage is contained in the large natural lakes in the upper basin which are controlled for power storage. The 1,095 square miles above Errol, New Hampshire, about 32 per cent of the total

basin area, are very completely controlled, containing 678,000 acre-feet of storage.

9. Hydrology. - The climate is variable, with temperatures ranging from below freezing for the two or three winter months to the high summer temperatures required to support a varied plant life. The mean annual precipitation of 39.4 inches is rather uniformly distributed throughout the year, but it is characterized by short, frequent periods of heavy rain. The annual snowfall is quite heavy, ranging from about 77 inches near the coast to 130 inches on the northern headwaters. Comparative data are shown in the following table:

TABLE II - MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION - ANDROSCOGGIN RIVER BASIN

| Month | Mean Temperature (°F.) | Mean Precipitation (inches) | Equivalent Run-off in Inches at Rumford, Me. (D.A. - 2090 sq.mi., or 60% of total basin) |
|---|---|---|---|
| Jan. | 16.0 | 3.03 | 1.36 |
| Feb. | 17.4 | 2.86 | 1.16 |
| Mar. | 28.6 | 3.35 | 2.07 |
| Apr. | 41.2 | 2.95 | 3.88 |
| May | 53.3 | 3.31 | 3.77 |
| June | 62.0 | 3.53 | 2.09 |
| July | 68.0 | 3.60 | 1.38 |
| Aug. | 65.2 | 3.64 | 1.24 |
| Sept. | 58.0 | 3.43 | 1.23 |
| Oct. | 47.3 | 3.24 | 1.41 |
| Nov. | 34.1 | 3.39 | 1.65 |
| Dec. | 21.3 | 3.07 | 1.41 |
| Annual | 42.7 | 39.40 | 22.65 |

10. Records of Precipitation. - There are 9 observation stations for precipitation maintained by the United States Weather Bureau in the Androscoggin watershed. The data concerning these stations are listed in the following table:

TABLE III - PRECIPITATION STATIONS - ANDROSCOGGIN RIVER BASIN

| Station | Elevation (Feet above M.S.L.) | Period of Record | Length of Record (Years) | Remarks |
|---|---|---|---|---|
| Oquossoc, Me. | 1534 | 1900-1930 | 31 | 1902,03,07,09,12-16, 30 records incomplete |
| Upper Dam, Me. | 1484 | 1886-1935 | 50 | |
| Middle Dam, Me. | 1430 | 1905-1935 | 31 | 1935 record incomplete |
| Aziscohos Dam, Me. | 1528 | 1911-1933 | 23 | 1933 record incomplete |
| Errol, N. H. | 1260 | 1885-1935 | 51 | 1929, 30, 32, 34 records incomplete |
| Milan, N. H. | 1190 | 1887-1898<br>1926-1935 | 22 | 1898, 1926 records incomplete |
| Berlin, N. H. | 1120 | 1887-1903<br>1918-1935 | 35 | |
| Rumford, Me. | 505 | 1894-1935 | 42 | |
| Lewiston, Me. | 182 | 1875-1935 | 61 | |

11. Records of Stream Flow. - There are 11 stream gaging stations in the basin maintained by the United States Geological Survey. Data concerning these stations are given in the following table:

TABLE IV - GAGING STATIONS - ANDROSCOGGIN RIVER BASIN

| Location of Gaging Station | Drainage Area (sq.mi.) | Period of Record | Discharge of Record in Cubic Feet Per Second | | |
|---|---|---|---|---|---|
| | | | Mean | Maximum | Minimum |
| **Androscoggin River** | | | | | |
| Errol, N. H. | 1090 | 1905-1923 | ** | | |
| Berlin, N. H. | 1380 | 1913-1922 | 2180 | 14,300 | * |
| Gorham, N. H. | 1390 | 1929-1936 | 2360 | 19,900 | 960* |
| Shelburne, N. H. | 1500 | 1903-1907 | - | 15,600 | * |
| Rumford, Me. | 2090 | 1892-1936 | 3460 | 74,000 | * |
| Dixfield, Me. | 2230 | 1902-1908 | 4940 | - | * |
| Gulf Island, Me. | 2860 | 1936 | - | 118,000 | 1550* |
| Auburn, Me. | 3260 | 1928-1936 | 5420 | 135,000 | 465* |
| **Magalloway River** | | | | | |
| Aziscohos Dam, N. H. | 233 | 1912-1935 | ** | | |
| **Swift River** | | | | | |
| Roxbury, Me. | 95 | 1929-1936 | 178 | 13,000 | 5 |
| **Little Androscoggin River** | | | | | |
| South Paris, Me. | 76 | 1913-1924<br>1931-1936 | 139 | 6,980 | 1 |

* Flow affected by controlled storage.
** Completely regulated.

12. Accuracy of Gaging Stations. - In general, the accuracy of the stream gaging stations in the basin is very good. The discharge is computed from the flow over dams or through gates or wheels at five of the eleven stations. Good rating curves have been developed for most of the stations for medium and high stages. The records are considered very good, except during periods of ice cover, when they are fair.

13. General Flood Situation. - About 40 per cent of the Androscoggin watershed is at least partially controlled by the natural lakes and ponds, most of which are regulated for power storage. This storage, although it does not provide positive flood control at all times, is quite effective in reducing flood stages for ordinary floods. It is not, however, generally effective for extreme floods. The extreme floods in this basin, on the other hand, are possible only from the

combination of heavy rain and melting snow, and their occurrence is comparatively infrequent. The resulting damages are confined generally to the industrial areas near the river channel in the lower portions of the watershed.

14. Types of Storms. - The storms which occur in the Androscoggin Basin may be classified into three general types as follows: (1) extratropical cyclones; (2) tropical hurricanes; and (3) rain storms caused by the rapid displacement upward of a warm air mass by a colder, denser air mass, usually accompanied by an extratropical cyclone or a tropical hurricane. Of these, the extratropical cyclones are the most numerous. They occur throughout the year and are the principal factor in providing the uniform year-round precipitation of the basin. The more severe rains are caused by the second and third types of storms. The tropical hurricanes, however, are restricted generally to the summer and early fall seasons, - a time when the ground conditions are such that much of the heavy rainfall can be absorbed without causing unusual flooding. The most dangerous storms, from a flood standpoint, are the rains caused by the movements of warm and cold air masses. Such storms may occur at any time of the year and the most severe floods in the basin are caused by this type of disturbance bringing unusual temperatures and heavy rainfall to a snow-covered basin.

15. Effect of Snow. - Recent snow surveys of storage operators in the basin indicate that there is usually an accumulated water equivalent of about 10 inches in the annual snow cover at the time of the spring "thaw" and that this cover is usually converted to run-off in one continuous period of about 10 to 15 days. Additional studies on snow run-off made by this office support these observations and lead to the conclusion that snow is usually a contributing factor to the spring floods in this basin and it may be the principal cause.

16. Effect of Ice. - Ice is also a factor in the floods which occur early in the spring. It is not always, however, of great importance. The Androscoggin River flows in a general southerly directions and normally the ice in the lower reaches softens and goes out sooner than that in the upper reaches and headwaters. On the other hand, when the spring break-up occurs early, ice jams, comprising thick, solid "blue ice", are likely to form at obstructions in the river. On these occasions serious damage may be caused by these ice jams, as during the flood of March, 1936, when a railroad bridge at Brunswick was carried out by the force of the jam.

17. Record of Past Floods. - The six highest floods of record on the Androscoggin River at Rumford, Maine (drainage area, 2,090 square miles, of which 1,096 square miles are completely controlled) were as follows:

TABLE V - RECORD FLOODS - ANDROSCOGGIN RIVER AT RUMFORD, MAINE

| Date | Average 24-Hour Discharge (c.f.s.) | Instantaneous Peak Discharge (c.f.s.) | Average Run-off for One Day in c.f.s. per sq. mile |
|---|---|---|---|
| March 19, 1936 | 68,300 | 74,000 | 32.6 |
| April 15, 1895 | 55,230 | - | 26.4 |
| November 5, 1927 | 39,100 | - | 18.7 |
| March 2, 1896 | 39,010 | - | 18.6 |
| May 18, 1893 | 38,060 | - | 18.2 |
| March 13, 1936 | 35,600 | 38,200 | 17.0 |

18. Flood Frequency. - Spring, because of the occurrence of snow run-off with or without rain, is the season of high water and floods in the Androscoggin Basin. Of all peak discharges greater than the average annual flood over the period of record from 1893 to 1936 at Rumford, one-third occurred during the month of April and two-thirds occurred during the months of March, April and May. The

computed frequency for discharges at Rumford, Maine, is as follows:

| Period | 24-Hour Discharge in c.f.s. |
|---|---|
| Once in 1 year | 20,000 |
| Once in 10 years | 38,000 |
| Once in 50 years | 54,000 |
| Once in 75 years | 59,000 |
| Once in 100 years | 62,000 |

19. Description of the Worst Flood of Record. - The March, 1936, flood in this basin was the greatest on record. The maximum discharge of 65,300 c.f.s. exceeded the highest previously recorded (in 1895) by nearly 25 per cent and the flood losses were many times greater than any previously suffered. The flood was caused by a succession of two storms within a period of 11 days. Rainfall for the 11-day period was heavy throughout the entire New England area, varying from a few inches along the coast to a maximum of about 20 inches in the White Mountains, which are the common headwaters of the Connecticut, Merrimack, Kennebec and Saco Basins, as well as the Androscoggin Basin. Four lives were lost in the Androscoggin Basin during the flood and over 1,500 families, involving about 6,000 people, were temporarily homeless. About 2,000 buildings were affected by the flood. Eighteen bridges were wholly or partially destroyed and ten additional bridges suffered some damage. Although the actual area flooded was not large, several towns were practically cut off from the outside world for from one to four days as railroad, highway, telephone and telegraph facilities were disrupted. Several towns were temporarily without light, power and water. The depth of water in the area flooded varied greatly. In the towns and cities a few principal streets were covered to depths of from one to five feet generally, although depths as great as 15 feet were reported in Brunswick, Maine.

20. Flood Damages. - The only complete data on flood damages available for this basin are those collected after the flood of March, 1936. These figures, however, are very reliable, having been obtained by means of a thorough census of the individual sufferers in the basin shortly after the flood. The results of the census are shown in the following table. Of the total damages of $4,392,000 in the basin, $4,232,000, or 96 per cent were in the State of Maine and the remainder, only 4 per cent, in New Hampshire. There is no record of the losses in 1896, but it is known that several highway bridges were washed out and that a large number of logs were carried away. In November, 1927, there were severe losses, especially at Berlin and Gorham, totalling about $400,000 plus an unestimated amount for damage to railways. The losses from all prior floods, however, were probably much less than those for March, 1936, as tabulated below:

TABLE VI - FLOOD DAMAGES - ANDROSCOGGIN RIVER BASIN - MARCH, 1936

| Class | Indirect | Direct | Total |
|---|---|---|---|
| Industrial | $ 634,500 | $ 867,000 | $ 1,501,500 |
| Commercial | 87,200 | 302,200 | 389,400 |
| Farm and Rural | 900 | 232,600 | 233,500 |
| Residential | 2,600 | 319,600 | 322,200 |
| Railroads* | 86,800 | 290,900 | 377,700 |
| Highways* | | 550,300 | 550,300 |
| Utilities | 6,000 | 149,200 | 155,200 |
| Public Funds (Municipal) | | 44,200 | 44,200 |
| Total Reported | $ 818,000 | $ 2,756,000 | $ 3,574,000 |
| Estimated Unreported | $ 818,000 | - | $ 818,000 |
| Grand Total | $ 1,636,000 | $ 2,756,000 | $ 4,392,000 |

* Includes bridges.

21. Value and Productivity of Area Subject to Flooding. - Although the area subject to flooding in this basin is not large, a large amount of industrial property is subject to damage during extreme floods. Many of the industries of this region, consisting primarily of textile, boot and shoe, and pulp and paper mills, are located immediately adjacent to the normal river channel. Similarly, the commercial sections of several communities are located near the waterfront. These developments, together with power plants and bridges, are subject to appreciable losses within a comparatively small extent of flooded area. They are seriously affected, however, only by the more extreme floods. The amount of agricultural land flooded may be extensive for the extreme stages but the damage is moderate because the floods usually occur in the spring before crops have been planted. With the exception of bridges which, in many cases, have been rebuilt at higher elevations, most of the developments are subject to recurring damage. In general, the benefits of adequate flood control measures would be confined to the value of the elimination of flood damage to existing developments and would have little effect on increasing the value and productivity of the area subject to flooding.

22. Annual Value of Elimination of Flood Damage. - During the flood damage census, the increments of damage occurring in successive flood stages up to the maximum stage of the 1936 flood were determined. From these data, together with the expected stage-frequency as computed from existing records, a damage-frequency relation was determined. The average annual value of flood loss in that portion of the Androscoggin valley lying below prospective reservoir sites was determined as $453,500. This amount represents the total possible annual flood control benefit which may be realized by the complete elimination of flood damage.

23. Improvement Desired. - No definite opinion on the general plan and extent of flood control measures has been expressed by local interests.

24. Possible Methods of Flood Control. - The more important and most generally applicable methods for flood control are the protection by levees or river walls, control by channel improvement or rectification, diversion of the flood flows and control by reservoirs. In the Androscoggin Basin diversion of flood flows is not practicable. Channel improvements and flood protection by levees or river walls are not applicable for comprehensive flood control throughout the entire valley. These methods have been considered for local flood protection problems and as supplementary protection to possible reservoir control.

25. Reservoir Control. - The most desirable method of obtaining general flood relief in this basin is by means of reservoirs. A study of all possible reservoir sites throughout the basin has revealed that there are several favorable sites for flood control reservoirs which, in conjunction with existing power reservoirs and natural lakes, would afford control for about 75 per cent of the total watershed area. The provision of such reservoir control would afford appreciable reductions in flood stages at the principal damage centers in the basin and would eliminate about 80 per cent of the estimated possible flood damage.

26. Power Development in Conjunction with Reservoir Control. - There is little need for additional power in the Androscoggin Basin at the present time. The export of hydro-electric power from the State of Maine is prohibited by law and the present local needs are well taken care of by existing installations and by interconnection with the adjoining Kennebec Basin. There are several potential power sites in the basin remaining undeveloped and at least one site appears to be favorable for combined flood control and power storage with a power installation. However, in view of the excess generating capacity now available, it would not be practicable to develop any of these

possibilities at the present time. Even if the need for additional power should arise, the demand could be met more economically by redevelopment of existing installations.

27. Local Flood Protection. - An investigation of possibilities for local flood protection by means of channel improvements and levees or river walls at 13 critical damage centers in the basin has revealed that the cost of providing such protection would greatly exceed the benefits which could be realized. There is, however, opportunity for alleviation of the flood situation in many of these and other localities by increasing spillway capacities and the provision of flood gates at the power dams, the provision of greater clearances of bridges, and the elimination of channel encroachment of bridge piers, abutments, etc.

28. Flood Warnings. - Another practical method of lessening flood damages is by means of the flood-warning service maintained by the United States Weather Bureau. When a rainstorm is threatening to pass into the watershed, its probabilities are studied and the companies controlling the storage are informed of the expected rainfall. If the lakes are full and the rainfall threatens to be considerable, the water levels are drawn down in advance of the storm. The amount drawn is determined from the run-off records of the companies and depends on the saturation of the ground, snow cover, the season of the year, etc., as well as on the probable rainfall. By this means storage is made available when the run-off begins, and this not only reduces the flood levels of the lakes, but also lessens the maximum discharge of the river, thus alleviating flood losses. Of course, distant headwater reservoirs must be drawn down in ample time, for if discharged immediately prior to or during the early stages of a flood, they could contribute to an increase in downstream flood stages by filling the valley storage. Two important factors affecting floods in this basin are the extent and water equivalent of the snow cover

and the condition of the ground underneath the snow. Limited observations are now made of precipitation in the form of snow by the United States Weather Bureau, power companies, winter sport organizations and other agencies, but additional estimates by trained observers of the amount of snow cover and its water equivalent are necessary to increase the value of the flood-forecasting service. Extension and correlation of investigations of hydrologic conditions in the basin through cooperation of all agencies concerned, to the end that improved flood forecasts and adequate warning be provided to the companies controlling the storage and to the public, appear to be desirable.

29. Discussion. - Although appreciable flood losses may result from the occurrence of extreme rains on a snow-covered watershed, the frequency of damaging floods is not great and the average annual flood damage is comparatively small. General flood protection throughout the valley by means of levees, river walls, or channel improvements is not practicable and the most favorable local flood protection possibility by this means would cost about twice as much as the prospective benefits. Reservoir control, however, is entirely practicable and at least four sites are available where storage can be provided economically, either for flood control alone or for combined flood control and power storage developments. Although a reservoir system which would eliminate about 80 per cent of the estimated possible annual flood damage is entirely practicable, the cost of such a system would not be justified by the prospective benefits at the present time.

30. Conclusions. - Flood control by means of reservoirs, either for flood control alone or for combined flood control and power storage, is entirely practicable in this basin but complete protection by this means is not economically justified at the present time. It is possible, however, that partial protection may be warranted. It is also possible that, when and if further development takes place in the

valley, the need and justification for flood control may increase. Although local flood protection by means of river walls and channel improvements is not warranted, it is believed that much can be done to alleviate local flood problems by the reconstruction, repair, or removal of existing dams, bridges and buildings which now form obstructions to flood flows. Such improvements could be undertaken economically when a structure has reached the end of its economic or physical life, or when reconstruction is required for some purpose other than for flood control alone. It is also believed that a measure of flood protection can be realized by continuation and encouragement of the purposeful control of existing storage whenever hydrological conditions indicate a probable flood situation.

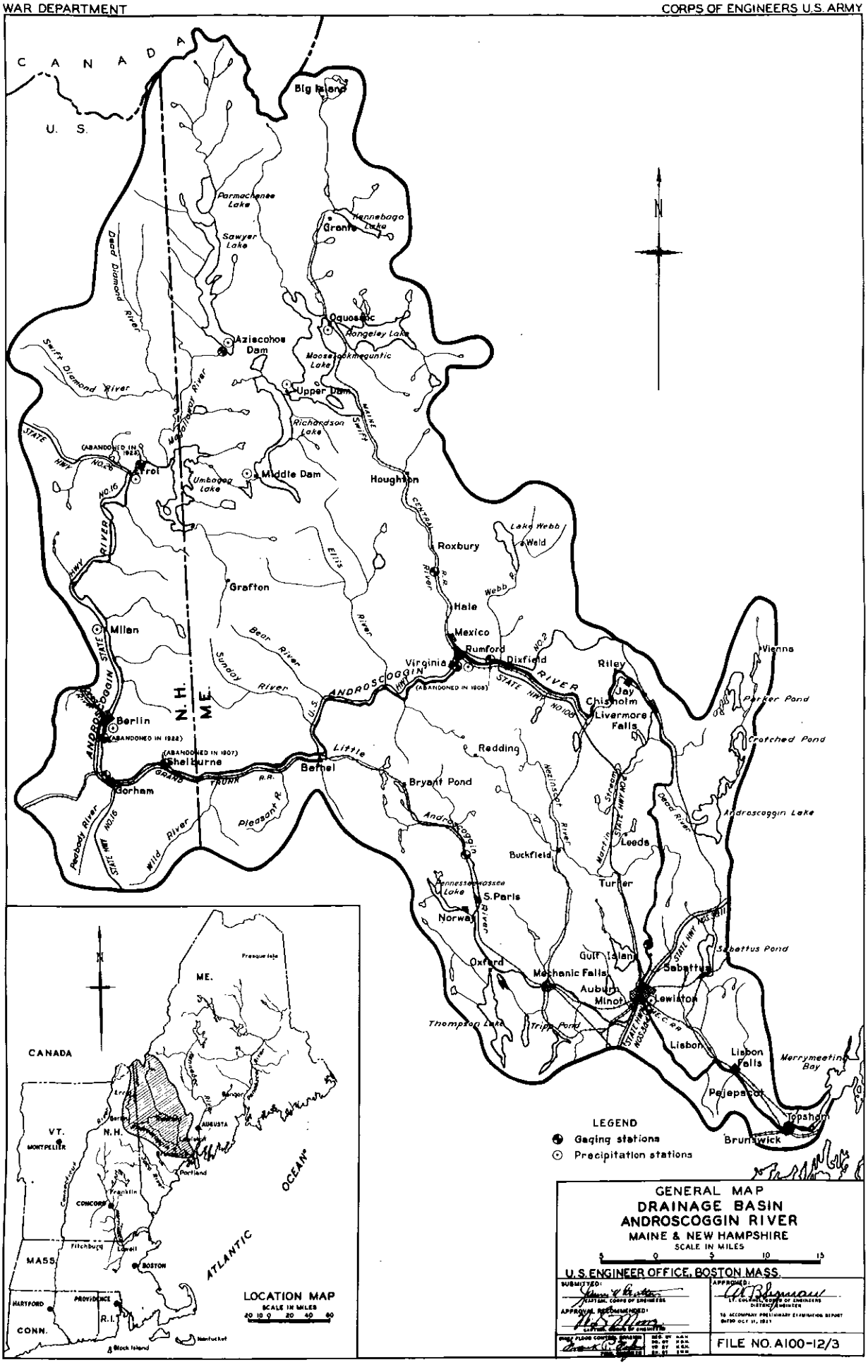
31. Recommendations. - It is recommended that a survey be made to determine the extent of flood protection by means of reservoirs which can be justified. It is also recommended that the states be encouraged to control the development along the river with a view to eliminating improper clearances and encroachments on the river channel and to coordinate the operation of existing storage reservoirs so as to achieve the maximum flood protection consistent with the conservation requirements of the storage. It is further recommended that the flood-warning and flood-forecasting services of all agencies concerned be extended and correlated through the United States Weather Bureau in order that improved forecasts and warnings may be provided.

