RES REG SEC
GARVEY

MISSOURI RIVER
MAIN STEM RESERVOIR SYSTEM
RESERVOIR REGULATION MANUAL

GARRISON MANUAL

U. S. ARMY ENGINEER DIVISION, MISSOURI RIVER
CORPS OF ENGINEERS
OMAHA, NEBRASKA
1978

MROED-HC 8 December 1978

SUBJECT: Reservoir Regulation Manual, Garrison Dam - Lake Sakakawea, North Dakota

Area Engineer, North Dakota Area

Inclosed for your information and retention are three copies of the above subject reservoir regulation manual.

FOR THE DISTRICT ENGINEER:

Murphy
gh/4610

1 Incl
as

R. G. BURNETT
Chief, Engineering Division

Garvey

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DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
P. O. BOX 103, DOWNTOWN STATION
OMAHA, NEBRASKA 68101

MRDED-R 31 August 1978

SUBJECT: Reservoir Regulation Manual, Garrison Reservoir, North Dakota

District Engineer, Omaha
ATTN: MROED-HC

Seven copies of the subject manual are inclosed for your information and retention. It was agreed in conversation between Messrs. A.M. Franklin, MRD, and B. Garvey, OD, that three of these manuals would be made available to the North Dakota area office.

FOR THE DIVISION ENGINEER:

1 Incl
as

LLOYD A. DUSCHA
Chief, Engineering Division

Franklin/pw/7349

MRDED-R 30 August 1978

SUBJECT: Reservoir Regulation Manual, Missouri River, Garrison Reservoir, North Dakota

HQDA (DAEN-CWE-Y)
WASH DC 20314

Inclosed in accordance with ER 1110-2-240 is one copy of the subject manual, as revised in this office, for your information and possible comment. Revision of the manuals for the four downstream projects (Oahe, Big Bend, Fort Randall and Gavins Point) is underway and should be finalized by early 1979.

FOR THE DIVISION ENGINEER:

McClendon/MRDED-R

Duscha/MRDED

1 Incl
as

LLOYD A. DUSCHA
Chief, Engineering Division

CF:
Main File (MRDED-R)
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MRDED-R (Franklin)

MISSOURI RIVER
MAIN STEM RESERVOIR SYSTEM
RESERVOIR REGULATION MANUAL

In 7 Volumes

Volume 3

GARRISON RESERVOIR (LAKE SAKAKAWEA)

Volume 1	Master Manual
Volume 2	Fort Peck (Fort Peck Reservoir)
Volume 3	Garrison (Lake Sakakawea)
Volume 4	Oahe (Lake Oahe)
Volume 5	Big Bend (Lake Sharpe)
Volume 6	Fort Randall (Lake Francis Case)
Volume 7	Gavins Point (Lewis and Clark Lake)

PREPARED BY
U.S. ARMY ENGINEER DIVISION, MISSOURI RIVER
CORPS OF ENGINEERS
OMAHA, NEBRASKA

1978

MISSOURI RIVER BASIN
MAIN STEM RESERVOIR SYSTEM
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GARRISON RESERVOIR (LAKE SAKAKAWEA) MANUAL

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GARRISON DAM AND RESERVOIR
MISSOURI RIVER
NORTH DAKOTA

PERTINENT DATA

1. PURPOSE

Garrison Dam and Reservoir, in coordination with other projects of the Missouri River main stem system, are operated as a multiple purpose project for navigation, flood control, hydroelectric power, irrigation, water supply, water quality control, recreation, fish and wildlife and allied purposes.

2. AUTHORIZATION

Authorized by the Flood Control Act approved 22 December 1944 (Public Law 534, 78th Congress, 2nd Session) as part of the general comprehensive plan for flood control and other purposes in the Missouri River Basin.

3. LOCATION OF DAM

State	North Dakota
Counties	McLean and Mercer
River	Missouri River, 1389, 86 river miles above the mouth (1960 mileage)
Town	Approximately 77 miles north of Bismarck, North Dakota

4. DRAINAGE AREAS

Missouri River Basin, sq. mi.	529,350
Above Garrison Dam, sq. mi. (includes 1350 square miles of non-contributing areas)	181,400
Fort Peck Dam to Garrison Dam, sq. mi.	123,900
Garrison Dam to Oahe Dam, sq.mi.	62,090

5. STREAM FLOW DATA

Observed Flow at Dam Site, cfs (1898-1953)	
Maximum of Record (1952)	348,000
Minimum (1940) (Approx.)	1,800
Average (Approx.)	25,000
Regulated Flow at Dam Site, cfs (1954-1976)	
Maximum (1975)	65,200
Minimum (1955)	4,900
Average	20,500

Average Annual Runoff at Dam Site (1898-1975), Acre-Feet 18,500,000(1)

(1)Adjusted to 1949 level of water resource development.

6. RESERVOIR DATA

Approximate Length of Reservoir, miles (Pool Level at Maximum Normal Operating Level and 1960 River Conditions)	178
Shoreline, miles at Elev. 1837.5	1,340

Storage Capacity	Elevation msl	Gross Storage Acre-Ft.	Gross Area Acres
Maximum Operating Pool	1854	24,100,000	383,000
Maximum Normal Operating Pool	1850	22,600,000	368,000
Base of Flood Control Pool	1837.5	18,300,000	315,000
Minimum Operating Pool	1775	5,000,000	129,000
Exclusive Flood Control Space	1850-1854	1,500,000	
Seasonal Flood Control Space	1837.5-1850	4,300,000	
Carryover Multiple Use Space	1775-1837.5	13,300,000	
Inactive Space	1673-1775	5,000,000	

7. DAM

Embankment Type - Rolled Earth Fill	
Abutment Formations - Fort Union Clay-Shale	
Top of Embankment, Elev. Ft. msl	1875
Total Crest Length, Feet (exclusing spillway)	11,300
Maximum Height, Feet	210
Damming Height (Low Water to Max. Oper. Pool)	180
Top Width, Feet	60
Maximum Base Width, Feet	2,600
Fill Quantity, Cubic Yards	66,500,000

8. SPILLWAY

Location	Left Bank - Remote
Type - Chute, Concrete Lined with Gated Overflow Weir	
Crest Elevation, Feet msl	1,825
Crest Length, Gross, Feet	1,336
Crest Length, Net, Feet	1,120
Gates - Tainter - No. & Size, Feet	28 - 40 x 29
Design Discharge Capacity, cfs (Elev. 1858.5)	827,000
Discharge Capacity at Maximum Operating Pool, (Elev. 1854) cfs	660,000

9. OUTLET WORKS

Location	Right Abutment
Type - Concrete Lined Tunnels	
Tunnels, No. and Dia. in Feet	1 - 26 2 - 22
Tunnels, Length, Feet Approx.	1529 (2)
Regulating Gates, Type	Tainter
Regulating Gates, No. and Size, Feet	3 - 18 x 24.5
Emergency Gate, Total No. & Type	1 - Vertical Lift Tractor
Discharge Capacity per Tunnel, cfs	1 - 37,200
(Reservoir Water Surface at Elev. 1854)	2 - 30,400
Present Tailwater Elevation, Feet msl	1678-1683
Intake Invert Elevation, Feet msl	1672
Exit Portal Invert Elevation, Feet msl	1662

Note (2) Length from upstream face of intake to downstream face of tunnel outlet portal.

10. POWER STRUCTURES

Location	Right Abutment
Power house, Type	Indoor, Reinforced Concrete
Tunnels - Concrete with Steel Penstocks	
Tunnels, No. & Size	5 - 29 ft dia with 24 ft dia penstocks
Tunnels, Length in Feet, Approx.	1829 (3)
Service Gates, Type	Vertical Lift Tractor
Service Gates per Tunnel, No. & Size in Feet	2 - 12 x 26
Emergency Gates, Type	Vertical Lift Bulkhead
Emergency Gates, Total No. & Size in Feet	2 - 15 x 26
Surge Tanks	2 per Penstock, each 65 Ft. Dia.

Note (3) Length from upstream face of intake to scroll case.

11. POWER INSTALLATION

Average Gross Head Available, Feet	154
Number of Generating Units	5
Turbine type	Francis
Turbine speed, rpm	90
Discharge Capacity at Rated Head (150ft) cfs	8,000
Generator Rating, KW	80,000

12. POWER AVAILABLE

Plant Capacity, KW	400,000
Dependable Capacity, KW (4)	367,000
Average Annual Energy	2,270,000,000

Note (4) Based on Operation Study 2-76-1975.

MISSOURI RIVER BASIN
MAIN STEM RESERVOIR SYSTEM
RESERVOIR REGULATION MANUAL
IN 7 VOLUMES - VOLUME NO. 3
GARRISON DAM AND RESERVOIR

SECTION I - AUTHORIZATION AND SCOPE

1-1. Authorization. This manual has been prepared as directed in ER 1110-2-240 and in accordance with pertinent sections of EM 1110-2-3600, "Reservoir Regulation".

1-2. Scope. This manual is one of the 7 volumes being prepared for the main stem system of reservoirs as follow:

Volume	Project
1	Master Manual
2	Fort Peck
3	Garrison
4	Oahe
5	Big Bend
6	Fort Randall
7	Gavins Point

1-3. The Missouri River Main Stem System of reservoirs consists of six projects, Fort Peck (Fort Peck Lake), Garrison (Lake Sakakawea), Oahe (Lake Oahe), Big Bend (Lake Sharpe), Fort Randall (Lake Francis Case), and Gavins Point (Lewis and Clark Lake) constructed by the Corps of Engineers for the purpose of flood control and other multiple use purposes. In order to achieve the multipurpose benefits for which the main stem reservoirs were authorized and constructed, they must be regulated as a hydraulically and electrically integrated system. Therefore, the Master Manual presents the basic operational objectives and the plans for their optimum fulfillment, with supporting basic data. The Garrison Manual supplements the Master Manual by discussing factors pertinent to the regulation of Garrison Reservoir. The regulation of major tributary reservoirs located within the Missouri River Basin affecting the regulation of Garrison Reservoir is detailed in separate manuals prepared for the individual tributary projects.

1-4. In an effort to reduce redundancy, frequent reference will be made in this, the Garrison project manual, to information contained in the Master Manual. This is particularly true with respect to details concerning organization, coordination with other projects and agencies, and other factors that are pertinent to operation of the system as a whole. This project manual should, therefore, be considered as a supplement to the master manual, presenting further information and expanding or emphasizing details that are of particular importance to the Garrison project.

SECTION II

DESCRIPTION OF MISSOURI RIVER AND DRAINAGE AREA

II-A Basin Geography

2-1. Areal Extent. The Missouri River Basin upstream from Garrison Dam includes northwestern North Dakota, all of Montana east of the continental divide, the central portion of northern Wyoming, a small part of South Dakota and portions of southern Canada lying in the tributary Milk River Basin. The total drainage area above Garrison Dam is 181,400 square miles including 57,500 square miles upstream from Fort Peck Dam. The Missouri River basin above Fort Peck Dam is described in detail in the Fort Peck Reservoir Regulation Manual. A detailed description of the Milk River and minor tributaries above the mouth of the Yellowstone River is also presented in the Fort Peck Manual. Although these Missouri River tributaries form an important portion of the Fort Peck to Garrison drainage area, experience has indicated that they are more critical to the regulation of Fort Peck than for the Garrison project. The portion of the Missouri Basin described in this manual consists of the 123,900 square mile incremental drainage area between Fort Peck and Garrison Dams and that portion of the basin below Garrison Dam draining to the Missouri River above the headwaters of the Oahe Reservoir. Plate 1 is a general map of the Missouri River Basin. The incremental drainage area between Fort Peck Dam and Garrison Dam and between Garrison Dam and the headwaters of the Oahe Reservoir are shown on Plate 2.

2-2. The major portion of the incremental area described in this manual is drained by a single tributary stream, the Yellowstone River, which enters the Missouri River in the headwaters region of the Garrison Reservoir. This tributary stream contributes by far the largest amount of runoff to the Missouri River reach under consideration in this manual and is also the major contributor of inflows to the entire main stem reservoir system.

2-3. Topography. The Rocky Mountains form the western boundary of the Yellowstone River Basin. They have an exceptionally rugged topography, with many peaks surpassing 14,000 feet in elevation. Within the basin, the mountains extend over an area of about 30,000 square miles. While the mountains contain many valleys, peaks and mountain spurs are the major characteristics.

2-4. Sloping eastward from the Rocky Mountains, the Great Plains form the remaining portion of the Missouri basin under consideration in this manual. The western boundary of these plains at the foot of the Rockies averages about 5,500 feet in elevation. West-to-east slopes of the plains average about 10 feet to the mile. Through a major portion of the drainage area the surface mantle and topography have been developed largely by erosion of the fluvial plain extending eastward from the mountains. However, particularly in those portions of North Dakota north and east of the Missouri River, the Great Plains have been affected by continental glaciation. Here, the topography was shaped primarily by erosion of the glacial drift and till.

2-5. Land Use. Agriculture represents the primary use of the land in this portion of the Missouri Basin, estimated to extend over 95 percent of the total area. The remainder is devoted to recreation, fish and wildlife, transportation and built-up areas. Pasture and range is the primary agricultural pursuit, utilizing about 80 percent of the total area. Cropland comprises only 8 percent of the Yellowstone River Basin but makes up about 20 percent of the remaining drainage area. Forests and woodland amount to 14 percent of the Yellowstone Basin and less than 5 percent of the remaining drainage area. Irrigation is practiced on about one-third of all cropland in the Yellowstone Basin but on only about 2 percent of cropland in the remainder of the drainage area under consideration. Water areas in this incremental drainage area make up about one percent of the total area, but the rivers, lakes reservoirs, farm ponds and other bodies of water involved are extremely important to the region's economy.

2-6. Drainage Pattern. The drainage pattern of the Missouri River Basin is shown on Plates 1 and 2. Noteworthy in the drainage basin above Garrison Dam are the large areas of the upper Missouri River controlled by the Fort Peck Reservoir. The Milk River, the first major tributary below Fort Peck Dam, drains a 23,000 square mile area, predominantly of the plains region, including a portion of Canada. The most significant tributary stream in this reach of the Missouri River is the Yellowstone River, originating on the western slopes of the Absaroka mountain range in Yellowstone National Park, and draining an area of about 70,000 square miles. Essentially all of the mountainous drainage area in the Fort Peck to Garrison incremental area is within the Yellowstone Basin. Streams tributary to the Yellowstone are of major importance, with regard to both contributing drainage area and water supply within the upper Missouri Basin. The other major Missouri River tributary in this area is the Little Missouri River with a drainage basin consisting of about 9,500 square miles entirely in the plains region of the basin. In the reach between Garrison Dam and the Oahe Reservoir, the major tributaries are the Knife and the Heart Rivers which flow into the Missouri River from the west and have drainage areas of 2,500 and 3,400 square miles respectively. The drainage area between Fort Peck Dam and Bismarck, North Dakota, is well defined except for portions of North Dakota, and northeastern Montana, north and east of the Missouri River, where numerous depressions and potholes occur.

2-7. The most prominent feature of the drainage pattern in this area is that every major tributary (except the Milk River) is a right bank tributary and flows in a north to east direction. This direction of flow is of particular importance from the standpoint of flow contribution from storms that typically move in an easterly direction. Additionally, it becomes important at the time of snowmelt and ice breakup in the spring since normal temperatures at that time in the headwaters regions are significantly higher than at the tributary mouths, resulting in an aggravation to ice jamming near their mouths during the ice break-up period.

2-8. Stream Slopes. The total fall of the Missouri River from Fort Peck Dam to Garrison Dam is approximately 365 feet and averages about 0.95 foot per mile along the thalweg of the stream. Slopes of the Yellowstone River and its tributaries in the headwaters area are very steep, ranging up to several hundred feet per mile. All tributary slopes progressively flatten as they approach their confluence with the Missouri River. Exceptionally flat is the Milk River through its lower reaches where a slope of less than 0.5 feet per mile exists. Most other major tributary streams have slopes ranging upward from 5 feet per mile, significantly steeper than the Missouri River throughout their length.

II-B. Climatology

2-9. General. The climate of the Missouri River drainage basin above Garrison Dam is preponderantly semiarid, except for small humid areas in the mountains along the Continental Divide. The climate of the basin is influenced by the barrier effect of the mountain ranges to the west and south of the Upper Missouri River basin; the differences in elevations; the interior location on the American continent; the latitude; and the movement of air masses and storms. These factors result in large variations in annual and daily temperatures and relatively low amounts of precipitation within the basin.

2-10. Annual Precipitation. Principal moisture-bearing air masses approach the upper Missouri River drainage basin from the Pacific Coast, however, a large portion of their moisture is lost as precipitation in crossing the more western mountain ranges of the continent. Crossing the main range of the Northern Rockies results in further uplift of the air masses and precipitation over the western part of Montana. These losses together with the warming and drying of the air during its descent over the eastern slope of the mountains largely account for the small amount of precipitation in the areas of lower elevation of the incremental drainage basin between Fort Peck Dam and Garrison Dam. In the mountainous regions of the basin the amount of precipitation tends to increase with elevation. There are also orographic barriers south and southeast of the Yellowstone basin which limit the amount of precipitable moisture entering the basin from these directions. Moisture-bearing air must rise to at least 8,000 feet to reach the portion of the Yellowstone basin west of the Absaroka Range. It must rise almost 7,000 feet to enter the Big Horn basin and about 3,500 feet to reach the lower Yellowstone basin in southeastern Montana. Average annual precipitation varies widely throughout the basin. Annual precipitation in the plains area varies from less than 6 inches in the upper Big Horn Basin to about 16 inches at the lower end of the basin near the Garrison Dam. The mean annual precipitation increases to about 26 inches in the vicinity of Yellowstone Park and to more than 40 inches in the high mountainous areas. The pattern of average annual precipitation throughout the Missouri Basin, including the incremental drainage area emphasized in this manual, is presented on an appropriate plate in the Master Manual.

2-11. Seasonal Precipitation. Approximately 70 percent of the total yearly precipitation upon the incremental plains drainage area between Fort Peck and Garrison Dams occurs during the months of April through September. Most of the spring and summer rainfall occurs in frequent showers or thunderstorms, however, steady rains lasting for several hours or days may occasionally occur. Excessive rainfall is unusual in the drainage basin above Garrison Dam. May and June are normally the wettest months in the Missouri River basin in Montana and Wyoming with May, June and July the wettest in North Dakota. Winter precipitation over the plains is generally light and falls as snow In the mountainous portions of the basin precipitation is more evenly distributed throughout the year. Large amounts of winter precipitation in the form of snow frequently occur at the higher elevations.

2-12. Normal annual snowfall varies from less than 20 inches over portions of the plains area to over 200 inches in mountain regions. Over the plains area snow does not usually progressively accumulate through the winter season but is melted by intermittent thaws. However, there have been notable exceptions when snow accumulations containing as much as 6 inches or more of water equivalent have blanketed large areas of the plains prior to a significant melt period. Mountain areas usually progressively accumulate snow through the winter and early spring season, up to a maximum accumulation in April or early May with a water content ranging upward to 24 inches or more at the higher elevations.

