CHAPTER 12 - RESERVOIR REGULATION

12-01. INTRODUCTION

12-01.01 General. - In the operation of reservoirs and other engineering works for the regulation of streamflow, two general types of problems are involved. One is concerned with short-term forecasts of inflow for the day-to-day planning of reservoir releases for power generation, flood control, etc. The other problem is concerned with seasonal runoff volume and is encountered in the determination of seasonal regulation schedules and flood control storage allocation and reservation diagrams. It is in the solution of this latter problem that the application of snow hydrology is especially useful and permits flexible and efficient use of multiple-purpose storage, by making flood control and conservation use of storage compatible on a seasonal basis. Ordinarily, in the case of rainfall, it is possible to estimate runoff volumes, with any degree of certainty, only a few days in advance of their occurrence. This follows from the fact that rainfall volumes can be accurately estimated only after the rainfall has actually fallen and been gaged. Then, only the natural lag time of the drainage basin remains before the resulting runoff is realized. This period may be extended somewhat by the use of 24- and 48-hour quantitative precipitation forecasts; however, the accuracy of such forecasts does not warrant their use without qualification. On the other hand, in the mountainous areas of the western United States (and elsewhere for areas having similar climatological conditions), it is possible to estimate accurately the volume of snowmelt runoff months in advance of its actual occurrence. Since the snowpack is, for the most part, deposited well in advance of its subsequent ablation by melting, it is, in effect, an immense natural reservoir. Its water content can be gaged quite accurately (either directly or indirectly) by any of the several methods outlined in the previous chapter. In this chapter, the manner in which runoff volume forecasts are utilized in the operation of reservoirs will be presented. Also, methods used in the day-to-day operation of reservoirs, based on short-term forecasts (see chap. 9), will be considered briefly.

12-01.02 Multiple-purpose reservoirs. - The climatic regime of the western mountain areas of the United States is such that the same reservoir storage space can be used for the usually incompatible requirements of flood control and conservation. The varied condition of rainfall and snowfall in this region are shown in plate 3-1, which gives the relationship between form of precipitation and elevation. Drainage basins whose runoff-producing areas are predominantly above 5000 to 6000 feet in elevation receive precipitation almost entirely in the form of snow. In these areas, winter rain runoff is usually negligible, with most of the annual runoff volume occurring during the spring and early summer as a result of melting of the accumulated snow. For basins lying within low and intermediate elevation ranges (below 5,000 feet), precipitation falls predominantly in the form of rain, and winter runoff from rainfall constitutes the primary source of streamflow. In the higher portions of these basins, however, a portion of the precipitation is accumulated in the form of snow, so that there is an appreciable contribution to runoff resulting from snowmelt during the spring. For both cases, reservoir storage regulation schedules may take advantage of the known storage of water in the snowpack for beneficial use on a seasonal basis. Reservoirs used in this manner are thus multiple-purpose in a true sense, unlike reservoirs where different portions of the total storage space are allocated for power generation, flood control, irrigation, etc., on a fixed and inflexible basis.

12-01.03 For reservoirs on streams whose drainage areas are low to intermediate in elevation (as in the case of tributaries along the coastal regions in western United States), the marked seasonal variation in precipitation allows the winter-rain-flood season to be rather definitely defined; generally speaking, by the time the spring snowmelt season begins, the threat of rain floods has passed for the year. The same reservoir space that was evacuated for control of winter rain floods may be filled from the volume of spring snowmelt, augmented by occasional runoff from spring rainfall, and thereby result in a full reservoir with non-damaging streamflow releases in downstream channels. The stored water may then be released to augment streamflow in the dry summer months and for power production during the fall in anticipation of the ensuing winter flood season. The spring filling of these reservoirs may be accomplished in accordance with a fixed seasonal regulation schedule as shown in plate 12-1, which was extracted from the reservoir regulation manual for Detroit and Big Cliff Reservoirs. 2/ Optimum use of the available storage for conservation as well as flood-control storage, however, requires that the possible variation in volume of snowmelt runoff also be considered in the filling schedule.

12-01.04 For reservoirs controlling flows from relatively high elevation areas, drawdown of the reservoir level is accomplished in accordance with the requirements for use of the stored water, either in the summer or through the fall and winter seasons. In the winter (usually beginning on the first of January), schedules may be prepared for providing flood control storage space on the basis of conditions known at that time, and revisions in the schedule may be made as the runoff potential develops through the winter and early spring. A storage allocation diagram giving the flood control storage required for different seasonal runoff volumes is shown as figure 1, plate 12-2. The use of such a diagram with its seasonal runoff parameter results, at all times, in the maximum possible flood control storage reservation compatible with the filling of the reservoir. Details of the construction of this diagram are given later in this chapter.

12-01.05 Peak flow forecasts. - Reservoir regulation for flood control requires predictions of peak flow as well as of volume. In the case of spring snowmelt floods, the peak rate of flow is, to a great extent, dependent upon variations in the rate of melt and hence upon the melt-producing meteorological conditions. Nevertheless, there exists a certain correlation between seasonal volume of runoff from snowmelt and the peak rate of flow. This is illustrated in figure 2, plate 12-2, which shows the relationship between peak flow and seasonal volume of runoff for the Columbia River near The Dalles, Oregon. The use of such a relationship in estimating peak flows requires, of course, a method of estimating volume of runoff.