A. K. B. Lyman
Lt. Col., Corps of Engineers
District Engineer

Inclos:
Map of Androscoggin Basin

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY




GENERAL MAP
DRAINAGE BASIN
ANDROSCOGGIN RIVER
MAINE & NEW HAMPSHIRE
SCALE IN MILES
5 0 5 10 15

U.S. ENGINEER OFFICE, BOSTON MASS.

SUBMITTED: CAPTAIN, CORPS OF ENGINEERS

APPROVED: LT. COLONEL, CORPS OF ENGINEERS DISTRICT ENGINEER

APPROVAL RECOMMENDED: CHIEF OF ENGINEERS

TO ACCOMPANY PRELIMINARY EXAMINATION REPORT DATED OCT 11, 1937

OHIO FLOOD CONTROL BOARD

FILE NO. A100-12/3

PRELIMINARY EXAMINATION OF THE ANDROSCOGGIN RIVER,
MAINE AND NEW HAMPSHIRE, FOR FLOOD CONTROL

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Syllabus

The District Engineer finds that, although the Androscoggin Basin is subject to appreciable flood losses, the annual flood damage is comparatively small and complete flood protection cannot be economically provided at the present time. General flood protection by means of levees or channel improvement is not practicable and local flood protection by these means is not justified at the present time. Reservoir control is entirely practicable, however, and it is possible that partial protection by this means may be justified. It is also possible that, if further development takes place in the valley, the need and justification for flood control may increase.

The District Engineer recommends that a survey be made to determine the extent of reservoir control which may be justified.

The District Engineer further recommends that the states be encouraged to provide regulation for the elimination of channel encroachments and for the control of existing storage and also that the flood warning and flood forecasting services of all agencies be extended and correlated through the United States Weather Bureau.

War Department
United States Engineer Office
Boston, Massachusetts

October 11, 1937

Subject: Report on a Preliminary Examination of the Androscoggin River, Maine and New Hampshire, for Flood Control

To: The Division Engineer, North Atlantic Division, New York, N.Y.

1. Authority. - This report is submitted in accordance with an Act (Public No. 812, 74th Congress) approved June 25, 1936, authorizing a "preliminary examination of the Androscoggin River, in Maine and New Hampshire, and its tributaries, with a view to control of their floods" and the Flood Control Act (Public No. 738, 74th Congress) approved June 22, 1936, which directs in part as follows:

"Section 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following-named localities, * * * * * * * * * * Androscoggin River, Maine * * * * * * * * * * ."

2. Prior Reports. - The only prior reports made on this river pertaining to flood control are the report made under the provisions of House Document No. 308, 69th Congress, 1st Session (printed as House Document No. 646, 71st Congress, 3d Session) and the review thereof (not printed) dated December 30, 1936, which was made under the authority of resolutions of the Committee on Commerce of the United States Senate and the Committee on Flood Control of the House of Representatives.

3. Existing Project. - There are no existing or prior projects for flood control for the Androscoggin River.

4. Description of the Watershed. - The Androscoggin River Basin is located principally in western Maine, with part of the headwater area, about 20 per cent of the total, lying in New Hampshire. The basin has a length of 110 miles, a maximum width of 55 miles, and a total drainage area of 3,470 square miles. The lake and pond area, amounting to 143 square miles or 4.1 per cent of the total basin area, exercises a considerable degree of control over about 1,400 square miles, or 40 per cent of the total basin area. The topography ranges from rough and mountainous in the upper portion to broad, low hills with considerable lake and swamp area in the lower portions. The river and its tributaries follow irregular, winding courses over deep glacial overburden beneath which the pre-glacial bedrock drainage courses are completely buried. Where the bedrock is exposed or close to the surface, as it is in numerous short channel reaches in the high hills and mountains , the channel has not been incised into the rock more than 5 to 10 feet. The bedrock is predominantly granite, schist and gneiss, with occasional areas of slate and other metamorphic rock. The overburden consists mainly of gravelly, somewhat silty sands.

5. Development Within the Basin. - The total population of the basin in 1930 was about 150,000, most of which is contained in the six largest cities, all over 3,000 population, which are located on the main stream. The upper part of the basin is largely forest covered and has comparatively few settlements. In the lower half of the basin there is a large volume of manufacturing, the principal products being cotton goods, pulp and paper. The lower part of the basin has good highways and is served by the Maine Central and Grand Trunk Railroads.

6. Description of the Main River. - The Androscoggin River rises at the Canadian border near the boundary between the States of Maine and New Hampshire, in mountainous territory, at an elevation of about 2,600 to 2,900 feet above mean sea level. From Umbagog Lake, about 35 miles south of the headwaters, the river flows in a southerly direction for about 35 miles, then turns easterly into Maine for about 70 miles, and thence flows in a general southerly direction for 60 miles to tidewater at Brunswick, Maine. The main stream has an average slope over its 200-mile length of about 13 feet per mile. Much of the fall is concentrated near Berlin, New Hampshire and at Rumford, Maine. The average discharge for the 9-year period of record at Auburn, Maine, (drainage area, 3,260 square miles) is 5,420 c.f.s.; the maximum, 135,000 c.f.s.; and the minimum, 465 c.f.s.

7. Tributaries. - The principal tributaries are shown in the following table:

TABLE I - TRIBUTARIES OF THE ANDROSCOGGIN RIVER

| River | Drainage Area (sq.mi.) | Location | | Distance of Mouth from Tidewater (miles) | Discharge of Record c.f.s./sq.mi. | | |
|---|---|---|---|---|---|---|---|
| | | Headwaters | Mouth | | Max. | Min. | Mean |
| Magalloway | 500 | At International boundary 13 mi. W. of Big Island, Me. | Errol, N. H. | 165 | Completely regulated | | |
| Swift | 135 | 5 mi. N. of Houghton, Me. | Rumford, Me. | 82 | 136.84 | .05* | 1.87 |
| Webb | 125 | 3 mi. N.E. of Weld, Me. | Dixfield, Me. | 75 | No gaging station | | |
| Dead | 100 | 4 mi. N. of Vienna, Me. | 5 mi. N. of Leeds, Me. | 46 | No gaging station | | |
| Nezinscot | 275 | 2 mi. N.W. of Redding, Me. | 4 mi. N. N. of Turner, Me. | 38 | No gaging station | | |
| Little Androscoggin | 380 | Bryant Pond, Me. | Auburn, Me. | 24 | 46.58 | .01* | 1.83 |

* Regulated by controlled storage.

8. Development of Water Resources. - The Androscoggin River has been very highly developed for power. Of an estimated 353,000 horsepower available, 246,469 horsepower in 42 installations have been developed. Twenty-eight installations, utilizing 775 feet of head and totalling 239,873 horsepower are on the main stream and the remaining 14 installations, with 310 feet of head and totalling 6,596 horsepower, are on the tributaries. The storage capacity is equally well developed, amounting to about 740,000 acre-feet for the entire drainage area, or about 213 acre-feet per square mile. Most of this storage is contained in the large natural lakes in the upper basin which are controlled for power storage. The 1,095 square miles above Errol, New Hampshire, about 32 per cent of the total

basin area, are very completely controlled, containing 678,000 acre-feet of storage.

9. Hydrology. - The climate is variable, with temperatures ranging from below freezing for the two or three winter months to the high summer temperatures required to support a varied plant life. The mean annual precipitation of 39.4 inches is rather uniformly distributed throughout the year, but it is characterized by short, frequent periods of heavy rain. The annual snowfall is quite heavy, ranging from about 77 inches near the coast to 130 inches on the northern headwaters. Comparative data are shown in the following table:

TABLE II - MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION - ANDROSCOGGIN RIVER BASIN

| Month | Mean Temperature (°F.) | Mean Precipitation (Inches) | Equivalent Run-off in Inches at Rumford, Me. (D.A = 2090 sq.mi., or 60% of total basin) |
|---|---|---|---|
| Jan. | 16.0 | 3.03 | 1.36 |
| Feb. | 17.4 | 2.86 | 1.16 |
| Mar. | 28.8 | 3.35 | 2.07 |
| Apr. | 41.2 | 2.95 | 3.88 |
| May | 53.3 | 3.31 | 3.77 |
| June | 62.0 | 3.53 | 2.09 |
| July | 68.0 | 3.60 | 1.38 |
| Aug. | 65.2 | 3.64 | 1.24 |
| Sept. | 58.0 | 3.43 | 1.23 |
| Oct. | 47.3 | 3.24 | 1.41 |
| Nov. | 34.1 | 3.39 | 1.65 |
| Dec. | 21.3 | 3.07 | 1.41 |
| Annual | 42.7 | 39.40 | 22.65 |

10. Records of Precipitation. - There are 9 observation stations for precipitation maintained by the United States Weather Bureau in the Androscoggin watershed. The data concerning these stations are listed in the following table.

TABLE III - PRECIPITATION STATIONS - ANDROSCOGGIN RIVER BASIN

| Station | Elevation (Feet above M.S.L.) | Period of Record | Length of Record (Years) | Remarks |
|---|---|---|---|---|
| Oquossuc, Me. | 1534 | 1900-1930 | 31 | 1902,03,07,09,12-16, 30 records incomplete |
| Upper Dam, Me. | 1484 | 1886-1935 | 50 | |
| Middle Dam, Me. | 1430 | 1905-1935 | 31 | 1935 record incomplete |
| Aziscohos Dam, Me. | 1528 | 1911-1933 | 23 | 1933 record incomplete |
| Errol, N. H. | 1260 | 1885-1935 | 51 | 1929, 30, 32, 34 records incomplete |
| Milan, N. H. | 1190 | 1887-1898<br>1926-1935 | 22 | 1898, 1926 records incomplete |
| Berlin, N. H. | 1110 | 1887-1903<br>1918-1935 | 35 | |
| Rumford, Me. | 505 | 1894-1935 | 42 | |
| Lewiston, Me. | 182 | 1875-1935 | 61 | |

11. Records of Stream Flow. - There are 11 stream gaging stations in the basin maintained by the United States Geological Survey. Data concerning these stations are given in the following table:

TABLE IV - GAGING STATIONS - ANDROSCOGGIN RIVER BASIN

| Location of Gaging Station | Drainage Area (sq.mi.) | Period of Record | Discharge of Record in Cubic Feet Per Second | | |
|---|---|---|---|---|---|
| | | | Mean | Maximum | Minimum |
| **Androscoggin River** | | | | | |
| Errol, N. H. | 1090 | 1905-1923 | ** | | |
| Berlin, N. H. | 1380 | 1913-1922 | 2180 | 14,300 | * |
| Gorham, N. H. | 1390 | 1929-1936 | 2360 | 19,900 | 960* |
| Shelburne, N. H. | 1500 | 1903-1907 | - | 15,600 | * |
| Rumford, Me. | 2090 | 1892-1936 | 3480 | 74,000 | * |
| Dixfield, Me. | 2230 | 1902-1908 | 4940 | - | * |
| Gulf Island, Me. | 2860 | 1936 | - | 118,000 | 1550* |
| Auburn, Me. | 3260 | 1928-1936 | 5420 | 135,000 | 465* |
| **Magalloway River** | | | | | |
| Aziscohos Dam, N. H. | 233 | 1912-1935 | ** | | |
| **Swift River** | | | | | |
| Roxbury, Me. | 95 | 1929-1936 | 178 | 13,000 | 5 |
| **Little Androscoggin River** | | | | | |
| South Paris, Me. | 76 | 1913-1924<br>1931-1936 | 139 | 6,980 | 1 |

* Flow affected by controlled storage.
** Completely regulated.

12. Accuracy of Gaging Stations. - In general, the accuracy of the stream gaging stations in the basin is very good. The discharge is computed from the flow over dams or through gates or wheels at five of the eleven stations. Good rating curves have been developed for most of the stations for medium and high stages. The records are considered very good, except during periods of ice cover, when they are fair.

13. General Flood Situation. - About 40 per cent of the Androscoggin watershed is at least partially controlled by the natural lakes and ponds, most of which are regulated for power storage. This storage, although it does not provide positive flood control at all times, is quite effective in reducing flood stages for ordinary floods. It is not, however, generally effective for extreme floods. The extreme floods in this basin, on the other hand, are possible only from the

combination of heavy rain and melting snow, and their occurrence is comparatively infrequent. The resulting damages are confined generally to the industrial areas near the river channel in the lower portions of the watershed.

14. Types of Storms. - The storms which occur in the Androscoggin Basin may be classified into three general types as follows: (1) extratropical cyclones; (2) tropical hurricanes; and (3) rain storms caused by the rapid displacement upward of a warm air mass by a colder, denser air mass, usually accompanied by an extratropical cyclone or a tropical hurricane. Of these, the extratropical cyclones are the most numerous. They occur throughout the year and are the principal factor in providing the uniform year-round precipitation of the basin. The more severe rains are caused by the second and third types of storms. The tropical hurricanes, however, are restricted generally to the summer and early fall seasons, - a time when the ground conditions are such that much of the heavy rainfall can be absorbed without causing unusual flooding. The most dangerous storms, from a flood standpoint, are the rains caused by the movements of warm and cold air masses. Such storms may occur at any time of the year and the most severe floods in the basin are caused by this type of disturbance bringing unusual temperatures and heavy rainfall to a snow-covered basin.

15. Effect of Snow. - Recent snow surveys of storage operators in the basin indicate that there is usually an accumulated water equivalent of about 10 inches in the annual snow cover at the time of the spring "thaw" and that this cover is usually converted to run-off in one continuous period of about 10 to 15 days. Additional studies on snow run-off made by this office support these observations and lead to the conclusion that snow is usually a contributing factor to the spring floods in this basin and it may be the principal cause.

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| Once in 100 years | 62,000 |

19. Description of the Worst Flood of Record. - The March, 1936, flood in this basin was the greatest on record. The maximum discharge of 68,300 c.f.s. exceeded the highest previously recorded (in 1895) by nearly 25 per cent and the flood losses were many times greater than any previously suffered. The flood was caused by a succession of two storms within a period of 11 days. Rainfall for the 11-day period was heavy throughout the entire New England area, varying from a few inches along the coast to a maximum of about 20 inches in the White Mountains, which are the common headwaters of the Connecticut, Merrimack, Kennebec and Saco Basins, as well as the Androscoggin Basin. Four lives were lost in the Androscoggin Basin during the flood and over 1,500 families, involving about 6,000 people, were temporarily homeless. About 2,000 buildings were affected by the flood. Eighteen bridges were wholly or partially destroyed and ten additional bridges suffered some damage. Although the actual area flooded was not large, several towns were practically cut off from the outside world for from one to four days as railroad, highway, telephone and telegraph facilities were disrupted. Several towns were temporarily without light, power and water. The depth of water in the area flooded varied greatly. In the towns and cities a few principal streets were covered to depths of from one to five feet generally, although depths as great as 15 feet were reported in Brunswick, Maine.

20. Flood Damages. - The only complete data on flood damages available for this basin are those collected after the flood of March, 1936. These figures, however, are very reliable, having been obtained by means of a thorough census of the individual sufferers in the basin shortly after the flood. The results of the census are shown in the following table. Of the total damages of $4,392,000 in the basin, $4,232,000, or 96 per cent were in the State of Maine and the remainder, only 4 per cent, in New Hampshire. There is no record of the losses in 1896, but it is known that several highway bridges were washed out and that a large number of logs were carried away. In November, 1927, there were severe losses, especially at Berlin and Gorham, totalling about $400,000 plus an unestimated amount for damage to railways. The losses from all prior floods, however, were probably much less than those for March, 1936, as tabulated below.

TABLE VI - FLOOD DAMAGES - ANDROSCOGGIN RIVER BASIN - MARCH, 1936

| Class | Indirect | Direct | Total |
|---|---|---|---|
| Industrial | $ 634,500 | $ 867,000 | $ 1,501,500 |
| Commercial | 87,200 | 302,200 | 389,400 |
| Farm and Rural | 900 | 232,600 | 233,500 |
| Residential | 2,600 | 319,600 | 322,200 |
| Railroads* | 86,800 | 290,900 | 377,700 |
| Highways* | | 550,300 | 550,300 |
| Utilities | 6,000 | 149,200 | 155,200 |
| Public Funds (Municipal) | | 44,200 | 44,200 |
| Total Reported | $ 818,000 | $ 2,756,000 | $ 3,574,000 |
| Estimated Unreported | $ 818,000 | - | $ 818,000 |
| Grand Total | $ 1,636,000 | $ 2,756,000 | $ 4,392,000 |

* Includes bridges.

21. Value and Productivity of Area Subject to Flooding. - Although the area subject to flooding in this basin is not large, a large amount of industrial property is subject to damage during extreme floods. Many of the industries of this region, consisting primarily of textile, boot and shoe, and pulp and paper mills, are located immediately adjacent to the normal river channel. Similarly, the commercial sections of several communities are located near the waterfront. These developments, together with power plants and bridges, are subject to appreciable losses within a comparatively small extent of flooded area. They are seriously affected, however, only by the more extreme floods. The amount of agricultural land flooded may be extensive for the extreme stages but the damage is moderate because the floods usually occur in the spring before crops have been planted. With the exception of bridges which, in many cases, have been rebuilt at higher elevations, most of the developments are subject to recurring damage. In general, the benefits of adequate flood control measures would be confined to the value of the elimination of flood damage to existing developments and would have little effect on increasing the value and productivity of the area subject to flooding.

22. Annual Value of Elimination of Flood Damage. - During the flood damage census, the increments of damage occurring in successive flood stages up to the maximum stage of the 1936 flood were determined. From these data, together with the expected stage-frequency as computed from existing records, a damage-frequency relation was determined. The average annual value of flood loss in that portion of the Androscoggin valley lying below prospective reservoir sites was determined as $453,500. This amount represents the total possible annual flood control benefit which may be realized by the complete elimination of flood damage.

23. Improvement Desired. - No definite opinion on the general plan and extent of flood control measures has been expressed by local interests.

24. Possible Methods of Flood Control. - The more important and most generally applicable methods for flood control are the protection by levees or river walls, control by channel improvement or rectification, diversion of the flood flows and control by reservoirs. In the Androscoggin Basin diversion of flood flows is not practicable. Channel improvements and flood protection by levees or river walls are not applicable for comprehensive flood control throughout the entire valley. These methods have been considered for local flood protection problems and as supplementary protection to possible reservoir control.

