Subject: Flood Control Requirement and Operating Procedure for Ross Reservoir, Skagit River, Wash.

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Office, District Engineer, Seattle District, Corps of Engineers, 4735 East Marginal Way, Seattle 4, Washington

TO: Division Engineer, North Pacific Division, Corps of Engineers, 500 Pittock Block, Portland 5, Oregon

1. In accordance with paragraph 1 of second indorsement, the proposed operation schedule submitted with basic letter has been reconsidered and revised. The revised flood control regulations submitted herewith as Inclosure 6, have been prepared to incorporate the suggestions contained in the second indorsement. With the inclusion of a regulation schedule for surcharge storage and emergency operation, the narrative schedule was becoming too lengthy, so the format was changed to the present style. The regulation schedule, storm studies and other pertinent data are incorporated in the Ross Reservoir Regulation Manual which is included as Inclosure 7.

2. A draft of the schedule presented herewith was submitted to the City of Seattle Light Department for comments and suggestions. Personnel of the Light Department studied the draft and suggested several changes. Whenever the suggested changes in no way impaired the effective operation of Ross Reservoir for flood control, they were incorporated in the inclosed schedule.

3. Operation of the project for flood control utilizing the revised regulation schedule is based primarily on forecasts to be issued by the U. S. Weather Bureau. As of the second indorsement date the Weather Bureau was not preparing forecasts for Skagit River at Concrete. However, in response to a request from this office, the Weather Bureau has completed studies which permit the issuance of 6, 12, 18 and 24-hour forecasts of discharge for this station. These forecasts will normally be available daily from 1 October through 31 March. Whenever floods are imminent or in progress, the Weather Bureau will issue forecasts every six hours. The Weather Bureau is also prepared to issue forecasts for discharges at Sedro Woolley which is at the head of the area subject to severe flooding. Additional studies are being made to increase the accuracy of these forecasts.

4. The City of Seattle constructed Ross Reservoir primarily as a power project and provision for inclusion of flood control requirements presents operational conflicts. The City of Seattle operates its plants on Skagit River in conjunction with the Northwest Power Pool and would normally, in the interest of power, maintain a full reservoir through

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November. The drawdown required for normal power operation will provide adequate flood control protection by the first of January. Maximum drawdown is usually reached in late March or April, with the reservoir being filled during the May and June snowmelt season.

5. The flood season in Skagit Basin begins in October while power interests still would maintain Ross Reservoir at full pool when the water supply permits. Floods of considerable damaging magnitude have occurred at Sedro Woolley from October through February. As normal power drawdown is adequate for flood control requirements after 1 January, it is only from October through December when power and flood control are in serious conflict. It is therefore necessary to establish a compromise between power losses caused by requiring drawdown for flood control and flood control benefits. The first step in this connection was to establish the discharges in the lower valley area at which flood control should begin. Plate 12 of Inclosure 7 shows that minor damages are experienced in the flood plain below Sedro Woolley when the discharge exceeds 45,000 second-feet. However, losses are relatively small until discharges exceed 100,000 second-feet and flood damage begins in the major developed areas. It was therefore decided to effect the maximum crest reduction practical of flood flows at Sedro Woolley which equal or exceed 100,000 second-feet. The term maximum crest reduction, as used herein, is defined as the maximum crest reduction possible at Sedro Woolley effected by making the maximum beneficial use of the flood control storage in Ross Reservoir, while currently allowing a power release from Ross Dam not to exceed 5,000 second-feet mean daily flow. The power release was determined by Seattle City Light as being the minimum flow necessary for them to meet their power commitments.

6. Flood control operations are based on observed and forecast flows at Concrete because of the greater reliability of forecasts at this station and to take advantage of the 12 to 16-hour estimated travel time between Concrete and Sedro Woolley. Inflow between Concrete and Sedro Woolley is normally low and may or may not compensate for channel storage and overflow between the two stations. As a factor of safety in the event inflow between the two stations exceeds that which would compensate for channel storage and overflow, the critical flow at Concrete for use in operating Ross Reservoir is determined to be 90,000 second-feet.