12-01.06 Incidental relationships. - Figure 3 of plate 12-2 presents some frequency distributions of seasonal runoff volume, peak discharge, and date of peak discharge for the Columbia River near The Dalles, Oregon. These data are of incidental value in reservoir regulation. In figure 4 of plate 12-2, a flood control storage reservation curve for the Columbia River near The Dalles is shown which gives the amounts of storage required to control to specified discharges the various seasonal runoff volumes, or, conversely, the controlled discharges that would result from various seasonal runoff volumes and available amounts of storage.

12-02. DAY-TO-DAY REGULATION

12-02.01 The day-to-day regulation of reservoirs in accordance with short-term forecasts of reservoir inflow is, for the most part, connected with the regulation of flood flows and the generation of power. The regulation of reservoirs for such other conservation uses as irrigation, navigation, recreation, pollution abatement, and domestic water supplies, is usually planned on a longer-term or seasonal basis, and changes in outflows are required infrequently. While seasonal operation schedules are used for the long-term planning of power releases and flood control reservations, as was previously mentioned, the fact that the rates of reservoir inflow and regulated outflows cannot be foretold much in advance necessitates that the operation also be based on short-term forecasts of inflow. Short-term forecasts of reservoir inflow from either rain-on-snow events or from snowmelt alone can be made as described in chapter 9. For the generation of power, such inflow forecasts, combined with the power requirements for the project in conjunction with the system as a whole, determines the schedule of releases. For flood control operation, such other factors as inflow from uncontrolled downstream areas and available storage capacity in the reservoir also influence the releases. Because of the complex relationships involved, flood control regulation schedules are drawn up on a basis of historical data to best accomplish the desired flood control regulation.

12-03. SEASONAL REGULATION

12-03.01 Storage allocation for flood control. - In the multiple use of reservoir space for the contradictory requirements of flood control and conservation of spring snowmelt floods, storage allocation diagrams are customarily derived from historical data, as previously mentioned. Such a diagram for Hungry Horse reservoir on the South Fork of the Flathead River, Montana, 1/ is given as figure 1 of plate 12-2. Such diagrams are determined by computing the storage required, both before and during the melt season, to control to a given outflow, the maximum and other critical historical flood events. Parameters of the remaining runoff from any given date to the end of the snowmelt runoff season (usually 30 September) are drawn to envelop these historical flood data. It is customary to limit the slope of these parameter lines to the maximum permissible rate of drawdown of the reservoir (maximum permissible discharge) as governed either by outlet capacity or downstream channel capacities. Thus, in the diagram of figure 1, plate 12-2, the slope of the pre-melt-season drawdown curves is equivalent to 20,000 cfs (approximately 1.2 million acre feet per month) which is the approximate maximum outlet capacity of the reservoir (outlet valves plus allowable flow through power turbines). The enveloping curves during the flood season proper (1 May to 30 June in fig. 1, pl. 12-2) also indicate an increasing storage requirement with time for a given parameter value. This is in consequence of the increase in the potential flood flows from the same volume of runoff, that occurs as the melt season progresses. The Hungry Horse flood-storage allocation diagram is designed to provide flood control for the lower Columbia River and for the reach of the Flathead River immediately downstream from the dam and above Flathead Lake in Montana. It is based on the criteria of (1) restricting the reservoir releases to 3,000 cfs during the period beginning five days before the natural flow of the Columbia River at The Dalles, Oregon reaches 500,000 cfs and ending five days before it again decreases to 500,000 cfs (five days being the time of travel between Hungry Horse dam and The Dalles), (2) restricting the releases to control the Flathead River, as gaged at Columbia Falls, Montana, to certain non-damaging flows, the permissible flows depending partially upon the backwater effect in the river resulting from varying lake stages, and (3) maintaining a minimum release of 500 cfs at all times.

12-03.02 Safety factors. - Factors of safety, beyond what is actually required to envelop the plotted historical flood data, may be included in storage allocation diagrams. Thus, in figure 1 of plate 12-2, a factor of safety of 200,000 acre-feet was incorporated in the parameters prior to 1 May, decreasing, from that date, at a uniform rate such that it equals zero on 30 June. This factor of safety allows for errors in the forecast volume of runoff, thereby assuring adequate flood-control reservation. An additional factor of safety was incorporated in the Hungry Horse flood-storage allocation diagram for those parameters outside the range of the historical data. An analysis of the parameters of 2.0 million acre-feet and less, which are based on historical data, indicated an increase of 0.83 acre-foot in flood-control allocation for each acre-foot increase in volume of runoff. For the parameters in excess of 2.0 million acre-feet, no historical data were available; consequently, it was considered prudent to increase the incremental changes in the flood control allocation for these large floods to an amount equal to the increase in the volume of runoff. This change is apparent in the change in spacing of the parameter lines of the figure.