25. Reservoir Control. - The most desirable method of obtaining general flood relief in this basin is by means of reservoirs. A study of all possible reservoir sites throughout the basin has revealed that there are several favorable sites for flood control reservoirs which, in conjunction with existing power reservoirs and natural lakes, would afford control for about 75 per cent of the total watershed area. The provision of such reservoir control would afford appreciable reductions in flood stages at the principal damage centers in the basin and would eliminate about 80 per cent of the estimated possible flood damage.

26. Power Development in Conjunction with Reservoir Control. - There is little need for additional power in the Androscoggin Basin at the present time. The export of hydro-electric power from the State of Maine is prohibited by law and the present local needs are well taken care of by existing installations and by interconnection with the adjoining Kennebec Basin. There are several potential power sites in the basin remaining undeveloped and at least one site appears to be favorable for combined flood control and power storage with a power installation. However, in view of the excess generating capacity now available, it would not be practicable to develop any of these

possibilities at the present time. Even if the need for additional power should arise, the demand could be met more economically by redevelopment of existing installations.

27. Local Flood Protection. - An investigation of possibilities for local flood protection by means of channel improvements and levees or river walls at 13 critical damage centers in the basin has revealed that the cost of providing such protection would greatly exceed the benefits which could be realized. There is, however, opportunity for alleviation of the flood situation in many of these and other localities by increasing spillway capacities and the provision of flood gates at the power dams, the provision of greater clearances of bridges, and the elimination of channel encroachment of bridge piers, abutments, etc.

28. Flood Warnings. - Another practical method of lessening flood damages is by means of the flood-warning service maintained by the United States Weather Bureau. When a rainstorm is threatening to pass into the watershed, its probabilities are studied and the companies controlling the storage are informed of the expected rainfall. If the lakes are full and the rainfall threatens to be considerable, the water levels are drawn down in advance of the storm. The amount drawn is determined from the run-off records of the companies and depends on the saturation of the ground, snow cover, the season of the year, etc., as well as on the probable rainfall. By this means storage is made available when the run-off begins, and this not only reduces the flood levels of the lakes, but also lessens the maximum discharge of the river, thus alleviating flood losses. Of course, distant headwater reservoirs must be drawn down in ample time, for if discharged immediately prior to or during the early stages of a flood, they could contribute to an increase in downstream flood stages by filling the valley storage. Two important factors affecting floods in this basin are the extent and water equivalent of the snow cover

and the condition of the ground underneath the snow. Limited observations are now made of precipitation in the form of snow by the United States Weather Bureau, power companies, winter sport organizations and other agencies, but additional estimates by trained observers of the amount of snow cover and its water equivalent are necessary to increase the value of the flood-forecasting service. Extension and correlation of investigations of hydrologic conditions in the basin through cooperation of all agencies concerned, to the end that improved flood forecasts and adequate warning be provided to the companies controlling the storage and to the public, appear to be desirable.

29. Discussion. - Although appreciable flood losses may result from the occurrence of extreme rains on a snow-covered watershed, the frequency of damaging floods is not great and the average annual flood damage is comparatively small. General flood protection throughout the valley by means of levees, river walls, or channel improvements is not practicable and the most favorable local flood protection possibility by this means would cost about twice as much as the prospective benefits. Reservoir control, however, is entirely practicable and at least four sites are available where storage can be provided economically, either for flood control alone or for combined flood control and power storage developments. Although a reservoir system which would eliminate about 80 per cent of the estimated possible annual flood damage is entirely practicable, the cost of such a system would not be justified by the prospective benefits at the present time.

30. Conclusions. - Flood control by means of reservoirs, either for flood control alone or for combined flood control and power storage, is entirely practicable in this basin but complete protection by this means is not economically justified at the present time. It is possible, however, that partial protection may be warranted. It is also possible that, when and if further development takes place in the

valley, the need and justification for flood control may increase. Although local flood protection by means of river walls and channel improvements is not warranted, it is believed that much can be done to alleviate local flood problems by the reconstruction, repair, or removal of existing dams, bridges and buildings which now form obstructions to flood flows. Such improvements could be undertaken economically when a structure has reached the end of its economic or physical life, or when reconstruction is required for some purpose other than for flood control alone. It is also believed that a measure of flood protection can be realized by continuation and encouragement of the purposeful control of existing storage whenever hydrological conditions indicate a probable flood situation.

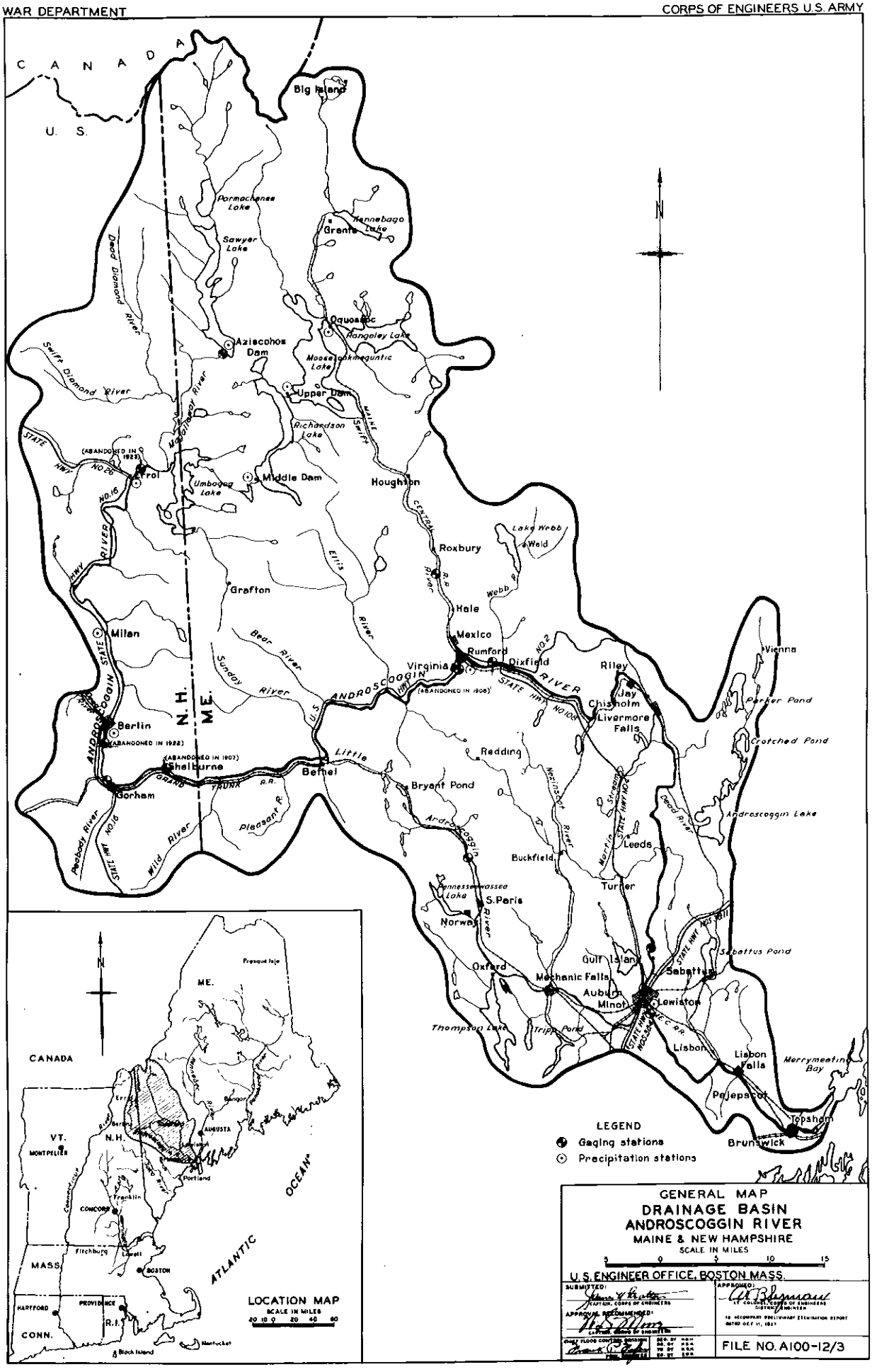
31. Recommendations. - It is recommended that a survey be made to determine the extent of flood protection by means of reservoirs which can be justified. It is also recommended that the states be encouraged to control the development along the river with a view to eliminating improper clearances and encroachments on the river channel and to coordinate the operation of existing storage reservoirs so as to achieve the maximum flood protection consistent with the conservation requirements of the storage. It is further recommended that the flood-warning and flood-forecasting services of all agencies concerned be extended and correlated through the United States Weather Bureau in order that improved forecasts and warnings may be provided.

A. K. B. Lyman
Lt. Col., Corps of Engineers
District Engineer

Inclos.:
Map of Androscoggin Basin

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY




GENERAL MAP
DRAINAGE BASIN
ANDROSCOGGIN RIVER
MAINE & NEW HAMPSHIRE
SCALE IN MILES
5 0 5 10 15

U. S. ENGINEER OFFICE, BOSTON MASS.

SUBMITTED: CAPTAIN, CORPS OF ENGINEERS

APPROVED: LT. COLONEL, CORPS OF ENGINEERS DISTRICT ENGINEER

TO ACCOMPANY PRELIMINARY EXAMINATION REPORT DATED OCT. 11, 1937

APPROVAL RECOMMENDED: CAPTAIN, CORPS OF ENGINEERS

CHIEF FLOOD CONTROL BRANCH

DES. BY H.B.H.
DR. BY R.S.K.
TR. BY R.S.K.
CK. BY I.B.K.

FILE NO. A100-12/3

PRELIMINARY EXAMINATION OF THE ANDROSCOGGIN RIVER,
MAINE AND NEW HAMPSHIRE, FOR FLOOD CONTROL

---

Syllabus

The District Engineer finds that, although the Androscoggin Basin is subject to appreciable flood losses, the annual flood damage is comparatively small and complete flood protection cannot be economically provided at the present time. General flood protection by means of levees or channel improvement is not practicable and local flood protection by these means is not justified at the present time. Reservoir control is entirely practicable, however, and it is possible that partial protection by this means may be justified. It is also possible that, if further development takes place in the valley, the need and justification for flood control may increase.

The District Engineer recommends that a survey be made to determine the extent of reservoir control which may be justified.

The District Engineer further recommends that the states be encouraged to provide regulation for the elimination of channel encroachments and for the control of existing storage and also that the flood warning and flood forecasting services of all agencies be extended and correlated through the United States Weather Bureau.

War Department
United States Engineer Office
Boston, Massachusetts

October 11, 1937

Subject: Report on a Preliminary Examination of the Androscoggin River, Maine and New Hampshire, for Flood Control

To: The Division Engineer, North Atlantic Division, New York, N.Y.

1. Authority. - This report is submitted in accordance with an Act (Public No. 812, 74th Congress) approved June 25, 1936, authorizing a "preliminary examination of the Androscoggin River, in Maine and New Hampshire, and its tributaries, with a view to control of their floods" and the Flood Control Act (Public No. 738, 74th Congress) approved June 22, 1936, which directs in part as follows:

"Section 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following-named localities, * * * * * * * * * * Androscoggin River, Maine * * * * * * * * * * ."

2. Prior Reports. - The only prior reports made on this river pertaining to flood control are the report made under the provisions of House Document No. 308, 69th Congress, 1st Session (printed as House Document No. 646, 71st Congress, 3d Session) and the review thereof (not printed) dated December 30, 1936, which was made under the authority of resolutions of the Committee on Commerce of the United States Senate and the Committee on Flood Control of the House of Representatives.

3. Existing Project. - There are no existing or prior projects for flood control for the Androscoggin River.

4. Description of the Watershed. - The Androscoggin River Basin is located principally in western Maine, with part of the headwater area, about 20 per cent of the total, lying in New Hampshire. The basin has a length of 110 miles, a maximum width of 55 miles, and a total drainage area of 3,470 square miles. The lake and pond area, amounting to 143 square miles or 4.1 per cent of the total basin area, exercises a considerable degree of control over about 1,400 square miles, or 40 per cent of the total basin area. The topography ranges from rough and mountainous in the upper portion to broad, low hills with considerable lake and swamp area in the lower portions. The river and its tributaries follow irregular, winding courses over deep glacial overburden beneath which the pre-glacial bedrock drainage courses are completely buried. Where the bedrock is exposed or close to the surface, as it is in numerous short channel reaches in the high hills and mountains , the channel has not been incised into the rock more than 5 to 10 feet. The bedrock is predominantly granite, schist and gneiss, with occasional areas of slate and other metamorphic rock. The overburden consists mainly of gravelly, somewhat silty sands.

5. Development Within the Basin. - The total population of the basin in 1930 was about 150,000, most of which is contained in the six largest cities, all over 3,000 population, which are located on the main stream. The upper part of the basin is largely forest covered and has comparatively few settlements. In the lower half of the basin there is a large volume of manufacturing, the principal products being cotton goods, pulp and paper. The lower part of the basin has good highways and is served by the Maine Central and Grand Trunk Railroads.

6. Description of the Main River. - The Androscoggin River rises at the Canadian border near the boundary between the States of Maine and New Hampshire, in mountainous territory, at an elevation of about 2,600 to 2,900 feet above mean sea level. From Umbagog Lake, about 35 miles south of the headwaters, the river flows in a southerly direction for about 35 miles, then turns easterly into Maine for about 70 miles, and thence flows in a general southerly direction for 60 miles to tidewater at Brunswick, Maine. The main stream has an average slope over its 200-mile length of about 13 feet per mile. Much of the fall is concentrated near Berlin, New Hampshire and at Rumford, Maine. The average discharge for the 9-year period of record at Auburn, Maine, (drainage area, 3,260 square miles) is 5,420 c.f.s.; the maximum, 135,000 c.f.s.; and the minimum, 465 c.f.s.

7. Tributaries. - The principal tributaries are shown in the following table:

TABLE I - TRIBUTARIES OF THE ANDROSCOGGIN RIVER

| River | Drainage Area (sq.mi.) | Location | | Distance of Mouth from Tidewater (miles) | Discharge of Record c.f.s./sq.mi. | | |
|---|---|---|---|---|---|---|---|
| | | Headwaters | Mouth | | Max. | Min. | Mean |
| Magalloway | 500 | At International boundary 13 mi. N. of Big Island, Me. | Errol, N. H. | 165 | Completely regulated | | |
| Swift | 135 | 5 mi. N. of Houghton, Me. | Rumford, Me. | 82 | 136.84 | .05* | 1.87 |
| Webb | 125 | 3 mi. N.E. of Weld, Me. | Dixfield, Me. | 75 | No gaging station | | |
| Dead | 100 | 4 mi. N. of Vienna, Me. | 5 mi. N. of Leeds, Me. | 46 | No gaging station | | |
| Nezinscot | 275 | 2 mi. N.W. of Redding, Me. | 4 mi. N. N. of Turner, Me. | 38 | No gaging station | | |
| Little Androscoggin | 360 | Bryant Pond, Me. | Auburn, Me. | 24 | 46.58 | .01* | 1.83 |

* Regulated by controlled storage.

8. Development of Water Resources. - The Androscoggin River has been very highly developed for power. Of an estimated 353,000 horsepower available, 246,469 horsepower in 42 installations have been developed. Twenty-eight installations, utilizing 775 feet of head and totalling 239,873 horsepower are on the main stream and the remaining 14 installations, with 310 feet of head and totalling 6,596 horsepower, are on the tributaries. The storage capacity is equally well developed, amounting to about 740,000 acre-feet for the entire drainage area, or about 213 acre-feet per square mile. Most of this storage is contained in the large natural lakes in the upper basin which are controlled for power storage. The 1,095 square miles above Errol, New Hampshire, about 32 per cent of the total

basin area, are very completely controlled, containing 678,000 acre-feet of storage.

9. Hydrology. - The climate is variable, with temperatures ranging from below freezing for the two or three winter months to the high summer temperatures required to support a varied plant life. The mean annual precipitation of 39.4 inches is rather uniformly distributed throughout the year, but it is characterized by short, frequent periods of heavy rain. The annual snowfall is quite heavy, ranging from about 77 inches near the coast to 130 inches on the northern headwaters. Comparative data are shown in the following table:

TABLE II - MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION - ANDROSCOGGIN RIVER BASIN

| Month | Mean Temperature (°F.) | Mean Precipitation (Inches) | Equivalent Run-off in Inches at Rumford, Me. (D.A = 2090 sq.mi., or 60% of total basin) |
|---|---|---|---|
| Jan. | 16.0 | 3.03 | 1.36 |
| Feb. | 17.4 | 2.86 | 1.16 |
| Mar. | 28.8 | 3.35 | 2.07 |
| Apr. | 41.2 | 2.95 | 3.88 |
| May | 53.3 | 3.31 | 3.77 |
| June | 62.0 | 3.53 | 2.09 |
| July | 68.0 | 3.60 | 1.38 |
| Aug. | 65.2 | 3.84 | 1.24 |
| Sept. | 58.0 | 3.43 | 1.23 |
| Oct. | 47.3 | 3.24 | 1.41 |
| Nov. | 34.1 | 3.39 | 1.65 |
| Dec. | 21.3 | 3.07 | 1.41 |
| Annual | 42.7 | 39.40 | 22.65 |

10. Records of Precipitation. - There are 9 observation stations for precipitation maintained by the United States Weather Bureau in the Androscoggin watershed. The data concerning these stations are listed in the following table.

TABLE III - PRECIPITATION STATIONS - ANDROSCOGGIN RIVER BASIN

| Station | Elevation (Feet above M.S.L.) | Period of Record | Length of Record (Years) | Remarks |
|---|---|---|---|---|
| Oquossuc, Me. | 1534 | 1900-1930 | 31 | 1902,03,07,09,12-16, 30 records incomplete |
| Upper Dam, Me. | 1484 | 1886-1935 | 50 | |
| Middle Dam, Me. | 1430 | 1905-1935 | 31 | 1935 record incomplete |
| Aziscohos Dam, Me. | 1528 | 1911-1933 | 23 | 1933 record incomplete |
| Errol, N. H. | 1260 | 1885-1935 | 51 | 1929, 30, 32, 34 records incomplete |
| Milan, N. H. | 1190 | 1887-1898<br>1926-1935 | 22 | 1898, 1926 records incomplete |
| Berlin, N. H. | 1110 | 1887-1903<br>1916-1935 | 35 | |
| Rumford, Me. | 505 | 1894-1935 | 42 | |
| Lewiston, Me. | 182 | 1875-1935 | 61 | |

11. Records of Stream Flow. - There are 11 stream gaging stations in the basin maintained by the United States Geological Survey. Data concerning these stations are given in the following table:

TABLE IV - GAGING STATIONS - ANDROSCOGGIN RIVER BASIN

| Location of Gaging Station | Drainage Area (sq.mi.) | Period of Record | Discharge of Record in Cubic Feet Per Second | | |
|---|---|---|---|---|---|
| | | | Mean | Maximum | Minimum |
| **Androscoggin River** | | | | | |
| Errol, N. H. | 1090 | 1905-1923 | ** | | |
| Berlin, N. H. | 1380 | 1913-1922 | 2180 | 14,300 | * |
| Gorham, N. H. | 1390 | 1929-1936 | 2360 | 19,900 | 960* |
| Shelburne, N. H. | 1500 | 1903-1907 | - | 15,600 | * |
| Rumford, Me. | 2090 | 1892-1936 | 3480 | 74,000 | * |
| Dixfield, Me. | 2230 | 1902-1908 | 4940 | - | * |
| Gulf Island, Me. | 2860 | 1936 | - | 118,000 | 1550* |
| Auburn, Me. | 3260 | 1928-1936 | 5420 | 135,000 | 465* |
| **Megalloway River** | | | | | |
| Aziscohos Dam, N. H. | 233 | 1912-1935 | ** | | |
| **Swift River** | | | | | |
| Roxbury, Me. | 95 | 1929-1936 | 178 | 13,000 | 5 |
| **Little Androscoggin River** | | | | | |
| South Paris, Me. | 76 | 1913-1924<br>1931-1936 | 139 | 6,980 | 1 |

* Flow affected by controlled storage.
** Completely regulated.