7. The next step was to determine the amount of storage required at Ross Reservoir to provide the maximum crest reduction at Sedro Woolley. All discharges of more than 65,000 second-feet at either Sedro Woolley (1908 through 1924) and Concrete (1924 to date) occurring in October, November, and December were studied. In many of these high-water periods the discharge was close to but did not exceed 90,000 second-feet at Concrete or 100,000 second-feet at Sedro Woolley. In such cases the forecasts may have been for flows above 90,000 second-feet at Concrete and according to the schedule storage would have been required. The

possible storage requirements for these periods are shown on Inclosure 5, together with an envelope curve of proposed flood control reservation requirements. These floods of record indicate that an increasing amount of storage should be made available for flood control from 1 October through 30 November when the maximum is attained and then maintained until the end of the flood season.

8. Storage requirements for most of the high-water periods shown on Inclosure 5 were estimated. However, detailed studies of the three major floods of record indicate that 86,000 acre-feet of storage would have been adequate to effect maximum crest reductions at Sedro Woolley. The three major floods studied were those of November 1909, December 1917, and December 1921. The observed or estimated natural flow and regulated flow at both Ross Reservoir and Sedro Woolley, together with reservoir stage, for these three floods are presented on plate 22 of Inclosure 7. The regulated flows were calculated by assuming gate operation in accordance with the proposed regulation schedule, Inclosure 6. This operation requires storing at Ross Reservoir only until the crest discharge has passed Concrete, after which discharges will gradually be increased until they equal inflow. Stored water will not be evacuated until discharges at Concrete have receded to 90,000 second-feet, and will not be released in amounts to produce discharges at Concrete in excess of 90,000 second-feet. The schedule thus produces the maximum crest reduction which could be effected by Ross Reservoir, but has a negligible effect on the duration of flows of 90,000 second-feet.

9. The maximum flood control reservation of 120,000 acre-feet, as shown by the envelope curve on Inclosure 5, is therefore adequate for floods somewhat greater than those of record. For floods of even greater magnitude it will also be possible to utilize induced surcharge storage up to elevation 1,606 feet which provides additional storage of approximately 95,000 acre-feet. This surcharge storage is not as effective in controlling floods as an equal amount of storage reservation would be. However, it can be utilized to effect maximum crest reductions for floods of a magnitude almost equal to that of the Standard Project Flood. The use of surcharge storage during large floods may increase the duration of discharges of 90,000 second-feet.

10. The effect of operation of Ross Reservoir on the Standard Project Flood was also studied. It was assumed that the reservoir would be drawn down to elevation 1,589.4 feet, providing 120,000 acre-feet of storage at the beginning of the flood. The operation outlined in Inclosure 6 was followed, and induced surcharge storage to elevation 1,607.3 feet, approximately 88,000 acre-feet, was utilized. The assumed natural and regulated flows at Ross Reservoir and Sedro Woolley, together

with reservoir stage, are shown on plate 22 of Inclosure 7. This system of operation would reduce the crest discharge at Sedro Woolley from 440,000 second-feet to 398,000 second-feet, and would increase the duration of flows in excess of 90,000 second-feet at Sedro Woolley by about 4 hours. Additional studies indicated that a flood control reservation of 212,000 acre-feet, with no induced surcharge storage utilized, would decrease the crest at Sedro Woolley to 397,000 second-feet, and the duration of flows above 90,000 second-feet by about an hour. Similarly, a reservation of 293,000 acre-feet, utilizing no surcharge storage, would effect the same maximum crest reduction to 397,000 second-feet, but would effect a maximum reduction in duration of flows in excess of 90,000 second-feet of about 10 hours.

11. The results of these studies indicate that the benefits from any flood control reservation greater than the proposed 120,000 acre-feet would be very small. Such benefits would accrue only for floods occurring so rarely that they could not possibly be equal to annual losses sustained by power operation through the additional loss of head. The annual power loss which would result from various flood control storage reservations as furnished this office by the City of Seattle Department of Lighting, are tabulated below:

Flood storage space (acre-feet)	Annual power loss (dollars)
0	0
100,000	20,000
125,000	25,000
150,000	47,000
175,000	65,000
200,000	92,000

12. The storage reservation of 120,000 acre-feet plus the available induced surcharge storage will, as previously stated, effect maximum crest reduction for floods almost equal to the standard project flood. A larger amount of storage could be utilized efficiently so infrequently that requiring such a reservation at the cost of large annual power losses cannot be justified.