2-13. Temperatures. Resulting from its mid-continent location, the plains area in this region experiences temperatures noted for fluctuations and extremes. Extreme recorded temperatures have varied from -65 degrees F to almost 120 degrees F. Winters are long and cold; however, cold temperatures may be frequently interrupted during periods of downslope or "chinook" winds when mild temperatures (for the season) prevail. Summers are normally relatively mild, particularly in higher elevations, but may be interrupted by short periods of extremely warm temperatures over all of the plains area.

2-14. Evaporation. Annual evaporation from the surface of the Garrison Reservoir is normally slightly less than three feet. Studies made by the Reservoir Control Center conclude that the average net evaporation (evaporation adjusted for precipitation on the reservoir surface, runoff that would have occurred from land area now inundated and the original channel surface area now inundated by the reservoir) amounts to about 20 inches annually. Due to seasonal precipitation patterns and to the lag in normal lake surface temperatures from corresponding air temperatures, nearly all of the annual net evaporation from the Garrison Reservoir can be expected to occur during the five-month period, August through December.

2-15. Storm Potentialities. The source of moisture for all major storms in the high plains region of the Missouri Basin is the Gulf of Mexico. Based on available moisture alone, major storms would be most probable in late July or early August, since it is at this time that normal and maximum recorded air mass moisture is at its highest. However, major storms result almost exclusively from conditions accompanying frontal systems, and since frontal passages are more numerous and more severe in May and June than later in the year, major storms occur more frequently in late spring and early summer than at the time of maximum moisture charges. Major storms alone do not provide a complete index to the probability of large amounts of runoff within the region. A sequence of minor storms may saturate the soil and subsequently contribute much larger volumes to streamflow than would be the case if dry conditions prevailed prior to the runoff producing events. During winter months continued minor storms are the rule, producing snow accumulations over the mountains and portions of the plains area. Usually the highest annual flows experienced in the region result from melt of these snow accumulations. Severe flooding due to an individual major storm event will occasionally occur over portions of the basin.

II-C. Runoff

2-16. Streamflow Records. With the exception of a few stations, records of runoff from the incremental area considered in this manual exist only from the early 1930's to date. The main exception is a record near the mouth of the Yellowstone River extending back almost to the turn of the century. As discussed in the Master Manual, planning of the main stem reservoir system made it desirable to extend Missouri River streamflow records to the extent practicable. From the studies carried on at the time, based on main stem stages and the discharge records available, records of monthly incremental flows between the Fort Peck and Garrison Dam sites were developed for an extended period and are now available from 1898 to date. Daily flows at many locations within the incremental area are available for varying periods of time since 1930. Inasmuch as water use for all purposes has expanded significantly since settlement of the region began, it is necessary to adjust main stem incremental inflow records to a common level of water resource development in order that flow data are directly comparable from year to year. The total flows originating in the Fort Peck to Garrison reach have been adjusted to the 1949 level of water resource development, with such adjustment being a continuing process as further data are accumulated. While any development level would have been satisfactory, the 1949 level, prior to recent accelerated resource development, was selected.

2-17. Sources of Runoff. The mountainous drainage area of the Yellowstone River is normally the major runoff source in the incremental drainage area between Fort Peck and Garrison Dams. However, on occasion rainfall or a particularly large winter snow accumulation will result in a very substantial runoff contribution from the plains area. Normal contributions to runoff from various drainage basins through this region are given in Table 1. Generalized estimates of mean annual runoff throughout the Missouri Basin are presetned on a plate in the Master Manual.

2-18. Seasonal Runoff Pattern. Runoff from the Missouri River drainage basin between Fort Peck and Garrison Dams usually follows a characteristic seasonal pattern as follows:

a. Winter is characterized by frozen streams, progressive accumulation of snow in the mountain areas and intermittent snowfall and thaws in the plains area where the season usually ends with a "spotty" snow cover of relatively low water content and a considerable amount of water in ice storage in the stream channels. Runoff during this period, which usually extends from late November into March, is quite low.

b. Early spring is marked by a rapid melting of snow and ice, usually in March or April, in the plains area as temperatures rise rapidly, accompanied usually by very little rainfall. This causes a characteristic early spring ice breakup and rise. Due to the tendency of temperatures to rise above freezing first to the south and west, and the northerly or easterly course of the tributaries through this region, ice jams are frequently experienced on the lower Yellowstone River and along other tributary streams during this period. The rapid release of water from melting snow and ice jams results in a flashy "March" rise in flow. Peak stages and flows usually occur at this time along lower Yellowstone River tributaries and other streams tributary to the Missouri River through the region. On tributary streams other than

TABLE 1

NORMAL ANNUAL RUNOFF, MISSOURI RIVER BASIN
BETWEEN FORT PECK DAM AND BISMARCK, NORTH DAKOTA

Contributing Area	Drainage, sq mi	Average Annual 1,000 AF	Runoff(1) Inches
Milk River			
Nashua	22,332	512	0.43
Yellowstone River			
Corwin Springs	2,623	2,263	16.18
Billings	11,795	5,061	8.05
Miles City	48,253	8,353	3.25
Sidney	69,103	9,520	2.58
Corwin Springs-Billings	9,172	2,798	5.72
Billings-Miles City	36,458	3,292	1.69
Miles City-Sidney	20,850	1,167	1.05
Little Missouri River			
Watford City	8,310	438	0.99
Knife River			
Hazen	2,240	131	1.10
Heart River			
Mandan	3,310	186	1.05
Missouri River(2)			
Fort Peck Dam	57,500	7,343	2.39
Garrison	181,400	18,527	1.92
Fort Peck-Garrison	123,900	11,184	1.69
Local Drainage			
Fort Peck-Garrison(3)	23,455	714	0.57

(1) Based on available record at each location.
(2) Missouri River runoff at the 1949 level of water resource development.
(3) Incremental drainage area between Fort Peck and Garrison Dams less Milk R. at Nashua, Yellowstone R. at Sidney and Little Missouri R. at Watford City.

the Yellowstone River a major portion of annual runoff frequently occurs during this period. Snow melt in the mountains also usually begins in this period but contributes little to runoff until later in the year.

c. Late spring, consists generally of the months of May, June and early July. At this time extensive general rains may occasionally occur, sometimes accompanied by severe local rainstorms. Plains area runoff is usually quite low unless these rains occur. This is the season of rapid melting of the mountain snow accumulations and results in the highest flows of the year over headwater's tributaries of the Yellowstone River. Since this headwater area is normally the major contributing area to the Fort Peck-Garrison reach of the Missouri River, incremental flow volume during this period normally exceeds that occurring during any other period of the year. Occasionally, runoff from severe rainstorms synchronizes with the high runoff from mountain snowmelt and general rainfall during this period.

d. Summer and autumn are generally characterized by diminishing general rainfall, fairly frequent widely scattered intense local rainstorms, and occasional severe storms. Flow in all streams originating in the Fort Peck to Garrison drainage area is usually quite low from late July through the remainder of this period. However, occasionally an intense local storm will result in significant runoff amounts.

2-19. Total unregulated Missouri River runoff originating above the Garrison damsite usually follows a definite and characteristic annual pattern as influenced by the factors described in the preceding paragraph and as illustrated on Plate 3. Normal monthly runoff shows a general increase from January through June and then decreases through December. As would be expected, the variations in maximum and minimum monthly runoff amounts that have been observed generally follow the trend established by normal monthly amounts as shown on this plate. Monthly runoff distribution from the Fort Peck-Garrison incremental area is also shown on Plate 3. A pattern very similar to the total Garrison drainage area pattern is evident. The effects of reservoir regulation on these patterns is discussed in Section X.

2-20. Floods. Regulation provided by the Fort Peck and Garrison projects, augmented by upstream tributary reservoir storage, has virtually eliminated flooding along the portion of the Missouri River extending from Fort Peck Dam to the mouth of the Yellowstone River and the portion extending from Garrison Dam to the headwaters of the Oahe reservoir below Bismarck, North Dakota. Many instances of above bankfull flows were experienced through these reaches prior to construction of the main stem projects and would be continuing if the projects were not in operation. All floods experienced in this portion of the Missouri River except one have occurred in the March-July season with snowmelt as an important flood component. The one exception occurred in September 1923 when a large rainstorm over portions of southern Montana and northern Wyoming resulted in an October flood on the Missouri River.

2-21. The Master Manual contains relatively detailed descriptions of several of the experienced Missouri River floods, including data that is pertinent to the incremental reach described in this Garrison Manual. Since there is little additional data beyond that given in the Master Manual for several of these floods, they will not be discussed further in this manual. Paragraphs that follow present a more detailed description of large flows that have originated in the Fort Peck to Garrison reach of the river as illustrative of events that could utilize storage space allocated for flood control in the Garrison Reservoir. Of necessity, the descriptions are limited to rather recent events for which stream flow data are available.

2-22. Flood of 1923. From Plate 3 it may be noted that the volume of runoff originating between Fort Peck and Garrison dams during October 1923 was almost four times the volume that normally occurs during October and that the maximum runoff recorded for each month, October through December, from this reach occurred in 1923. This much above normal runoff for this season of the year was caused almost entirely from direct runoff and residual flows of an unusually late September rainstorm centered over the Big Horn mountains in southern Montana and northern Wyoming. A crest flow of 134,000 cfs occurred near the mouth of the Yellowstone River while tributary locations in the Yellowstone Basin established record high discharges that have not been exceeded to the present time. This flood illustrates that, although large amounts of runoff from the Yellowstone River will usually occur during the March-July flood season, unusual rain storms with large amounts of runoff can occur during seasons when runoff and flows are normally near seasonal lows.

2-23. Floods of 1943. Above normal precipitation occurred over the Fort Peck to Bismarck drainage area during the 1942-1943 winter season, augmented by a heavy four-day snow storm in the middle of March over the plains portion of this area in eastern Montana and western North Dakota. Snow accumulations at winter's end over both the plains and mountain portions of the drainage area were well above normal. High temperatures during late March and early April resulted in rapid melt of the plain's snow over ice-sheathed and frozen ground. Sharp increases in plains-area tributary flows were augmented by the formation of ice jams on these streams and the subsequent progressive releases of impounded water. A crest flow of 132,000 cfs, almost 50,000 cfs greater than the corresponding mean daily flow, was observed on the Yellowstone

River at Sidney. Maximum mean daily flows were 17,300 cfs on the Milk River at Nashua and 25,000 cfs on the Little Missouri River at Watford City. Many of the minor tributaries in this region such as the Poplar River also recorded unusually large crest flows at the time of the plains' snow melt. It is estimated that if the main stem reservoir system had been in operation at the time, crest inflows to Lake Sakakawea would have exceeded 200,000 cfs. Runoff originating between Fort Peck and Garrison Dams during the February-April period was about 5.4 million acre-feet, more than twice that usually occurring. Below Garrison Dam the Knife River at Hazen had a crest discharge of 26,500 cfs, although mean daily flows were no higher than 11,000 cfs.

2-24. The melt of the mountain snow cover in 1943 coincided with general moderate rains over the incremental drainage area between Fort Peck and Garrison Dams. Crest flows on contributing streams were not exceptionally large with a maximum mean daily flow of 83,600 cfs at Sidney in late June. However, the volume of runoff during June and July from this incremental area approached 7 million acre-feet, almost one-half again as much as normally occurs. Annual runoff during 1943 from this reach totaled 16.4 million acre-feet, this being only 0.2 million acre-feet less than the maximum recorded during the 1898-1975 period of record. The 1943 March-July flood season runoff from the incremental area was the greatest of record.

2-25. Flood of 1950. Flood events during the early spring plains snowmelt period of 1950 were particularly severe over the incremental drainage area extending from Garrison Dam to the headwaters of the Oahe Reservoir. Snowfall had progressively accumulated through the preceding winter season which was much colder than normal with well above normal precipitation. Significant melt in this drainage area did not occur until mid-April at which time severe tributary flooding occurred. A maximum mean daily flow of 22,000 cfs occurred on the Knife River at Hazen while the Heart River at Mandan experienced its maximum-of-record crest flow of 30,500 cfs and a corresponding mean daily flow of 28,400 cfs. If a similar flood were to occur with the Garrison project in operation, and if the ice-cover in the vicinity of Bismarck continued in place through the flood period, damaging stages could be expected in this reach due to inflows from the tributaries below Garrison Dam.

2-26. Flood of 1952. The most severe early spring snowmelt flood recorded in the upper Missouri Basin occurred in April 1952. April runoff from the incremental drainage area defined by Fort Peck and Garrison dams totaled 4.9 million acre-feet, exceeding the annual flood control storage space provided in the Garrison Reservoir by about 0.6 million acre-feet. This monthly runoff volume has been exceeded only once during the available record period, that occurring in June 1909 when a volume of 5.1 million acre-feet originated from this incremental area. Causes of this flood were a wet fall during 1951, well above normal precipitation over the plains area during the 1951-1952 winter period, formation of a significant ice-layer over frozen ground during early portions of the winter period and colder than normal temperatures during the winter season, resulting in a progressive accumulation of snow over the drainage area. Warm temperatures in late March and early April resulted in rapid melt of the snow cover and extremely large tributary flows. Recorded crest flows were as follow:

Milk River, Nashua	45,300 cfs
Poplar River, Poplar	27,800 cfs
Yellowstone River, Sidney	138,000 cfs
Little Missouri River, Watford City	42,200 cfs
Knife River, Hazen	20,200 cfs
Heart River, Mandan	30,000 cfs

2-27. The Garrison project was not in operation at the time of this flood and a crest discharge of 348,000 cfs was observed at the damsite. One day later the crest occurred at Bismarck when a peak flow of 500,000 cfs, 152,000 cfs greater than the Garrison peak, occurred. However, analysis of the event indicates that most of this increase in peak flows resulted from the severe ice-jamming action occurring along the Missouri River at the time. If a similar flood were to occur at the present time the Garrison Reservoir would act as a trap for upstream ice and a Bismarck crest flow about 25,000 cfs greater than the coincident mean daily releases from Garrison would appear likely.

2-28. Flood of 1967. Runoff during June and July 1967 from the Fort Peck-Garrison reach had the greatest two-month volume (7.416 million acre-feet) since emphasis on obtaining streamflow data began in about 1930. Mountain snow accumulations immediately prior to the snowmelt period were the largest of record at several locations in the upper Yellowstone Basin. Unusually heavy rains coincided with the melt of this mountain snow. While crest flows along the Yellowstone River were not unusually high (due partially to the reservoir control provided on the tributary Big Horn River) flood season volumes were exceptionally large. The observed two month volume at Sidney was 6.4 million acre-feet. Regulation of this flood by the Garrison project is discussed in Section X.

2-29. Flood of 1972. Runoff from the Fort Peck to Garrison drainage area in March 1972 totaled 3.6 million acre-feet, the greatest for March since records began in 1898. For the early spring plains snowmelt period, extending from February through April, the monthly runoff occurring in 1972 was exceeded only during the unprecedented 1952 flood occurrence. Warm temperatures in early March melted a large accumulation of snow over western North Dakota and southeastern Montana, resulting in considerable tributary flooding in this region. Observed crest flows were as follow:

Milk River, Nashua	6,000 cfs
Yellowstone River, Sidney	52,000 cfs
Little Missouri River, Watford City	52,300 cfs
Knife River, Hazen	19,000 cfs
Heart River, Mandan	9,500 cfs

Regulation of this flood is discussed in Section X.

2-30. Flood of 1975. Runoff during the months of May, June and July 1975 from the Fort Peck-Garrison incremental drainage area totaled 9.6 million acre-feet, with this three month volume being exceeded only once since records began in 1898. Available data indicate that during the same three months in 1909 runoff from this area was about 0.2 million acre-feet more than occurred in 1975. However, the 1975 flood season runoff was the largest ever observed for the total drainage area above Garrison Dam (including the area controlled by Fort Peck Dam). Total May-July runoff above Garrison Dam amounted to 18.1 million acre-feet, 2.5 million acre-feet more than has occurred during any corresponding period since records began in 1898.

2-31. The extremely large amounts of runoff occurring in 1975 resulted primarily from excess precipitation over the upper Missouri Basin during the March-July period. Prior to March 1975 water content of the basin's mountain snow cover was less than usually observed. However, by the time that significant melt from this region occurred, maximum of record amounts of snow water content were being reported at several locations. Unusually heavy precipitation over the plains area through the flood period contributed directly to streamflow. The flood season was climaxed by an extremely heavy rainstorm after mid-June centered to the east of the continental divide in Montana. This rainstorm had a center with a rainfall depth of over 15 inches. Average rainfall depths of 10 inches covered a 2,500 square mile area while a 10,000 square mile area had average rainfall exceeding 6 inches. Tributary streamflow in the Fort Peck-Garrison reach of the basin was not characterized by particularly high crest flows. It was an extended period of moderately large flows that resulted in the unusually large flood. Regulation of the runoff is discussed in the Master Manual and Section X of this manual.

2-32. Effects of Garrison Project on Flood Inflows. Studies conducted by the Reservoir Control Center indicate that operation of the Garrison project in conjunction with other upstream reservoir projects would virtually eliminate significant flood damages in the reach extending from Garrison Dam to the Oahe Reservoir if any past floods of record were to recur. Further discussion of regulation effects on flood inflows is given in Section X of this manual, Examples or Regulation.

2-33. Water Travel Time to the Garrison Reservoir. The Master Manual contains plates from which estimates of water travel time throughout the Missouri Basin can be obtained. Table 2 presents the approximate time involved for changes in flow at upstream locations in the Fort Peck-Garrison drainage area to be reflected in Garrison Reservoir inflows.

TABLE 2

WATER TRAVEL TIME TO THE GARRISON RESERVOIR

Stream	Location	Approx. Travel Time in Days
Missouri River	Fort Peck Dam	4
	Wolf Point	3
	Culbertson	2
Milk River	Vandalia	6
	Nashua	4
Yellowstone River	Corwin Springs	7
	Livingston	6
	Billings	5
	Yellowtail Dam	5
	Miles City	3
	Sidney	1
Little Missouri River	Marmarth	3
	Watford City	1

2-34. Water Quality. The Fort Peck to Garrison drainage area is relatively thinly populated with no large concentration of industry. The quality of water originating in this area is generally considered to be good. With the exception of tributary flows originating in western North Dakota and adjacent areas in Montana and Wyoming, total dissolved solids are generally less than 500 milligrams per liter. However, waters of the little Missouri River are in the 1,000 to 2,000 milligrams per liter range, due to the soluble salts contained in the readily erodible soils. Some pollution problems exist below cities due to inadequate treatment of municipal and industrial organic wastes. Irrigation, feedlots, overgrazing of range land and new industrial development also contribute to stream pollution. The main stem reservoirs, including the Garrison Reservoir, have a very stabilizing effect upon water quality parameters.

2-35. Sediment. Although the Missouri River has long been known as "Big Muddy", the proportion of sediment to total flow is only moderate. The characteristic turbid appearance of the flow is due to the high proportion of clay in the transported sediment. Approximately 1.5 million tons of sediment are contributed from the Milk River annually. Corresponding volumes are 21.0 million tons from the Yellowstone River, 5.8 million tons from the Little Missouri River, 0.2 million tons from the Knife River while the Heart River produces 1.0 million tons. Some of this tributary sediment is now trapped in tributary reservoir projects with most of the remainder trapped in the Garrison Reservoir. Average annual sediment inflow to this reservoir is estimated to be 38,100 acre-feet. Releases from Garrison Dam are clear; however, they immediately begin picking up sediment in the channel degradation process. Since the only source of fine sediments is caving river banks or tributary inflow, the river remains relatively clear through the reach extending to the headwaters of the Oahe Reservoir.