12-03.03 In the foregoing example, the factor-of-safety allowances were made to assure adequate flood-control allocations, at the expense of conservation storage, for situations more critical (from the flood control viewpoint) than those given by historical data or to allow for possible errors in the volume forecasts. Consequently, there is this added risk of not filling the reservoir, especially where errors in volume forecasts result in over-estimates of runoff volume. It is to be pointed out that factors of safety may also be provided from the viewpoint of conservation of water. There is also included in the storage allocation diagrams derived for Hungry Horse project, a factor of safety for refilling the reservoir at the expense of some flood control storage. By establishing a minimum release at the project of 3000 cfs for downstream flood control as measured at The Dalles, a flexibility of regulation is established. If late season forecasts indicate that original volume inflow forecasts were too high, release from the reservoir may be reduced to the minimum discharge of 500 cfs, and thereby refill storage at a faster than normal rate so as to assure the refilling of the reservoir by the season's end. A study of the Hungry Horse flood control storage allocation diagram 3/ indicates the factors of safety incorporated therein do not seriously affect the refilling of the reservoir even when possible errors in the forecast runoff volumes are considered. Moreover, forecasts which are some 200,000 acre-feet too low (approximately average error of Hungry Horse inflow forecasts) 4/, do not seriously affect the flood control operation of the reservoir. Concerning the testing of the flood control storage allocation diagram for Hungry Horse reservoir, the following excerpt from the previously cited study 3/ is quoted:

"The summary indicates that, with completely accurate forecasts, the reservoir would have refilled in every year of the 31 years studied. In 1931 and in 1942, both of which were very dry years, the reservoir would have refilled prior to the date of the last significant peak at The Dalles. The time required for the effect of spills at Hungry Horse to reach The Dalles is such that the latest significant peak at The Dalles would have been reduced by storage in Hungry Horse Reservoir in both years. If forecasts 200,000 acre-feet too low had been used, the reservoir would have refilled in every year of the 31 years, but would have refilled prior to the date of the latest significant peak in 10 of the 31 years. Of these ten years, only 1911, 1936, and 1948 were years in which the natural peak flow at The Dalles exceeded 500,000 cfs, and in each of these three years the time required for spilled flows at Hungry Horse to reach The Dalles would have been such that the latest significant peak at The Dalles would have been reduced by storage in Hungry Horse Reservoir. If forecasts 200,000 acre-feet too high had been used, the reservoir would have failed to refill in only four years of the 31 years studied and would not have refilled prior to the date of the latest significant peak at The Dalles in any year. The four years in which the reservoir would have failed to refill were 1931, 1937, 1941, and 1944, all of which were dry years, but the greatest deficiency would have been only 32,000 acre-feet in 1931 which is only slightly more than one percent of the live storage capacity of the reservoir. Therefore, such failure to refill under these assumed conditions has little significance."

12-03.04 Volume forecasts. - Forecasts of seasonal volume of runoff are, of course, necessary in the application of flood-control storage allocation diagrams (in the place of the observed historical values which were used in the derivation of the diagrams). Errors inherent in these forecasts may possibly result in the undesirable operation of a reservoir, as was discussed in the previous paragraph. Methods by which seasonal volume forecasts can be made were discussed in the preceding chapter. For situations where a definite method of seasonal-runoff forecasting is used in conjunction with the storage-allocation diagram in the operation of a reservoir, it is possible to assess, rather definitely, the effect of errors in the forecasting method upon the operation of the reservoir. The effect of errors in volume forecasts is also pertinent to the discussion in the section which follows, where volume forecasts are used to estimate peak flows.

12-04. PEAK-TO-VOLUME RELATIONSHIP

12-04.01 General. - As previously mentioned, there exists a general relationship between the peak snowmelt discharge and the seasonal snowmelt runoff volume for most basins which have appreciable winter snowpack accumulations. Since the volume of runoff from spring snowmelt can be estimated quite accurately some months in advance, it is likewise possible to make forecasts of peak flows resulting from springtime snowmelt well in advance of their actual occurrence. Intelligent application of long-range forecasts of unregulated peak discharges resulting from snowmelt requires full understanding of (1) the significance of peak-to-volume ratios, (2) the best method of applying them to specific cases, and (3) the probable accuracy of the estimates. Closely allied to the peak-to-volume determination is that of evaluating flood-control storage reservation requirements. Examination of the peak-to-volume relationship in this section is accompanied by an illustration of the relationship for the Columbia River near The Dalles, Oregon, one of the major snowmelt runoff rivers in the United States. Reference is made to the report, "Relationship between peak discharge and volume runoff of the Columbia River near The Dalles, Oregon" by the Water Management Subcommittee of the Columbia Basin Inter-Agency Committee (CBIAC), 6/ for a more complete discussion of peak-to-volume relationship for Columbia River near The Dalles.

12-04.02 Peak-to-volume diagram. - Figure 2 of plate 12-2 gives the basic relationship between peak flows and volume of snowmelt runoff for the Columbia River near The Dalles, Oregon. The peak flows given there are mean daily values and include adjustments for relatively minor flood control regulation by Grand Coulee and Hungry Horse dams during recent years. The seasonal runoff volumes used in the relationship were for the period April through September, and adjustments for storage in six major reservoirs were made. 5/ The entire 77 years of available record of flows for the Columbia River at The Dalles (1879 through 1955) were used in the determination of the relationship of figure 2. The regression line fitted to these data is as follows:

$$Y = 6.77X - 118 \qquad (12\text{-}1)$$

where Y is the peak daily flow in thousand cfs and X is the April through September runoff in million acre-feet. The standard error of estimate of the relationship amounts to 76.2 thousand cfs in contrast to the standard deviation of 172.6 thousand cfs for the peak flows. The resulting correlation coefficient is 0.90.