12. Accuracy of Gaging Stations. - In general, the accuracy of the stream gaging stations in the basin is very good. The discharge is computed from the flow over dams or through gates or wheels at five of the eleven stations. Good rating curves have been developed for most of the stations for medium and high stages. The records are considered very good, except during periods of ice cover, when they are fair.

13. General Flood Situation. - About 40 per cent of the Androscoggin watershed is at least partially controlled by the natural lakes and ponds, most of which are regulated for power storage. This storage, although it does not provide positive flood control at all times, is quite effective in reducing flood stages for ordinary floods. It is not, however, generally effective for extreme floods. The extreme floods in this basin, on the other hand, are possible only from the

combination of heavy rain and melting snow, and their occurrence is comparatively infrequent. The resulting damages are confined generally to the industrial areas near the river channel in the lower portions of the watershed.

14. Types of Storms. - The storms which occur in the Androscoggin Basin may be classified into three general types as follows: (1) extratropical cyclones; (2) tropical hurricanes; and (3) rain storms caused by the rapid displacement upward of a warm air mass by a colder, denser air mass, usually accompanied by an extratropical cyclone or a tropical hurricane. Of these, the extratropical cyclones are the most numerous. They occur throughout the year and are the principal factor in providing the uniform year-round precipitation of the basin. The more severe rains are caused by the second and third types of storms. The tropical hurricanes, however, are restricted generally to the summer and early fall seasons, - a time when the ground conditions are such that much of the heavy rainfall can be absorbed without causing unusual flooding. The most dangerous storms, from a flood standpoint, are the rains caused by the movements of warm and cold air masses. Such storms may occur at any time of the year and the most severe floods in the basin are caused by this type of disturbance bringing unusual temperatures and heavy rainfall to a snow-covered basin.

15. Effect of Snow. - Recent snow surveys of storage operators in the basin indicate that there is usually an accumulated water equivalent of about 10 inches in the annual snow cover at the time of the spring "thaw" and that this cover is usually converted to run-off in one continuous period of about 10 to 15 days. Additional studies on snow run-off made by this office support these observations and lead to the conclusion that snow is usually a contributing factor to the spring floods in this basin and it may be the principal cause.

16. Effect of Ice. - Ice is also a factor in the floods which occur early in the spring. It is not always, however, of great importance. The Androscoggin River flows in a general southerly direction and normally the ice in the lower reaches softens and goes out sooner than that in the upper reaches and headwaters. On the other hand, when the spring break-up occurs early, ice jams, comprising thick, solid "blue ice", are likely to form at obstructions in the river. On these occasions serious damage may be caused by these ice jams, as during the flood of March, 1936, when a railroad bridge at Brunswick was carried out by the force of the jam.

17. Record of Past Floods. - The six highest floods of record on the Androscoggin River at Rumford, Maine (drainage area, 2,090 square miles, of which 1,096 square miles are completely controlled) were as follows:

TABLE V - RECORD FLOODS - ANDROSCOGGIN RIVER AT RUMFORD, MAINE

| Date | Average 24-Hour Discharge (c.f.s.) | Instantaneous Peak Discharge (c.f.s.) | Average Run-off for One Day in c.f.s. per sq. mile |
|---|---|---|---|
| March 19, 1936 | 68,300 | 74,000 | 32.6 |
| April 15, 1895 | 55,230 | - | 26.4 |
| November 5, 1927 | 39,100 | - | 18.7 |
| March 2, 1896 | 39,010 | - | 18.6 |
| May 18, 1893 | 38,060 | - | 18.2 |
| March 13, 1936 | 35,600 | 38,200 | 17.0 |

18. Flood Frequency. - Spring, because of the occurrence of snow run-off with or without rain, is the season of high water and floods in the Androscoggin Basin. Of all peak discharges greater than the average annual flood over the period of record from 1893 to 1936 at Rumford, one-third occurred during the month of April and two-thirds occurred during the months of March, April and May. The

computed frequency for discharges at Rumford, Maine, is as follows:

| Period | 24-Hour Discharge in c.f.s. |
|---|---|
| Once in 1 year | 20,000 |
| Once in 10 years | 38,000 |
| Once in 50 years | 54,000 |
| Once in 75 years | 59,000 |
| Once in 100 years | 62,000 |

19. Description of the Worst Flood of Record. - The March, 1936, flood in this basin was the greatest on record. The maximum discharge of 68,300 c.f.s. exceeded the highest previously recorded (in 1895) by nearly 25 per cent and the flood losses were many times greater than any previously suffered. The flood was caused by a succession of two storms within a period of 11 days. Rainfall for the 11-day period was heavy throughout the entire New England area, varying from a few inches along the coast to a maximum of about 20 inches in the White Mountains, which are the common headwaters of the Connecticut, Merrimack, Kennebec and Saco Basins, as well as the Androscoggin Basin. Four lives were lost in the Androscoggin Basin during the flood and over 1,500 families, involving about 6,000 people, were temporarily homeless. About 2,000 buildings were affected by the flood. Eighteen bridges were wholly or partially destroyed and ten additional bridges suffered some damage. Although the actual area flooded was not large, several towns were practically cut off from the outside world for from one to four days as railroad, highway, telephone and telegraph facilities were disrupted. Several towns were temporarily without light, power and water. The depth of water in the area flooded varied greatly. In the towns and cities a few principal streets were covered to depths of from one to five feet generally, although depths as great as 15 feet were reported in Brunswick, Maine.

20. Flood Damages. - The only complete data on flood damages available for this basin are those collected after the flood of March, 1936. These figures, however, are very reliable, having been obtained by means of a thorough census of the individual sufferers in the basin shortly after the flood. The results of the census are shown in the following table. Of the total damages of $4,392,000 in the basin, $4,232,000, or 96 per cent were in the State of Maine and the remainder, only 4 per cent, in New Hampshire. There is no record of the losses in 1896, but it is known that several highway bridges were washed out and that a large number of logs were carried away. In November, 1927, there were severe losses, especially at Berlin and Gorham, totalling about $400,000 plus an unestimated amount for damage to railways. The losses from all prior floods, however, were probably much less than those for March, 1936, as tabulated below.

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| Industrial | $ 634,500 | $ 867,000 | $ 1,501,500 |
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| Estimated Unreported | $ 818,000 | - | $ 818,000 |
| Grand Total | $ 1,636,000 | $ 2,756,000 | $ 4,392,000 |

* Includes bridges.

21. Value and Productivity of Area Subject to Flooding. - Although the area subject to flooding in this basin is not large, a large amount of industrial property is subject to damage during extreme floods. Many of the industries of this region, consisting primarily of textile, boot and shoe, and pulp and paper mills, are located immediately adjacent to the normal river channel. Similarly, the commercial sections of several communities are located near the waterfront. These developments, together with power plants and bridges, are subject to appreciable losses within a comparatively small extent of flooded area. They are seriously affected, however, only by the more extreme floods. The amount of agricultural land flooded may be extensive for the extreme stages but the damage is moderate because the floods usually occur in the spring before crops have been planted. With the exception of bridges which, in many cases, have been rebuilt at higher elevations, most of the developments are subject to recurring damage. In general, the benefits of adequate flood control measures would be confined to the value of the elimination of flood damage to existing developments and would have little effect on increasing the value and productivity of the area subject to flooding.

22. Annual Value of Elimination of Flood Damage. - During the flood damage census, the increments of damage occurring in successive flood stages up to the maximum stage of the 1936 flood were determined. From these data, together with the expected stage-frequency as computed from existing records, a damage-frequency relation was determined. The average annual value of flood loss in that portion of the Androscoggin valley lying below prospective reservoir sites was determined as $453,500. This amount represents the total possible annual flood control benefit which may be realized by the complete elimination of flood damage.

23. Improvement Desired. - No definite opinion on the general plan and extent of flood control measures has been expressed by local interests.

24. Possible Methods of Flood Control. - The more important and most generally applicable methods for flood control are the protection by levees or river walls, control by channel improvement or rectification, diversion of the flood flows and control by reservoirs. In the Androscoggin Basin diversion of flood flows is not practicable. Channel improvements and flood protection by levees or river walls are not applicable for comprehensive flood control throughout the entire valley. These methods have been considered for local flood protection problems and as supplementary protection to possible reservoir control.

25. Reservoir Control. - The most desirable method of obtaining general flood relief in this basin is by means of reservoirs. A study of all possible reservoir sites throughout the basin has revealed that there are several favorable sites for flood control reservoirs which, in conjunction with existing power reservoirs and natural lakes, would afford control for about 75 per cent of the total watershed area. The provision of such reservoir control would afford appreciable reductions in flood stages at the principal damage centers in the basin and would eliminate about 80 per cent of the estimated possible flood damage.

26. Power Development in Conjunction with Reservoir Control. - There is little need for additional power in the Androscoggin Basin at the present time. The export of hydro-electric power from the State of Maine is prohibited by law and the present local needs are well taken care of by existing installations and by interconnection with the adjoining Kennebec Basin. There are several potential power sites in the basin remaining undeveloped and at least one site appears to be favorable for combined flood control and power storage with a power installation. However, in view of the excess generating capacity now available, it would not be practicable to develop any of these

possibilities at the present time. Even if the need for additional power should arise, the demand could be met more economically by redevelopment of existing installations.

27. Local Flood Protection. - An investigation of possibilities for local flood protection by means of channel improvements and levees or river walls at 13 critical damage centers in the basin has revealed that the cost of providing such protection would greatly exceed the benefits which could be realized. There is, however, opportunity for alleviation of the flood situation in many of these and other localities by increasing spillway capacities and the provision of flood gates at the power dams, the provision of greater clearances of bridges, and the elimination of channel encroachment of bridge piers, abutments, etc.

28. Flood Warnings. - Another practical method of lessening flood damages is by means of the flood-warning service maintained by the United States Weather Bureau. When a rainstorm is threatening to pass into the watershed, its probabilities are studied and the companies controlling the storage are informed of the expected rainfall. If the lakes are full and the rainfall threatens to be considerable, the water levels are drawn down in advance of the storm. The amount drawn is determined from the run-off records of the companies and depends on the saturation of the ground, snow cover, the season of the year, etc., as well as on the probable rainfall. By this means storage is made available when the run-off begins, and this not only reduces the flood levels of the lakes, but also lessens the maximum discharge of the river, thus alleviating flood losses. Of course, distant headwater reservoirs must be drawn down in ample time, for if discharged immediately prior to or during the early stages of a flood, they could contribute to an increase in downstream flood stages by filling the valley storage. Two important factors affecting floods in this basin are the extent and water equivalent of the snow cover

and the condition of the ground underneath the snow. Limited observations are now made of precipitation in the form of snow by the United States Weather Bureau, power companies, winter sport organizations and other agencies, but additional estimates by trained observers of the amount of snow cover and its water equivalent are necessary to increase the value of the flood-forecasting service. Extension and correlation of investigations of hydrologic conditions in the basin through cooperation of all agencies concerned, to the end that improved flood forecasts and adequate warning be provided to the companies controlling the storage and to the public, appear to be desirable.

29. Discussion. - Although appreciable flood losses may result from the occurrence of extreme rains on a snow-covered watershed, the frequency of damaging floods is not great and the average annual flood damage is comparatively small. General flood protection throughout the valley by means of levees, river walls, or channel improvements is not practicable and the most favorable local flood protection possibility by this means would cost about twice as much as the prospective benefits. Reservoir control, however, is entirely practicable and at least four sites are available where storage can be provided economically, either for flood control alone or for combined flood control and power storage developments. Although a reservoir system which would eliminate about 50 per cent of the estimated possible annual flood damage is entirely practicable, the cost of such a system would not be justified by the prospective benefits at the present time.

30. Conclusions. - Flood control by means of reservoirs, either for flood control alone or for combined flood control and power storage, is entirely practicable in this basin but complete protection by this means is not economically justified at the present time. It is possible, however, that partial protection may be warranted. It is also possible that, when and if further development takes place in the

valley, the need and justification for flood control may increase. Although local flood protection by means of river walls and channel improvements is not warranted, it is believed that much can be done to alleviate local flood problems by the reconstruction, repair, or removal of existing dams, bridges and buildings which now form obstructions to flood flows. Such improvements could be undertaken economically when a structure has reached the end of its economic or physical life, or when reconstruction is required for some purpose other than for flood control alone. It is also believed that a measure of flood protection can be realized by continuation and encouragement of the purposeful control of existing storage whenever hydrological conditions indicate a probable flood situation.

31. Recommendations. - It is recommended that a survey be made to determine the extent of flood protection by means of reservoirs which can be justified. It is also recommended that the states be encouraged to control the development along the river with a view to eliminating improper clearances and encroachments on the river channel and to coordinate the operation of existing storage reservoirs so as to achieve the maximum flood protection consistent with the conservation requirements of the storage. It is further recommended that the flood-warning and flood-forecasting services of all agencies concerned be extended and correlated through the United States Weather Bureau in order that improved forecasts and warnings may be provided.

A. K. B. Lyman
Lt. Col., Corps of Engineers
District Engineer

Incloa.:
Map of Androscoggin Basin

PRELIMINARY EXAMINATION OF THE ANDROSCOGGIN RIVER,
MAINE AND NEW HAMPSHIRE, FOR FLOOD CONTROL

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Syllabus

The District Engineer finds that, although the Androscoggin Basin is subject to appreciable flood losses, the annual flood damage is comparatively small and complete flood protection cannot be economically provided at the present time. General flood protection by means of levees or channel improvement is not practicable and local flood protection by these means is not justified at the present time. Reservoir control is entirely practicable, however, and it is possible that partial protection by this means may be justified. It is also possible that, if further development takes place in the valley, the need and justification for flood control may increase.

The District Engineer recommends that a survey be made to determine the extent of reservoir control which may be justified.

The District Engineer further recommends that the states be encouraged to provide regulation for the elimination of channel encroachments and for the control of existing storage and also that the flood warning and flood forecasting services of all agencies be extended and correlated through the United States Weather Bureau.

War Department
United States Engineer Office
Boston, Massachusetts

October 11, 1937

Subject: Report on a Preliminary Examination of the Androscoggin River, Maine and New Hampshire, for Flood Control

To: The Division Engineer, North Atlantic Division, New York, N.Y.

1. Authority. - This report is submitted in accordance with an Act (Public No. 812, 74th Congress) approved June 25, 1936, authorizing a "preliminary examination of the Androscoggin River, in Maine and New Hampshire, and its tributaries, with a view to control of their floods" and the Flood Control Act (Public No. 738, 74th Congress) approved June 22, 1936, which directs in part as follows:

"Section 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following-named localities, * * * * * * * * * * Androscoggin River, Maine * * * * * * * * * *."

2. Prior Reports. - The only prior reports made on this river pertaining to flood control are the report made under the provisions of House Document No. 348, 69th Congress, 1st Session (printed as House Document No. 646, 71st Congress, 3d Session) and the review thereof (not printed) dated December 30, 1936, which was made under the authority of resolutions of the Committee on Commerce of the United States Senate and the Committee on Flood Control of the House of Representatives.

3. Existing Project. - There are no existing or prior projects for flood control for the Androscoggin River.

4. Description of the Watershed. - The Androscoggin River Basin is located principally in western Maine, with part of the headwater area, about 20 per cent of the total, lying in New Hampshire. The basin has a length of 110 miles, a maximum width of 55 miles, and a total drainage area of 3,470 square miles. The lake and pond area, amounting to 143 square miles or 4.1 per cent of the total basin area, exercises a considerable degree of control over about 1,400 square miles, or 40 per cent of the total basin area. The topography ranges from rough and mountainous in the upper portion to broad, low hills with considerable lake and swamp area in the lower portions. The river and its tributaries follow irregular, winding courses over deep glacial overburden beneath which the pre-glacial bedrock drainage courses are completely buried. Where the bedrock is exposed or close to the surface, as it is in numerous short channel reaches in the high hills and mountains , the channel has not been incised into the rock more than 5 to 10 feet. The bedrock is predominantly granite, schist and gneiss, with occasional areas of slate and other metamorphic rock. The overburden consists mainly of gravelly, somewhat silty sands.

5. Development Within the Basin. - The total population of the basin in 1930 was about 150,000, most of which is contained in the six largest cities, all over 3,000 population, which are located on the main stream. The upper part of the basin is largely forest covered and has comparatively few settlements. In the lower half of the basin there is a large volume of manufacturing, the principal products being cotton goods, pulp and paper. The lower part of the basin has good highways and is served by the Maine Central and Grand Trunk Railroads.

6. Description of the Main River. - The Androscoggin River rises at the Canadian border near the boundary between the States of Maine and New Hampshire, in mountainous territory, at an elevation of about 2,600 to 2,900 feet above mean sea level. From Umbagog Lake, about 35 miles south of the headwaters, the river flows in a southerly direction for about 35 miles, then turns easterly into Maine for about 70 miles, and thence flows in a general southerly direction for 60 miles to tidewater at Brunswick, Maine. The main stream has an average slope over its 200-mile length of about 13 feet per mile. Much of the fall is concentrated near Berlin, New Hampshire and at Rumford, Maine. The average discharge for the [illegible]-year period of record at Auburn, Maine, (drainage area, 3,260 square miles) is 5,420 c.f.s.; the maximum, 135,000 c.f.s.; and the minimum, 465 c.f.s.

7. Tributaries. - The principal tributaries are shown in the following table:

TABLE I - TRIBUTARIES OF THE ANDROSCOGGIN RIVER

| River | Drainage Area (sq.mi.) | Location | | Distance of Mouth from Tidewater (miles) | Discharge of Record c.f.s./sq.mi. | | |
|---|---|---|---|---|---|---|---|
| | | Headwaters | Mouth | | Max. | Min. | Mean |
| Magalloway | 500 | At International boundary 13 mi. N. of Big Island, Me. | Errol, N. H. | 165 | Completely regulated | | |
| Swift | 135 | 5 mi. N. of Houghton, Me. | Rumford, Me. | 82 | 136.84 | .05* | 1.87 |
| Webb | 125 | 3 mi. N.E. of Weld, Me. | Dixfield, Me. | 75 | No gaging station | | |
| Dead | 100 | 4 mi. N. of Vienna, Me. | 5 mi. N. of Leeds, Me. | 46 | No gaging station | | |
| Nezinscot | 275 | 2 mi. N.W. of Hebron, Me. | 4 mi. N. E. of Turner, Me. | 38 | No gaging station | | |
| Little Androscoggin | 350 | Bryant Pond, Me. | Auburn, Me. | 24 | 46.58 | .01* | 1.83 |

* Regulated by controlled storage.

6. Development of Water Resources. - The Androscoggin River has been very highly developed for power. Of an estimated 353,000 horsepower available, 246,469 horsepower in 42 installations have been developed. Twenty-eight installations, utilizing 775 feet of head and totalling 239,873 horsepower are on the main stream and the remaining 14 installations, with 310 feet of head and totalling 6,596 horsepower, are on the tributaries. The storage capacity is equally well developed, amounting to about 740,000 acre-feet for the entire drainage area, or about 213 acre-feet per square mile. Most of this storage is contained in the large natural lakes in the upper basin which are controlled for power storage. The 1,095 square miles above Errol, New Hampshire, about 32 per cent of the total

basin area, are very completely controlled, containing 675,000 acre-feet of storage.

9. Hydrology. - The climate is variable, with temperatures ranging from below freezing for the two or three winter months to the high summer temperatures required to support a varied plant life. The mean annual precipitation of 39.4 inches is rather uniformly distributed throughout the year, but it is characterized by short, frequent periods of heavy rain. The annual snowfall is quite heavy, ranging from about 77 inches near the coast to 130 inches on the northern headwaters. Comparative data are shown in the following table:

TABLE II - MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION - ANDROSCOGGIN RIVER BASIN

| Month | Mean Temperature (°F.) | Mean Precipitation (Inches) | Equivalent Run-off in Inches at Rumford, Me. (D.A = 2090 sq.mi., or 60% of total basin) |
|---|---|---|---|
| Jan. | 16.0 | 3.03 | 1.36 |
| Feb. | 17.4 | 2.86 | 1.16 |
| Mar. | 28.8 | 3.35 | 2.07 |
| Apr. | 41.2 | 2.95 | 3.85 |
| May | 53.3 | 3.31 | 3.77 |
| June | 62.0 | 3.53 | 2.09 |
| July | 68.0 | 3.60 | 1.38 |
| Aug. | 65.2 | 3.64 | 1.24 |
| Sept. | 58.0 | 3.43 | 1.23 |
| Oct. | 47.3 | 3.24 | 1.41 |
| Nov. | 34.1 | 3.39 | 1.65 |
| Dec. | 21.3 | 3.07 | 1.41 |
| Annual | 42.7 | 39.40 | 22.65 |

10. Records of Precipitation. - There are 9 observation stations for precipitation maintained by the United States Weather Bureau in the Androscoggin watershed. The data concerning these stations are listed in the following table.