II-D. Missouri River Channel Below Garrison Dam

2-36. General. The physical characteristics of the Missouri River channel below Garrison Dam constrain releases made from the project. Release scheduling must consider these constraints which are determined by channel dimensions, the degree of encroachment on the flood plain and the type of flood plain development involved. Plates 4 to 9 present pertinent details of the channel and adjoining features extending from Garrison Dam to the headwaters of Lake Oahe. Recording gages designed to provide stage records through this reach of the Missouri have been established as shown on Table 3. Stages observed at each gage during 1975 when flows through this reach were in the 65,000 cfs range are given on the table for comparative purposes.

TABLE 3

MISSOURI RIVER STAGE RECORDERS,
GARRISON DAM TO LAKE OAHE

Gage	1960 River Mile	1975 Crest Stage[1/]
Garrison Tailwater	1389.9	1680.9
Stanton (Mo. River Below Garr. Dam)	1381.4	1676.3 (Old Gage Loc)
Ft. Clark (Mo. River near Stanton)	1372.6	1671.4 (Est.)
Hensler	1362.6	1664.8
Washburn	1355.1	1659.5
Price	1338.0	1647.5
Bismarck	1314.2	1632.6

1/ Crest stage associated with release of 65,000 cfs from Garrison.

2-37. Real estate has been acquired as a part of the Oahe project below river mile 1303.4, leaving a reach of 86.5 river miles extending below Garrison Dam that can be affected by Garrison releases. Problems associated with high river stages through this reach have mostly been confined from the Bismarck area downstream to the headwaters of Lake Oahe. The river valley immediately above the Oahe project taking line is known as the Sibley Island area within which low land flooding has been experienced during Garrison operations at the time that an ice cover has formed through the reach.

2-38. Aggradation has been occurring in the headwaters region of Lake Oahe and is expected to influence stages along the river below Bismarck. At river mile 1303.4 (the upper limit of the Oahe taking line), with an Oahe Reservoir level in the exclusive flood control operating range of elevations 1617 to 1620, flows of 60,000 cfs and 120,000 cfs resulted in respective river elevations estimated as 1624.2 and 1628.7 prior to aggradation. By 1993 (25 years after initial fill of Oahe) aggradation in this reach is expected to raise river stages about one foot for similar flows and Oahe Reservoir levels. This aggradation effect diminishes in an upstream direction and is expected to be insignificant at the Bismarck gage, mile 1314.5.

2-39. Channel Description. The Missouri River in the reach from Garrison Dam to the headwaters of the Oahe Reservoir is an alluvial stream contained in a relatively wide valley. An average channel of about 1,000 feet in width meanders through numerous sand bars and sloping sand banks between near-veritcal loam banks deposited by previous flood flows. Erosion of these vertical banks is quite common as a result of the meander process. In recent years bank stabilization has been accomplished in several areas and the river has been partially confined, particularly in the Bismarck, North Dakota area downstream from Garrison Dam.

2-40. Channel Deterioration. Typical of experience following construction of a dam, it appears that there has been a deterioration in the flood-carrying capacity of the Missouri River channel below Garrison Dam, in addition to the Oahe aggradation effects discussed in paragraph 2-38. This deterioration is partially due to the absence of flood flows, with their scouring effects, since dam construction. Channel encroachment, encouraged by the control afforded by the Garrison Reservoir, and bank stabilization measures also are believed to contribute to this loss of capacity. Deterioration is evident at Bismark, N.D., the principal damage center below Garrison Dam. At the time the dam was constructed a stage of 13 feet was approximately equivalent to an open water flow of 90,000 cfs. However, in 1975, after 22 years of project operation, flows of 50,000 cfs resulted in a similar stage.

2-41. Flood Plain Encroachment. Construction of the main stem reservoirs has encouraged encroachment upon the flood plain adjacent to the Missouri River channel. Adverse effects to extensive new developments in the vicinity of Bismarck begins at river levels as much as 6 feet lower than the long-established flood stage in the vicinity. A similar problem exists with the irrigation intake facilities adjacent to the channel throughout the reach of the river from Garrison to Bismarck. These facilities are usually designed to function at a near constant river stage, and complaints have been made relative to both low and high releases, as well as to release changes. Other water intakes serving power plants and municipalities in the reach must also receive consideration during the regulation process. This change in land use along the river was instrumental in the decision by the National Weather Service to lower flood stage at Bismarck from the long-established level of 19 feet to 16 feet in 1976.

2-42. River Ice. The Missouri River and its tributaries in the incremental drainage basin between Fort Peck Dam and Bismarck, North Dakota are at least partially ice covered for several months of the year. The period usually extends from late November to late March or early April. Ice thickness on the Garrison Reservoir has reached 41 inches and on the streams in the Garrison drainage basin a thickness in excess of 36 inches has occurred. An ice cover has formed on the reservoir as early as November 23 and remained until as late as May 8.

2-43. Construction of Garrison Dam has materially altered the ice experience along the Missouri River below the dam from that occurring prior to the project. Immediately below the dam a complete ice cover is now seldom experienced. The extent of open water in this reach during the winter period is primarily dependent upon air temperatures and release water temperatures. In recent years there has usually been at least seven miles of open water downstream from the project, although this may be materially reduced during extremely cold temperature periods. Formation of an ice cover in the entire reach below Garrison Dam has also been materially delayed from pre-project expectations. Release water temperatures during the normal ice formation period are significantly higher than previously experienced river water temperatures. This tends to maintain the Missouri River in a relatively ice-free condition well beyond the time that contributing tributaries are frozen.

2-44. Regulation of the Garrison project also influences the downstream ice break-up. Ice loss on the downstream river now results almost entirely from melting, with this melt progressing downstream from Garrison Dam. This contrasts with the pre-project mechanical breakup of the Missouri River ice by the higher flows from earlier breakup on the northward flowing tributaries. The Garrison Reservoir also acts as a trap to ice contributed from the upstream river and tributaries. Experience to date has also indicated that, in combination with the effects of Garrison releases, ice contributions from tributary streams between Garrison Dam and Lake Oahe, do not normally present a significant threat for ice jamming along the main stem channel. Consequently ice jams in the Missouri River reach below Garrison Dam are no longer the major concern they were prior to project construction.

2-45. Channel Capacity. The main damage center along the Missouri River in the reach immediately below Garrison Dam is Bismarck, the capital city of North Dakota. If Bismarck stages are not allowed to rise significantly above 13 feet, few complaints relating to high Garrison releases can be expected. As noted earlier in the manual, this stage presently indicates an open water flow of about 50,000 cfs, although 20 years ago open water flows of 90,000 cfs resulted in a stage of this magnitude. Further channel deterioration is a distinct possibility. During periods of ice cover in the Bismarck vicinity, flows resulting in a stage of 13 feet will vary. At the time an initial ice cover forms a stage of 13 feet is reached at a flow of about 20,000 cfs. As the ice cover remains in place a gradual adjustment occurs and increasing flows can be accommodated with a 13-foot stage. The adjustment is due primarily to the gradual smoothing out of the ice cover under surface and the bed of the river. After about one month of continuing ice cover the discharge capacity of the channel can be expected to almost double, allowing Garrison releases in the 35,000 to 40,000 cfs range without materially exceeding a target stage of 13 feet at Bismarck, provided significant inflows are not occurring to the reach.

2-46. Stage-Discharge Relationship. The relationship between river stages and corresponding discharges on the Missouri River below Garrison Dam are illustrated by the rating curves for the river at Bismarck, North Dakota, shown on Plate 10. The current open water curve indicates that, if an ice cover is not present, a change in river flow of about 5,000 cfs will result in a corresponding stage change of one foot when stages are near the maximum non-damaging level of 13 feet. If an ice-cover is present, the stage-discharge relationship is warped materially. Due to continuing adjustments after an ice cover first forms there is no single rating curve applicable for ice conditions at Bismarck. However, in general an ice-covered change in stage of one foot approximates a discharge change of about 3,000 cfs at Bismarck when stages are near the level of 13 feet. The pre-project rating curve for Bismarck is shown on Plate 10 for comparison.

2-47. Travel Time from Garrison Dam. The effects of Garrison release changes generally travel downstream at a rate of about three river miles per hour if an ice cover is not present. As a consequence, any change in an average release rate on one day is usually reflected by a changed Bismarck stage on the following day, provided there is not a significant ice cover upstream from Bismarck. An ice cover over most of the reach has the effect of slowing travel times to such an extent that two days may be required before the effects of release modifications become apparent on the Bismarck gage. Plate 11 relates water travel time to specific locations in the reach extending from Garrison Dam to the headwaters of the Oahe Reservoir.

SECTION III

WATER RESOURCE DEVELOPMENT

III-A General

3-1. History. Due to the generally arid climate as well as the lack of transportation facilities, development of water resources in that portion of the Missouri Basin extending from Fort Peck Dam downstream to the headwaters of the Oahe Reservoir began soon after settlement by the white man in the early 1800's. Initial development was concerned with navigation, as a means of transportation in the region, and irrigation. In later years, as population increased, the development of hydroelectric power facilities, generally in connection with irrigation projects, received emphasis. Control of floods became a major concern in the 1940's and in recent years municipal and industrial water supply, recreation, water quality enhancement and fish and wildlife have been major objectives of water resource development. All of these developments have used and affected the availability of water to a varying degree.

3-2. Legislation. Federal legislation pertinent to water resource development throughout the Missouri Basin is summarized in the Master Manual. As indicated in that publication, the Flood Control Act of 1944 is of primary importance through this portion of the basin. This act authorized the construction of Garrison Dam, as well as the other main stem project and many tributary projects, and emphasized the multiple-purpose aspects of water resource development.

3-3. Reservoirs. The most important water resource development in this section of the Missouri Basin has been construction of dams and development of the associated reservoirs. In addition to the Garrison Reservoir and the associated Lake Audubon, a number of tributary reservoir projects have been constructed in the incremental drainage area between Fort Peck Dam and the Oahe Reservoir. While initially these tributary projects may have been constructed for a single purpose, they all now serve several functions - although service to some functions may be incidental to the primary purpose. The U.S. Bureau of Reclamation, the Montana State Water Conservation Board, irrigation districts, the Bureau of Indian Affairs and various private organizations have numerous reservoirs in this incremental basin that were constructed primarily for irrigation purposes. Most of these are located in the Yellowstone and Milk River basins. The Yellowtail and Boysen reservoirs contain storage dedicated to flood control and assist the main stem reservoirs in controlling Missouri River floods.

Reservoirs in the incremental drainage basin having a usable storage capability of 5,000 acre-feet or more are shown in Table 4 and on Plate 2. Many additional reservoirs with a storage capacity of less than 5,000 acre-feet are used for irrigation and other conservation purposes and numerous small stock ponds have been constructed in the arid regions of the incremental drainage basin.

3-4. The upstream tributary reservoirs stabilize flows and affect the regulation of the Garrison Project by usually reducing the crest inflows, providing significant runoff contributing to the crest flows originates above these reservoirs. In certain instances a reservoir may increase the size of the crest below the project over that which would be observed naturally either by the speed-up of travel time through the length of the reservoir or by delaying a portion of the runoff from a subarea to more nearly coincide with the crest on the main stream. However, with the storage space provided and the large number of reservoirs tributary to the main stem, the possibility of the aggregate effect increasing Missouri River crest flows is very remote. Tributary projects in this region also store significant volumes of flood season runoff and some contribute inflows to the Garrison Reservoir during subsequent low water periods.

III-B Functional Water Resource Development

3-5. Flood Control. In addition to the flood control storage space provided in the Garrison project, reservoir storage space allocated to this purpose has been provided in the Boysen and Yellowtail projects in the Yellowstone River Basin and in the Heart Butte Reservoir on the Heart River. Respective flood control storage allocations in these projects are 300,000 acre-feet, 509,000 acre-feet, and 150,000 acre-feet. While no additional tributary reservoir storage space is allocated to flood control, regulation for other purposes frequently provides flood reductions through the river reaches below reservoir projects. This is particularly true for irrigation storage space provided in reservoirs within the Yellowstone River basin. Fill of the storage space is accomplished at times flood inflows are occurring and this storage often reduces downstream flooding.

3-6. The overall effect of upstream tributary reservoir operation is generally beneficial to Garrison operations. Storage accumulated during the flood season represents a volume of water that will not appear as flood inflow to the Garrison Reservoir, allowing the available space in this project to be used for a firmer degree of control of the total water supply. In actual practice, Garrison operations are geared to recognize the vacant storage space available in the major upstream tributary projects, space that would be utilized for storage of flood inflows should they occur.

TABLE 4
RESERVOIRS IN THE INCREMENTAL DRAINAGE BASIN
BETWEEN FORT PECK DAM AND THE OAHE RESERVOIR HEADWATERS
(Over 5,000 Acre-Feet Storage Capacity)

Reservoir	Stream	Basin	State	Usable Storage[1] Acre-Feet	Date Completed	Owner or Operator[2]
Anchor	Owl Creek	Bighorn R.	Wyoming	17,355	1961	USBR
Park	E. Fork Goose Cr.	Tongue R.	Wyoming	7,350	1933	Park Reservoir Co.
Boysen	Bighorn R.	Yellowstone R.	Wyoming	560,000	1952	USBR
Buffalo Bill	Shoshone R.	Bighorn R.	Wyoming	439,581	1909	USBR
Bull Lake	Bull Lake Cr.	Wind R.	Wyoming	131,800	1936	USBR
Cooney	Red Lodge Cr.	Clarks Fork	Montana	24,400	1936	Rock Cr. Water Users Assn.
Frenchman	Frenchman Cr.	Milk R.	Montana	7,010	1952	MWCB
Fresno	Milk R.	Milk R.	Montana	127,200	1939	USBR
Lake Adam	Sweetgrass Cr.	Yellowstone R.	Montana	5,720	1912	Big Timber Land Co.
Lake De Smet	Piney Cr.	Powder R.	Wyoming	25,000	1921	Estate L.Z.Leiter Clearmont, Wyo.
Lake Walvoord	Sweetgrass Cr.	Yellowstone R.	Montana	9,710	1912	Big Timber LandCo.
Mystic Lake	West Rosebud Cr.	Yellowstone R.	Montana	20,800	1925	MPC
Nelson	Milk R.	Milk R.	Montana	66,800	1922	USBR
Pilot Butte	Wind R.	Yellowstone R.	Wyoming	31,600	1928	USBR
Ray Lake	Mill Creek	Little Wind R.	Wyoming	7,500	1906	USBIA
Shoshone Lake	N. Fk. Popo Agie R.	Wind R.	Wyoming	9,740		State of Wyoming
Tongue R.	Tongue R.	Yellowstone R.	Montana	68,000	1939	MWCB
Upper Sunshine	Greybull R.	Bighorn R.	Wyoming	53,000	1939	Greybull Valley Irrig. District
Willow Creek	Lodgegrass Cr.	Bighorn R.	Montana	23,000	1942	USBIA
Yellowtail	Bighorn R.	Yellowstone R.	Montana	872,000	1966	USBR
Dickinson	Heart R.	Heart R.	North Dakota	5,500	1950	USBR
Heart Butte	Heart R.	Heart R.	North Dakota	69,000	1949	USBR

(1) Storage available for release below the maximum controllable level.
(2) MWCB - Montana State Water Conservation Board
USBR - U.S. Bureau of Reclamation
USBIA - U.S. Bureau of Indian Affairs
MPC - Montana Power Co,

3-7. There are no local flood protection projects that affect, or are affected by, Garrison operations. Levees have been constructed along the Missouri River adjacent to Williston, North Dakota, in the headwater's region of the Garrison Reservoir. These levees are considered to be an integral portion of the Garrison Project, provided to permit normal operation of the project, rather than a separate protection project.

3-8. Irrigation. The drainage area between Fort Peck Dam and the Garrison Reservoir contains a total of about 1,377,000 acres of irrigated land with approximately 1,147,000 irrigated acres in the Yellowstone basin, 148,000 acres in the Milk River basin, 44,000 acres in the Little Missouri River basin and about 38,000 acres along the main stem of the Missouri River and its minor tributaries between Fort Peck Dam and Williston, North Dakota. About one-third of all cropland in this portion of the Missouri Basin is irrigated. Irrigation is the primary purpose of most major tributary reservoirs that have been constructed within the incremental drainage area discussed in this manual.

3-9. Irrigation development between Garrison Dam and Bismarck includes the Fort Clark Unit of the North Dakota Pumping Division developed by the Bureau of Reclamation and privately owned irrigation developments along the bottomlands of the Missouri River. The Fort Clark Unit is located near the town of Stanton in Oliver and Mercer Counties. Facilities of the unit provide full water supply for the irrigation of 2,039 acres of land lying on two benches adjacent to the Missouri River. The privately owned irrigation developments vary from 30 acres to 1,500 acres in size and include a total of about 5,000 acres of irrigated land supplied with water from the Missouri River by individual pumping units.

3-10. Buford-Trenton and Lewis and Clark Irrigation Districts. Prior to development of the Garrison project there were two irrigation districts along the Missouri River at and immediately below the confluence of the Yellowstone River. Since these would be in the headwater area of the Garrison Reservoir, problems associated with continued operation of these districts were anticipated. The downstream Lewis and Clark District, located on the right bank of this river, was purchased to form a portion of project lands. However, the Buford Trenton District, located on the left bank was at a higher elevation and continued operation of at least a portion of this district appeared feasible through the early years of the Garrison project life.

3-11. The Buford Trenton Irrigation District was developed by the Bureau of Reclamation in the early 1940's and is divided by bends in the Missouri River into four areas. Proceeding downstream these are called Zero, West, Middle and East Bottoms extending for about 35 miles along the Missouri River from immediately above the Yellowstone River confluence to near Williston, North Dakota. The project consisted of about 16,800 acres of which 10,000 were irrigable. The East Bottom was purchased by the Corps of Engineers in 1958 in recognition of the probable flooding and ground water problems that would occur when Lake Sakakawea reached normal operating levels, reducing the area of the District to about 10,100 acres of which 7,100 acres are irrigated. The East Bottom lands and the downstream Lewis and Clark Project lands were leased to former owners for continued agricultural use until these lands were needed for project purposes.

3-12. Since the Garrison Reservoir first approached normal operating levels in 1965, ground water problems in the remaining portion of the Buford Trenton District have been increasing. These problems include flooded basements, improper functioning of drains, and water logging of the irrigated acreage. Analysis of the Corps of Engineers indicates that the problems are influenced by operation of the Garrison project and result primarily from sediment accumulations in the headwaters of the reservoir. Resolution of the problem would appear to require either purchase or a means of protection. The Omaha District has recently developed a protection plan consisting of blocks (levee structures) across the main drains with pumps as well as gated structures to discharge interior runoff and to lower ground water levels. However, these remedial measures have not yet been undertaken.