12-04.03 Time changes in relationship. - In recent years there has been a tendency for higher peak flows to be associated with a given volume of runoff for the Columbia River near The Dalles, Oregon. A study of the peak-to-volume relationship, analyzing the periods from 1879 through 1916 and from 1917 through 1955 separately, resulted in the following regression equations:

PERIOD	EQUATION	
1879 - 1955	Y = 6.77X - 118	(12-1)
1879 - 1916	Y = 7.10X - 179	(12-2)
1917 - 1955	Y = 7.63X - 177	(12-3)

where Y is the peak discharge in thousand cfs and X is the April-September volume of runoff in million acre-feet. Equation 12-1 is also repeated in the above tabulation for comparative purposes. Although this change in the relationship with time could be attributed to man-made changes in the basin, careful consideration of the nature and order-of-magnitude of such changes shows that such is not likely. The change in the relationship appears to be associated with the natural changes in climate that occurred within the period and therefore is characteristic of large-scale climatic variations.

12-04.04 Errors of estimate for prediction of peak discharge. - It is possible to combine the effect of errors in forecasts of runoff volume and of the historical peak-to-volume ratio by statistical relationships (see Wilm 7/ for a discussion of the statistical derivation of such relationships), whereby comparisons of reliability of estimates of peak discharge through use of differing periods of runoff may be determined. Tests of the relative accuracy of peak discharge forecasts, using total and residual volume forecasts, were made by the Technical Staff of the Water Management Subcommittee using data for the Columbia River near The Dalles. 6/ The results of these tests are tabulated below:

STANDARD ERROR OF ESTIMATE OF AN INDIVIDUAL MEAN PREDICTION
OF PEAK DISCHARGE
(In thousands of second feet)

For peak-volume relationships based on total and on residual runoff

Forecast Date	Period for which runoff volume forecast is made					
	April through June		April through July		April through Sept.	
	From Total Volume Forecast	From Residual Volume Forecast	From Total Volume Forecast	From Residual Volume Forecast	From Total Volume Forecast	From Residual Volume Forecast
1 April	106.3	106.3	101.8	101.8	102.8	102.8
1 May	102.8	104.1	90.6	86.6	95.4	94.4
16 May	98.9	107.0	86.5	83.6	85.7	83.3

In general it may be stated from this study that forecasts of peak discharge for Columbia River near The Dalles based on April through July runoff are most reliable, but that little difference exists in using the April through September period. The April through June period gives consistently poorer results. It is also seen that for both 1 May and 16 May forecast dates, there is a slight improvement by using residual rather than total volume forecasts; however, the differences are generally small and of little significance.

12-05. FLOOD CONTROL STORAGE RESERVATION

12-05.01 From what has been stated, it is apparent that a relationship exists between the seasonal runoff volume and the amount of storage which would be required to control the peak discharge near The Dalles, Oregon to some given regulated outflow. Diagrams giving this relationship may be determined from an analysis of historical data wherein the volume of runoff in excess of the desired regulated discharge rate is plotted as a function of the seasonal runoff volume and lines drawn to envelop these data. Several parameters of regulated outflow may thus be determined to give the flood control storage reservation associated with various regulated discharges. Such a diagram for the Columbia River near The Dalles, Oregon is included as figure 4 of plate 12-2. Also shown on this diagram is a line representing the volume of the record 1894 spring snowmelt flood.

12-05.02 The entire 77-year record for the Columbia River near The Dalles was used in the derivation of the diagram; however, only a few of the years were critical in determining the parameters. For example, those years whose peak discharges were less than the parameters obviously could not enter in their determination. The parameters were not drawn to envelop the 1948 flood data. With the exception of this year, all other pertinent data, including the 1894 flood, gave a consistent relationship which defined the parameters quite well. The data for 1948 were, however, so far out of line that to envelop them would result in grossly inefficient use of flood control storage space in all other years. It is necessary, therefore, that in utilizing this set of curves, provision must be made for the occurrence of exceptionally high peak-to-volume ratios, such as occurred in 1948. With the repetition of such an occurrence, it would be necessary to adjust upward the regulated discharge in the lower Columbia River during the progress of the flood. It is pointed out that the curves shown in figure 4 of plate 12-2 are provisional in nature and are presented as a guide for over-all flood control regulation of the Columbia River. The diagram assumes flood control storage which is 100 percent effective in controlling discharges in the lower Columbia River. Much of the present and planned flood control storage in the basin is so located that its effectiveness is considerably less than 100 percent, and appropriate factors must be applied to determine the amount at each project which is effective for downstream flood control.

12-06. SUMMARY

12-06.01 One of the most useful applications of snow hydrology is to be found in the reservoir regulation of snowmelt runoff. For areas where much of the winter precipitation is stored in deep snowpacks, there is an interval of several months between the time the precipitation falls and the time it melts and contributes to runoff. Since this portion of the total runoff can be gaged well in advance of its realization as streamflow, allowances can be made in the operation of reservoirs in anticipation of this runoff volume. For flood control operation, the reservoir can be drawn down in advance to allow for the estimated volume of inflow. At the same time, this forecast of future inflow volume assures that the reservoir storage space evacuated for flood control can be refilled for conservation uses from the spring snowmelt flood. Reservoirs operated in such a manner are multiple-purpose reservoirs in the true sense of the term.