TABLE III - PRECIPITATION STATIONS - ANDROSCOGGIN RIVER BASIN

| Station | Elevation (Feet above M.S.L.) | Period of Record | Length of Record (Years) | Remarks |
|---|---|---|---|---|
| Oquossuc, Me. | 1534 | 1900-1930 | 31 | 1902,03,07,09,12-16, 30 records incomplete |
| Upper Dam, Me. | 1484 | 1886-1935 | 50 | |
| Middle Dam, Me. | 1430 | 1905-1935 | 31 | 1935 record incomplete |
| Aziscohos Dam, Me. | 1528 | 1911-1933 | 23 | 1933 record incomplete |
| Errol, N. H. | 1260 | 1885-1935 | 51 | 1929, 30, 32, 34 records incomplete |
| Milan, N. H. | 1190 | 1887-1898<br>1926-1935 | 22 | 1898, 1926 records incomplete |
| Berlin, N. H. | 1110 | 1887-1903<br>1918-1935 | 35 | |
| Rumford, Me. | 505 | 1894-1935 | 42 | |
| Lewiston, Me. | 182 | 1875-1935 | 61 | |

11. Records of Stream Flow. - There are 11 stream gaging stations in the basin maintained by the United States Geological Survey. Data concerning these stations are given in the following table:

TABLE IV - GAGING STATIONS - ANDROSCOGGIN RIVER BASIN

| Location of Gaging Station | Drainage Area (sq.mi.) | Period of Record | Discharge of Record in Cubic Feet Per Second | | |
|---|---|---|---|---|---|
| | | | Mean | Maximum | Minimum |
| **Androscoggin River** | | | | | |
| Errol, N. H. | 1090 | 1905-1923 | ** | | |
| Berlin, N. H. | 1380 | 1913-1922 | 2180 | 14,300 | * |
| Gorham, N. H. | 1390 | 1929-1936 | 2360 | 19,900 | 960* |
| Shelburne, N. H. | 1500 | 1903-1907 | - | 15,600 | * |
| Rumford, Me. | 2090 | 1892-1936 | 3480 | 74,000 | * |
| Dixfield, Me. | 2230 | 1902-1908 | 4980 | - | * |
| Gulf Island, Me. | 2860 | 1936 | - | 118,000 | 1550* |
| Auburn, Me. | 3260 | 1928-1936 | 5420 | 135,000 | 465* |
| **Magalloway River** | | | | | |
| Aziscohos Twn, N. H. | 233 | 1912-1935 | ** | | |
| **Swift River** | | | | | |
| Roxbury, Me. | 95 | 1929-1936 | 178 | 13,000 | 5 |
| **Little Androscoggin River** | | | | | |
| South Paris, Me. | 76 | 1913-1924<br>1931-1936 | 139 | 6,980 | 1 |

* Flow affected by controlled storage.
** Completely regulated.

12. Accuracy of Gaging Stations. - In general, the accuracy of the stream gaging stations in the basin is very good. The discharge is computed from the flow over dams or through gates or wheels at five of the eleven stations. Good rating curves have been developed for most of the stations for medium and high stages. The records are considered very good, except during periods of ice cover, when they are fair.

13. General Flood Situation. - About 40 per cent of the Androscoggin watershed is at least partially controlled by the natural lakes and ponds, most of which are regulated for power storage. This storage, although it does not provide positive flood control at all times, is quite effective in reducing flood stages for ordinary floods. It is not, however, generally effective for extreme floods. The extreme floods in this basin, on the other hand, are possible only from the

combination of heavy rain and melting snow, and their occurrence is comparatively infrequent. The resulting damages are confined generally to the industrial areas near the river channel in the lower portions of the watershed.

14. Types of Storms. - The storms which occur in the Androscoggin Basin may be classified into three general types as follows: (1) extratropical cyclones; (2) tropical hurricanes; and (3) rain storms caused by the rapid displacement upward of a warm air mass by a colder, denser air mass, usually accompanied by an extratropical cyclone or a tropical hurricane. Of these, the extratropical cyclones are the most numerous. They occur throughout the year and are the principal factor in providing the uniform year-round precipitation of the basin. The more severe rains are caused by the second and third types of storms. The tropical hurricanes, however, are restricted generally to the summer and early fall seasons, - a time when the ground conditions are such that much of the heavy rainfall can be absorbed without causing unusual flooding. The most dangerous storms, from a flood standpoint, are the rains caused by the movements of warm and cold air masses. Such storms may occur at any time of the year and the most severe floods in the basin are caused by this type of disturbance bringing unusual temperatures and heavy rainfall to a snow-covered basin.

15. Effect of Snow. - Recent snow surveys of storage operators in the basin indicate that there is usually an accumulated water equivalent of about 10 inches in the annual snow cover at the time of the spring "thaw" and that this cover is usually converted to run-off in one continuous period of about 10 to 15 days. Additional studies on snow run-off made by this office support these observations and lead to the conclusion that snow is usually a contributing factor to the spring floods in this basin and it may be the principal cause.

16. Effect of Ice. - Ice is also a factor in the floods which occur early in the spring. It is not always, however, of great importance. The Androscoggin River flows in a general southerly direction and normally the ice in the lower reaches softens and goes out sooner than that in the upper reaches and headwaters. On the other hand, when the spring break-up occurs early, ice jams, comprising thick, solid "blue ice", are likely to form at obstructions in the river. On these occasions serious damage may be caused by these ice jams, as during the flood of March, 1936, when a railroad bridge at Brunswick was carried out by the force of the jam.

17. Record of Past Floods. - The six highest floods of record on the Androscoggin River at Rumford, Maine (drainage area, 2,090 square miles, of which 1,096 square miles are completely controlled) were as follows:

TABLE V - RECORD FLOODS - ANDROSCOGGIN RIVER AT RUMFORD, MAINE

| Date | Average 24-Hour Discharge (c.f.s.) | Instantaneous Peak Discharge (c.f.s.) | Average Run-off for One Day in c.f.s. per sq. mile |
|---|---|---|---|
| March 19, 1936 | 68,300 | 74,000 | 32.6 |
| April 15, 1895 | 55,230 | - | 26.4 |
| November 5, 1927 | 39,100 | - | 18.7 |
| March 2, 1896 | 39,010 | - | 18.6 |
| May 18, 1893 | 38,060 | - | 18.2 |
| March 13, 1936 | 35,600 | 38,200 | 17.0 |

18. Flood Frequency. - Spring, because of the occurrence of snow run-off with or without rain, is the season of high water and floods in the Androscoggin Basin. Of all peak discharges greater than the average annual flood over the period of record from 1893 to 1936 at Rumford, one-third occurred during the month of April and two-thirds occurred during the months of March, April and May. The

computed frequency for discharges at Rumford, Maine, is as follows:

| Period | 24-Hour Discharge in c.f.s. |
|---|---|
| Once in 1 year | 20,000 |
| Once in 10 years | 38,000 |
| Once in 50 years | 54,000 |
| Once in 75 years | 59,000 |
| Once in 100 years | 62,000 |

19. Description of the Great Flood of Record. - The March, 1936, flood in this basin was the greatest on record. The maximum discharge of 68,300 c.f.s. exceeded the highest previously recorded (in 1895) by nearly 25 per cent and the flood losses were many times greater than any previously suffered. The flood was caused by a succession of two storms within a period of 11 days. Rainfall for the 11-day period was heavy throughout the entire New England area, varying from a few inches along the coast to a maximum of about 20 inches in the White Mountains, which are the common headwaters of the Connecticut, Merrimack, Kennebec and Saco Basins, as well as the Androscoggin Basin. Four lives were lost in the Androscoggin Basin during the flood and over 1,500 families, involving about 6,000 people, were temporarily homeless. About 2,000 buildings were affected by the flood. Eighteen bridges were wholly or partially destroyed and ten additional bridges suffered some damage. Although the actual area flooded was not large, several towns were practically cut off from the outside world for from one to four days as railroad, highway, telephone and telegraph facilities were disrupted. Several towns were temporarily without light, power and water. The depth of water in the area flooded varied greatly. In the towns and cities a few principal streets were covered to depths of from one to five feet generally, although depths as great as 15 feet were reported in Brunswick, Maine.

20. Flood Damages. - The only complete data on flood damages available for this basin are those collected after the flood of March, 1936. These figures, however, are very reliable, having been obtained by means of a thorough census of the individual sufferers in the basin shortly after the flood. The results of the census are shown in the following table. Of the total damages of $4,392,000 in the basin, $4,232,000, or 96 per cent were in the State of Maine and the remainder, only 4 per cent, in New Hampshire. There is no record of the losses in 1896, but it is known that several highway bridges were washed out and that a large number of logs were carried away. In November, 1927, there were severe losses, especially at Berlin and Gorham, totalling about $400,000 plus an unestimated amount for damage to railways. The losses from all prior floods, however, were probably much less than those for March, 1936, as tabulated below.

TABLE VI - FLOOD DAMAGES - ANDROSCOGGIN RIVER BASIN - MARCH, 1936

| Class | Indirect | Direct | Total |
|---|---|---|---|
| Industrial | $ 634,500 | $ 867,000 | $ 1,501,500 |
| Commercial | 87,200 | 302,200 | 389,400 |
| Farm and Rural | 900 | 232,600 | 233,500 |
| Residential | 2,600 | 319,600 | 322,200 |
| Railroads* | 86,800 | 290,900 | 377,700 |
| Highways* | | 550,300 | 550,300 |
| Utilities | 6,000 | 149,200 | 155,200 |
| Public Funds (Municipal) | | 44,200 | 44,200 |
| Total Reported | $ 818,000 | $ 2,756,000 | $ 3,574,000 |
| Estimated Unreported | $ 818,000 | - | $ 818,000 |
| Grand Total | $ 1,636,000 | $ 2,756,000 | $ 4,392,000 |

* Includes bridges.

21. Value and Productivity of Area Subject to Flooding. - Although the area subject to flooding in this basin is not large, a large amount of industrial property is subject to damage during extreme floods. Many of the industries of this region, consisting primarily of textile, boot and shoe, and pulp and paper mills, are located immediately adjacent to the normal river channel. Similarly, the commercial sections of several communities are located near the waterfront. These developments, together with power plants and bridges, are subject to appreciable losses within a comparatively small extent of flooded area. They are seriously affected, however, only by the more extreme floods. The amount of agricultural land flooded may be extensive for the extreme stages but the damage is moderate because the floods usually occur in the spring before crops have been planted. With the exception of bridges which, in many cases, have been rebuilt at higher elevations, most of the developments are subject to recurring damage. In general, the benefits of adequate flood control measures would be confined to the value of the elimination of flood damage to existing developments and would have little effect on increasing the value and productivity of the area subject to flooding.

22. Annual Value of Elimination of Flood Damage. - During the flood damage census, the increments of damage occurring in successive flood stages up to the maximum stage of the 1936 flood were determined. From these data, together with the expected stage-frequency as computed from existing records, a damage-frequency relation was determined. The average annual value of flood loss in that portion of the Androscoggin valley lying below prospective reservoir sites was determined as $453,300. This amount represents the total possible annual flood control benefit which may be realized by the complete elimination of flood damage.

23. Improvement Desired. - No definite opinion on the general plan and extent of flood control measures has been expressed by local interests.

24. Possible Methods of Flood Control. - The more important and most generally applicable methods for flood control are the protection by levees or river walls, control by channel improvement or rectification, diversion of the flood flows and control by reservoirs. In the Androscoggin Basin diversion of flood flows is not practicable. Channel improvements and flood protection by levees or river walls are not applicable for comprehensive flood control throughout the entire valley. These methods have been considered for local flood protection problems and as supplementary protection to possible reservoir control.

25. Reservoir Control. - The most desirable method of obtaining general flood relief in this basin is by means of reservoirs. A study of all possible reservoir sites throughout the basin has revealed that there are several favorable sites for flood control reservoirs which, in conjunction with existing power reservoirs and natural lakes, would afford control for about 75 per cent of the total watershed area. The provision of such reservoir control would afford appreciable reductions in flood stages at the principal damage centers in the basin and would eliminate about 50 per cent of the estimated possible flood damage.

26. Power Development in Conjunction with Reservoir Control. - There is little need for additional power in the Androscoggin Basin at the present time. The export of hydro-electric power from the State of Maine is prohibited by law and the present local needs are well taken care of by existing installations and by interconnection with the adjoining Kennebec Basin. There are several potential power sites in the basin remaining undeveloped and at least one site appears to be favorable for combined flood control and power storage with a power installation. However, in view of the excess generating capacity now available, it would not be practicable to develop any of these

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28. Flood Warnings. - Another practical method of lessening flood damages is by means of the flood-warning service maintained by the United States Weather Bureau. When a rainstorm is threatening to pass into the watershed, its probabilities are studied and the companies controlling the storage are informed of the expected rainfall. If the lakes are full and the rainfall threatens to be considerable, the water levels are drawn down in advance of the storm. The amount drawn is determined from the run-off records of the companies and depends on the saturation of the ground, snow cover, the season of the year, etc., as well as on the probable rainfall. By this means storage is made available when the run-off begins, and this not only reduces the flood levels of the lakes, but also lessens the maximum discharge of the river, thus alleviating flood losses. Of course, distant headwater reservoirs must be drawn down in ample time, for if discharged immediately prior to or during the early stages of a flood, they could contribute to an increase in downstream flood stages by filling the valley storage. Two important factors affecting floods in this basin are the extent and water equivalent of the snow cover

and the condition of the ground underneath the snow. Limited observations are now made of precipitation in the form of snow by the United States Weather Bureau, power companies, winter sport organizations and other agencies, but additional estimates by trained observers of the amount of snow cover and its water equivalent are necessary to increase the value of the flood-forecasting service. Extension and correlation of investigations of hydrologic conditions in the basin through cooperation of all agencies concerned, to the end that improved flood forecasts and adequate warning be provided to the companies controlling the storage and to the public, appear to be desirable.

29. Discussion. - Although appreciable flood losses may result from the occurrence of extreme rains on a snow-covered watershed, the frequency of damaging floods is not great and the average annual flood damage is comparatively small. General flood protection throughout the valley by means of levees, river walls, or channel improvements is not practicable and the most favorable local flood protection possibility by this means would cost about twice as much as the prospective benefits. Reservoir control, however, is entirely practicable and at least four sites are available where storage can be provided economically, either for flood control alone or for combined flood control and power storage developments. Although a reservoir system which would eliminate about 80 per cent of the estimated possible annual flood damage is entirely practicable, the cost of such a system would not be justified by the prospective benefits at the present time.

30. Conclusions. - Flood control by means of reservoirs, either for flood control alone or for combined flood control and power storage, is entirely practicable in this basin but complete protection by this means is not economically justified at the present time. It is possible, however, that partial protection may be warranted. It is also possible that, when and if further development takes place in the

valley, the need and justification for flood control may increase. Although local flood protection by means of river walls and channel improvements is not warranted, it is believed that much can be done to alleviate local flood problems by the reconstruction, repair, or removal of existing dams, bridges and buildings which now form obstructions to flood flows. Such improvements could be undertaken economically when a structure has reached the end of its economic or physical life, or when reconstruction is required for some purpose other than for flood control alone. It is also believed that a measure of flood protection can be realized by continuation and encouragement of the purposeful control of existing storage whenever hydrological conditions indicate a probable flood situation.

31. Recommendations. - It is recommended that a survey be made to determine the extent of flood protection by means of reservoirs which can be justified. It is also recommended that the states be encouraged to control the development along the river with a view to eliminating improper clearances and encroachments on the river channel and to coordinate the operation of existing storage reservoirs so as to achieve the maximum flood protection consistent with the conservation requirements of the storage. It is further recommended that the flood-warning and flood-forecasting services of all agencies concerned be extended and correlated through the United States Weather Bureau in order that improved forecasts and warnings may be provided.

A. K. B. Lyman
Lt. Col., Corps of Engineers
District Engineer

Incloe.:
Map of Androscoggin Basin

PRELIMINARY EXAMINATION OF THE ANDROSCOGGIN RIVER,
MAINE AND NEW HAMPSHIRE, FOR FLOOD CONTROL

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Syllabus

The District Engineer finds that, although the Androscoggin Basin is subject to appreciable flood losses, the annual flood damage is comparatively small and complete flood protection cannot be economically provided at the present time. General flood protection by means of levees or channel improvement is not practicable and local flood protection by these means is not justified at the present time. Reservoir control is entirely practicable, however, and it is possible that partial protection by this means may be justified. It is also possible that, if further development takes place in the valley, the need and justification for flood control may increase.

The District Engineer recommends that a survey be made to determine the extent of reservoir control which may be justified.

The District Engineer further recommends that the states be encouraged to provide regulation for the elimination of channel encroachments and for the control of existing storage and also that the flood warning and flood forecasting services of all agencies be extended and correlated through the United States Weather Bureau.

War Department
United States Engineer Office
Boston, Massachusetts

October 11, 1937

Subject: Report on a Preliminary Examination of the Androscoggin River, Maine and New Hampshire, for Flood Control

To: The Division Engineer, North Atlantic Division, New York, N.Y.

1. Authority. - This report is submitted in accordance with an Act (Public No. 812, 74th Congress) approved June 25, 1936, authorizing a "preliminary examination of the Androscoggin River, in Maine and New Hampshire, and its tributaries, with a view to control of their floods" and the Flood Control Act (Public No. 738, 74th Congress) approved June 22, 1936, which directs in part as follows:

"Section 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following-named localities, * * * * * * * * * * Androscoggin River, Maine * * * * * * * * * * ."

2. Prior Reports. - The only prior reports made on this river pertaining to flood control are the report made under the provisions of House Document No. 348, 69th Congress, 1st Session (printed as House Document No. 646, 71st Congress, 3d Session) and the review thereof (not printed) dated December 30, 1936, which was made under the authority of resolutions of the Committee on Commerce of the United States Senate and the Committee on Flood Control of the House of Representatives.

3. Existing Project. - There are no existing or prior projects for flood control for the Androscoggin River.

4. Description of the Watershed. - The Androscoggin River Basin is located principally in western Maine, with part of the headwater area, about 20 per cent of the total, lying in New Hampshire. The basin has a length of 110 miles, a maximum width of 55 miles, and a total drainage area of 3,470 square miles. The lake and pond area, amounting to 143 square miles or 4.1 per cent of the total basin area, exercises a considerable degree of control over about 1,400 square miles, or 40 per cent of the total basin area. The topography ranges from rough and mountainous in the upper portion to broad, low hills with considerable lake and swamp area in the lower portions. The river and its tributaries follow irregular, winding courses over deep glacial overburden beneath which the pre-glacial bedrock drainage courses are completely buried. Where the bedrock is exposed or close to the surface, as it is in numerous short channel reaches in the high hills and mountains , the channel has not been incised into the rock more than 5 to 10 feet. The bedrock is predominantly granite, schist and gneiss, with occasional areas of slate and other metamorphic rock. The overburden consists mainly of gravelly, somewhat silty sands.

5. Development Within the Basin. - The total population of the basin in 1930 was about 150,000, most of which is contained in the six largest cities, all over 3,000 population, which are located on the main stream. The upper part of the basin is largely forest covered and has comparatively few settlements. In the lower half of the basin there is a large volume of manufacturing, the principal products being cotton goods, pulp and paper. The lower part of the basin has good highways and is served by the Maine Central and Grand Trunk Railroads.