3-13. Garrison Diversion Unit. The Garrison Diversion Unit is now being developed by the U.S. Bureau of Reclamation and is expected to eventually irrigate about one million acres of land, principally in North Dakota and partly in South Dakota, and to make a water supply available through a large area for fish and wildlife, recreational, municipal, industrial, and other incidental uses. The unit is a modification of the Missouri-Souris Unit described in Senate Document 191, 78th Congress. The Snake Creek Embankment, constructed across Snake Creek about 10 miles northeast of Garrison Dam, serves as a highway (U.S. 83) and a railroad (Soo Line) relocation, and also forms Lake Audubon, a separate impoundment. Lake Audubon has a total storage capacity of 426,000 acre-feet at elevation 1,850. The Snake Creek Pumping Plant will pump water from the Garrison Reservoir into Lake Audobon to maintain the lake at elevation 1850. From this lake the water will be conveyed eastward by gravity flow through facilities built by the Bureau of Reclamation to irrigate initially 250,000 acres, and ultimately 1,007,000 acres, if subsequent units are found feasible.

3-14. In general, the Garrison Diversion Unit will serve irrigable lands between the Missouri River and western edge of the

Red River Valley, and between the Canadian boundary and Crow Creek in South Dakota. The principal features of the Garrison Diversion Unit are the Snake Creek Pumping Plant, Lake Audubon, the McClusky Canal, Lonetree Reservoir, and a series of distribution canals. The McClusky Canal will divert water from Lake Audubon and carry it by gravity to Lonetree Reservoir, a regulating reservoir in the headwaters of the Sheyenne River southwest of Harvey, North Dakota. Lonetree Reservoir is the principal regulating reservoir for the Garrison Diversion Unit and will be the focal point for main canals extending to the major areas of water use.

3-15. Although the principal purpose of the Garrison Diversion Unit is irrigation, the plan of development provides for the delivery of municipal water suplies to 41 towns and cities throughout the project area. It has also been assumed that large industrial users concentrated in the larger cities will use water from the unit. Lake Audubon and the immediately surrounding area have been made a game refuge under the jurisdiction of the United States Fish and Wildlife Service, and long-range programs are underway to make this a major nesting area for migratory waterfowl. Development of the Garrison Diversion Unit will provides increased recreation opportunities in an area which now does not offer a wide range of outdoor activity. New or enlarged bodies of water will add to the attractiveness of the region. From a recreation standpoint, the restoration of Devils and Stump Lakes in eastern North Dakota is the most important proposal incorporated in the project plans. With its waters freshened and stabilized at a level along the edge of the existing woodlands, Devils Lake will recapture much of its original natural beauty and could once more become an outstanding vacation spot and playground.

3-16. Navigation. Although navigation on the Missouri River through North Dakota and eastern Montana opened up this region for initial caucasion settlement, there is now no commercial navigation through this reach of the river. No tributary reservoir storage space has been allocated for this purpose. Storage has been provided in the Garrison Reservoir to serve multiple purposes, including Missouri River navigation; however, storage and releases from the Garrison project serve navigation only indirectly. A description of the Missouri River navigation project is contained in the Master Manual.

3-17. Hydroelectric Power. At the present time there are eight hydroelectric power plants in operation in the Garrison incremental drainage basin. These include the Garrison Power Plant, constructed by the Corps of Engineers, and seven plants in the Yellowstone River basin; six constructed and operated by the Bureau of Reclamation and the other by the Montana Power Company. The installed capacity of these Yellowstone basin plants totals 688,000 kw, whereas the installed capacity at Garrison is 400,000 kw. All power generated by Federal facilities in the Missouri Basin is marketed by the Western Area Power Administration and power generation at the Federal tributary power plants is integrated with the generation provided from Garrison and other main stem projects. Further details concerning WAPA's power marketing and transmission facilities are provided in the Master Manual.

3-18. Municipal and Industrial Water Supply. The Missouri River between Garrison Dam and Lake Oahe is the source of water supply for the North Dakota municipalities of Riverdale, Washburn, Bismarck and Mandan. Industrial water intakes in this reach of the river include the Standard Oil refinery near Mandan, the Basin Electric and United Power Association coal fired power plants near Stanton, Ottertail Power Company plant at Washburn and the Montana-Dakota Utilities power plant at Mandan. The Garrison Diversion Unit is expected to furnish municipal and industrial water supply for 15 towns and cities in the initial stage of development and for 41 towns and cities in the ultimate potential development all by pumping from Garrison Reservoir.

3-19. Relatively recent plans have been made to utilize water stored in the Garrison Reservoir for development of the large reserves of coal that are available through western North Dakota. Most of these plans envision conversion of the coal to gas which will be used to supplement available natural gas supplies. Utilization of water from the reservoir for industrial purposes requires a water right from the State of North Dakota in addition to Corps of Engineers' permits. The only water right which has been granted for this purpose was based on withdrawals from the Little Missouri Arm of the reservoir. It is quite probable that energy development in this area will be accelerated substantially in future years. Industrial water marketing arrangements for the water contained in the Garrison Reservoir have as yet not been finalized, but preliminary agreements assign this responsibility to the Department of Interior. A similar type of energy development is quite probable in the Yellowstone Basin, and is expected to make use of tributary reservoir water storage.

3-20. Land Treatment. In response to a program administered by the Department of Agriculture, land treatment measures designed to reduce erosion and local floods and to increase the local surface water supply are in operation throughout large portions of the incremental drainage area discussed in this manual. Associated with this program are the many stock ponds or farm ponds that have been developed in the past 40-50 years. While these ponds and other land treatment measures have a depleting effect on the overall water supply to the Missouri River and provide a degree of local flood protection, their effect on major Missouri River flood flows is minimal.

3-21. Fish, Wildlife and Recreation. The effects of water resource development upon fish and wildlife is a major concern through the drainage area in the planning and operational processes. Recreation opportunities have generally been increased as a result of water resource developments. To the degree practical, fish and wildlife interests are consulted prior to operation of projects and the potential effects upon these functions become important constraints upon operation. Recreational use of tributary reservoirs in the basin and of the Garrison Reservoir continues to increase through the years and is a factor to be considered in actual regulation of these projects.

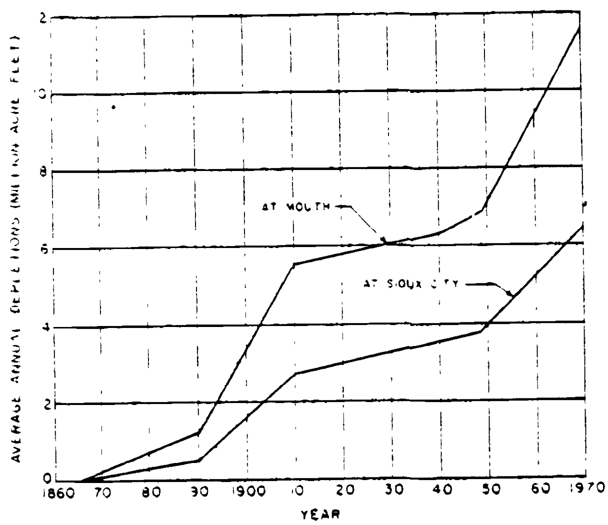
3-22. Streambank Stabilization. Streambank erosion is a continuing process along the Missouri River below Garrison Dam and also along the tributaries in the region. Prior to construction of Garrison Dam, accretions comparable to the eroded area could be expected to occur; however, the Garrison Reservoir now acts as a sediment trap, interferring with the accretion process. Based on studies made in 1968, pre-project (1938-1954) erosion totalled about 225 acres per year in the Garrison-Oahe headwaters reach - compared to about 85 acres per year during the 1954-1968 period. Subsequent erosion data have been clouded somewhat by construction of bank protection projects in the reach. These bank stabilization structures have been constructed at scattered locations between Garrison Dam and the Oahe Reservoir where erosion has been most active or threatens concentrated shoreline development, such as in the Bismarck vicinity. While these measures are effective in restricted reaches, there remain large lengths of unprotected banks that are subject to future erosion. There is also some evidence that the structures built for this purpose have had the effect of reducing the capacity of the downstream channel. Nevertheless, land owners adjacent to the river channel frequently request operational constraints, in the belief that these would minimize erosion below the dam. Adoption of these constraints on release fluctuations from Garrison could seriously affect the primary functions of the project, with no assurance that they would be effective for erosion control.

III-C. Streamflow Depletions.

3-23. General. Water resource developments in the incremental drainage between the Fort Peck and Garrison Dams have two major effects on the regulation of the Garrison Reservoir - a depletion in the available water supply and a partial redistribution of inflows. As resource development continues, a growth in depletions can be expected. While increasing depletions probably benefit the flood control function, it is evident that they would generally have adverse effects on other functions dependent on the availability of a continuing water supply.

3-24. Depletion Growth. Prior to 1865, streamflow in the region was largely unused, except for transportation. Settlers and homesteaders in the late 1800's and soon after the turn of the century started substantial irrigation and mining ventures. Additional irrigation occurred on established Indian reservations. As these uses increased, they began to have a significant effect upon streamflow. By 1910, it is estimated that the average annual Missouri River depletion above Sioux City, Iowa, totaled about 2.7 million acre-feet with approximately one-half of this total occurring in the drainage area under consideration in this manual. Between 1910 and 1949, water use increased at a moderate rate with the resulting increase in the average annual depletion to streamflow amounting to about 300,000 acre-feet from this drainage area. Since 1949, water resource development has accelerated. It is estimated that average annual depletions between Fort Peck Dam and Bismarck increased by over one million acre-feet during the 1949-1970 period. The estimated growth in depletions for the Missouri basin as a whole, and for the area above Sioux City, is shown on the inset graph.

GROWTH OF STREAMFLOW DEPLETIONS



Source: 1969 Framework Study

3-25. A continuing increase in depletion is expected from this drainage area. Estimates are that with a reasonable rate of water resource development, the increase in average annual streamflow depletion from the area extending from Fort Peck to Garrison Dams will approach five million acre-feet during the next 50 years. A major future depleting influence in this reach will be the Garrison

Diversion Unit. In addition to normal depletions resulting from serving irrigation and water supply projects in the Missouri Basin, almost two million acre-feet will be exported annually from the Missouri Basin, primarily for irrigation and the improvement of water quality in the Souris and Red River basins.

3-26. By 1970, the average annual depletions for the total drainage area above Garrison Dam, including the area controlled by Fort Peck Dam, had increased by about two million acre-feet above the 1949 "base level" selected for adjustment of streamflow records in the Missouri Basin. This amounts to about 11 percent of the total 1949 water supply available above Garrison Dam. Projections in the 1969 Framework Study were that during the next 50 years, average annual depletions from this total area would increase to the extent that depletion growth since 1910 would represent about 43 percent of the 1949 runoff originating above Garrison Dam. Subsequent estimates have lowered this depletion growth rate significantly.

3-27. Depleting Functions. The water resource development function resulting in most depletions in the Missouri Basin is irrigation, as shown in the following table:

Distribution of Missouri Basin Streamflow Depletions 1949-1970

Activity		Millions of Acre-Feet
Irrigation		2.1
Evaporation from Major Impoundments		1.8
Fish and Wildlife		0.1
Land Treatment		0.3
Minor Impoundments		0.4
Rural domestic water supply		0.1
Municipal and Industrial water supply		0.2
Forestry		0.1
	Total	4.9

Source: 1969 Framework Study

Similarly, about 59 percent of the increase in average annual depletions in the Yellowstone River drainage between 1949 and 1970 can be attributed to water losses resulting directly from irrigation. Land treatment measures, including stock ponds, resulted in a depletion increase amounting to 18 percent of the total. Depletion increases resulting from rural domestic, livestock, mining and municipal and industrial uses together amounted to only 4 percent of the total increase. Of interest is that this 4 percent increase in depletions was almost entirely balanced by forestry practices in the upper Yellowstone Basin that had the effect of increasing the water supply. An important depletions factor that cannot be assigned to any particular development function is evaporation from large multiple-purpose reservoirs. The 1949-1970 depletion increase in the Yellowstone Basin resulting from large reservoir evaporation, amounted to about 23 percent of the total increase. Average annual evaporation losses occurring from large tributary reservoirs developed during the 1949-1970 period, together with main stem reservoirs, above Garrison Dam total 1.2 million acre-feet or almost 7 percent of the 1949 water supply above this location.

SECTION IV - HISTORY AND DESCRIPTION OF THE GARRISON PROJECT

IV-A Project Development

4-1. General. Early studies and investigations for construction of a dam near Garrison, North Dakota, were made by the Corps of Engineers Kansas City District under supervision of the Upper Mississippi Valley Division. Additional investigations, studies, preliminary design and the preparation of the definite project report for the Garrison project were accomplished by the Omaha District under the supervision of the Missouri River Division and the Office of the Chief of Engineers. The Garrison District, with headquarters at Bismarck, was established on 1 July 1946 and moved to Riverdale near the damsite in December 1953. Final design and supervision of construction of the Garrison project was the responsibility of the Garrison District until 1 April 1960 when it became an Area Office under the Omaha District. Construction of the project was initiated in 1946, closure of the dam was made in April 1953 and in December 1953 and the project was placed in operation for flood control, as an aid to navigation on the Missouri River and for storage. Power generation began in January 1956 when the first unit went on the line. Since 1956 the Garrison project has been operating as an integral unit of the Missouri River main stem reservoir system.

4-2. Project Authorization.

a. The Garrison project was included in the general comprehensive plan for the Missouri River basin set forth in House Document 475 and Senate Document 247, 78th Congress, 2d Session.

b. The project was authorized by the Flood Control Act of 1944 (Public Law 534, 78th Congress, 2d Session, approved 22 December 1944).

c. Garrison Reservoir was designed as Lake Sakakawea by Public Law 90-46, 93rd Congress, 1st Session, Approved July 4, 1967.

4-3. Early Investigations. Prior to 1927, local interests proposed to divert water from the Missouri River for developing irrigation, improvement of water supply, raising the slowly receding level of Devils

Lake and increasing low flows of the James River and the Sheyenne River in the eastern part of North Dakota. A damsite in the general vicinity of the present location of Garrison Dam was considered in the plan.

4-4. The 69th Congress, 1st Session, in House Document No. 308, authorized a survey by the Corps of Engineers of navigable streams in the United States (with certain exceptions) to formulate general plans for the most effective improvement of such streams. The purpose contemplated was navigation with the most efficient development of potential water power, control of floods and irrigation. A damsite near Garrison, North Dakota, was considered in the reports convering the James River and the Missouri River investigations.

4-5. The "308" report of the James River was printed as House Document No. 83, 73rd Congress, 1st Session. This report contained as appendices reports by the State Engineer of North Dakota and a report by the State Geologist of North Dakota which had been submitted to the State Governor. The State Engineer suggested a hydraulic fill dam 173 feet high with concrete overflow spillway at approximately the site of the present Garrison Dam. From the reservoir created by the dam, water was to be supplied through a system of conduits to the headwaters of the James and Sheyenne Rivers and to Devils Lake. The purpose of the diversion was to raise lake levels and to furnish water for irrigation and domestic water supply. Flood control, navigation improvement, erosion control, and power were incidental benefits. The State Geologist, in his report, stated that the foundation at that site was unsatisfactory for the high dam proposed by the State Engineer. The "308" report for the James River states ". . . all available data strongly indicate that the foundation conditions obtaining at the site are inadequate . . ."

4-6. The "308" report of the Missouri River was printed as House Document No. 238, 73rd Congress, 2d Session. The "308" report considered a dam at the Garrison site and states ". . . borings indicate that the foundation materials at that point do not have sufficient crushing strength to support a high dam. The site was accordingly abandoned in favor of other sites on the main stem above the mouth of the Yellowstone River."

4-7. Project Planning. Advances in the fields of soil mechanics and foundation engineering caused renewed interest in the proposed dam and reservoir near Garrison. In 1933, a firm of consulting engineers submitted a report to the State Engineer of North Dakota, recommending that an improvement similar to that previously proposed by the State Engineer be initiated. This report recommended a main dam of the rolled fill type, rather than the type proposed by the State Engineer. A board of consultants inspected the Garrison Damsite and by letter to the Missouri River Diversion Board on 31 July 1943 concluded that a safe high dam at the proposed site was reasonably feasible and that the proposed location appeared generally satisfactory.

4-8. House Document 475, 78th Congress, 2d Session, presented the U.S. Engineer Department plan for the overall development of the main stem of the Missouri River. A dam at the Garrison site was recommended in the plan. Because of previous uncertainties of the foundation condition, investigations for this report were as comprehensive as those ordinarily considered appropriate for a definite project report.

4-9. The 78th Congress, 2d Session, considered the Missouri River development plans submitted by the U.S. Engineer Department in H.D. 475 and by the U.S. Bureau of Reclamation in S.D. 191. The differences between the two plans were adjusted at an interdepartmental conference and the coordinated plan of which the Garrison project is a feature is contained in S.D. 247 and was approved by the 1944 Flood Control Act (Public Law 534, 78th Congress, 2d Session). Definite project planning was begun as a result of this authorization. The Definite Project Report for Garrison Dam and Reservoir was completed and dated January 1946. Surveys and investigations for this report were made in more complete detail than usually required in view of the tremendous size of the project, the unfavorable conclusions of earlier investigations for the Garrison Dam, and the possibility that it might be desirable to undertake construction at an early date as a part of the overall post-war planning requirements for the Nation.

4-10. The investigation program for the Garrison project inaugurated prior to completion of the definite project report was continued and served as a basis for the final design. A board of consultants was appointed to advise on the design and construction of the project. Details of design studies made by the Corps of Engineers, private consultants and the board of consultants are contained in the record documents on file in the Lake Sakakawea Area Office.