13. The original requirement of a reservation of 200,000 acre-feet of flood storage at Ross Reservoir was established in 1946. No flood routings were done at the time and an arbitrary assumption was made that the flood storage should equal the entire maximum 5-day run-off at the

[illegible]
[illegible]

able for the maximum flood of record, namely December 1917-January 1918. In that study no provisions were made for any releases for power during the 3-day period. If a minimum power release of 5,000 second-feet had been considered, the 200,000 acre-feet reservation requirement could have been reduced to approximately 130,000 acre-feet. Routing studies performed during the present study indicated that such an arbitrary schedule needlessly stored water at times when no benefit accrued to the lower valley. In the original study the 3-day storage period required storing to continue for several hours after flows at Sedro Woolley had receded to less than 100,000 second-feet.

14. Pending formal approval of the inclosed regulation schedule, it is planned to implement the flood control operation on 1 October 1953 on an informal basis with City Light and the Weather Bureau. Copies of the manual are being furnished both these organizations.

Incl file

LLOYD L. BALL
Lt. Col., Corps of Engineers
Acting District Engineer

3 Incl (trip)
w/d 2 Incl 4 & 5
Added 3 Incl
6. Regulation for Flood Control (Revised 1 Jul 53)
7. Reservoir Regulation Manual
8. Storage Requirement Curve

Gedney
Boswell
Steinborn
~~Bosley~~
Ball/s/
~~H & R~~

cc: Gedney, Engr. Div.
Planning & Reports Branch

Inclosure No. 1

Proposed Revision of Article 36, License for Project No. 553-Washington

Flood Control Operation of Ross Dam and Reservoir, Skagit River, Washington

During the period 1 November to 15 March, Ross Reservoir will be operated in the interest of flood control as prescribed herein.

1. Except as specified in following paragraphs 2 to 5, the following minimum amounts of storage space will be reserved for flood control:

Date	Storage space (acre-feet)
1 November	0
5 "	21,000
10 "	42,000
15 "	62,000
20 "	83,000
25 "	104,000
30 "	125,000
1 December to 15 March	125,000

2. Schedule of operation during flood periods:

a. When the flow of Skagit River at the gaging station near Concrete reaches a discharge of 50,000 second-feet and has increased at least 5,000 second-feet in the preceding hour, or when the discharge exceeds 60,000 second-feet, the licensee shall release only such flows from Ross Reservoir as are necessary to the normal production of electric energy at the Ross, Diablo, and Gorge plants (approximately 6,000 second-feet maximum).

b. Normal power releases only shall continue until the discharge at the gage near Concrete has remained constant for one hour or has commenced to decrease, and the discharge of Sauk River at the U. S. Geological Survey gaging station near Sauk has decreased for at least four hours, or until the reservoir level reaches the top of the gates.

c. If the reservoir level reaches the top of gates (elevation 1,600 feet), release of water shall be regulated to maintain the reservoir at that level until downstream discharge conditions of item b. are obtained or until all gates are completely opened.

3. Evacuation of water stored during floods: After discharge at Concrete has remained constant for an hour or has commenced to decrease and the discharge of Sauk River near Sauk has decreased for four hours, Ross Reservoir shall be operated in accordance with whichever of the following schedules is applicable.

a. If the reservoir level is less than 1,600 feet, releases from Ross Reservoir shall be increased hourly at a rate equal to the rate of decrease of discharge at Sauk, but not to exceed an increase in rate of 5,000 second-feet per hour. These increases shall continue until a maximum discharge of 20,000 second-feet shall be reached at Newhalem. This discharge at Newhalem shall be maintained until the required amount of flood control storage space is again available.