12-06.02 For basins having deep winter snowpack accumulations, there exists a relationship between the peak discharge and the spring snowmelt flood volume. This peak-to-volume relationship is useful in advance flood-control planning. Like the volume forecast, estimates of peak flow can be made many months in advance of their realization.

12-06.03 Diagrams which serve as guides in the operation of reservoirs are prepared from historical streamflow data. Examples of such diagrams are: (1) seasonal regulation schedules, (2) flood-control storage allocation diagrams, and (3) flood-control storage reservation diagrams. The first of these is, basically, a curve showing the maximum allowable reservoir content as a function of the time of year (see plate 12-1). During the winter rain flood season, the reservoir is held in an evacuated condition, insofar as is possible, to provide storage space for the control of rain-on-snow floods. It is filled during the spring, as the danger of rain floods diminishes, by utilizing snowmelt runoff augmented by spring rains, thereby conserving water for use during the summer and fall months. It is drawn down in the fall to again provide flood-control storage space. Filling and drawdown rates are in accordance with channel capacities and available water. The second diagram, which makes use of forecasts of spring snowmelt runoff volume, indicates, as a function of time of year, the reservoir storage space that must be allocated to flood control for different parameters of seasonal runoff volume (fig. 1, plate 12-2). Rate of drawdown is controlled by existing downstream channel and outlet capacities. The required storage allocations are also governed by given permissible releases during flood-control operation. The third diagram, unlike the first two, does not include the time of year as a factor. It shows the amount of storage, as a function of flood volume, required to control snowmelt floods to various parameters of regulated outflow (see fig. 4, plate 12-2). Nothing is said of when or where the storage reservation must be available. With an existing flood control reservation, the diagram gives the regulated outflow which may be attained for various floods or the flood volume that can be controlled to a given outflow.

12-07. REFERENCES

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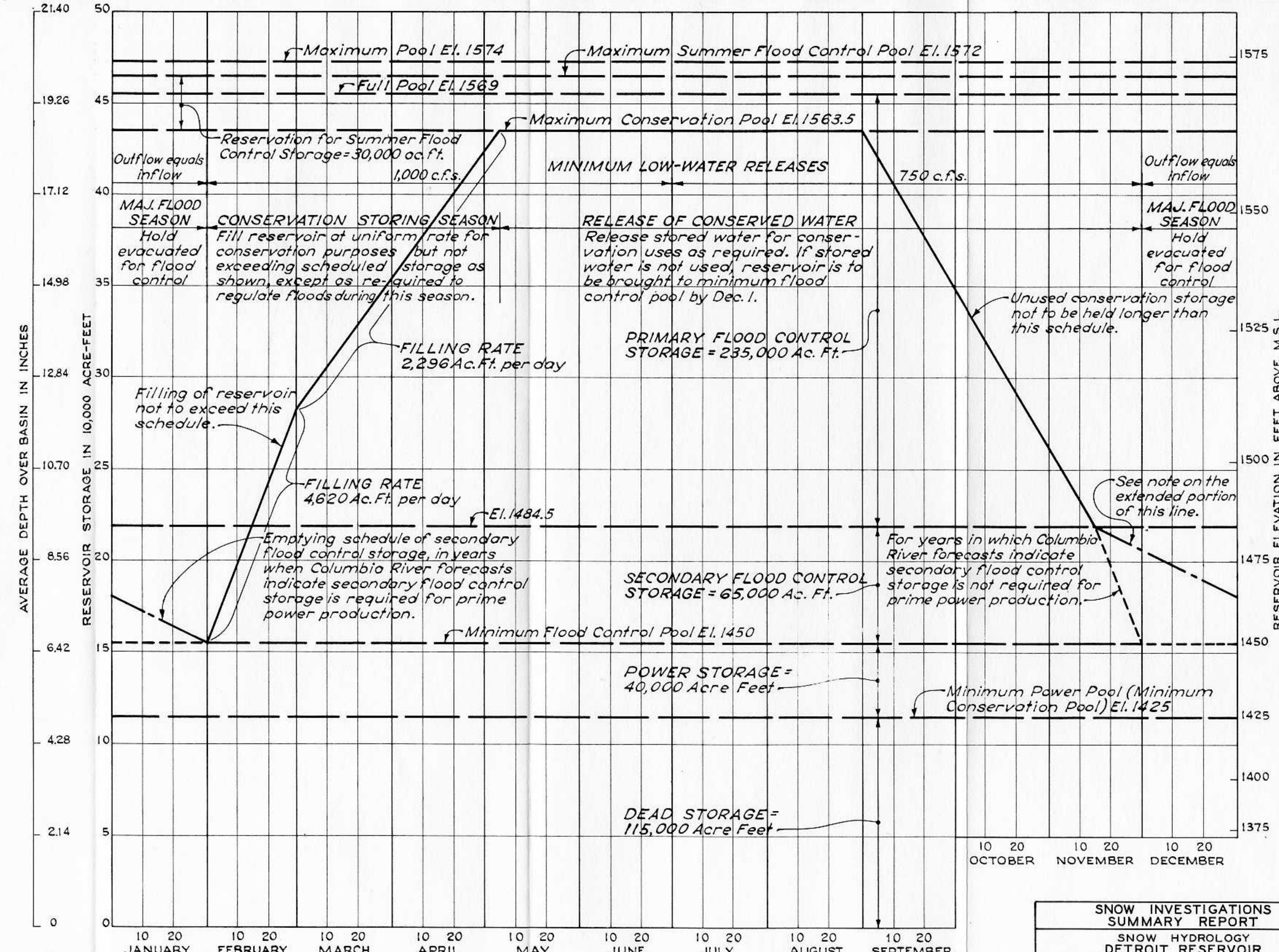
4/ WATER MANAGEMENT SUBCOMMITTEE, CBIAC, "Review of procedures for forecasting inflow to Hungry Horse Reservoir, Montana," (Mimeo. report). June 1953.