6. Description of the Main River. - The Androscoggin River rises at the Canadian border near the boundary between the States of Maine and New Hampshire, in mountainous territory, at an elevation of about 2,600 to 2,900 feet above mean sea level. From Umbagog Lake, about 35 miles south of the headwaters, the river flows in a southerly direction for about 35 miles, then turns easterly into Maine for about 70 miles, and thence flows in a general southerly direction for 60 miles to tidewater at Brunswick, Maine. The main stream has an average slope over its 200-mile length of about 13 feet per mile. Much of the fall is concentrated near Berlin, New Hampshire and at Rumford, Maine. The average discharge for the 5-year period of record at Auburn, Maine, (drainage area, 3,260 square miles) is 5,420 c.f.s.; the maximum, 135,000 c.f.s.; and the minimum, 458 c.f.s.

7. Tributaries. - The principal tributaries are shown in the following table:

TABLE 1 - TRIBUTARIES OF THE ANDROSCOGGIN RIVER

| River | Drainage Area (sq.mi.) | Location | | Distance of Mouth from Tidewater (miles) | Discharge of Record c.f.s./sq.mi. | | |
|---|---|---|---|---|---|---|---|
| | | Headwaters | Mouth | | Max. | Min. | Mean |
| Magalloway | 500 | At International boundary 13 mi. W. of Big Island, Me. | Errol, N. H. | 165 | Completely regulated | | |
| Swift | 135 | 5 mi. N. of Houghton, Me. | Rumford, Me. | 82 | 136.84 | .05* | 1.87 |
| Webb | 125 | 3 mi. N.W. of Weld, Me. | Dixfield, Me. | 75 | No gaging station | | |
| Dead | 100 | 4 mi. N. of Vienna, Me. | 5 mi. N. of Leeds, Me. | 46 | No gaging station | | |
| Nezinscot | 275 | 2 mi. N.W. of Redding, Me. | 4 mi. N. E. of Turner, Me. | 38 | No gaging station | | |
| Little Androscoggin | 380 | Bryant Pond, Me. | Auburn, Me. | 24 | 46.58 | .01* | 1.83 |

* Regulated by controlled storage.

8. Development of Water Resources. - The Androscoggin River has been very highly developed for power. Of an estimated 353,000 horsepower available, 246,469 horsepower in 42 installations have been developed. Twenty-eight installations, utilizing 775 feet of head and totalling 239,873 horsepower are on the main stream and the remaining 14 installations, with 310 feet of head and totalling 6,596 horsepower, are on the tributaries. The storage capacity is equally well developed, amounting to about 740,000 acre-feet for the entire drainage area, or about 217 acre-feet per square mile. Most of this storage is contained in the large natural lakes in the upper basin which are controlled for power storage. The 1,095 square miles above Errol, New Hampshire, about 32 per cent of the total

basin area, are very completely controlled, containing 675,000 acre-feet of storage.

9. Hydrology. - The climate is variable, with temperatures ranging from below freezing for the two or three winter months to the high summer temperatures required to support a varied plant life. The mean annual precipitation of 39.4 inches is rather uniformly distributed throughout the year, but it is characterized by short, frequent periods of heavy rain. The annual snowfall is quite heavy, ranging from about 77 inches near the coast to 130 inches on the northern headwaters. Comparative data are shown in the following table:

TABLE II - MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION - ANDROSCOGGIN RIVER BASIN

| Month | Mean Temperature (°F.) | Mean Precipitation (Inches) | Equivalent Run-off in Inches at Rumford, Me. (D.A = 2090 sq.mi., or 60% of total basin) |
|---|---|---|---|
| Jan. | 16.0 | 3.03 | 1.36 |
| Feb. | 17.4 | 2.86 | 1.16 |
| Mar. | 28.8 | 3.35 | 2.07 |
| Apr. | 41.2 | 2.95 | 3.88 |
| May | 53.3 | 3.31 | 3.77 |
| June | 62.0 | 3.53 | 2.09 |
| July | 68.0 | 3.60 | 1.38 |
| Aug. | 65.2 | 3.64 | 1.24 |
| Sept. | 58.0 | 3.43 | 1.23 |
| Oct. | 47.3 | 3.24 | 1.41 |
| Nov. | 34.1 | 3.39 | 1.65 |
| Dec. | 21.3 | 3.07 | 1.41 |
| Annual | 42.7 | 39.40 | 22.65 |

10. Records of Precipitation. - There are 9 observation stations for precipitation maintained by the United States Weather Bureau in the Androscoggin watershed. The data concerning these stations are listed in the following table.

TABLE III - PRECIPITATION STATIONS - ANDROSCOGGIN RIVER BASIN

| Station | Elevation (Feet above M.S.L.) | Period of Record | Length of Record (Years) | Remarks |
|---|---|---|---|---|
| Oquossuc, Me. | 1534 | 1900-1930 | 31 | 1902,03,07,09,12-16, 30 records incomplete |
| Upper Dam, Me. | 1484 | 1886-1935 | 50 | |
| Middle Dam, Me. | 1430 | 1905-1935 | 31 | 1935 record incomplete |
| Aziscohos Dam, Me. | 1528 | 1911-1933 | 23 | 1933 record incomplete |
| Errol, N. H. | 1260 | 1885-1935 | 51 | 1929, 30, 32, 34 records incomplete |
| Milan, N. H. | 1190 | 1887-1898<br>1926-1935 | 22 | 1898, 1926 records incomplete |
| Berlin, N. H. | 1110 | 1887-1903<br>1918-1935 | 35 | |
| Rumford, Me. | 505 | 1894-1935 | 42 | |
| Lewiston, Me. | 182 | 1875-1935 | 61 | |

11. Records of Stream Flow. - There are 11 stream gaging stations in the basin maintained by the United States Geological Survey. Data concerning these stations are given in the following table:

TABLE IV - GAGING STATIONS - ANDROSCOGGIN RIVER BASIN

| Location of Gaging Station | Drainage Area (sq.mi.) | Period of Record | Discharge of Record in Cubic Feet Per Second | | |
|---|---|---|---|---|---|
| | | | Mean | Maximum | Minimum |
| **Androscoggin River** | | | | | |
| Errol, N. H. | 1090 | 1905-1923 | ** | | |
| Berlin, N. H. | 1380 | 1913-1922 | 2180 | 14,300 | * |
| Gorham, N. H. | 1390 | 1929-1936 | 2360 | 19,900 | 960* |
| Shelburne, N. H. | 1500 | 1903-1907 | - | 15,600 | * |
| Rumford, Me. | 2090 | 1892-1936 | 3480 | 74,000 | * |
| Dixfield, Me. | 2230 | 1902-1908 | 4940 | - | * |
| Gulf Island, Me. | 2860 | 1936 | - | 116,000 | 1550* |
| Auburn, Me. | 3260 | 1928-1936 | 5420 | 135,000 | 465* |
| **Magalloway River** | | | | | |
| Aziscohos Dam, N. H. | 233 | 1912-1935 | ** | | |
| **Swift River** | | | | | |
| Roxbury, Me. | 95 | 1909-1936 | 178 | 13,000 | 5 |
| **Little Androscoggin River** | | | | | |
| South Paris, Me. | 76 | 1913-1924<br>1931-1936 | 139 | 6,980 | 1 |

* Flow affected by controlled storage.
** Completely regulated.

12. Accuracy of Gaging Stations. - In general, the accuracy of the stream gaging stations in the basin is very good. The discharge is computed from the flow over dams or through gates or wheels at five of the eleven stations. Good rating curves have been developed for most of the stations for medium and high stages. The records are considered very good, except during periods of ice cover, when they are fair.

13. General Flood Situation. - About 40 per cent of the Androscoggin watershed is at least partially controlled by the natural lakes and ponds, most of which are regulated for power storage. This storage, although it does not provide positive flood control at all times, is quite effective in reducing flood stages for ordinary floods. It is not, however, generally effective for extreme floods. The extreme floods in this basin, on the other hand, are possible only from the

combination of heavy rain and melting snow, and their occurrence is comparatively infrequent. The resulting damages are confined generally to the industrial areas near the river channel in the lower portions of the watershed.

14. Types of Storms. - The storms which occur in the Androscoggin Basin may be classified into three general types as follows: (1) extratropical cyclones; (2) tropical hurricanes; and (3) rain storms caused by the rapid displacement upward of a warm air mass by a colder, denser air mass, usually accompanied by an extratropical cyclone or a tropical hurricane. Of these, the extratropical cyclones are the most numerous. They occur throughout the year and are the principal factor in providing the uniform year-round precipitation of the basin. The more severe rains are caused by the second and third types of storms. The tropical hurricanes, however, are restricted generally to the summer and early fall seasons, - a time when the ground conditions are such that much of the heavy rainfall can be absorbed without causing unusual flooding. The most dangerous storms, from a flood standpoint, are the rains caused by the movements of warm and cold air masses. Such storms may occur at any time of the year and the most severe floods in the basin are caused by this type of disturbance bringing unusual temperatures and heavy rainfall to a snow-covered basin.

15. Effect of Snow. - Recent snow surveys of storage operators in the basin indicate that there is usually an accumulated water equivalent of about 10 inches in the annual snow cover at the time of the spring "thaw" and that this cover is usually converted to run-off in one continuous period of about 10 to 15 days. Additional studies on snow run-off made by this office support these observations and lead to the conclusion that snow is usually a contributing factor to the spring floods in this basin and it may be the principal cause.

16. Effect of Ice. - Ice is also a factor in the floods which occur early in the spring. It is not always, however, of great importance. The Androscoggin River flows in a general southerly direction and normally the ice in the lower reaches softens and goes out sooner than that in the upper reaches and headwaters. On the other hand, when the spring break-up occurs early, ice jams, comprising thick, solid "blue ice", are likely to form at obstructions in the river. On these occasions serious damage may be caused by these ice jams, as during the flood of March, 1936, when a railroad bridge at Brunswick was carried out by the force of the jam.

17. Record of Past Floods. - The six highest floods of record on the Androscoggin River at Rumford, Maine (drainage area, 2,090 square miles, of which 1,096 square miles are completely controlled) were as follows:

TABLE V - RECORD FLOODS - ANDROSCOGGIN RIVER AT RUMFORD, MAINE

| Date | Average 24-Hour Discharge (c.f.s.) | Instantaneous Peak Discharge (c.f.s.) | Average Run-off for One Day in c.f.s. per sq. mile |
|---|---|---|---|
| March 19, 1936 | 68,300 | 74,000 | 32.6 |
| April 15, 1895 | 55,230 | - | 26.4 |
| November 5, 1927 | 39,100 | - | 18.7 |
| March 2, 1896 | 39,010 | - | 18.6 |
| May 18, 1893 | 38,060 | - | 18.2 |
| March 13, 1936 | 35,600 | 38,200 | 17.0 |

18. Flood Frequency. - Spring, because of the occurrence of snow run-off with or without rain, is the season of high water and floods in the Androscoggin Basin. Of all peak discharges greater than the average annual flood over the period of record from 1893 to 1936 at Rumford, one-third occurred during the month of April and two-thirds occurred during the months of March, April and May. The

computed frequency for discharges at Rumford, Maine, is as follows:

| Period | 24-Hour Discharge in c.f.s. |
|---|---|
| Once in 1 year | 20,000 |
| Once in 10 years | 38,000 |
| Once in 50 years | 54,000 |
| Once in 75 years | 59,000 |
| Once in 100 years | 62,000 |

19. Description of the Worst Flood of Record. - The March, 1936, flood in this basin was the greatest on record. The maximum discharge of 68,300 c.f.s. exceeded the highest previously recorded (in 1895) by nearly 25 per cent and the flood losses were many times greater than any previously suffered. The flood was caused by a succession of two storms within a period of 11 days. Rainfall for the 11-day period was heavy throughout the entire New England area, varying from a few inches along the coast to a maximum of about 20 inches in the White Mountains, which are the common headwaters of the Connecticut, Merrimack, Kennebec and Saco Basins, as well as the Androscoggin Basin. Four lives were lost in the Androscoggin Basin during the flood and over 1,500 families, involving about 6,000 people, were temporarily homeless. About 2,000 buildings were affected by the flood. Eighteen bridges were wholly or partially destroyed and ten additional bridges suffered some damage. Although the actual area flooded was not large, several towns were practically cut off from the outside world for from one to four days as railroad, highway, telephone and telegraph facilities were disrupted. Several towns were temporarily without light, power and water. The depth of water in the area flooded varied greatly. In the towns and cities a few principal streets were covered to depths of from one to five feet generally, although depths as great as 15 feet were reported in Brunswick, Maine.

20. Flood Damages. - The only complete data on flood damages available for this basin are those collected after the flood of March, 1936. These figures, however, are very reliable, having been obtained by means of a thorough census of the individual sufferers in the basin shortly after the flood. The results of the census are shown in the following table. Of the total damages of $4,392,000 in the basin, $4,272,000, or 96 per cent were in the State of Maine and the remainder, only 4 per cent, in New Hampshire. There is no record of the losses in 1896, but it is known that several highway bridges were washed out and that a large number of logs were carried away. In November, 1927, there were severe losses, especially at Berlin and Gorham, totalling about $400,000 plus an unestimated amount for damage to railways. The losses from all prior floods, however, were probably much less than those for March, 1936, as tabulated below.

TABLE VI - FLOOD DAMAGES - ANDROSCOGGIN RIVER BASIN - MARCH, 1936

| Class | Indirect | Direct | Total |
|---|---|---|---|
| Industrial | $ 634,500 | $ 867,000 | $ 1,501,500 |
| Commercial | 87,200 | 302,200 | 389,400 |
| Farm and Rural | 900 | 232,600 | 233,500 |
| Residential | 2,600 | 319,600 | 322,200 |
| Railroads* | 86,800 | 290,900 | 377,700 |
| Highways* | | 550,300 | 550,300 |
| Utilities | 6,000 | 149,200 | 155,200 |
| Public Funds (Municipal) | | 44,200 | 44,200 |
| Total Reported | $ 818,000 | $ 2,756,000 | $ 3,574,000 |
| Estimated Unreported | $ 818,000 | - | $ 818,000 |
| Grand Total | $ 1,636,000 | $ 2,756,000 | $ 4,392,000 |

* Includes bridges.

21. Value and Productivity of Area Subject to Flooding. - Although the area subject to flooding in this basin is not large, a large amount of industrial property is subject to damage during extreme floods. Many of the industries of this region, consisting primarily of textile, boot and shoe, and pulp and paper mills, are located immediately adjacent to the normal river channel. Similarly, the commercial sections of several communities are located near the waterfront. These developments, together with power plants and bridges, are subject to appreciable losses within a comparatively small extent of flooded area. They are seriously affected, however, only by the more extreme floods. The amount of agricultural land flooded may be extensive for the extreme stages but the damage is moderate because the floods usually occur in the spring before crops have been planted. With the exception of bridges which, in many cases, have been rebuilt at higher elevations, most of the developments are subject to recurring damage. In general, the benefits of adequate flood control measures would be confined to the value of the elimination of flood damage to existing developments and would have little effect on increasing the value and productivity of the area subject to flooding.

22. Annual Value of Elimination of Flood Damage. - During the flood damage census, the increments of damage occurring in successive flood stages up to the maximum stage of the 1936 flood were determined. From these data, together with the expected stage-frequency as computed from existing records, a damage-frequency relation was determined. The average annual value of flood loss in that portion of the Androscoggin valley lying below prospective reservoir sites was determined as $453,500. This amount represents the total possible annual flood control benefit which may be realized by the complete elimination of flood damage.

23. Improvement Desired. - No definite opinion on the general plan and extent of flood control measures has been expressed by local interests.

24. Possible Methods of Flood Control. - The more important and most generally applicable methods for flood control are the protection by levees or river walls, control by channel improvement or rectification, diversion of the flood flows and control by reservoirs. In the Androscoggin Basin diversion of flood flows is not practicable. Channel improvements and flood protection by levees or river walls are not applicable for comprehensive flood control throughout the entire valley. These methods have been considered for local flood protection problems and as supplementary protection to possible reservoir control.

25. Reservoir Control. - The most desirable method of obtaining general flood relief in this basin is by means of reservoirs. A study of all possible reservoir sites throughout the basin has revealed that there are several favorable sites for flood control reservoirs which, in conjunction with existing power reservoirs and natural lakes, would afford control for about 75 per cent of the total watershed area. The provision of such reservoir control would afford appreciable reductions in flood stages at the principal damage centers in the basin and would eliminate about 50 per cent of the estimated possible flood damage.

26. Power Development in Conjunction with Reservoir Control. - There is little need for additional power in the Androscoggin Basin at the present time. The export of hydro-electric power from the State of Maine is prohibited by law and the present local needs are well taken care of by existing installations and by interconnection with the adjoining Kennebec Basin. There are several potential power sites in the basin remaining undeveloped and at least one site appears to be favorable for combined flood control and power storage with a power installation. However, in view of the excess generating capacity now available, it would not be practicable to develop any of these

possibilities at the present time. Even if the need for additional power should arise, the demand could be met more economically by redevelopment of existing installations.

27. Local Flood Protection. - An investigation of possibilities for local flood protection by means of channel improvements and levees or river walls at 13 critical damage centers in the basin has revealed that the cost of providing such protection would greatly exceed the benefits which could be realized. There is, however, opportunity for alleviation of the flood situation in many of these and other localities by increasing spillway capacities and the provision of flood gates at the power dams, the provision of greater clearances of bridges, and the elimination of channel encroachment of bridge piers, abutments, etc.

28. Flood Warnings. - Another practical method of lessening flood damages is by means of the flood-warning service maintained by the United States Weather Bureau. When a rainstorm is threatening to pass into the watershed, its probabilities are studied and the companies controlling the storage are informed of the expected rainfall. If the lakes are full and the rainfall threatens to be considerable, the water levels are drawn down in advance of the storm. The amount drawn is determined from the run-off records of the companies and depends on the saturation of the ground, snow cover, the season of the year, etc., as well as on the probable rainfall. By this means storage is made available when the run-off begins, and this not only reduces the flood levels of the lakes, but also lessens the maximum discharge of the river, thus alleviating flood losses. Of course, distant headwater reservoirs must be drawn down in ample time, for if discharged immediately prior to or during the early stages of a flood, they could contribute to an increase in downstream flood stages by filling the valley storage. Two important factors affecting floods in this basin are the extent and water equivalent of the snow cover

and the condition of the ground underneath the snow. Limited observations are now made of precipitation in the form of snow by the United States Weather Bureau, power companies, winter sport organizations and other agencies, but additional estimates by trained observers of the amount of snow cover and its water equivalent are necessary to increase the value of the flood-forecasting service. Extension and correlation of investigations of hydrologic conditions in the basin through cooperation of all agencies concerned, to the end that improved flood forecasts and adequate warning be provided to the companies controlling the storage and to the public, appear to be desirable.

29. Discussion. - Although appreciable flood losses may result from the occurrence of extreme rains on a snow-covered watershed, the frequency of damaging floods is not great and the average annual flood damage is comparatively small. General flood protection throughout the valley by means of levees, river walls, or channel improvements is not practicable and the most favorable local flood protection possibility by this means would cost about twice as much as the prospective benefits. Reservoir control, however, is entirely practicable and at least four sites are available where storage can be provided economically, either for flood control alone or for combined flood control and power storage developments. Although a reservoir system which would eliminate about 80 per cent of the estimated possible annual flood damage is entirely practicable, the cost of such a system would not be justified by the prospective benefits at the present time.

30. Conclusions. - Flood control by means of reservoirs, either for flood control alone or for combined flood control and power storage, is entirely practicable in this basin but complete protection by this means is not economically justified at the present time. It is possible, however, that partial protection may be warranted. It is also possible that, when and if further development takes place in the

valley, the need and justification for flood control may increase. Although local flood protection by means of river walls and channel improvements is not warranted, it is believed that much can be done to alleviate local flood problems by the reconstruction, repair, or removal of existing dams, bridges and buildings which now form obstructions to flood flows. Such improvements could be undertaken economically when a structure has reached the end of its economic or physical life, or when reconstruction is required for some purpose other than for flood control alone. It is also believed that a measure of flood protection can be realized by continuation and encouragement of the purposeful control of existing storage whenever hydrological conditions indicate a probable flood situation.