4-11. Major Departures from Definite Project Report.

a. Spillway. The tentative spillway design as shown in the definite project report provided for a chute type spillway with a low flat weir surmounted by 29 tainter gates (40 feet wide by 29 feet high), and a discharge capacity of 600,000 c.f.s. with the reservoir at elevation 1858. Final spillway design flood studies for the Garrison Reservoir was based on hydrometeorological estimates supplied by the U.S. Weather Bureau and supplemented by detailed meteorologic, hydrologic and hydraulic studies by the Corps of Engineers. The flood adopted for the final design of the Garrison spillway represents the maximum runoff from maximum possible winter's snow accumulation, combined with the maximum possible early-spring snowstorm over the plains region above the damsite. The final design of the Garrison spillway provides for a chute type spillway with an ogee weir surmounted by 28 tainter gates (40 feet wide by 29 feet high), and a discharge capacity of 827,000 c.f.s. with the reservoir at elevation 1858.5 ft msl.

b. Outlet Works and Power Conduits. The definite project report provided for eight power conduits, 24 feet wide by 24 feet high, with semi-circular tops and five rectangular sluices, 11 feet wide by 18 feet high, to be constructed by cut-and-cover methods. Steel penstocks, 18 feet in diameter were planned for erection within the power conduits. Gates planned for the tunnels included 21 service gates of the self-closing type and five crane-operated emergency gates. All gates were to be identical in size (11 feet wide and 18 feet high) and interchangeable. The overall dimension of the intake structure as shown in the definite project report were 110 feet wide, 430 feet long and 230 feet high with the operating deck at elevation 1880. Further investigations and studies resulted in adoption of tunneling in lieu of cut-and-cover methods. This resulted in large savings both in time and costs. Other major changes in the outlet works included the size of the tunnels, size of penstocks; the type, number and size of control and emergency gates and the dimensions of the intake structure. The final design of the outlet works provided for five power conduits, 29 feet in diameter, and three flood control tunnels, one 26 feet in diameter and two 22 feet in diameter. Penstocks having an inside diameter of 24 feet were installed in the power conduits. One 18 feet by 24.5 feet tainter gate was provided for each flood control tunnel for fine regulation. Two vertical-lift caterpillar gates, each 26 feet high by 12 feet wide, were provided for each of the power tunnels. Tractor type vertical life emergency gates were provided for the three flood control tunnels and four sliding vertical-lift bulkhead gates for use ahead of any pair of penstock gates. The final design also provided an intake structure with a base 170 feet wide, 540 feet long and a height of 203 feet from the foundation to the operating deck at elevation 1865.

c. Hydropower Installation. The definite project report provided for an initial power installation of 80,000 kw and an ultimate installation of 320,000 kw. The proposed installation included a total of eight 40,000 kw units with penstocks having a diameter of 18 feet. Station service hydroelectric units were also proposed in the definite project report. The final design of the power plant provided for a 400,000 kw power installation consisting of five 80,000 kw power units with penstocks, 29 feet in diameter and ten surge tanks (two for each power unit), 65 feet in diameter. The station service units were deleted in the final design.

d. Substation and Switchyard. In the definite project report all main power transformers were located in the switchyard with leads from each main generator being carried from the plant to the switchyard in a power cable tunnel which is separated from the tunnel carrying control cable. The definite project report also provided for the switchyard to have initial circuits for three 115 kv lines with positions for a fourth 115 kv and two 230 kv lines to be installed in the future. The final design provided for the main power transformer for each unit to be located on a transformer deck on the downstream side of the powerhouse. The main power circuits consist of 13.8 kv isolated busses from the generator terminals to the main power transformer, and high tension cables in oil filled pipes from the main power transformer to the switchyard. The switchyard as constructed provides for termination facilities for the main generators and for four 115 kv outgoing lines and three 230 kv outgoing lines.

e. Protective Works for Headwater Areas. The definite project report included plans for the protection of Williston, North Dakota and two irrigation projects at the head of Garrison Reservoir. The irrigated land to be protected included the Lewis and Clark Project comprising about 8,100 acres and Units 1, 2, and 3 of the Bufort-Trenton Project comprising about 15,700 acres. Plans for protection from backwater from the reservoir during floods by means of levees and pumping facilities were included for Williston, the Lewis and Clark Project and for the east portion of the Buford-Trenton Project. The balance of the land in the Buford-Trenton Project was not expected to require protection until such time that aggradation caused high backwater stages during floods. In order to conform with the desires of local interests and for economical reasons, actual project development resulted in Federal purchase of all of the land in the Lewis and Clark Project and in the east bottom portion of the Buford-Trenton Project. The Williston area was protected by construction of levels designed for "initial" aggradation additions.

4-12. Construction History.

a. Embankment. Construction of the rolled fill embankment began in October 1947 and was completed in 1956. Material for the embankment was obtained primarily from the excavations which were necessary for the intake structure and power house foundations, intake and outlet channels, spillway construction and spillway pilot channel.

b. Spillway. Construction of spillway facilities began in June 1952, with the crest structures completed in 1955. Work on the spillway stilling basin continued into 1957.

c. Outlet Works. Construction of the eight outlet and power tunnels and associated intake structure and stilling basin began in 1949. Tunnels were completed in 1951 and the intake structure in 1954. Installation of emergency gates, penstock gates, regulating gates, stop logs, gate hoists and associated mechanical and electrical equipment was completed by 30 June 1955.

d. Power Plant and Switchyard. Construction of the power house foundation began in 1949 and work continued on power generation and distribution facilities into 1962. The first power unit was placed on-line in February 1956. Succeeding units went on-line in March 1956, August 1956, December 1959 and May 1960. Terminal facilities and switchyards were completed in July 1962.

4-13. Relocations. The relocations required for the Garrison Project included two Federal highways, five State highways, several county roads and Indian Agency roads, two railroads, numerous power transmission lines, telegraph and telephone lines, gas lines, two towns, the Fort Berthold Indian Reservation and several small cemeteries. A complete new town (New Town) was constructed to replace Sanish and Van Hook, North Dakota, which were inundated by the reservoir. Portions of

U.S. Highways 82 and 85 and North Dakota State Highways 2, 8, 22, 23 and 28 were relocated. A new highway bridge (Four Bears Bridge) was constructed across Garrison Reservoir on State Highway 23 near New Town. Lost Bridge over the Little Missouri River arm of the reservoir on State Highway 22, and county road bridges over Little Muddy Creek and Stoney Creek east of Williston was raised. U.S. Highway 83 and the Minneapolis, St. Paul and Sault Ste. Marie Railway (SOO Line) were re-routed across the Snake Creek embankment. The branch line of the SOO Line in the vicinity of Sanish and Van Hook was relocated to a terminus at New Town. The Great Northern Railway required relocation east of Williston, North Dakota. Detailed description of the relocations are contained in appendix VII to Volume II of the definite project report for the Garrison Dam and Reservoir dated January 1946. Relocations were started early in 1949 and were essentially complete in 1962.

4-14. Real Estate Acquisition. Lands required for the Garrison project total almost one-half million acres. Most of this area was acquired in fee, with easements totaling less than 3,000 acres. The basis for real estate acquisition was a guide-taking line of elevation 1855 feet msl over a major portion of the reservoir area. In upstream areas the guide-taking line was as high as elevation 1860 ft msl, recognizing backwater and aggradation that was likely to occur. While most of this real estate has been acquired, there are numerous small parcels of land below these elevations that have not as yet been acquired due to faulty surveys or inadequate blocking out and acquisition of these parcels continues at this time (1976).

4-15. Operational History. Closure of Garrison Dam and the first impoundment of water occurred 15 April 1953. In early operation the reservoir was utilized for flood control and the accumulation of storage that was subsequently released to help support navigation on the lower Missouri River. As power units came on the line and additional storage was accumulated, service to all authorized functions began. The project has been fully operational since 1960, except that initial filling of the reservoir to normal operating levels was not completed until 1966. Further information concerning historical operation is contained in Section X of this manual. Detailed descriptions of project operations for each year since 1953 are in the Annual Operating Plan reports published every August.

IV-B Description of Garrison Project

4-16. Location. Garrison Dam is located at mile 1389.86 (1960 mileage) on the Missouri River in McLean and Mercer counties, North Dakota, approximately 75 river miles upstream from Bismarck, the capitol city of North Dakota. Lake Sakakawea, formed by the dam, extends in a generally northwest direction through western North Dakota, terminating near Williston, North Dakota.

4-17. Embankment. The dam consists of a rolled fill earth embankment 11,300 feet in length at the crest with a crest at elevation 1875 ft msl, over 200 feet above the old riverbed. The upstream portion of the embankment is composed of dense impervious material, and the downstream portion is semipervious with a pervious drainage blanket over the old streambed. The maximum width of the base is about 2,600 feet with an impervious blanket extending an additional 1,250 feet upstream from the upstream toe of the dam. The crest width is 60 feet and side slopes range from 1 on 8 and 1 on 10 in the lower portions of the embankment to 1 on 3 and 1 on 2-1/2 in the upper portions. Seepage control is effected by a combination of the upstream impervious blanket, steel sheet piling cutoff walls, impervious filled cutoff trenches, grout curtains at the abutments and a toe drain in the downstream section of the embankment. A system of relief wells located about 175 feet downstream from the toe of the dam also facilitates drainage of seepage water and reduces hydrostatic pressures in the foundation material downstream from the cutoff walls. The upstream face of the dam is protected from wave action by riprap placed above elevation 1800 feet (m.s.l.). A gravel blanket extends from the bottom of the riprap to elevation 1770 feet (m.s.l.). Detailed description of the embankment is contained in the Operation and Maintenance Manual for the Garrison Dam Embankment. The plan and section of the embankment are shown on Plate 12.

4-18. Embankment freeboard was based on a lake level at elevation 1859 ft. msl. A wind tide allowance of 1.8 feet and wave height plus ride-up allowance of 6.3 feet was developed in design studies. An additional safety factor of 7.9 feet resulted in the total free board allowance of 16 feet, establishing the embankment crest at elevation 1875 ft msl.

4-19. Spillway. The spillway is located in the left abutment and separated from the main embankment by about 800 feet of natural ground. The spillway is of the conventional concrete chute type with crest gates at the upper end, and consists of the approach channel, control gate structure, lined chute, stilling basin and unlined discharge channel. The bottom of the approach channel is at elevation 1810 ft msl with an upstream width of 2,200 feet narrowing to 1356 feet at the spillway crest structure. The spillway crest consists of an ogee type weir, divided into 28 bays, with a crest elevation 1825 ft msl. Each bay contains a tainter gate 40 feet wide by 29 feet high. The gates are electrically operated and can be individually controlled from the service bridge. Selective operation of all gates is accomplished from the control house at the west abutment on the downstream side of the abutment wall.

4-20. A concrete-lined discharge chute extends from the crest structure 2,605 feet downstream to the stilling basin. The stilling basin is 800 feet wide and over 200 feet long with a floor at elevation 1620 ft msl. The lower portion of the stilling basin contains baffles 10 feet high and 8 feet wide spaced on 10 feet centers. Below the stilling basin an unlined pilot discharge channel has been constructed to guide flows to the Missouri River channel below the dam. Should spillway discharges occur, this pilot channel is expected to erode and adjust itself to the flow conditions. Plan, profile and section of the spillway are shown on Plate 12. Spillway discharge rating curves are shown on Plate 13.

4-21. Outlet Works and Power Tunnels. The outlet works and power tunnels include an approach channel, an intake structure, eight concrete lined tunnels of which three are for flood control and five for water supply to power units, a stilling basin at the downstream end of the flood control tunnels and a discharge channel leading to the old river channel. The approach channel to the intake structure served to carry Missouri River flows at the time of embankment closure. It consisted of a channel excavated to near elevation 1670 ft msl about 500 feet wide and 2-1/2 miles long along the right (west) bank of the Missouri River channel that lay upstream from the dam prior to closure. It is now continuously submerged and ends at the intake structure. The intake structure houses gate-controlled inlets to all of the eight tunnels provided through the dam. It is a massive reinforced concrete structure, having overall dimensions 540 feet in length, 170 feet in width at the base and 203 feet in height from the foundation to the operating deck at elevation 1865 ft msl. A superstructure extends upward another 65 feet. Gates housed in the structure include an 18 by 24.5 feet tainter gate for each of the three flood control tunnels and two 12 by 26 feet vertical lift gates for each of the five power tunnels. Emergency gates are provided for closure ahead of any of the regulating gates described above.

4-22. Tunnels through the dam are approximately 1,320 feet long, having an invert near elevation 1671 ft msl at the upstream end and elevation 1662 at the downstream exit. The easterly five tunnels, Nos. 1 through 5, serve as conduits for the penstocks supplying the power units. The remaining three tunnels, Nos. 6, 7 and 8, are for flood control and discharge into a stilling basin. The five power tunnels have an inside diameter of 29 feet, except for a short distance of tunnel No. 4, which is 30 feet inside diameter. Tunnels Nos. 6, 7, and 8 are for flood control; tunnel No. 6 has an inside diameter of 26 feet and tunnels Nos. 7 and 8 have inside diameters of 22 feet. A stilling basin extends below the three flood control tunnels and contains stop log slots in the upper end to provide for basin unwatering. Below the stop log slots is a 250 foot long chute section, followed by a level stilling basin section about 165 feet long with a bottom at elevation 1619 ft msl leading into a paved slab section that slopes upward to elevation 1650 ft msl at the entrance to the unpaved discharge channel. The discharge channel extends from the downstream edge of the tailrace and stilling basin to the Missouri River channel, a distance of almost 4,000 feet. Sloping sides of the discharge channel are protected by riprap. A more detailed description of the outlet works is contained in the Garrison Operation and Maintenance Manual. A plan and profile are shown on Plate 12 of this manual, while rating curves for the flood control tunnels are on plates 14 and 15.

4-23. Power Plant and Switchyard. Principal features of the power production facilities of the Garrison project include penstocks and surge tanks, the powerhouse that houses the generators, turbines, control room and related equipment, the tailrace, and the outdoor switchyard. Water is supplied to the turbines by five 24-foot diameter steel penstocks contained in the 29 feet diameter power tunnels previously described. Two surge tanks, each 65 feet in diameter and almost 140 feet in height (extending upward to elevation 1885.67) are provided for each penstock. A bubbler system is provided to prevent a solid ice cover from forming on the water surface in the surge tanks during freezing weather.

4-24. The powerhouse structure encloses the five generator bays, erection bay, space for mechanical and electrical accessories, erection and repair facilities, control facilities and office space. Five hydraulic turbines of the vertical shaft, single-runner Francis type, with plate steel scroll cases and elbow type draft tubes are installed in the powerhouse. Each turbine has a capacity of 90,000 h.p. at the rated speed of 90 rpm under 150 feet net head. Governors are capable of full-opening or full-closing of the wicket gatet in five seconds. The five generators installed in the powerhouse are each rated at 80,000 Kw. The main transformers for each generator unit consist of a bank of three single-phase 33,333 kva, 60 cycle, delta/wye connected transformers. They are located on the transformer deck on the downstream side of the powerhouse and supply power to the switchyard by a high-voltage, oil-filled, pipe-type cable system. The tailrace extends from the downstream face of the powerhouse through a distance of about 150 feet to the discharge channel described in a preceding paragraph. Tailrace paving slopes upward from elevation 1629 ft msl at the draft tube exit up to elevation 1650 ft msl at the entrance to the discharge channel. Power plant tailwater rating curves and power plant characteristic curves are shown on Plates 16 and 17 respectively. The Garrison switchyard is located to the southeast of the powerhouse between the discharge channel of the outlet works and the downstream slope of the dam.

4-25. Garrison Reservoir. The reservoir formed by Garrison Dam, named Lake Sakakawea, lies in northwestern North Dakota. At the maximum operating pool level of 1854 the reservoir has a shoreline of 1,600 miles, a surface area of 383,000 acres and a maximum depth of about 180 feet. In general the reservoir is relatively narrow for its length, being confined to the Missouri River valley. There are three major exceptions to this configuration. Immediately upstream from Garrison Dam is the Snake Creek area of the reservoir that has been separated from the remainder of the reservoir by construction of an earth embankment. The reservoir upstream from this secondary embankment has been named Lake Audubon and will be described in more detail in later paragraphs. The major Missouri River tributary entering the Garrison Reservoir is the Little Missouri River and the tributary valley forms the Little Missouri Arm of the reservoir. Upstream from the mouth of the Little Missouri River a large relatively flat bench exists and forms an area known as the Van Hook Arm. A map of the reservoir area is shown on Plate 18.

4-26. Allocation of storage in the Garrison Reservoir was based on main stem system requirements as described in Section V of the Master Manual. Storage allocations to each of the four storage zones are given in Table 5.

TABLE 5

Garrison Reservoir Storage Space Allocations

Storage Designation	Elevation msl From	Elevation msl To	Storage Space Acre-Feet
Exclusive Flood Control	1850	1854	1,500,000
Flood Control & Multiple Use	1837.5	1850	4,300,000
Carry Over Multiple Use	1775	1837.5	13,400,000
Inactive	1673	1775	5,000,000
Total Storage			24,200,000

More detailed area capacity data for the Garrison Reservoir are given on Plate 18. Storage volumes in the above table and on Plate 18 are exclusive of Lake Audubon and are based on 1971 capacity tables.

4-27. Boat Ramps and Recreation Facilities. Fluctuating reservoir levels have a major effect on recreational use of the reservoir. Numerous public-use areas have been established around the shoreline and a common development of most of these areas is a boat ramp providing access to the reservoir. Boat ramp elevations are as given in Table 6 below.

TABLE 6

Garrison Reservoir Boat Ramps

Area	Ramp Type	Ramp Width	Elevation msl Top	Elevation msl Bottom	Date of Construc.
Beulah Bay	Conc. plank	24 ft			1965
Charging Eagle Bay	Conc. plank	24 ft			
Deepwater Creek	Poured concrete	40 ft	1865.5	1826.0	1965
Downstream Boat Ramp	Concrete poured & plank	62 ft	1683.0	1667.0	1963
Fort Stevenson	Poured concrete	60 ft	1856.0	1826.0	1964
Four Bears	Poured concrete	40 ft	1850.0	1835.0	1964
Lake Sakakawea State Park	Poured concrete	60 ft	1857.0	1826.0	1964
Lewis & Clark	Poured concrete	60 ft	1858.5	1826.0	1965
Little Missouri	Poured concrete	60 ft	1856.0	1834.0	1963
Little Missouri	Poured concrete	12 ft	1838.5	1824.5	1963
Red Butte Bay	Poured concrete	60 - 24 ft	1857.0	1826.0	1965
Tobacco Garden	Poured concrete	20 ft	1857.0	1840.5	1968
Totten Trail	Poured concrete	60 ft	1850.0	1826.0	1965
Wolf Creek	Steel landing mat				

Boat ramps have also been constructed for access to the Missouri River below the dam. While some are considered to be a portion of the Garrison project, others have been constructed by private interests or as a part of other Federal, State and private recreational developments. These downstream ramps generally continue to be operable through the normal range of releases from the Garrison project.

4-28. Williston Levee. A levee about nine miles long was constructed as a portion of the Garrison project to protect the city of Williston, North Dakota and immediately surrounding area in the headwaters region of the reservoir. Levee grades were based on the higher of two computed water surface profiles, one associated with a flow rate of 250,000 cfs with the Garrison Reservoir at elevation 1850, and the other based 150,000 cfs with the reservoir at elevation 1854. Freeboard and aggradation allowances of three feet and five feet respectively, with a minimum levee top elevation of 1860 were also used in design. The basic levee section has a 10-foot top width and side slopes of 1 on 2-1/2 on the riverside and 1 on 2 on the landside, with slopes flattened to 1 on 3 and 1 on 3-1/2 respectively along reaches of weaker foundation material. Generally, the levee is about 15 feet high and constructed with berms for raising the levee on the landside for anticipated future aggradation. The levee top is graveled and side slopes topsoiled and seeded. Riprap protection has been provided on the side of the levee exposed to the reservoir. A pumping plant was provided to convey the interior drainage from Williston and vicinity into Garrison Reservoir during periods of high reservoir stages. The pumping plant has a total capacity of 75,000 g.p.m. and consists of three 25,000 g.p.m. pumps. It is located southeast of Williston on the landside of the levee.