5/ WATER MANAGEMENT SUBCOMMITTEE, CBIAC, "Recommended reservoir storage adjustments to seasonal runoff volume forecasts in the Columbia River basin," (Mimeo. report). February 1954.

6/ WATER MANAGEMENT SUBCOMMITTEE, CBIAC, "Relationship between peak discharge and volume runoff of the Columbia River near The Dalles, Oregon," (Mimeo. report). June 1955.

7/ WILM, H. G., "Statistical control in hydrologic forecasting," Research Note No. 61, Pacific Northwest Forest and Range Experiment Station, Forest Service, Portland, Oregon, January 1950.



This diagram taken from Plate 20, Reservoir Regulation Manual for Detroit and Big Cliff Reservoirs, North Santiam River, prepared by Portland District, Corps of Engineers, 1 Sep 1953.

SNOW INVESTIGATIONS
SUMMARY REPORT

SNOW HYDROLOGY
DETROIT RESERVOIR
NORTH SANTIAM RIVER, OREGON

SEASONAL REGULATION SCHEDULE

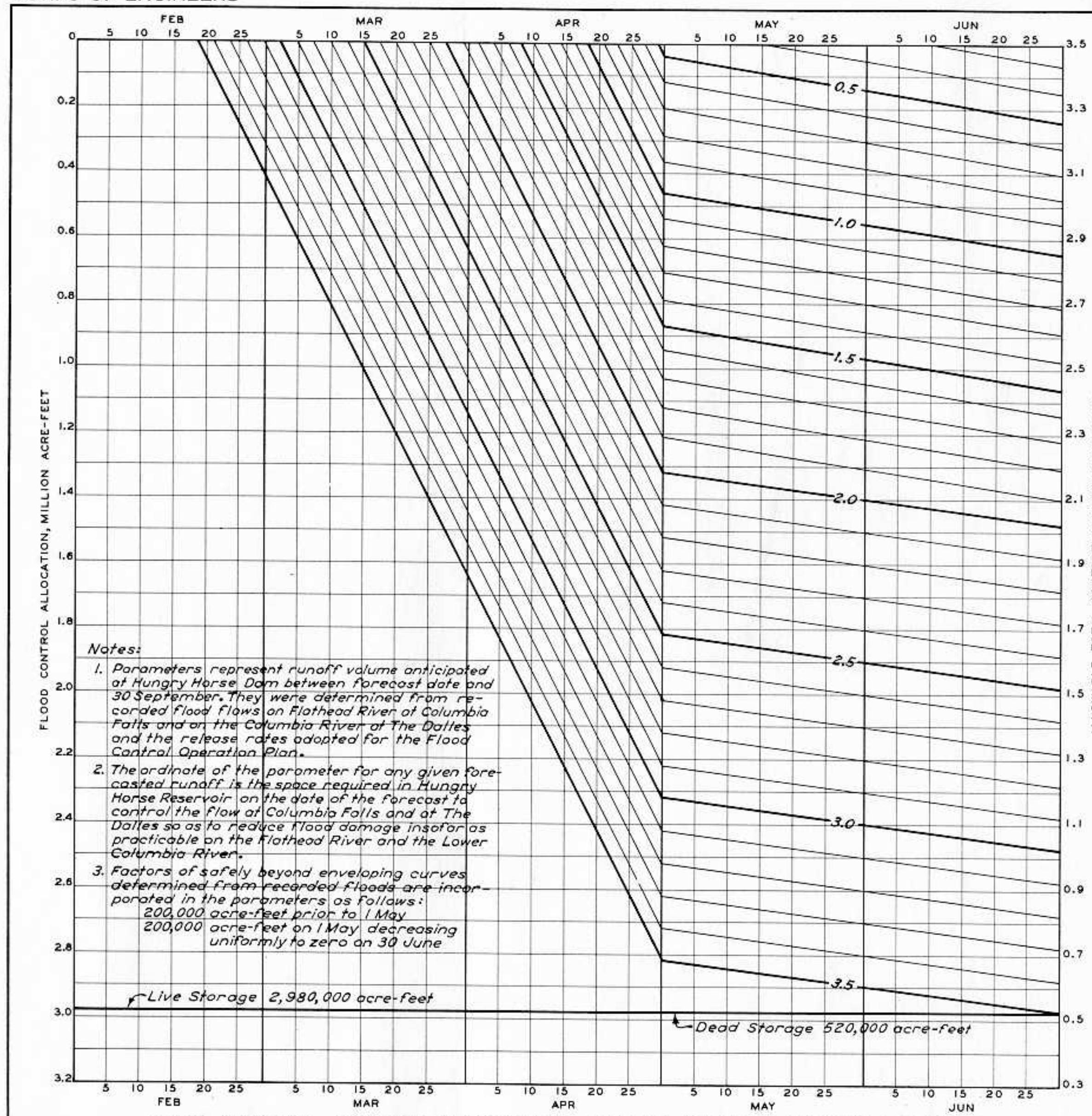
OFFICE OF DIVISION ENGINEER, NORTH PACIFIC DIVISION
CORPS OF ENGINEERS U.S. ARMY