31. Recommendations. - It is recommended that a survey be made to determine the extent of flood protection by means of reservoirs which can be justified. It is also recommended that the states be encouraged to control the development along the river with a view to eliminating improper clearances and encroachments on the river channel and to coordinate the operation of existing storage reservoirs so as to achieve the maximum flood protection consistent with the conservation requirements of the storage. It is further recommended that the flood-warning and flood-forecasting services of all agencies concerned be extended and correlated through the United States Weather Bureau in order that improved forecasts and warnings may be provided.

A. K. B. Lyman
Lt. Col., Corps of Engineers
District Engineer

Incloe.:
Map of Androscoggin Basin

PRELIMINARY EXAMINATION OF THE ANDROSCOGGIN RIVER,

MAINE AND NEW HAMPSHIRE, FOR FLOOD CONTROL

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## Syllabus

The District Engineer finds that, although the Androscoggin Basin is subject to appreciable flood losses, the annual flood damage is comparatively small and complete flood protection cannot be economically provided at the present time. General flood protection by means of levees or channel improvement is not practicable and local flood protection by these means is not justified at the present time. Reservoir control is entirely practicable, however, and it is possible that partial protection by this means may be justified. It is also possible that, if further development takes place in the valley, the need and justification for flood control may increase.

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War Department
United States Engineer Office
Boston, Massachusetts

October 11, 1937

Subject: Report on a Preliminary Examination of the Androscoggin River, Maine and New Hampshire, for Flood Control

To: The Division Engineer, North Atlantic Division, New York, N.Y.

1. Authority. - This report is submitted in accordance with an Act (Public No. 512, 74th Congress) approved June 25, 1936, authorizing a "preliminary examination of the Androscoggin River, in Maine and New Hampshire, and its tributaries, with a view to control of their floods" and the Flood Control Act (Public No. 738, 74th Congress) approved June 22, 1936, which directs in part as follows:

"Section 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following-named localities. * * * * * * * * * * Androscoggin River, Maine * * * * * * * * * * ."

2. Prior Reports. - The only prior reports made on this river pertaining to flood control are the report made under the provisions of House Document No. 308, 69th Congress, 1st Session (printed as House Document No. 646, 71st Congress, 3d Session) and the review thereof (not printed) dated December 30, 1936, which was made under the authority of resolutions of the Committee on Commerce of the United States Senate and the Committee on Flood Control of the House of Representatives.

3. Existing Project. - There are no existing or prior projects for flood control for the Androscoggin River.

4. Description of the Watershed. - The Androscoggin River Basin is located principally in western Maine, with part of the headwater area, about 20 per cent of the total, lying in New Hampshire. The basin has a length of 110 miles, a maximum width of 55 miles, and a total drainage area of 3,470 square miles. The lake and pond area, amounting to 143 square miles or 4.1 per cent of the total basin area, exercises a considerable degree of control over about 1,400 square miles, or 40 per cent of the total basin area. The topography ranges from rough and mountainous in the upper portion to broad, low hills with considerable lake and swamp area in the lower portions. The river and its tributaries follow irregular, winding courses over deep glacial overburden beneath which the pre-glacial bedrock drainage courses are completely buried. Where the bedrock is exposed or close to the surface, as it is in numbrous short channel reaches in the high hills and mountains, the channel has not been incised into the rock more than 5 to 10 feet. The bedrock is predominantly granite, schist and gneiss, with occasional areas of slate and other metamorphic rock. The overburden consists mainly of gravelly, somewhat silty sands.

5. Development Within the Basin. - The total population of the basin in 1930 was about 150,000, most of which is contained in the six largest cities, all over 3,000 population, which are located on the main stream. The upper part of the basin is largely forest covered and has comparatively few settlements. In the lower half of the basin there is a large volume of manufacturing, the principal products being cotton goods, pulp and paper. The lower part of the basin has good highways and is served by the Maine Central and Grand Trunk Railroads.

6. Description of the Main River. - The Androscoggin River rises at the Canadian border near the boundary between the States of Maine and New Hampshire, in mountainous territory, at an elevation of about 2,600 to 2,900 feet above mean sea level. From Umbagog Lake, about 35 miles south of the headwaters, the river flows in a southerly direction for about 35 miles, then turns easterly into Maine for about 70 miles, and thence flows in a general southerly direction for 60 miles to tidewater at Brunswick, Maine. The main stream has an average slope over its 200-mile length of about 13 feet per mile. Much of the fall is concentrated near Berlin, New Hampshire and at Rumford, Maine. The average discharge for the 9-year period of record at Auburn, Maine, (drainage area, 3,260 square miles) is 5,420 c.f.s.; the maximum, 135,000 c.f.s.; and the minimum 465 c.f.s.

7. Tributaries. - The principal tributaries are shown in the following table:

TABLE I - TRIBUTARIES OF THE ANDROSCOGGIN RIVER

| River | Drainage Area (sq.mi.) | Location Headwaters | Location Mouth | Distance of Mouth from Tidewater (miles) | Discharge of Record c.f.s./sq.mi. Max. | Min. | Mean |
|---|---|---|---|---|---|---|---|
| Magalloway | 500 | At International boundary 13 mi. W. of Big Island, Me. | Errol, N. H. | 165 | Completely regulated | | |
| Swift | 135 | 5 mi. N. of Houghton, Me. | Rumford, Me. | 82 | 136.84 | .05* | 1.87 |
| Webb | 125 | 3 mi. N.W. of Weld, Me. | Dixfield, Me. | 75 | No gaging station | | |
| Dead | 100 | 4 mi. N. of Vienna, Me. | 5 mi. N. of Leeds, Me. | 46 | No gaging station | | |
| Nezinscot | 275 | 2 mi. N.W. of Redding, Me. | 4 mi. N. W. of Turner, Me. | 38 | No gaging station | | |
| Little Androscoggin | 380 | Bryant Pond, Me. | Auburn, Me. | 24 | 46.58 | .01* | 1.83 |

* Regulated by controlled storage.

8. Development of Water Resources. - The Androscoggin River has been very highly developed for power. Of an estimated 353,000 horsepower available, 246,469 horsepower in 42 installations have been developed. Twenty-eight installations, utilizing 775 feet of head and totalling 239,873 horsepower are on the main stream and the remaining 14 installations, with 310 feet of head and totalling 6,596 horsepower, are on the tributaries. The storage capacity is equally well developed, amounting to about 740,000 acre-feet for the entire drainage area, or about 213 acre-feet per square mile. Most of this storage is contained in the large natural lakes in the upper basin which are controlled for power storage. The 1,095 square miles above Errol, New Hampshire, about 32 per cent of the total

basin area, are very completely controlled, containing 678,000 acre-feet of storage.

9. Hydrology. - The climate is variable, with temperatures ranging from below freezing for the two or three winter months to the high summer temperatures required to support a varied plant life. The mean annual precipitation of 39.4 inches is rather uniformly distributed throughout the year, but it is characterized by short, frequent periods of heavy rain. The annual snowfall is quite heavy, ranging from about 77 inches near the coast to 130 inches on the northern headwaters. Comparative data are shown in the following table:

TABLE II - MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION - ANDROSCOGGIN RIVER BASIN

| Month | Mean Temperature (°F.) | Mean Precipitation (inches) | Equivalent Run-off in Inches at Rumford, Me. (D.A. - 2090 sq.mi., or 60% of total basin) |
|---|---|---|---|
| Jan. | 16.0 | 3.03 | 1.36 |
| Feb. | 17.4 | 2.86 | 1.16 |
| Mar. | 28.8 | 3.35 | 2.07 |
| Apr. | 41.2 | 2.95 | 3.88 |
| May | 53.3 | 3.31 | 3.77 |
| June | 62.0 | 3.53 | 2.09 |
| July | 68.0 | 3.60 | 1.38 |
| Aug. | 65.2 | 3.64 | 1.24 |
| Sept. | 58.0 | 3.43 | 1.23 |
| Oct. | 47.3 | 3.24 | 1.41 |
| Nov. | 34.1 | 3.39 | 1.65 |
| Dec. | 21.3 | 3.07 | 1.41 |
| Annual | 42.7 | 39.40 | 22.65 |

10. Records of Precipitation. - There are 9 observation stations for precipitation maintained by the United States Weather Bureau in the Androscoggin watershed. The data concerning these stations are listed in the following table:

TABLE III - PRECIPITATION STATIONS - ANDROSCOGGIN RIVER BASIN

| Station | Elevation (Feet above M.S.L.) | Period of Record | Length of Record (Years) | Remarks |
|---|---|---|---|---|
| Oquossuc, Me. | 1534 | 1900-1930 | 31 | 1902,03,07,09,12-16, 30 records incomplete |
| Upper Dam, Me. | 1484 | 1886-1935 | 50 | |
| Middle Dam, Me. | 1430 | 1905-1935 | 31 | 1935 record incomplete |
| Aziscohos Dam, Me. | 1528 | 1911-1933 | 23 | 1933 record incomplete |
| Errol, N. H. | 1260 | 1885-1935 | 51 | 1929, 30, 32, 34 records incomplete |
| Milan, N. H. | 1190 | 1887-1898<br>1926-1935 | 22 | 1898, 1926 records incomplete |
| Berlin, N. H. | 1130 | 1887-1903<br>1918-1935 | 35 | |
| Rumford, Me. | 505 | 1894-1935 | 42 | |
| Lewiston, Me. | 182 | 1875-1935 | 61 | |

11. Records of Stream Flow. - There are 11 stream gaging stations in the basin maintained by the United States Geological Survey. Data concerning these stations are given in the following table:

TABLE IV - GAGING STATIONS - ANDROSCOGGIN RIVER BASIN

| Location of Gaging Station | Drainage Area (sq.mi.) | Period of Record | Discharge of Record in Cubic Feet Per Second | | |
|---|---|---|---|---|---|
| | | | Mean | Maximum | Minimum |
| **Androscoggin River** | | | | | |
| Errol, N. H. | 1090 | 1905-1923 | ** | | |
| Berlin, N. H. | 1380 | 1913-1922 | 2180 | 14,300 | * |
| Gorham, N. H. | 1390 | 1929-1936 | 2360 | 19,900 | 960* |
| Shelburne, N. H. | 1500 | 1903-1907 | - | 15,600 | * |
| Rumford, Me. | 2090 | 1892-1936 | 3480 | 74,000 | * |
| Dixfield, Me. | 2230 | 1902-1908 | 4940 | - | * |
| Gulf Island, Me. | 2860 | 1936 | - | 118,000 | 1550* |
| Auburn, Me. | 3260 | 1928-1936 | 5420 | 135,000 | 465* |
| **Magalloway River** | | | | | |
| Aziscohos Dam, N. H. | 233 | 1912-1935 | ** | | |
| **Swift River** | | | | | |
| Roxbury, Me. | 95 | 1929-1936 | 178 | 13,000 | 5 |
| **Little Androscoggin River** | | | | | |
| South Paris, Me. | 76 | 1913-1924<br>1931-1936 | 139 | 6,980 | 1 |

* Flow affected by controlled storage.
** Completely regulated.

12. Accuracy of Gaging Stations. - In general, the accuracy of the stream gaging stations in the basin is very good. The discharge is computed from the flow over dams or through gates or wheels at five of the eleven stations. Good rating curves have been developed for most of the stations. for medium and high stages. The records are considered very good, except during periods of ice cover, when they are fair.

13. General Flood Situation. - About 40 per cent of the Androscoggin watershed is at least partially controlled by the natural lakes and ponds, most of which are regulated for power storage. This storage, although it does not provide positive flood control at all times, is quite effective in reducing flood stages for ordinary floods. It is not, however, generally effective for extreme floods. The extreme floods in this basin, on the other hand, are possible only from the

combination of heavy rain and melting snow, and their occurrence is comparatively infrequent. The resulting damages are confined generally to the industrial areas near the river channel in the lower portions of the watershed.

14. Types of Storms. - The storms which occur in the Androscoggin Basin may be classified into three general types as follows: (1) extratropical cyclones; (2) tropical hurricanes; and (3) rain storms caused by the rapid displacement upward of a warm air mass by a colder, denser air mass, usually accompanied by an extratropical cyclone or a tropical hurricane. Of these, the extratropical cyclones are the most numerous. They occur throughout the year and are the principal factor in providing the uniform year-round precipitation of the basin. The more severe rains are caused by the second and third types of storms. The tropical hurricanes, however, are restricted generally to the summer and early fall seasons, - a time when the ground conditions are such that much of the heavy rainfall can be absorbed without causing unusual flooding. The most dangerous storms, from a flood standpoint, are the rains caused by the movements of warm and cold air masses. Such storms may occur at any time of the year and the most severe floods in the basin are caused by this type of disturbance bringing unusual temperatures and heavy rainfall to a snow-covered basin.

15. Effect of Snow. - Recent snow surveys of storage operators in the basin indicate that there is usually an accumulated water equivalent of about 10 inches in the annual snow cover at the time of the spring "thaw" and that this cover is usually converted to run-off in one continuous period of about 10 to 15 days. Additional studies on snow run-off made by this office support these observations and lead to the conclusion that snow is usually a contributing factor to the spring floods in this basin and it may be the principal cause.

16. Effect of Ice. - Ice is also a factor in the floods which occur early in the spring. It is not always, however, of great importance. The Androscoggin River flows in a general southerly directions and normally the ice in the lower reaches softens and goes out sooner than that in the upper reaches and headwaters. On the other hand, when the spring break-up occurs early, ice jams, comprising thick, solid "blue ice", are likely to form at obstructions in the river. On these occasions serious damage may be caused by these ice jams, as during the flood of March, 1936, when a railroad bridge at Brunswick was carried out by the force of the jam.

17. Record of Past Floods. - The six highest floods of record on the Androscoggin River at Rumford, Maine (drainage area, 2,090 square miles, of which 1,096 square miles are completely controlled) were as follows:

TABLE V - RECORD FLOODS - ANDROSCOGGIN RIVER AT RUMFORD, MAINE

| Date | Average 24-Hour Discharge (c.f.s.) | Instantaneous Peak Discharge (c.f.s.) | Average Run-off for One Day in c.f.s. per sq. mile |
|---|---|---|---|
| March 19, 1936 | 68,300 | 74,000 | 32.6 |
| April 15, 1895 | 55,230 | - | 26.4 |
| November 5, 1927 | 39,100 | - | 18.7 |
| March 2, 1896 | 39,010 | - | 18.6 |
| May 18, 1893 | 38,060 | - | 18.2 |
| March 13, 1936 | 35,600 | 38,200 | 17.0 |

18. Flood Frequency. - Spring, because of the occurrence of snow run-off with or without rain, is the season of high water and floods in the Androscoggin Basin. Of all peak discharges greater than the average annual flood over the period of record from 1893 to 1936 at Rumford, one-third occurred during the month of April and two-thirds occurred during the months of March, April and May. The

computed frequency for discharges at Rumford, Maine, is as follows:

| Period | 24-Hour Discharge in c.f.s. |
|---|---|
| Once in 1 year | 20,000 |
| Once in 10 years | 38,000 |
| Once in 50 years | 54,000 |
| Once in 75 years | 59,000 |
| Once in 100 years | 62,000 |

19. Description of the Worst Flood of Record. - The March, 1936, flood in this basin was the greatest on record. The maximum discharge of 68,300 c.f.s. exceeded the highest previously recorded (in 1895) by nearly 25 per cent and the flood losses were many times greater than any previously suffered. The flood was caused by a succession of two storms within a period of 11 days. Rainfall for the 11-day period was heavy throughout the entire New England area, varying from a few inches along the coast to a maximum of about 20 inches in the White Mountains, which are the common headwaters of the Connecticut, Merrimack, Kennebec and Saco Basins, as well as the Androscoggin Basin. Four lives were lost in the Androscoggin Basin during the flood and over 1,500 families, involving about 6,000 people, were temporarily homeless. About 2,000 buildings were affected by the flood. Eighteen bridges were wholly or partially destroyed and ten additional bridges suffered some damage. Although the actual area flooded was not large, several towns were practically cut off from the outside world for from one to four days as railroad, highway, telephone and telegraph facilities were disrupted. Several towns were temporarily without light, power and water. The depth of water in the area flooded varied greatly. In the towns and cities a few principal streets were covered to depths of from one to five feet generally, although depths as great as 15 feet were reported in Brunswick, Maine.

20. Flood Damages. - The only complete data on flood damages available for this basin are those collected after the flood of March, 1936. These figures, however, are very reliable, having been obtained by means of a thorough census of the individual sufferers in the basin shortly after the flood. The results of the census are shown in the following table. Of the total damages of $4,392,000 in the basin, $4,232,000, or 96 per cent were in the State of Maine and the remainder, only 4 per cent, in New Hampshire. There is no record of the losses in 1896, but it is known that several highway bridges were washed out and that a large number of logs were carried away. In November, 1927, there were severe losses, especially at Berlin and Gorham, totalling about $400,000 plus an unestimated amount for damage to railways. The losses from all prior floods, however, were probably much less than those for March, 1936, as tabulated below:

TABLE VI - FLOOD DAMAGES - ANDROSCOGGIN RIVER BASIN - MARCH, 1936

| Class | Indirect | Direct | Total |
|---|---|---|---|
| Industrial | $ 634,500 | $ 867,000 | $ 1,501,500 |
| Commercial | 87,200 | 302,200 | 389,400 |
| Farm and Rural | 900 | 232,600 | 233,500 |
| Residential | 2,600 | 319,600 | 322,200 |
| Railroads* | 86,800 | 290,900 | 377,700 |
| Highways* | | 550,300 | 550,300 |
| Utilities | 6,000 | 149,200 | 155,200 |
| Public Funds (Municipal) | | 44,200 | 44,200 |
| Total Reported | $ 818,000 | $ 2,756,000 | $ 3,574,000 |
| Estimated Unreported | $ 818,000 | - | $ 818,000 |
| Grand Total | $ 1,636,000 | $ 2,756,000 | $ 4,392,000 |

* Includes bridges.

21. Value and Productivity of Area Subject to Flooding. - Although the area subject to flooding in this basin is not large, a large amount of industrial property is subject to damage during extreme floods. Many of the industries of this region, consisting primarily of textile, boot and shoe, and pulp and paper mills, are located immediately adjacent to the normal river channel. Similarly, the commercial sections of several communities are located near the waterfront. These developments, together with power plants and bridges, are subject to appreciable losses within a comparatively small extent of flooded area. They are seriously affected, however, only by the more extreme floods. The amount of agricultural land flooded may be extensive for the extreme stages but the damage is moderate because the floods usually occur in the spring before crops have been planted. With the exception of bridges which, in many cases, have been rebuilt at higher elevations, most of the developments are subject to recurring damage. In general, the benefits of adequate flood control measures would be confined to the value of the elimination of flood damage to existing developments and would have little effect on increasing the value and productivity of the area subject to flooding.

22. Annual Value of Elimination of Flood Damage. - During the flood damage census, the increments of damage occurring in successive flood stages up to the maximum stage of the 1936 flood were determined. From these data, together with the expected stage-frequency as computed from existing records, a damage-frequency relation was determined. The average annual value of flood loss in that portion of the Androscoggin valley lying below prospective reservoir sites was determined as $453,500. This amount represents the total possible annual flood control benefit which may be realized by the complete elimination of flood damage.

23. Improvement Desired. - No definite opinion on the general plan and extent of flood control measures has been expressed by local interests.

24. Possible Methods of Flood Control. - The more important and most generally applicable methods for flood control are the protection by levees or river walls, control by channel improvement or rectification, diversion of the flood flows and control by reservoirs. In the Androscoggin Basin diversion of flood flows is not practicable. Channel improvements and flood protection by levees or river walls are not applicable for comprehensive flood control throughout the entire valley. These methods have been considered for local flood protection problems and as supplementary protection to possible reservoir control.

25. Reservoir Control. - The most desirable method of obtaining general flood relief in this basin is by means of reservoirs. A study of all possible reservoir sites throughout the basin has revealed that there are several favorable sites for flood control reservoirs which, in conjunction with existing power reservoirs and natural lakes, would afford control for about 75 per cent of the total watershed area. The provision of such reservoir control would afford appreciable reductions in flood stages at the principal damage centers in the basin and would eliminate about 50 per cent of the estimated possible flood damage.