b. If the pool elevation is 1,600 feet and spillway gates have been partially opened to maintain the pool at that elevation, release of water shall be regulated to maintain that pool elevation until the discharge at Newhalem decreases to 25,000 second-feet. Release of water will then be regulated to maintain the discharge at Newhalem at 25,000 second-feet until the required flood control storage is attained.

c. If all gates have been fully opened during the storage period, they shall remain fully open until the pool elevation recedes to elevation 1,600 feet. Release of water will then be regulated to maintain the pool elevation at elevation 1,600 feet until the discharge at Newhalem recedes to 25,000 second-feet. Releases shall then be made from Ross Reservoir to maintain the flow at Newhalem at 25,000 second-feet until all gates are fully closed and the required flood control storage is available.

4. Reservoir operation for a flood series: If a second flood appears imminent and the flood storage of the previous flood has not been completely evacuated, the licensee will, upon the direction of the Corps of Engineers, increase the rate of evacuation to yield a maximum flow of 40,000 second-feet at Newhalem. When the discharge near Concrete again increases above 60,000 second-feet, releases from Ross Reservoir shall be reduced hourly at a rate equal to the rate of increase of discharge of Skagit River near Concrete, but not to exceed a decrease in rate of 5,000 second-feet per hour. Releases shall be decreased in this manner until only flows necessary to the normal production of electric energy are released. Storage shall then continue as outlined in section 2.

5. The licensee shall be responsible for providing a reliable communications network that will insure receipt of the information at Ross Dam necessary to operate the reservoir during emergency flood conditions in accordance with the preceding regulations.

6. The above flood-control operation schedule is subject to revision by the Federal Power Commission at any future date if more detailed hydrologic data become available with which to refine the schedule.

Inclosure No. 2

Ross Reservoir Operation for Flood Control

Skagit River, Washington

Factors Affecting Proposed Regulation Plan

1. The data contained herein apply to the proposed revision of Article 36 of the Federal Power Commission license for Project No. 553-Washington which is given in inclosure 1.

2. Effect of Upper Skagit River regulation. - Ross dam and reservoir are located in a far upstream position with relation to the primary flood plain area which lies west of Sedro-Woolley. Furthermore, the drainage basin subject to regulation by Ross reservoir is one having considerably less unit flood run-off than other portions of the Skagit Basin. Ross reservoir by itself cannot, with any amount of storage, prevent all damaging floods in the important downstream areas. Ross reservoir can, however, achieve reductions in flood peaks which are particularly significant for medium floods which start to damage the downstream levee system.

3. Flood season. - A study of the monthly distribution of damaging flows at Sedro-Woolley shows that flows in excess of the downstream channel capacity would normally occur in the period from 1 November to 15 March each season. The slight chance of a minor flood flow in October does not warrant flood storage in Ross reservoir when the loss of valuable power storage in that month is considered. After March the reservoir would be drawn down by normal power operation in any case, and later minor flood flows would be retained to replenish the power storage. The proposed regulation is therefore applied to this November to March period. The study has also shown that flood potentialities after 1 December are much greater than in November, and accordingly a uniform drawdown period during November so as to reach the full amount of storage at the end of the month has been stipulated.

4. Amount of flood-control storage space. - Determination of this requirement has been based on several considerations as follows:

a. Storage required for floods of record.
b. Storage required for standard project flood.
c. Effect on power revenues.

Each of these points will be briefly discussed in turn.

5. Storage for floods of record. - Using the hydrographs of floods of record and the operating procedure as given in inclosure 1.

the maximum amount of storage required is 85,000 acre-feet. This storage would have been needed for the maximum flood of record in 1909 and would have reduced the Sedro-Woolley peak discharge from 220,000 second-feet to 205,000 second-feet. The non-damaging flow at Sedro-Woolley is 120,000 second-feet.

6. Storage for standard project flood. - Basin hydrological factors and river hydrographs have been prepared for the standard project flood in connection with the current flood-control report on Skagit River. For this flood 155,000 acre-feet of storage space would be required in Ross reservoir to achieve its maximum effect on the peak discharge at Sedro-Woolley. The standard project flood peak at Sedro-Woolley is 440,000 second-feet and Ross storage would reduce it to 415,000 second-feet. For such a large flood the reduction given by Ross reservoir is of little importance when no storage control exists on the other major tributaries. The flood-control report studies indicate that control by storage on other tributaries is not economically feasible in the foreseeable future.