4-29. Aggradation and Backwater Effect of the Garrison Reservoir. While aggradation, or delta formation, occurs at the mouths of all streams entering the reservoir, a major portion of the 38,100 acre-feet of average annual sediment inflow to the reservoir is contributed by the Missouri River into the upstream end of the reservoir. Since the reservoir approached normal operating levels in 1965, a delta has been forming and now extends from about the mouth of the Yellowstone River downstream well into the reservoir. A significant effect of this delta formation has been the reduction in channel capacity in the Missouri River above the reservoir, thereby resulting in increased stages. At the mouth of the Yellowstone River it is estimated that stages have increased about four feet at a discharge of 80,000 cfs during the 1965-1975 period. A further increase of about two feet in stages with a flow of 80,000 cfs is expected during the next 25 years. About 11 river miles below the mouth of the Yellowstone River, adjacent to the Middle Bottom of the Buford-Trenton Irrigation District, the stage increase from preproject to 1975 for 80,000 cfs flows appears to be about seven feet, dependent somewhat upon the coincident level of the Garrison Reservoir. A further increase approximating four feet is expected during the next 25 years.

4-30. Of operational interest are the estimated effects of the elevation of the reservoir upon stages through this reach of the Missouri River. Analyses indicate that at the mouth of the Yellowstone River the level of the reservoir will have no effect upon Missouri River stages. Opposite the west bottom of the Buford-Trenton Irrigation District (about 4.5 miles below the Yellowstone River confluence) the effect of reservoir levels is minimal, estimated as less than one-half foot with the reservoir at its maximum operating levels with flows at or above 80,000 cfs. At a location opposite the middle bottom of the Buford-Trenton Irrigation

District (about 11 miles below the Yellowstone River confluence) back water effects resulting from Garrison Reservoir levels are estimated to be as much as two feet for flows of 50,000 cfs or less, about one foot for 80,000 cfs flows, ranging down to no apparent effect during flows in excess of 120,000 cfs.

4-31. Snake Creek Embankment. The Snake Creek Embankment, also known as the Totten Trail Crossing, is located eight miles northeast of Riverdale, North Dakota. Its primary purpose is to form Lake Audubon, the major impoundment serving the Garrison Division irrigation project described in Section III of this manual. The embankment also provides a crossing for the Soo Line railway, US Highway 83, power transmission lines, and telephone and telegraph lines. The embankment is about 12,900 feet long and through most of its length less than 45 feet in height, with a maximum height of 85 feet. Top of the embankment is at elevation 1865 ft msl. A gated conduit seven feet wide by 10 feet high with invert at elevation 1810 ft msl has been provided through the embankment for gravity diversion of water; however, most water diverted from Garrison Reservoir to Lake Audubon will be pumped by the Totten Trail pumping plant, constructed by the Bureau of Reclamation. A rating curve for the gated conduit is shown on Plate 20.

4-32. Totten Trail Pumping Plant. This structure was constructed by the Bureau of Reclamation in the Garrison Reservoir adjacent to the Snake Creek Dam to supply water required for the initial unit of about 250,000 acres of the Garrison diversion Project. The structure housing the pumps rises to a height of 180 feet above the reservoir bottom. Three electrically powered pumps with a total capacity of 2,050 cfs have been installed, with power for pump operation supplied directly from the Garrison switchyard.

4-33. Lake Audubon. The lake formed by the Snake Creek embankment has been named Lake Audubon. At its normal operating level of elevation, 1850 ft msl, it has a surface area of 20,600 acres and a storage capacity of 396,000 acre-feet. Prior to initial operation of the Garrison Diversion Project, the lake may be maintained below elevation 1850; however, after diversions begin a level very close to 1850 ft elevation is expected to be maintained at all times, by gravity diversion from the Garrison Reservoir to the extent possible, but mainly by pumping. Lake Audubon and the sorrounding shoreline were made available to the Bureau of Sport Fisheries and Wildlife of the Department of Interior for use in carrying out the National Migratory Bird Management Program. Subsequently, the northern half of the lake was made available by the Secretary of Interior to the North Dakota Game and Fish Department for creation of the Snake Creek Game Management area.

4-34. Leasing Project Lands. As indicated previously, essentially all land surrounding the Garrison Reservoir below elevation 1855 ft msl has been acquired by the Government for project purposes. Unless inflows to the reservoir are decidedly above normal, inundation of lands above 1850 elevation will usually not occur. Also, following years of abnormal water supply, with decreasing Garrison Reservoir levels, the possible maximum reservoir level during the following year will be correspondingly lowered. Consequently, on an annual basis, the Corps makes tracts of land available for leasing, generally for agricultural purposes, as a part of their land management program. The extent of leased lands is based on an analysis of expected reservoir levels, as well as land management considerations. A major portion of the revenue from this leasing program is returned to the countries within which the leased land lies. All such leases are subject to possible flooding of land, if needed for operational purposes, and do not serve as constraints upon regulation of the reservoir for authorized purposes.

SECTION V

ORGANIZATION FOR RESERVOIR REGULATION

5-1. Normal Regulation. The Garrison project is regulated as a component of the six-project main stem reservoir system. As such, regulation must be fully coordinated with regulation of the other five projects. Therefore, all the main stem reservoirs are regulated by the Missouri River Division Reservoir Control Center. Full details relating to organizational responsibilities, coordination, and communications pertinent to the system's regulation process, are contained in Section VI of the Master Manual. Consequently, only a brief summarization is presented in this project manual and reference must be made to the Master Manual for a complete understanding of these factors.

5-2. Reservoir regulation and power production orders for the Garrison project are issued directly to project personnel. These orders specify daily average release rates and power generation within specified tolerances. The orders issued by the Reservoir Control Center are based on detailed analysis of current and expected hydrologic conditions throughout the Missouri Basin and functional needs of the Garrison project, as well as the system as a whole. The coordination with other Corps of Engineer offices, outside governmental agencies, and special interest groups is a responsibility of the Reservoir Control Center, as described in the Master Manual.

5-3. Garrison project personnel are expected to continually furnish the Reservoir Control Center all information they may receive that is pertinent to the regulation process. This includes observations made by personnel as well as complaints or suggestions from those affected by project regulation. In addition, responsible project personnel are expected to inform the public of current and probable near-future regulation activities. It is the responsibility of the Reservoir Control Center to keep project personnel informed of such activities. Any requests for information that are complex, long-term in nature, or that involve policy are referred to the Reservoir Control Center.

5-4. The Omaha District is responsible for project maintenance, including maintenance of those facilities required to support the regulation process. They also collect data pertinent to Garrison regulation and are responsible for analysis of runoff events, particularly over tributary drainage areas, flood fighting activities, and flood control regulation of the USBR Boysen, Yellowtail and Heart Butte reservoir projects located in the incremental drainage area between the Fort Peck and Garrison Dams. Information available to the Omaha District considered pertinent to regulation of the Garrison project or other main stem reservoirs is immediately furnished the Reservoir Control Center.

5-5. Emergency Regulation. Development of emergency conditions associated with regulation of the Garrison project is always a possibility. Any emergency which poses an immediate threat to serious injury or loss of life at the project or the probability that serious damage may occur or has occurred to project facilities, requires prompt action. If such events occur, project personnel are expected to take the actions deemed necessary, then inform the Omaha District and Reservoir Control Center of the circumstances and actions initiated. Resumption of normal regulations, or scheduling of changes in releases or power generation, would be based on evaluation of conditions and effects by all offices concerned and would be directed by the Reservoir Control Center.

5-6. Prolonged interruption of communications between the Reservoir Control Center and Garrison project personnel may also constitute an emergency. Exhibit B of this manual provides instructions for project personnel in case of such an event. These instructions are designed to continue the functions for which the project was constructed through the period of communications failure. As indicated by Exhibit B, continuing efforts will be made to re-establish communications with either the Reservoir Control Center or Omaha District Reservoir Regulation Section (or responsible personnel of these offices) in an effort to terminate the emergency.

SECTION VI

HYDROLOGIC DATA

6-1. General. Section VII of the Master Manual outlines the basic hydrologic data required for regulation of the Missouri River Main Stem Reservoir System, including the Garrison project, and gives agency responsibilities, communications methods and other details relevant to the data collection process. Reference is made to the Master Manual for this information. Succeeding paragraphs provide further details of particular interest to the regulation of the Garrison Reservoir.

6-2. Garrison Project Data. Daily reports from the project to the Reservoir Control Center and to the Omaha District include hourly lake level, release and pool elevations, as well as periodic reports of tailwater elevations and wind conditions, and daily reports of maximum and minimum air temperatures, precipitation, pan evaporation and tailwater temperatures. Hourly data are obtained by power plant personnel from recorders located in the powerhouse. A tailwater elevation recorder is also available at this location. Tailwater temperatures are obtained from a thermometer located in a power penstock. Air temperature, wind and evaporation data are obtained from a site located near the Riverdale water treatment plant.

6-3. During the winter season the data given above are supplemented by occasional reports of ice thickness on the reservoir and on Lake Audubon. When there is a significant snow accumulation, weekly reports of the depth and water content of the existing snow cover in the vicinity of the damsite are furnished, along with frost penetration depths. Frequent reconnaisances of the reach of the Missouri River extending from Garrison Dam to the headwaters of the Oahe Reservoir are made by project personnel through the winter season, with particular emphasis during the time an ice cover is forming within this reach. Pertinent observations during each reconnaisance include location of the head of ice cover, ice conditions, available freeboard at critical locations and river stages at established intermediate locations not normally available on a routine basis. Reconnaisance observations are telephoned to the Omaha District Reservoir Regulation Section or to the Reservoir Control Center.

6-4. Throughout the year project personnel investigate complaints that occur as a result of Garrison regulation and report their findings to the Reservoir Control Center. The effects of significant changes in release rates through the downstream reach are also investigated. Project personnel are also responsible for informing downstream interests of any major change in the general level of release rates that may be anticipated.

6-5. Precipitation and Temperatures. Whenever significant amounts of precipitation occur, reports from many more locations are received for the Fort Peck-Garrison area than shown on the basic precipitation network plate of the Master Manual. The key stations which are received by the Reservoir Control Center from the National Weather Service's RAWARC teletype network are shown on Plate 21. These stations are also shown and listed in monthly summaries published and furnished the Reservoir Control Center by the National Weather Service. Temperature data obtained from first order National Weather Service stations, and made available daily to the Reservoir Control Center, are adequate for regulation purpose. During periods of ice formation below Garrison Dam, the temperature data from Bismarck, North Dakota, is particularly important for Garrison regulation.

6-6. Snow. During the winter season reports of snowfall and accumulated snow depths are received from many of the National Weather Service stations shown on Plate 21. These reports are supplemented by weekly snow and water content reports from first order Weather Service stations and plains snow surveys conducted by Corps of Engineers' personnel, as described in the Master Manual. Reports of mountain snow accumulations in the upper Yellowstone and Milk River basins are furnished by the Soil Conservation Service about the first of each month during the period January through June, as described in the Master Manual. Locations of these mountain snow pack observation points are given in the Montana and Wyoming snow survey reports issued monthly by the SCS.

6-7. Stages and Discharges. Stage information reported to the Reservoir Control Center as indicated by the basic streamflow reporting network in the Master Manual is supplemented by reports from many tributary locations, particularly during the March-July flood season or at other times of the year if unusual stages are occurring. Plate 22 indicates locations within the incremental drainage area reporting on a regularly scheduled basis. These are augmented by stage reports from additional locations during flood occurrences. Most reports are received over the National Weather Service RAWARC Teletype. Most of the principal tributary locations have been rated by Geological Survey measurements and estimates of flows along the principal streams corresponding to reported stages are available at all times by consultation of available rating curves or tables. Daily reports of elevations and releases are furnished the Reservoir Control Center from the Boysen, Buffalo Bill and Yellowtail reservoirs in the Yellowstone River basin.

SECTION VII - ANALYSES PERTINENT TO REGULATION OF GARRISON RESERVOIR

7-1. General. Regulation of the Garrison project as a component of the main stem reservoir system requires continuing analyses of available hydrologic and meteorologic information and development of forecasts to be prepared to best meet the demands imposed in serving the various project purposes. These analyses and forecasts may be of a long-term nature or may be based on anticipated inflows and demands for a relatively short period in the future. The Master Manual discusses the analyses, forecasts, and studies which, while important for the regulation of Garrison Reservoir, have essentially the same degree of importance for all of the other main stem projects. Analyses considered to be unique, or particularly important, to Garrison regulation are presented in the following paragraphs.

7-2. Precipitation and Temperature Forecasts. As discussed in the Master Manual, Weather Service forecasts of all meteorological elements are utilized by the Reservoir Control Center to the degree practicable in the regulation process. Weather Service forecasts are supplemented by forecasts developed by the Reservoir Control Center staff meteorologist. Pertinent to the regulation of the Garrison project are forecasts prepared for eastern Montana as well as western and central North Dakota. Temperature forecasts are of particular importance in scheduling Garrison releases during the period an ice cover is forming on the Missouri River below the project. Forecast maximum and minimum temperatures for Bismarck, which are critical to ice conditions in this reach, are received daily by the Reservoir Control Center over the Weather Service teletype network and verified by the staff meteorologist.

7-3. Precipitation-Runoff Relationships. Annual precipitation in the Fort Peck-Garrison incremental drainage area ranges from less than 8" to more than 40". Annual runoff ranges from less than 0.25" to more than 20". The runoff-precipitation ratio varies from less than 5% over much of the plains area to over 50% in the mountainous headwaters of the Yellowstone and its tributaries. This great variability makes it difficult to generalize in discussing analyses of rainstorm and snowmelt runoff, but past analyses of these factors indicate that utilizing initial loss values of from 0.50" to 0.75" and hourly infiltration losses of from 0.10" to 0.15" give reasonably satisfactory results for streamflow estimation purposes. These values are based on relatively few rainfall events because of the rarity of heavy rainfall centers in the area. Snowmelt infiltration ranges from zero for frozen ground, or ice under snow, to approximately the values shown for rainfall. In actual practice estimating the rainfall or snowmelt runoff is very imprecise. This is due to the lack of a dense network of precipitation reporting stations, errors in estimating the snow cover available for melt, errors in estimating the snowmelt rate as well as marked departures from the average infiltration or loss rates as given above. Annual runoff and precipitation maps for the entire Missouri basin are presented in the Master Manual.

7-4. Unit Hydrograph Analyses. A conventional means of forecasting flows from a particular drainage area is by the use of unit hydrographs. However, unit hydrograph development and subsequent use of the developed hydrographs as a forecasting tool has been found to be largely impractical for the drainage area under consideration in this manual. Reasons for this include the large size of the drainage area, requiring the division of the area into many subareas, the lack of sufficient past rainfall and subsequent runoff events for unit-hydrograph definition, the sparsity of rainfall reporting stations needed for both analyses and forecasting purposes, and the fact that by far the greatest amount of runoff that occurs from this drainage area does not result from particular rainfall events but results from progressive snowmelt, making runoff definition in a selected time period very imprecise. Further, with the large amount of storage space available in the Garrison Reservoir compared to the volume of runoff from individual storms, and the very nature of the regulation process, the effort necessary for a valid, continuing, and complete analysis by means of unit-hydrograph procedures has not been warranted. However, as additional storms are experienced and computer modeling efforts intensified, unit-hydrograph procedures will continue to receive consideration as a means of possibly improving the regulation process for the Garrison project.

7-5. Plains Area Snowmelt Volume. In many years a major portion of the annual runoff from the plains contributing area above the Garrison Dam is a result of melting the plains snow cover accumulated during the winter months. This melt usually occurs during late March or April and often results in the annual peak flow from the Fort Peck to Garrison drainage area, even though a major portion of the Yellowstone basin usually contributes little to crest flows at this time of the year. Basic data pertinent to estimation of plains area snowmelt volumes are precipitation during the late fall and winter months, winter season temperatures, water content of the accumulated snow cover prior to the melt period and soil conditions. However, even with these data, forecasts of the plains snowmelt runoff volume are usually quite imprecise.

7-6. Plains area snow surveys are made during any year that a substantial snow accumulation exists over the drainage area. One method used to obtain quantitative estimates of flows at specific points is to compare the water content and ground conditions for the current survey with similar data from surveys made in preceding years. This comparison will indicate which of the past years is most analogous to the current year for each portion of the total drainage basin between Fort Peck and Garrison Dams. Forecasts are developed by assuming that the volume of snowmelt runoff from each portion of the basin should be similar to that observed in the most analogous year. These estimates are tempered by available ground condition data, which could either increase or decrease the losses at the time of runoff.

7-7. The techniques for forecasting runoff volumes resulting from plains snowmelt are being investigated by personnel of the Reservoir Control Center under a continuing technical study which is designed to develop more precise and objective methods. In addition, the National Weather Service is investigating this subject and has initiated forecasts of plains snowmelt runoff volumes prior to the melt season. As additional snowmelt data and forecast experience is gained it appears probable that more valid estimates will be available than in the past.

7-8. Mountain Snowmelt Volumes. A large portion of the annual runoff entering the Fort Peck to Garrison reach of the Missouri River occurs during the May-July period of which snowmelt runoff from the mountainous portions of the basin is an important component. Over 80% of the annual runoff above the Garrison Dam originates in mountainous areas (above 6,000 feet, msl). As discussed in Section VI, numerous mountain snow courses are in operation in this area which report snow depth and water content at the beginning of each month, January through June. These data are supplemented by the precipitation reports from adjacent low level stations to develop forecasts of seasonal runoff from the Yellowstone River drainage area. Such forecasts are also made by the National Weather Service and Soil Conservation Service. These forecasts of flows are furnished the Corps of Engineers as soon after the first of each month prior to the mountain snowmelt period. Seasonal runoff forecast procedures developed by the Omaha District for the Yellowstone River at Sidney are appended to this manual as Exhibit A. The Reservoir Control Center forecasts of expected monthly inflow to the main stem reservoirs are largely subjective in nature, giving consideration to the forecasts prepared by the NWS, the SCS and the Omaha District and to independent analyses of the snow course information and antecedent conditions.

7-9. Monthly Reach Inflow Forecasts. Soon after the first of each month throughout the year a forecast of incremental monthly inflows to the main stem reservoirs (including those originating between Fort Peck and Garrison Dams) is prepared by the Reservoir Control Center. The Fort Peck to Garrison reach normally generates more annual runoff than any of the other incremental areas defined by the individual main stem projects. Forecasts of monthly runoff extend from the current date through the remainder of the calendar year to 1 March of the succeeding year. These forecasts are utilized as a basis for monthly regulation studies of the main stem reservoir system, as described in the Master Manual. Details and techniques currently applicable for forecast development are contained in the MRD-RCC Technical Report MH-73, "Missouri River Main Stem Reservoirs, Long Range Inflow Forecasting Procedures."

7-10. Short Range Forecasts of Daily Inflow. Experience has indicated that the most satisfactory method of anticipating Garrison Reservoir inflows for periods of up to a week or two beyond the current date is a combination of routing observed flows from upstream and tributary locations and extrapolating incremental inflows above or between observation points. In most cases a simple translation of flows from upstream to downstream points by appropriate travel times as given in Table 2, Section II, is as satisfactory as utilizing more sophisticated routing procedures. The extrapolation process includes an allowance for anticipated runoff. In this connection it should be recognized that most of the inflows to Garrison Reservoir are a combination of Fort Peck releases, Yellowstone River flows at Sidney, Montana, Milk River flows at Nashua, Montana, and Little Missouri flows as observed at Watford City, North Dakota. Reliable estimates of flows at these locations will result in satisfactory inflow estimates unless unusual runoff circumstances occur.