26. Power Development in Conjunction with Reservoir Control. - There is little need for additional power in the Androscoggin Basin at the present time. The export of hydro-electric power from the State of Maine is prohibited by law and the present local needs are well taken care of by existing installations and by interconnection with the adjoining Kennebec Basin. There are several potential power sites in the basin remaining undeveloped and at least one site appears to be favorable for combined flood control and power storage with a power installation. However, in view of the excess generating capacity now available, it would not be practicable to develop any of these

possibilities at the present time. Even if the need for additional power should arise, the demand could be met more economically by redevelopment of existing installations.

27. Local Flood Protection. - An investigation of possibilities for local flood protection by means of channel improvements and levees or river walls at 13 critical damage centers in the basin has revealed that the cost of providing such protection would greatly exceed the benefits which could be realized. There is, however, opportunity for alleviation of the flood situation in many of these and other localities by increasing spillway capacities and the provision of flood gates at the power dams, the provision of greater clearances of bridges, and the elimination of channel encroachment of bridge piers, abutments, etc.

28. Flood Warnings. - Another practical method of lessening flood damages is by means of the flood-warning service maintained by the United States Weather Bureau. When a rainstorm is threatening to pass into the watershed, its probabilities are studied and the companies controlling the storage are informed of the expected rainfall. If the lakes are full and the rainfall threatens to be considerable, the water levels are drawn down in advance of the storm. The amount drawn is determined from the run-off records of the companies and depends on the saturation of the ground, snow cover, the season of the year, etc., as well as on the probable rainfall. By this means storage is made available when the run-off begins, and this not only reduces the flood levels of the lakes, but also lessens the maximum discharge of the river, thus alleviating flood losses. Of course, distant headwater reservoirs must be drawn down in ample time, for if discharged immediately prior to or during the early stages of a flood, they could contribute to an increase in downstream flood stages by filling the valley storage. Two important factors affecting floods in this basin are the extent and water equivalent of the snow cover

and the condition of the ground underneath the snow. Limited observations are now made of precipitation in the form of snow by the United States Weather Bureau, power companies, winter sport organizations and other agencies, but additional estimates by trained observers of the amount of snow cover and its water equivalent are necessary to increase the value of the flood-forecasting service. Extension and correlation of investigations of hydrologic conditions in the basin through cooperation of all agencies concerned, to the end that improved flood forecasts and adequate warning be provided to the companies controlling the storage and to the public, appear to be desirable.

29. Discussion. - Although appreciable flood losses may result from the occurrence of extreme rains on a snow-covered watershed, the frequency of damaging floods is not great and the average annual flood damage is comparatively small. General flood protection throughout the valley by means of levees, river walls, or channel improvements is not practicable and the most favorable local flood protection possibility by this means would cost about twice as much as the prospective benefits. Reservoir control, however, is entirely practicable and at least four sites are available where storage can be provided economically, either for flood control alone or for combined flood control and power storage developments. Although a reservoir system which would eliminate about 60 per cent of the estimated possible annual flood damage is entirely practicable, the cost of such a system would not be justified by the prospective benefits at the present time.

30. Conclusions. - Flood control by means of reservoirs, either for flood control alone or for combined flood control and power storage, is entirely practicable in this basin but complete protection by this means is not economically justified at the present time. It is possible, however, that partial protection may be warranted. It is also possible that, when and if further development takes place in the

valley, the need and justification for flood control may increase. Although local flood protection by means of river walls and channel improvements is not warranted, it is believed that much can be done to alleviate local flood problems by the reconstruction, repair, or removal of existing dams, bridges and buildings which now form obstructions to flood flows. Such improvements could be undertaken economically when a structure has reached the end of its economic or physical life, or when reconstruction is required for some purpose other than for flood control alone. It is also believed that a measure of flood protection can be realized by continuation and encouragement of the purposeful control of existing storage whenever hydrological conditions indicate a probable flood situation.

31. Recommendations. - It is recommended that a survey be made to determine the extent of flood protection by means of reservoirs which can be justified. It is also recommended that the states be encouraged to control the development along the river with a view to eliminating improper clearances and encroachments on the river channel and to coordinate the operation of existing storage reservoirs so as to achieve the maximum flood protection consistent with the conservation requirements of the storage. It is further recommended that the flood-warning and flood-forecasting services of all agencies concerned be extended and correlated through the United States Weather Bureau in order that improved forecasts and warnings may be provided.

A. K. B. Lyman
Lt. Col., Corps of Engineers
District Engineer

Incloe:
Map of Androscoggin Basin

WAR DEPARTMENT
OFFICE OF DIVISION ENGINEER
NORTH ATLANTIC DIVISION
Room 1400, 80 Broad Street,
NEW YORK, N. Y.

Androscoggin R. 2/3.15 December 17, 1937.

SUBJECT: Report on preliminary examination of the Androscoggin River, Maine and New Hampshire, for Flood Control.

TO: The Chief of Engineers, U. S. Army.

SYLLABUS

The Division Engineer finds that the Androscoggin River is subject to floods. Complete flood protection can be provided by a system of reservoirs and extensive local protection works. Complete flood protection is not economically justified at the present time. Partial flood protection can be provided by means of reservoir control. It is recommended that a survey be made to determine the possibility of providing flood control in the Androscoggin basin.

1. AUTHORITY. - This report is submitted in compliance with two Acts as follows: (1) Section 6 of the Flood Control Act (Public No. 738 - 74th Congress), approved June 22, 1936, which reads in part as follows:

> "The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following named localities * * * * * * * Androscoggin River, Maine, * * *"

(2) An Act (Public No. 812 - 74th Congress) approved June 25, 1936, which reads in part as follows:

> "That the Secretary of War is hereby authorized and directed to cause a preliminary examination to be made of the Androscoggin River and its tributaries in the States of Maine and New Hampshire, with a view to the control of their floods, * * *"

2. PRIOR REPORTS. - The Engineer Department has made two prior reports involving flood control on this stream. They are (1) the "308" report published as House Document No. 646 - 71st Congress, 3d session, and (2) the review thereof, dated December 30, 1936, made pursuant to resolutions of the Committee on Commerce of the U. S. Senate and the

Committee on Flood Control of the House of Representatives. This review report has not been printed. This report of preliminary examination contains pertinent data included in the review report.

3. EXISTING PROJECT. - There are no existing or prior projects for flood control on the Androscoggin River.

4. DESCRIPTION. - The watershed lies in western Maine and northeastern New Hampshire. It has a length of 110 miles and a maximum width of 55 miles. The total drainage area is 3,470 square miles. Roughly, 80% of the drainage area is in Maine and the remainder in New Hampshire. About 143 square miles of the watershed are occupied by lakes and ponds.

5. The region is blanketed with deep glacial overburden deposited upon the pre-glacial bedrock valley system. Bedrock is exposed in numerous short channel reaches in the high hills and mountains. The rock formations are predominately granite, schist, and gneiss, with occasional areas of slate and other metamorphic rock. The overburden is mainly gravelly, silty sands.

6. The upper portion of the basin is rough, mountainous, and almost entirely covered with forests. The lower portions have low, partly wooded hills, considerable cultivated land, lakes, and swamp area.

7. The total population of the basin in 1930 was about 150,000. The six largest cities in the basin are located on the main stream. They have populations ranging from approximately 4,000 to 35,000. The lower part of the basin has good highways and is served by the Maine Central and Grand Trunk Railroads. There is a large volume of manufacturing in this section. The principal products are cotton goods, pulp and paper products.

8. MAIN STREAM. - The Androscoggin River rises at the Canadian border near the Maine-New Hampshire boundary at an elevation of about 2,900 feet. It flows in a general southeasterly direction for about 200 miles to tidewater at Brunswick, Maine. The stream has an average slope

of about 13 feet per mile. Much of the fall is concentrated near Berlin, New Hampshire and at Rumford, Maine.

9. TRIBUTARIES. - The principal tributaries of the Androscoggin River are as follows:

| Stream | Drainage Area Square Miles | Miles from Mouth to Tidewater |
|---|---|---|
| Magalloway | 500 | 165 |
| Swift | 135 | 82 |
| Webb | 125 | 75 |
| Dead | 100 | 46 |
| Nezinscot | 275 | 38 |
| Little Androscoggin | 380 | 24 |

10. DEVELOPMENT OF WATER RESOURCES. - The Androscoggin River has been very highly developed for power. There are 28 installations on the main stream totalling 239,873 horsepower utilizing 775 feet of head. There are 14 installations on the tributaries totalling 6,596 horsepower utilizing 310 feet of head. The basin has been equally well developed for storage. The existing controlled storage capacity, mostly contained in the large natural lakes in the upper basin, is about 740,000 acre feet. About 678,000 acre feet of this storage is in the 1,095 square miles above Errol, New Hampshire. This portion of the basin, amounting to about 32% of the total area, is controlled well by this storage.

11. HYDROLOGY. - The mean monthly temperatures vary from 16.0° F. in January to 68.0° F. in July. The mean annual temperature is 42.7° F. The mean annual precipitation is 39.4 inches. The equivalent run-off at Rumford, Maine, drainage area 2,090 square miles, is 22.65 inches. The annual snow fall varies from about 77 inches at the coast to 130 inches in the headwaters.

12. Two general types of storms occur over the Androscoggin basin. These are (1) continental storms and (2) tropical hurricanes. The con-

tinental storms occur throughout the year. They account for the unusually uniform distribution of average monthly rainfall. The tropical hurricanes, accompanied by severe rains, generally occur in the summer and early fall seasons when the ground is dry. The resulting run-off is correspondingly small. The most severe floods in the basin are caused by general storms accompanied by warm temperatures and heavy rainfall on a snow-covered watershed.

13. FLOOD CHARACTERISTICS. - The existing storage in the Androscoggin basin exercises some degree of control over about 40 per cent of the drainage area. This storage is effective in reducing flood stages for ordinary floods. It is not sufficient to prevent damages from extreme floods. Snow is usually a contributing factor to spring floods in this basin and it may be the principal cause. Ice may be an important factor in spring floods. Generally, the ice in the lower river moves out before that in the upper reaches breaks up on account of the southerly direction of flow of the stream. When the spring break-up occurs early ice jams are likely to form at obstructions in the river. High stages result above these jams and a standing wave of high velocity is released on the valley below when the jams break.

14. RECORD OF PAST FLOODS. - The six highest floods of record at Rumford, Maine, drainage area 2,090 square miles, are as follows:

| Date | Mean Daily Discharge (c.f.s.) |
|---|---|
| March 19, 1936 | 68,300* |
| April 15, 1895 | 55,230 |
| November 5, 1927 | 39,100 |
| March 2, 1896 | 39,010 |
| May 18, 1893 | 38,060 |
| March 13, 1936 | 35,600** |

* Instantaneous peak discharge 74,000 c.f.s.

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Very rare floods with peak discharges approaching 90,000 c.f.s. may be expected.

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17. The total damages resulting from the March 1936 flood amounted to $4,392,000. Of this amount $4,232,000, or 96 per cent, occurred in Maine and the remainder, or only 4 per cent, in New Hampshire. There is no reliable record of the losses that resulted from the floods of 1896 and 1927. Losses from the latter flood were severe but they did not reach the magnitude of the losses resulting from the 1936 flood. The annual damages from floods in that portion of the basin lying below prospective reservoir sites were determined as $453,500. This amount was considered as the basis for the justification of possible flood control measures.

18. The area subject to flooding in the basin is not large. A large amount of industrial property located immediately adjacent to the normal river channel is subject to damage from extreme floods. The commercial sections of several communities located near the waterfront are seriously affected by extreme floods. Inundation of agricultural land is not serious as floods usually occur in the spring before crops are planted. In general the benefits from adequate flood control measures in the basin would be confined to the elimination of damages to existing developments. Benefits from increased value and productivity of the area subject to flooding would be negligible.

19. POSSIBLE METHODS OF FLOOD CONTROL. - The most desirable method of obtaining general flood relief in this basin is by means of reservoirs. Diversion of flood flows is not practicable. Channel improvements and flood protection by levees are not applicable for general flood protection throughout the valley on account of the excessive cost, and the problem of tributaries. These methods can be considered for positive local protection as supplements to possible reservoir control.

20. There are several favorable sites in the basin for flood control reservoirs. In conjunction with existing controlled storage these sites would control about 75 per cent of the watershed area. This is an unusually large degree of control. It would afford appreciable reductions

in flood stages at the principal damage centers and eliminate approximately 80 per cent of the estimated annual flood damage. Of the 75 per cent of the watershed area controlled, the flood control reservoirs would provide about 42 per cent and existing power storage about 33 per cent. To be effective, the operation of the flood control storage would have to be coordinated with the operation of the existing power storage.

21. An investigation was made at thirteen damage centers to determine the possibility of providing local protection works. The cost of full protection would exceed the benefits which could be realized. Protection works supplementing the reduction in flood heights obtained by prospective reservoir control may be justified.

22. Some alleviation of the flood situation in many localities can be secured by the exercise of State or local zoning control at the time present objectionable structures are replaced because of obsolescence or deterioration.

23. POWER DEVELOPMENT IN CONJUNCTION WITH RESERVOIR CONTROL. - The export of hydro-electric power from the State of Maine is prohibited by law. Present local needs are supplied well by existing installations and inter-connections with other systems. There is a possibility that at least one of the sites considered in this report could be developed for flood control and power. In view of the excess generating capacity now available, a combined development would not be practicable at the present time.

24. VIEWS AND RECOMMENDATIONS OF THE DISTRICT ENGINEER. - The District Engineer finds that flood control, either alone or in conjunction with power developments, by means of reservoirs is practicable. He finds that partial protection may be economically justified. Local flood problems may be alleviated by exercising State or local zoning control at the time existing structures that form obstructions to flood flows are replaced due to obsolescence or deterioration. The District Engineer recom-

mends a survey to determine the extent of flood protection which can be justified.

25. VIEWS OF THE ACTING DIVISION ENGINEER. - The Acting Division Engineer concurs with the views and recommendations of the District Engineer. The extent of flood loss in the basin warrants accurate determination of the justifiable extent of federal participation in flood control measures. A continuance of the study under a survey report should develop further the possibilities of requirements of local cooperation from State and municipal authorities in the form of zoning in the interest of reduction of flood heights and flood damages through elimination of channel obstructions.

26. RECOMMENDATION. - It is recommended that a survey be made to determine the possibility of providing flood control for the Androscoggin River, Maine and New Hampshire.

JOHN C. H. LEE,
Lieut. Colonel, Corps of Engineers,
Acting Division Engineer.

Incl.accpg.:
2/3.14, in quad.

WAR DEPARTMENT
OFFICE OF DIVISION ENGINEER
NORTH ATLANTIC DIVISION
Room 1400, 80 Broad Street,
NEW YORK, N. Y.

Androscoggin R. 2/3.15 December 17, 1937.

SUBJECT: Report on preliminary examination of the Androscoggin River, Maine and New Hampshire, for Flood Control.

TO: The Chief of Engineers, U. S. Army.

SYLLABUS

The Division Engineer finds that the Androscoggin River is subject to floods. Complete flood protection can be provided by a system of reservoirs and extensive local protection works. Complete flood protection is not economically justified at the present time. Partial flood protection can be provided by means of reservoir control. It is recommended that a survey be made to determine the possibility of providing flood control in the Androscoggin basin.

1. AUTHORITY. - This report is submitted in compliance with two Acts as follows: (1) Section 6 of the Flood Control Act (Public No. 738 - 74th Congress), approved June 22, 1936, which reads in part as follows:

> "The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following named localities * * * * * * * Androscoggin River, Maine, * * **

(2) An Act (Public No. 812 - 74th Congress) approved June 25, 1936, which reads in part as follows:

> "That the Secretary of War is hereby authorized and directed to cause a preliminary examination to be made of the Androscoggin River and its tributaries in the States of Maine and New Hampshire, with a view to the control of their floods, * * **"

2. PRIOR REPORTS. - The Engineer Department has made two prior reports involving flood control on this stream. They are (1) the "308" report published as House Document No. 646 - 71st Congress, 3d session, and (2) the review thereof, dated December 30, 1936, made pursuant to resolutions of the Committee on Commerce of the U. S. Senate and the

Committee on Flood Control of the House of Representatives. This review report has not been printed. This report of preliminary examination contains pertinent data included in the review report.

3. EXISTING PROJECT. - There are no existing or prior projects for flood control on the Androscoggin River.

4. DESCRIPTION. - The watershed lies in western Maine and northeastern New Hampshire. It has a length of 110 miles and a maximum width of 55 miles. The total drainage area is 3,470 square miles. Roughly, 80% of the drainage area is in Maine and the remainder in New Hampshire. About 14[illegible] square miles of the watershed are occupied by lakes and ponds.

5. The region is blanketed with deep glacial overburden deposited upon the pre-glacial bedrock valley system. Bedrock is exposed in numerous short channel reaches in the high hills and mountains. The rock formations are predominately granite, schist, and gneiss, with occasional areas of slate and other metamorphic rock. The overburden is mainly gravelly, silty sands.

6. The upper portion of the basin is rough, mountainous, and almost entirely covered with forests. The lower portions have low, partly wooded hills, considerable cultivated land, lakes, and swamp area.

7. The total population of the basin in 1930 was about 150,000. The six largest cities in the basin are located on the main stream. They have populations ranging from approximately 4,000 to 35,000. The lower part of the basin has good highways and is served by the Maine Central and Grand Trunk Railroads. There is a large volume of manufacturing in this section. The principal products are cotton goods, pulp and paper products.

8. MAIN STREAM. - The Androscoggin River rises at the Canadian border near the Maine-New Hampshire boundary at an elevation of about 2,900 feet. It flows in a general southeasterly direction for about 200 miles to tidewater at Brunswick, Maine. The stream has an average slope

of about 13 feet per mile. Much of the fall is concentrated near Berlin, New Hampshire and at Rumford, Maine.

9. THE TRIBUTARIES. - The principal tributaries of the Androscoggin River are as follows:

| Stream | Drainage Area Square Miles | Miles from Mouth to Tidewater |
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| Magalloway | 500 | 165 |
| Swift | 135 | 82 |
| Webb | 125 | 75 |
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10. DEVELOPMENT OF WATER RESOURCES. - The Androscoggin River has been very highly developed for power. There are 28 installations on the main stream totalling 239,873 horsepower utilizing 775 feet of head. There are 14 installations on the tributaries totalling 6,596 horsepower utilizing 310 feet of head. The basin has been equally well developed for storage. The existing controlled storage capacity, mostly contained in the large natural lakes in the upper basin, is about 740,000 acre feet. About 678,000 acre feet of this storage is in the 1,095 square miles above Errol, New Hampshire. This portion of the basin, amounting to about 32% of the total area, is controlled well by this storage.

11. HYDROLOGY. - The mean monthly temperatures vary from 16.0° F. in January to 68.0° F. in July. The mean annual temperature is 42.7° F. The mean annual precipitation is 39.4 inches. The equivalent run-off at Rumford, Maine, drainage area 2,090 square miles, is 22.65 inches. The annual snow fall varies from about 77 inches at the coast to 130 inches in the headwaters.

12. Two general types of storms occur over the Androscoggin basin. These are (1) continental storms and (2) tropical hurricanes. The con-

tinental storms occur throughout the year. They account for the unusually uniform distribution of average monthly rainfall. The tropical hurricanes, accompanied by severe rains, generally occur in the summer and early fall seasons when the ground is dry. The resulting run-off is correspondingly small. The most severe floods in the basin are caused by general storms accompanied by warm temperatures and heavy rainfall on a snow-covered watershed.

13. FLOOD CHARACTERISTICS. - The existing storage in the Androscoggin basin exercises some degree of control over about 40 per cent of the drainage area. This storage is effective in reducing flood stages for ordinary floods. It is not sufficient to prevent damages from extreme floods. Snow is usually a contributing factor to spring floods in this basin and it may be the principal cause. Ice may be an important factor in spring floods. Generally, the ice in the lower river moves out before that in the upper reaches breaks up on account of the southerly direction of flow of the stream. When the spring break-up occurs early ice jams are likely to form at obstructions in the river. High stages result above these jams and a standing wave of high velocity is released on the valley below when the jams break.

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