PREP: WAM-GEG SUBM: CEH
DRAWN: GW APPR: DMR

TO ACCOMPANY REPORT DATED 30 JUNE 1956

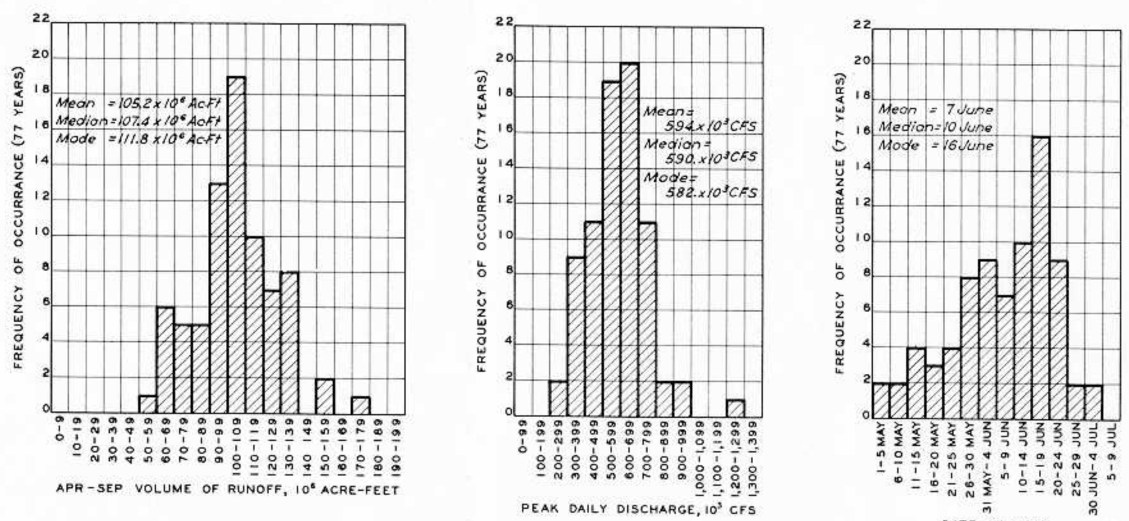
PD-20-25/71

PLATE 12-1



FLOOD CONTROL STORAGE ALLOCATION, HUNGRY HORSE RESERVOIR, MONTANA

FIGURE 1



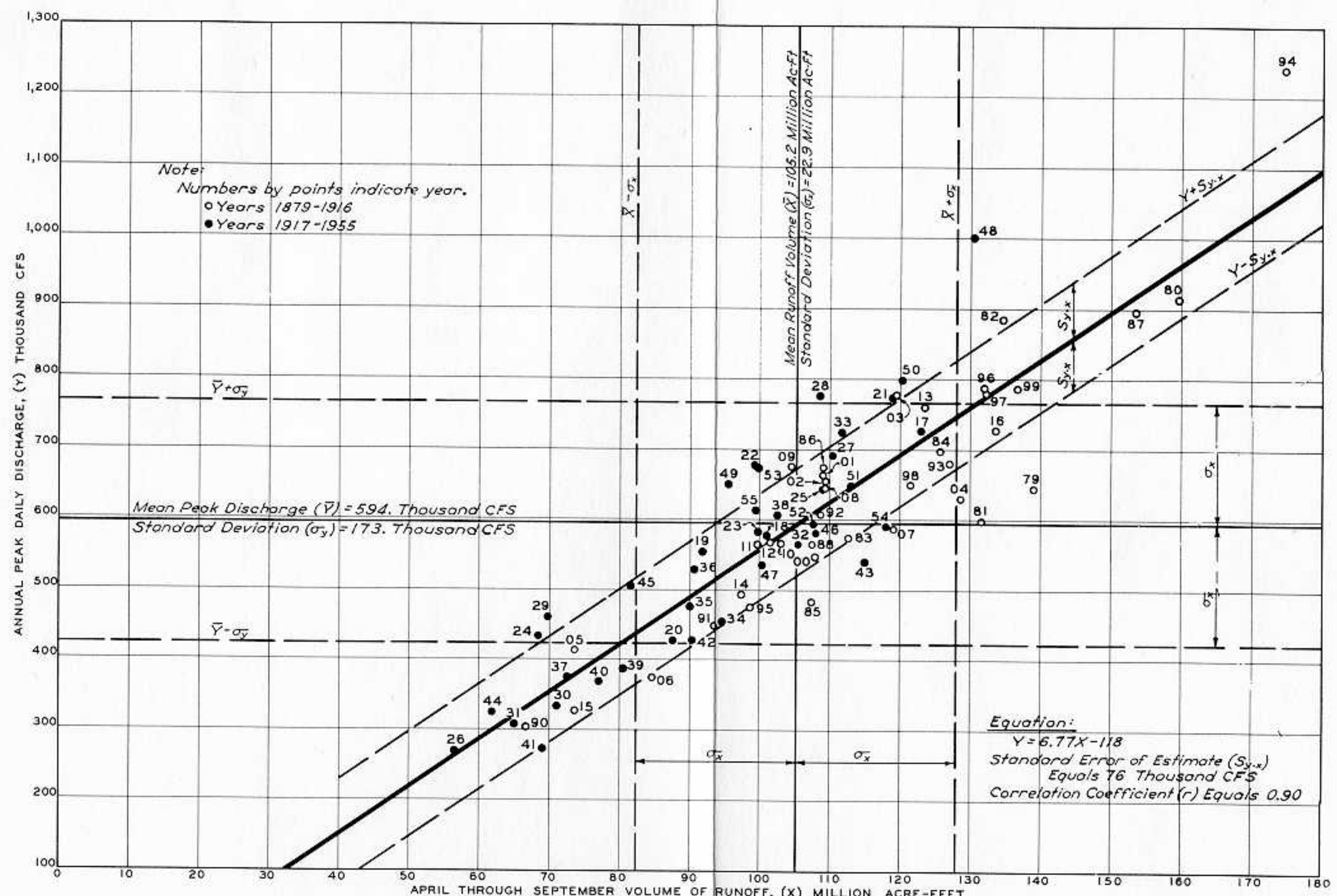
(a) RUNOFF VOLUME

(b) PEAK DISCHARGE

(c) DATE OF PEAK

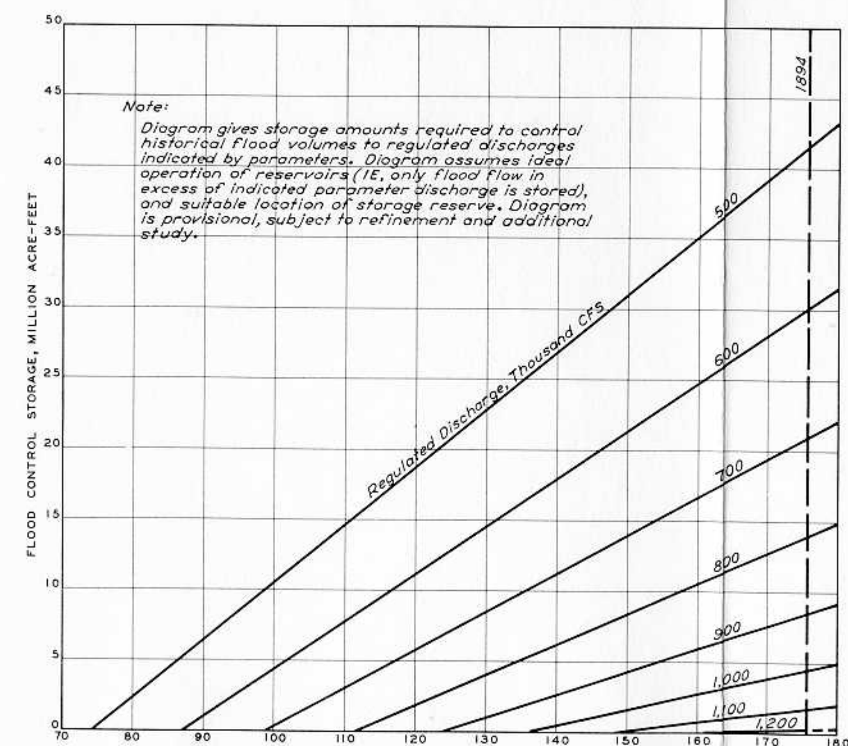
FREQUENCY DISTRIBUTIONS FOR THE COLUMBIA RIVER NR THE DALLES, OREGON

FIGURE 3



RELATIONSHIP BETWEEN PEAK DISCHARGE AND VOLUME OF RUNOFF
FOR THE COLUMBIA RIVER NEAR THE DALLES, OREGON

FIGURE 2



FLOOD CONTROL STORAGE RESERVATION DIAGRAM,
COLUMBIA RIVER NEAR THE DALLES, OREGON

FIGURE 4

Figure 1 was prepared by Hydrologic Studies Office, Bureau of Reclamation, Boise, Idaho. It is taken from the Reservoir Regulation Manual for Hungry Horse Dam, issued by Seattle District, Corps of Engineers, dated December 1952.

SNOW INVESTIGATIONS
SUMMARY REPORT

SNOW HYDROLOGY

RESERVOIR REGULATION DIAGRAMS

OFFICE OF DIVISION ENGINEER, NORTH PACIFIC DIVISION
CORPS OF ENGINEERS U. S. ARMY

PREPARED: C.E.H. SUBMITTED: C.E.H.
DRAWN: R.V. APPROVED: D.M.R.

TO ACCOMPANY REPORT
DATED 30 JUNE 1956

PD-20-25/72

PLATE 12-2