7-11. Stage-discharge relationships are maintained in the Reservoir Control Center for all important streamflow stations in the Fort Peck to Oahe incremental drainage area. These are kept current on the basis of discharge measurements made by the US Geological Survey. Plate 23 indicates the present relationships at locations that are most important for developing short range inflow forecasts.

7-12. Flow Forecasts at Downstream Locations. During a major portion of each year Missouri River flows through the entire reach from

Garrison Dam to the headwaters of the Oahe Reservoir consist almost entirely of Garrison releases. Only during those relatively short periods when substantial runoff occurs from the intervening tributary area will significant additions to Garrison releases occur. The Knife River is the only major tributary entering above Bismarck, North Dakota, and for practical purposes flows between the mouth of the Knife River and Bismarck will be equivalent to the sum of Knife River flows at Hazen, North Dakota, and Garrison releases. Travel time from these locations to Bismarck, North Dakota, is about one day under open water conditions. The Heart River enters the Missouri immediately below Bismarck and Missouri River flows below the mouth of the Heart River are equivalent to Heart River flows at Mandan plus the previous day's Hazen flow and Garrison releases, plus any ungaged flows. Forecasts of Mandan and Hazen flows are derived by noting observed upstream flows on each tributary together with estimates derived by principles described in paragraph 7-3.

7-13. Downstream Stage Forecasts. Bismarck, North Dakota, is the main damage center between the Garrison and Oahe Dams and Missouri River stage forecasts for this location are based on expected discharges and the Bismarck rating curve which is kept current on the basis of frequent USGS discharge measurements. Typical open-water and ice-covered stage-discharge relationships for this location are given on Plate 10. The effect of Garrison release changes upon existing stages at other locations in the Garrison Dam to Bismarck reach may be estimated from the Bismarck rating curve. In general, a mean daily discharge change of 1,000 cfs during the open water season will result in a mean stage change of about 0.25 foot in the usual range of power plant releases. With a stabilized ice cover a stage change of about 0.4 foot will occur with a discharge change of 1,000 cfs.

7-14. Power plant releases from Garrison can have wide fluctuations during any one day as a result of varying power loads. With daily releases fluctuating from zero to the full powerplant capacity, changes in Garrison tailwater elevation of 10 feet or more will occur. With increasing distances from the dam a diurnal fluctuation of this type attenuates quite rapidly. Under open water conditions a 10-foot diurnal fluctuation in the Garrison tailwater is reduced to approximately four feet (40%) at the large Basin Electric and United Power powerplant intakes some 18 miles below Garrison Dam. At Washburn, 35 miles below Garrison Dam, the associated diurnal fluctuation may be expected to be about two feet (20% of the tailwater fluctuation) while at Bismarck, located 75 river miles below the dam, the corresponding diurnal fluctuation would be about one foot (10% of the Garrison tailwater fluctuation). Records also indicate that it requires about 6.5 hours for tailwater crests and troughs to travel to the large powerplant intakes. Corresponding travel time to Washburn and Bismarck are 13.5 and 28.5 hours respectively, indicating an average travel time of these events to be about 2.7 river miles per hour. Values given above are approximate for open water conditions. A substantial ice cover in the reach will result in a marked travel time increase and will also tend to reduce downstream diurnal fluctuations. Estimates of diurnal fluctuations which will occur at downstream locations for any particular release pattern are possible through use of the above information and current tailwater rating curves. When making such estimates consideration should be given to the fact that, with diurnal fluctuations in release rates, the tailwater will normally not have an opportunity to stabilize at either the maximum or minimum value indicated by Garrison releases.

7-15. Routing Procedures. For purposes of anticipating inflows to the Garrison Reservoir a simple translation of observed or anticipated upstream flows by the approximate travel time from the upstream location, as discussed in a previous paragraph, is an adequate routing procedure for reservoir regulation purposes. This conclusion is based on the relatively sluggish characteristics of inflow hydrographs to the Garrison Reservoir. In addition, the large Garrison storage volumes and associated regulation procedures do not require precise definition of anticipated inflows. The lack of tributary streamflow information from a considerable portion of the incremental Fort Peck to Garrison drainage area also precludes such precision.

7-16. Routing procedures are also utilized to translate the effects of upstream tributary and main stem reservoirs to the Garrison damsite in order that the total reservoir effects at this location may be determined. These procedures are based on travel time to the Garrison damsite which were appropriate prior to the development of either tributary or main stem reservoirs. A simple lag-average routing method is used with coefficients as given in Table 7 below.

TABLE 7

Lag-Average Routing Coefficients
Upstream Reservoir to Garrison Dam

Reservoir	Average Days	Lag Days
Fort Peck	3	6
Fresno	5	10
Bull Lake	5	8
Boysen	5	7
Buffalo Bill	5	7
Yellowtail	3	6
Garrison inflow	1	3

Notes:
1. Data averaged is at the mean daily streamflow rate.
2. Lag given is the number of days from the last day of mean daily values averaged.
3. Lag rates listed assume non-existence of intervening reservoirs.

7-17. Garrison Reservoir Evaporation Estimates. Due to the large surface area, evaporation is an important component of the overall water budget of the Garrison Reservoir. An estimate of the daily evaporation volume is required for developing daily inflow estimates, as well as for more precisely estimating the effects of reservoir development upon the available water supply. While one means of estimating daily evaporation depths is application of the common 0.7 factor to adjacent pan evaporation measurements, this is not considered reliable due to the marked difference between reservoir surface temperatures and pan temperatures. Pan temperatures tend to follow air temperatures fairly closely, but reservoir surface temperatures lag air temperatures by about one month and exhibit much less seasonal variation. MRD-RCC Technical Report JE-73, "Reservoir Evaporation Estimates," addresses these factors in detail and recommends the use of a variable pan-to-reservoir factor. This factor for the Garrison Reservoir varies from as little as 0.14 during periods when reservoir surface temperatures are less than air temperatures to as high as 5.04 when lake surface temperatures materially exceed air temperatures. During those portions of the year when pan data are not available, utilizing normal evaporation depths for the season of the year appears to offer the most practical means of developing evaporation estimates for day-to-day regulation activities. Reference is made to the cited Technical Report for further details pertinent to the development of evaporation estimates for this project. This report also recommends procedures for the adjustment of initial estimates at the time of detailed analyses of the effects of the project upon streamflow.

7-18. The gross evaporation (E_G) estimates discussed above must be modified womewhat before being utilized to determine the effects of the Garrison project on downstream flows. This modification requires consideration of three other factors:

a. Precipitation upon the reservoir surface (P_L).

b. Runoff which would have occurred from the land area now covered by the reservoir.

c. The original channel surface area now inundated by the reservoir.

Proper consideration of all of the above factors results in a quantity which may be defined as "net evaporation" (E_N). Analysis of channel areas now inundated by the main stem reservoirs indicates that a reasonable estimate of this channel area is 10% of the reservoir area. Similarly, over the land areas adjacent to the original river channel which are now inundated by the reservoir, a reasonable estimate is that 15% of the precipitation that fell appeared as surface runoff. Therefore, the net evaporation from the reservoir surface is equal to 90% of the gross evaporation minus 75% of the precipitation on the reservoir; or:

$$E_N = 0.90\ E_G - 0.75\ P_L$$

7-19. Wind Effects on Water Surface Elevations. The general orientation of Garrison Reservoir is to the west northwest of the damsite where the pool level recorder is located. Winds with a component from this direction result in set-up at the dam while a wind component from the opposite direction results in set-down. Plate 24 is a wind correction table for the pool level recorder at the dam. An anemometer is located adjacent to the dam; however, it should be recognized that only approximations of the wind effect on the reported pool level can be obtained with these data. The time required for set-up to be fully established, variations in wind velocity and direction over the reservoir surface and the unrepresentativeness of the observations at the dam will all result in deviations from calculated values. Synoptic surface weather maps may also be used to augment the anemometer and to obtain qualitative wind estimates.

7-20. Daily Inflow Estimates. Estimates of inflow to the Garrison Reservoir are made each day for operational purposes. The steps involved consist of the following:

a. A plot of hourly pool elevations as given by the pool level recorder is maintained.

b. Utilizing reported winds, the set-up or set-down effects are estimated and average lake levels, adjusted for wind, throughout the past 24-hour period are determined.

c. Storage change equivalent to the estimated 24-hour elevation change is determined. Combining this with reported releases and estimated evaporation, an equivalent inflow is computed.

d. Fort Peck releases and gaged tributary flows are routed to Garrison Reservoir. These are combined with estimates of ungaged flow and precipitation on the reservoir surface to obtain an additional estimate of reservoir inflow.

e. Differences in inflow estimates as determined by c. and d. are reconciled by judgement and reservoir level estimates adjusted accordingly.

f. At times it will be necessary to adjust previous day's data on the basis of continuing trends in the lake level which were not evident during previous days.

7-21. Unregulated Flows. Construction of Garrison Dam, together with the other main stem and tributary projects in the basin, has materially altered flows downstream from the dam. Flood peaks have been reduced and low flows augmented by reservoir regulation. Quantitative estimates of the effects of regulation upon flows at the damsite and important locations immediately downstream are frequently required. This represents a continuing effort by the Reservoir Control Center and involves such factors as reservoir evaporation, precipitation on the reservoir, variations in travel time resulting from reservoir development, channel area inundated by the reservoir, runoff that could have been expected from previous overbank areas now inundated by the reservoir, inflows, outflows, diversions to the Garrison Irrigation Project (through Lake Audubon) and storage changes. Details of the required analyses are contained in the RCC Technical Study S-73, "Unregulated Flow Development."

7-22. In addition to unregulated flows, development of flows at the 1949 level of basin development (prior to construction of Garrison Dam and most other water resource developments in the Missouri Basin) represent a continuing effort of the Reservoir Control Center. Garrison Dam represents a location where an analysis of such development is made. This process of deriving flows for a common base level involves not only the removal of regulation effects for post-1949 projects, but the consideration of depletion to flow by consumptive use purposes, such as irrigation. Reference is made to Section VIII of the Master Manual for further details of these analyses.

7-23. Evaluation of Regulation Effects. In the evaluation of the effects of regulation upon downstream flows in order to obtain flood damage reduction estimates, the Garrison project is considered to be a component of the main stem reservoir system. Damage reductions attributable to regulation of this individual project are not differentiated from those resulting from the six-project system as a whole. Details of the evaluation process are given in Section VIII of the Master Manual and in other references cited in that publication.

7-24. Ice Formation Below Garrison Dam. Optimum regulation of the Garrison project involves careful release scheduling during the winter months at which time the power demand from Garrison is high while the downstream channel capacity is materially reduced by the ice cover. Procedures have been developed to determine the extent of the ice cover below Garrison, based on the release rate, release water temperature and air temperature. These procedures are detailed in MRD-RCC Technical Study F-73, "Freezing of the Missouri River Below Garrison Dam," and provide guidance for release scheduling from the project through the winter months and in particular during the most critical times which occur during periods of increasing ice cover.

SECTION VIII

MULTIPLE-PURPOSE REGULATION OF GARRISON RESERVOIR

8-1. General. Aspects of multi-purpose regulation that are pertinent to the system as a whole, including planning for this regulation, are discussed in Section IX of the Master Manual. Since continuing development of system operating plans requires coordination of plans for all main stem projects, this subject has been explored thoroughly in the Master Manual and will not be repeated in this, the Garrison project manual. Rather, the following paragraphs will be concerned with amplifying the operational objectives and requirements given in the Master Manual as they are pertinent to regulation of the Garrison project for the functions of irrigation, navigation, water supply, power, fish and wildlife, water quality and recreation. Regulation of the Garrison project for flood control is discussed in Section IX.

8-2. Basis for Service. Regulation of the Garrison project must conform to certain storage provisions and basic regulation criteria. The bottom inactive storage zone of the Garrison Reservoir, or that zone lying below elevation 1775 ft msl, is to remain permanently filled with water. This insures maintenance of minimum power heads, a minimum level for the design of irrigation diversion and water supply facilities, and a minimum pool for recreation, fish and wildlife purposes. The top storage zones in the lake, extending above elevation 1850 ft msl, are provided only for the handling of the largest floods and to insure safety of the project structures. These zones are reserved exclusively for this purpose. Storage space intermediate to the upper and lower zones, extending from 1775 to 1850 ft msl, provides for the multiple-purposes enumerated above as well as for the control of moderate floods. Use of storage in the upper portion of the intermediate zone, together with the upper zones above elevation 1850, allows a high degree of control of major floods, including those approaching the maximum possible.

8-3. The following general approach is observed during regulation of the Garrison project:

a. Regulation of Garrison as an individual project must be subordinate to regulation of the entire main stem system as a whole.

b. Flood control will be provided for by evacuating storage space to about elevation 1837.5 ft msl prior to March of each year.

c. Releases will be such as not to contribute to significant flooding along the Missouri River between Garrison Dam and the Oahe Reservoir.

d. All irrigation and other upstream water uses for beneficial consumptive purposes will be served.

e. Releases will be sufficient to serve irrigation, water supply and water quality demands in the reach extending from Garrison Dam to the Oahe Reservoir. In this connection, the responsibility is to maintain an adequate flow quantity, with downstream users responsible for providing satisfactory intake facilities to divert the needed water supply.

f. Within the limits designated above, the Garrison project will participate in the intrasystem adjustment of releases to achieve optimum power generation to the degree consistent with other multiple-purpose uses.

g. Releases from the reservoir system to support Missouri River navigation will be backed up by releases from the Garrison project as appropriate to maintain storage reserves in the system at a generally balanced level.

h. Insofar as possible without serious interference with the foregoing, the Garrison Reservoir will be regulated for maximum benefit to recreation, fish and wildlife.

8-4. Flood Control. Regulation of the Garrison project for flood control purposes is discussed in Section IX of this manual and therefore not presented in detail in this Section. However, it is evident that the storage of water during periods of high runoff and subsequent release during low water periods for other multiple-use purposes is compatible with flood control. Similarly, water storage for flood control purposes is generally compatible with multiple-use regulation of the project.

8-5. Irrigation. When the Garrison Diversion Project becomes operable, large quantities of water will be withdrawn from the Garrison Reservoir through the adjacent Lake Audobon. These withdrawals will be controlled entirely by the Bureau of Reclamation. Corps of Engineers regulation responsibilities in this connection will be limited to utilizing the daily withdrawal data in the determination of reservoir inflows and in deriving estimates of the actual available water supply. If other major irrigation withdrawals directly from the Garrison Reservoir should occur, similar regulation responsibilities would be involved. At this time only three private irrigators obtain water from the reservoir to irrigate about 600 acres.

8-6. Considerable irrigation is served by withdrawals from the Missouri River in the reach extending from Garrison Dam to the Oahe Reservoir. With the exception of the Fort Clark project in the vicinity of Stanton, North Dakota, irrigation intakes are of a portable nature, located on sand bars or along the river bank and are not capable of operating over a wide range of river stages without relocation. With very low river stages access to the water at some intake locations becomes extremely difficult, even though the available flow adjacent to the intake location may be many times that needed for irrigation. Consequently, although current regulation criteria contemplates minimum daily releases in the 6,000 cfs range, mean daily releases of 10,000 cfs or less for any extended period of time during the irrigation season are avoided unless the need for such low project outflows is a critical factor in system regulation. Long range regulation studies based on the current level of water resource development indicate that mean monthly Garrison releases of at least 10,000 cfs can be made at all times. However, if resource development proceeds as expected during the next fifty years, maintenance of a 10,000 cfs mean daily rate will eventually become impossible during extended periods of well below normal water supply. Major fluctuations in mean daily releases from day-to-day during the irrigation season require relocation of the portable intakes, either to maintain access or to prevent pumps from being flooded; therefore, frequent wide fluctuations in daily rates are avoided. When a significant change in the prevailing level of releases becomes necessary, irrigators below Garrison Dam are given advance notification by Garrison project personnel.

8-7. Water Supply and Quality Control. In addition to the irrigation intakes discussed in the preceding paragraph, there are several intakes serving municipalities, thermal electric plants and industrial uses in the reach extending from Garrison Dam to the headwaters of the Oahe Reservoir. These intakes have reported problems in obtaining water in a few instances in past years. These problems have been associated with inadequate intake levels or sandbar formations adjacent to the intake, rather than insufficient flow in the river. In order to minimize intake problems without unduly penalizing the hydropower operation, the minimum release values listed in Table 8 have been established:

TABLE 8

Minimum Garrison Releases for Water Supply

Duration	Condition: Open Water	Condition: Downstream Ice Cover
4 - hours	2,000 cfs	0 cfs[1/]
8 - hours	3,400 cfs	1,000 cfs
12 - hours	6,000 cfs	-
24 - hours	6,000 cfs	4,000 cfs

[1/] If the mean daily release exceeds 12,000 cfs the ice-covered restrictions can be eased and a duration of up to nine hours of zero flow can be tolerated.

Observations and studies for this reach of the river are continuing to determine if the above restrictions can be modified. Due to the high quality of the water stored in Garrison Reaservoir, and the lack of major pollution sources in the reach below the dam, minimum releases required for water supply purposes are also adequate for water quality control.

8-8. In future years the Garrison Reservoir is expected to be a source of water for development of nearby coal fields. Withdrawal facilities are expected to be operable through the entire range of pool levels above the top of the inactive storage zone, elevation 1775. As a consequence, it would not now appear that this development will effect regulation beyond consideration of its depleting effect upon the available water supply.

8-9. Navigation. All Garrison releases are re-regulated by downstream main stem reservoirs prior to serving the system's navigation function. Consequently, the regulation of Garrison for this function consists primarily of backing up the downstream projects' navigation releases. This is not a day-by-day regulation consideration, but a long term operation, approaching an annual water scheduling matter.

8-10. Power Production. Hydroelectric power generated by the Garrison project is integrated with the power generated by the other main stem projects and many other public and private generation facilities in the Missouri Basin and surrounding areas. To the extent practical all releases from the Garrison project are made through the power plant. Since the Garrison power plant came on the line in 1960, through 1976, there has been only one year, 1975, that any significant release has occurred other than through the power plant. Even in the large runoff of 1975, during which flood-season runoff above Garrison Dam was the greatest in the available record period extending back to 1898, releases bypassing the power plant were less than 12 percent of the total annual release. A supplementary release is occasionally required for test and maintenance purposes during normal operation; however, such outflows during any year represent only a very minute fraction of total releases.

8-11. While hourly loadings of the Garrison power plant are scheduled by the Western Area Power Administration's system power dispatcher in Watertown, South Dakota, these loadings must be within limits prescribed by the Corps of Engineers. These limits are developed on the basis of daily as well as hourly releases required to serve functions other than power. Due to changing power loads during the day, releases often fluctuate widely between zero at times when demand is light up to the full power plant capacity in the 35,000 to 40,000 cfs range during the heavy load hours. Further discussion on power scheduling is presented in the Master Manual.