7. Effect on power revenues. - The Seattle City Light Department was asked by the district engineer to evaluate expected power revenue losses for varying amounts of flood-control storage reservation in Ross reservoir. The Light Department furnished excellent cooperation on this and other matters in connection with the proposed revision. The Light Department estimates that over a long period of time and assuming operation of the Skagit system plants in the Northwest Power Pool expected losses are as follows:

Flood control storage	Annual revenue loss
100,000 acre-feet	$20,000
125,000 "	25,000
150,000 "	47,000
175,000 "	65,000
200,000 "	92,000

From the tabulation it appears that revenue losses for storage up to 125,000 acre-feet are nominal and above that amount they appreciably increase.

8. A maximum flood-control storage space of 125,000 acre-feet has been selected because it is well in excess of that required for the maximum flood of record and it does not cause an undue loss to the Seattle Light Department. A flood storage requirement of 155,000 acre-feet for protection against the standard project flood is not believed to be warranted when consideration is given to its very remote chance of occurrence and also to the negligible flood peak reduction that Ross storage could give.

9. Operating procedure. - The detailed method of operating the reservoir in the interest of flood control has been arrived at after careful study of the pattern of flood occurrence in the Skagit River Basin and after discussion with Light Department representatives to insure that the plan is workable. Pertinent points regarding the operating requirements are given in the following paragraphs.

10. Start of flood storage. - Commencement of flood storage in Ross reservoir is related to the following factors:

a. Travel time from Ross dam to confluence of Skagit and Sauk Rivers - about 2 hours.

b. The fact that Sauk River is a major flood contributary. Unless Sauk stages are high or rising, serious flooding below at Sedro-Woolley would not occur.

c. The flood hydrographs on Skagit River are all characterized by rapid rises. The river can change from normal flows to flood flows within a 24-hour period.

The time for starting flood storage has therefore been set in relation to Sauk discharge and Skagit discharge at Concrete so as to be neither too early, and thereby waste storage, nor too late to be effective. The travel time from Ross dam to Sauk necessitates storage at Ross before flood discharges are reached at Concrete.

11. Control gaging stations. - Established gaging stations exist for Skagit River at Concrete and Newhalem, and for Sauk River near its mouth. These stations are properly located geographically to give the needed streamflow data for flood-control operation of Ross reservoir. The Skagit at Concrete and Sauk gages are in rather isolated locations and might not be working because of mechanical breakdown when needed during floods. If one of these gages became inoperative during a flood, the other could serve quite well for operation under emergency conditions. The gage at Newhalem is readily available to operating personnal of the Gorge plant of the Seattle Light Department and data from this gage could be counted on except in the most unusual circumstances.

12. Dependable and frequent information about river stages is essential to the proposed operation procedure. To achieve this end automatic radio reporting gages at Concrete and on Sauk River are required. Location of the gages is such that reports might be directly transmitted to the Baker River power plant, owned by the Puget Sound Power and Light Company, from where they could be relayed over carrier circuit telephone communication to Ross dam via Seattle. This general type of plan has been discussed with Light Department representatives and it appears to be feasible.

13. Time of release of stored flood waters. - The specified time for releasing flood waters is also dependent upon the factors enumerated in paragraph 10 preceding. Time of release has also been governed by the principle that once a flood peak has been attained at Sedro-Woolley, releases from Ross reservoir which would tend to extend the recession side of the hydrograph will not cause any significant additional damage. Early release of stored flood waters is important so that the space may be evacuated to take care of a possible second and higher flood peak. The occurrence of storms in a series is characteristic of the Puget Sound region so that one flood peak is frequently a warning for another following a short time later.

14. Rates of release of stored flood waters have been specified so as to cause the least damage and inconvenience in the Upper Skagit Valley, while accomplishing a rapid evacuation of the reservoir.