8-12. During years of normal or below normal water supply there will also be a seasonal variation in Garrison power releases, reflecting the concurrent service being provided other functions as well as the seasonal nature of power demand. During the navigation season relatively large releases are required from the lower-most reservoir of the main stem system (Gavins Point) for navigation. These are normally backed up by correspondingly large releases from the Fort Randall, Big Bend and Oahe projects, since relatively little inflow usually originates from the Oahe-Gavins Point portion of the basin during the navigation season. These large releases generate substantial amounts of power leaving only a relatively small portion of the firm power loads to be served by the upstream Garrison and Fort Peck projects. Consequently, low releases from Garrison will satisfy all system functions. During the winter months when navigation is not possible, releases from the downstream reservoirs are usually restricted to less than one-half their navigation season level due to the reduced capacity of the ice-covered Missouri River channel. Winter is also the season of peak firm power demands over a large portion of the system's marketing area. Consequently, Garrison releases during the winter season are often at the maximum rate consistent with the ice-covered channel capacity from the dam downstream to below Bismarck, North Dakota. Flat-load releases at near full Garrison power plant capacity are not unusual after the winter ice-cover stabilizes.

8-13. Fish and Wildlife. Regulation of the Garrison project for fishery purposes largely involves pool level manipulations which will provide a suitable environment for the spawning and initial growth of game and forage fish. Stationary or rising reservoir levels through the late-March to early-July period are desirable for this purpose.

Additionally, some species such as the northern pike require the inundation of terrestial vegetation during late March and April for a suitable spawning habitat. Providing such conditions becomes rather complex and difficult considering typical runoff and regulation requirements for other purposes. Since prolonged inundation destroys terrestial vegetation, it can only be re-established by lowering and maintaining the Garrison pool below the vegetative zone for an extended length of time during the growing season. The growing season coincides with the March-July flood season; therefore, maintenance of lowered pool levels to establish vegetation becomes practical only when inflows during this period are well below normal. After terrestial vegetation is established, successful spawning requires that it be inundated during the late-March through April pike spawning period. In view of the typical Garrison regulation pattern, with pool levels lowered through the fall and winter months after the end of the growing season, inundation of terrestial vegetation established during the preceding year prior to the end of April is not practical unless well above normal runoff from plains snowmelt occurs at the time. Due to the difficulties involved, pool level manipulations of Garrison Reservoir specifically designed to enhance spawning of northern pike have not been possible up to this time. However, the possibility of this type of regulation during future years when runoff conditions are appropriate, should be recognized.

8-14. Recreation. Water based recreation upon Garrison Reservoir is dependent on the constructed access facilities. Boat ramps constructed around the perimeter of the project have top elevations extending from 1850 to 1858 ft msl and bottom elevations from 1824.5 to 1840.5 ft msl. Insofar as practical, consistent with the water supply, other functions, and conditions in the other main stem projects, Garrison Reservoir levels will be scheduled to provide continued access to the reservoir area for recreational use. Boating on the Missouri River below Garrison Dam is also a popular recreational activity during the summer months. Diurnal fluctuations in release rates resulting from power peaking operations have not had a reported significant adverse effect on this type of activity. Afternoon and evening power releases are usually high, coinciding with the time most pleasure boating occurs. At Bismarck, where the greatest amount of river boating is concentrated, diurnal power release fluctuations are attenuated to a large extent. Extended very low flows, particularly during weekend periods, adversely affects pleasure boating.

8-15. Release Scheduling. As discussed in the Master Manual, scheduling of releases from the Garrison project, as well as all other main stem reservoir projects, is normally based on continuing studies by the Reservoir Control Center in which all functional requirements, including flood control, are considered. These studies are made at maximum intervals of one month and incorporate current conditions with the most recent estimates of future runoff as expressed in terms of forecast inflow to the individual reservoir projects. Service to all authorized functions receives consideration including current projections of power demands and navigation requirements. The frequency of these studies, perhaps resulting in modifications of the Garrison release level, is increased when previously unanticipated inflows occur that may have a substantial effect on system regulation. An example of these studies is included in the Annual Operating Plan, published each year as described in the Master Manual.

8-16. Reservoir regulation orders, furnished by the Reservoir Control Center over the interoffice teletype system to operating personnel at the Garrison project, are the basis of scheduling daily releases from the project. Since exact power demands cannot be anticipated, regulation orders frequently allow a specified variation from the scheduled mean daily release rate. Hourly patterning of the mean daily release rate within limits prescribed by the Reservoir Control Center, is determined by the Bureau of Reclamation through scheduling of hourly power production from the Garrison project.

8-17. Long-term regulation studies extending through the period of available hydrologic record are conducted without the benefit of forecasts of subsequent runoff. In these studies Garrison release rates during the March-July flood season are largely defined by the accumulation of storage in the combined Fort Peck and Garrison projects during periods the reservoir system and each project in the system are near normal operating levels. Table 9 is an approximation to the developed criteria applicable to the 1975 level of water resource development. As such, it may be used as a guide to scheduling Garrison releases, with modifications based on anticipated needs and available forecasts.

TABLE 9

Approximate Garrison Release Rates Based on Long-Term Analyses

Fort Peck Plus Garrison Storage, Million AF					Garrison
1 April	1 May	1 June	1 July	1 August	Releases
32.2	32.2	32.2	36.0	37.0	15,000 cfs
33.2	33.8	34.2	38.9	38.9	25,000 cfs
36.6	36.6	37.6	39.6	40.6	38,000 cfs

SECTION IX - FLOOD CONTROL REGULATION OF GARRISON RESERVOIR

9-1. Objectives of Flood Control Regulation. The flood control regulation objectives of the Garrison project are: (1) to coordinate regulation of Garrison Reservoir with the regulation of the other main stem reservoirs on the Missouri River to prevent runoff from the drainage basin above Garrison Dam from contributing to damaging flows through the lower reaches of the Missouri River; (2) to utilize available storage space in the best possible manner to prevent or reduce flooding in the reach from Garrison Dam to the Oahe Reservior. The first objective given is the primary flood control objective for the main stem system as a whole. As a consequence, it is discussed in detail in the Master Manual. The primary discussion in this manual concerns regulation geared to reduce flooding along the Missouri River immediately below Garrison Dam.

9-2. Method of Flood Control Regulation. In general, the developed method of regulation of Garrison Reservoir may be classified as Method C defined in EM 1110-2-3600. This represents a combination of the maximum beneficial use of the available storage space in Garrison Reservoir during each flood event with regulation procedures based on the control of floods of approximate project design magnitude.

9-3. Storage Space Available for Flood Control Regulation. During any specific flood event all available space in the Garrison Reservoir will be utilized to the maximum extent practicable for flood control purposes. The control of floods will be combined with regulation for other beneficial water uses. Storage space allocated for flood control in the reservoir totals 5.8 million acre-feet. Of this 1.5 million acre-feet is exclusive flood control storage space, to be utilized only during unusually large flood season inflows. The remainder is annual flood control and multiple-use storage space that will be filled seasonally to the extent allowed by flood control considerations and the amount of inflow in excess of current requirements for other purposes. Surcharge storage space has also been provided in the Garrison Reservoir, the only purpose being to insure the safety of the Garrison project; however, its utilization will usually provide some downstream flood reductions during extreme flood events. Carryover storage space in the reservoir, when evacuated, will also serve the flood control function although deliberate evacuation of this space to serve flood control will not be scheduled.

9-4. As discussed in the Master Manual, replacement flood control storage space has been provided in certain tributary reservoirs upstream from Fort Peck Dam. There is reasonably firm assurance that in years of large runoff from the total drainage area above Garrison Dam (including the drainage area above Fort Peck Dam) that the replacement storage space in these tributary reservoirs will be utilized for the control of main stem floods. Due to the relative ease of transferring storage between the main stem projects, including Fort Peck to Garrison or vice versa, the availability of existing tributary replacement storage space allows regulation of the Garrison Reservoir at higher levels than would be possible with a strict adherence to specified flood control storage allocations given in this manual. Essentially, tributary replacement flood control storage space is utilized to replace a corresponding amount of the annual flood control and multiple-use space in the main stem system, including such space in the Garrison Reservoir.

9-5. Operations of some tributary reservoir projects constructed in recent years in the drainage area above Garrison Dam without specific allocations of replacement flood control storage space can also have an effect on the amount of annual flood control and multiple-use space evacuated from the Garrison Reservoir prior to any specific flood season. At times these tributary reservoirs are drawn well below their deliberate fill level prior to the flood season. Efficient basin water resources management requires that the status of storage in all upstream tributary reservoirs be considered to the extent practicable, and to the extent that filling of tributary storage during the flood season is reasonably assured, in regulation of the Garrison project.

9-6. Flow Regulation Devices. Releases from the Garrison Reservoir may be made through the Garrison power plant, outlet works and the spillway. Normally discharge through the power plant will be used to the fullest extent possible in order to achieve the maximum economic return from the project. The discharge capacity of the power plant ranges up to 38,000 cfs. When it is necessary to release at rates greater than the power plant is capable of maintaining, the outlet tunnels, which are capable of passing almost 100,000 cfs, will be used. If still higher releases are required, they must be made over the spillway, which has a capacity of 827,000 cfs at maximum storage levels.

9-7. General Plan of Flood Regulation. Flood control regulation of the Garrison Reservoir to meet the stated objectives is based on consideration of the following factors:

a. Coordination of flood control regulation of Garrison Reservoir with the regulation of the other main stem reservoirs and upstream tributary reservoirs as described in Section X of the Master Manual.

b. Channel capacity through the reach of the Missouri River from Garrison Dam to the headwaters of the Oahe Reservoir.

c. Observed and anticipated runoff from the incremental drainage area between Garrison Dam and the headwaters of Oahe.

d. Observed and anticipated inflows to the Garrison Reservoir.

e. Space currently available within Garrison and Fort Peck for storage of future runoff.

f. Release requirements from the Garrison project for purposes other than flood control.

9-8. The general plan of regulation applicable to most of the main stem reservoirs including Garrison is based on having the flood control storage space evacuated prior to the beginning of the March-July flood season. Flood season inflows that are in excess of the current multiple-use requirements are deliberately impounded in the annual flood control and multiple-use storage space until such time there is reasonable assurance that adequate reserves are stored to satisfy multiple-use requirements to the beginning of the next flood season without drawdown into the carryover zone of storage. This deliberate storage for future multiple use also serves the flood control function. Following the time that an adequate supply of multiple-use storage is reasonably assured, releases in excess of current multiple-use requirements are made as a storage evacuation measure when they are not anticipated to contribute to significant downstream flooding.

9-9. Local Flood Control Constraints. Bismarck, North Dakota, is the principal location where flood damages are likely to occur in the reach extending from Garrison Dam to Oahe. Prior to 1976, the Bismarck flood stage was 19 feet. However, extensive bottom land development, encouraged in part by the flood protection provided by the main stem reservoirs, resulted in the flood stage being lowered to 16 feet by the National Weather Service in 1976. Damage, initially confined to bottom land access, occurs if the Bismarck stage exceeds about 13 feet. Consequently, a primary flood control regulation objective of the Garrison project is preventing the Bismarck stage from materially exceeding 13 feet at all times there is a reserve of vacant annual flood control and multiple-use storage space in the Garrison Reservoir. When encroachment into the exclusive flood control space occurs or is anticipated, target Bismarck stages may be increased up to the established flood stage of 16 feet, dependent upon analyses of probable future runoff above Garrison Dam and storage evacuation requirements. With encroachment into the surface zone, Bismarck stages in excess of 16 feet will probably be necessary, with Garrison releases and resultant downstream stages dependent upon the degree of encroachment and anticipated future inflows to the Garrison Reservoir.

9-10. Open water channel capacity corresponding to a Bismarck stage of 13 feet is now about 58,000 cfs, well above the full Garrison power plant capacity of 38,000 cfs. Therefore, with an ice-free Missouri River channel, local flood control requirements will restrict Garrison power releases only if unusually heavy runoff should occur in the drainage area between Garrison Dam and the headwaters of Oahe. However, the ice covered Missouri River channel capacity at a stage of 13 feet at Bismarck never materially exceeds the Garrison power plant release capacity, and is as low as 20,000 cfs during initial ice formation. The Knife River is the only tributary of consequence entering the Missouri River between Garrison Dam and the primary damage center of Bismarck although high flows from the Heart River could contribute to bottomland flooding along the Missouri River immediately below Bismarck. Flows on these streams are monitored during periods of significant tributary runoff in order that Garrison releases can be restricted as deemed necessary.

9-11. The main period of large inflows between Garrison Dam and the Oahe Reservoir is during the early spring season when melt of snow accumulated during the winter and ice-breakup on streams occur. In exceptionally large snowmelt runoff years, such as occurred in 1950 and 1952, incremental flows from the tributaries alone could exceed the channel capacity in the Bismarck vicinity, particularly if the Missouri River channel is ice-covered at the time of tributary runoff. Rainfall runoff alone will seldom require reductions in release to less than the Garrison power plant capacity. Such runoff can be expected only when the Missouri River is free of ice. Experience indicates that annual tributary crest flows in this region resulting only from rainfall are usually much smaller than annual crests resulting from snowmelt. When large tributary crests do occur as a result of rainfall they attenuate rapidly within the Missouri River channel. For example, the maximum flow of record from the Knife River occurred in June 1966 when a crest of 35,300 cfs was observed at Hazen, North Dakota. However, coincident mean daily flows at Bismarck were less than 10,000 cfs greater than the Garrison release contributions at the time.

9-12. Ice formation through the reach from Garrison Dam to the Oahe Reservoir occurs every year. As active formation occurs, channel capacities are materially reduced, particularly at the head of the forming ice cover. Experience indicates that during the time an ice cover forms in the Bismarck area, coincident Garrison releases should be at 20,000 cfs or less to prevent Bismarck stages from materially exceeding 13 feet. Local lowland flooding has also occurred in other areas of this reach, as a result of ice formation, particularly if the ice formation is proceeding at a rapid rate such as occurs when extremely cold temperatures are accompanied by high winds. In most years the ice formation period through this reach of the river is the most critical insofar as flood control regulation of the Garrison project for local conditions is concerned.

9-13. After the ice cover forms, stabilization of the ice cover, a smoothing of its undersurface and an increase in channel capacity occurs. With a continuing ice cover at Bismarck, Garrison releases can be gradually increased by 500 to 1,000 cfs per day up to near the power plant capacity of 38,000 cfs without materially exceeding a stage of 13 feet. Increased release scheduling must be based on careful observations of Bismarck stages and effects of previous release increases upon these stages. Also involved is a field reconnaissance of river and ice conditions throughout the reach by Garrison project personnel. These inspections are made several times a week during the period of active ice formation.

9-14. Since the Garrison project has been in operation, ice breakup below the dam to the headwaters of the Oahe Reservoir has been orderly with no high water problems. Observations indicate that the ice melts from the river progressively downstream from the dam. Garrison release reductions coincident with this melt are not necessary. However, as previously discussed, on occasion appreciable snowmelt on the Knife and Heart Rivers will occur while the Missouri River at Bismarck is still ice covered. With such conditions, a reduction in Garrison releases is necessary to prevent flows in the Bismarck vicinity from exceeding the 35,000 to 40,000 cfs range or stages from materially exceeding 13 feet.

9-15. Coordinated System Flood Control Regulation. The main stem system of reservoirs, of which Garrison Reservoir is an integral component, is regulated to reduce flooding to the maximum degree practical along the Missouri River below the system. Long range release scheduling from the Garrison project is based on studies performed by the Reservoir Control Center which project system operations from the current date through the succeeding 6-18 months. All factors listed in paragraph 9-7 are considered to the extent possible in these studies. Such studies are made at a maximum interval of one month as new estimates of future inflows are developed. If conditions change materially from those anticipated in the monthly studies, additional within-month studies are made. The published Annual Operating Plan for the Missouri River Main Stem Reservoirs, discussed in the Master Manual, is based on one of these studies. Deviations from the published plan are based on the results of subsequent monthly (or more frequent) studies. Details of flood control regulation procedures applicable to the system of reservoirs are given in Section X of the Master Manual.

9-16. Exclusive Flood Control Regulation Techniques. The Garrison Reservoir will usually be operated at an elevation of 1850 ft msl or lower. However, occasionally flood inflows will be of such magnitude that encroachment into the exclusive flood control zone above elevation 1850 will occur. Consequential actions will be dependent upon conditions existing or anticipated in the other reservoirs in the main stem system. If a portion of the annual flood control and multiple use space is vacant in Fort Peck Reservoir and is expected to remain vacant, an obvious action is to reduce Fort Peck releases to the minimum consistent with all functions being served. If exclusive flood control space is being utilized in all reservoirs, action will be on the basis of the studies described in the preceding paragraphs, with system releases and the balance of exclusive storage scheduled in each reservoir of the system as defined by procedures discussed in the Master Manual. Generally these procedures recognize the desirability of maintaining somewhat more vacant storage space in the lower reservoirs than in Fort Peck and Garrison, since this storage distribution provides more and better opportunities for controlling downstream floods at the major damage centers.

9-17. At times encroachment into the Garrison exclusive flood control space will occur or will be anticipated when ample annual flood control storage space remains vacant in the downstream Oahe and Fort Randall projects. Normally when this occurs Garrison releases will be maintained at full power plant capacity in an effort to transfer the excess storage downstream while at the same time obtaining the maximum practical power revenue for the Government. However, significant encroachment into the exclusive flood control space will require releases in excess of the power plant capacity in order that a storage space reserve can be maintained for future flood inflows. Regulation curves shown on Plate 24 serve as a guide for defining releases at such times. These curves relate pool elevation and inflows to releases. The curves applicable to plains snowmelt and rainfall floods recognize the relatively sharp hydrographs typical of this type of inflow while the mountain snowmelt curves are based on the relatively long recession characteristics of this type of flood event.

9-18. As discussed above, these curves serve only as a guide for possible regulation, since they are based on typical recession hydrographs for the particular types of floods indicated. Final release selection could be greater or less than indicated by the curves and would be based on anticipated inflows, the effects of release through downstream reaches, and the anticipated maximum pool level of the Garrison Reservoir.

9-19. Surcharge Regulation Techniques. During exceptionally large flood inflows all available flood control storage space may be utilized and the Garrison Reservoir may rise into the surcharge zone above elevation 1854 ft msl. Since the primary reason for providing surcharge space was to insure the safety of Garrison Dam, and since real estate surrounding the reservoir has in general not been acquired above elevation 1855 ft msl, significant surcharge encroachment should be allowed only when necessary to prevent extensive downstream damage or if unprecedented flood inflows occur. When reservoir levels approach and are expected to exceed elevation 1854, maintenance of a Bismarck stage at 13 feet or less no longer is the essential criterion. Prior to allowing the reservoir level to exceed elevation 1855 (one foot of surcharge storage) releases should be based on maintaining a Bismarck stage at the level of 16 feet, the established flood stage. At the present time this corresponds to a flow of about 80,000 cfs. Therefore, with an allowance for moderate incremental inflows, Garrison outflows in the 75,000 cfs range should be scheduled whenever it appears probable that such releases are required to prevent the reservoir level from rising more than one foot into the surcharge zone.

9-20. Emergency Regulation. Rapid communication is usually available between the Reservoir Control Center and operating personnel of the Garrison project. When communications are interrupted for any extended period of time, project personnel will be required to continue regulation, as discussed in Section V. Exhibit B of this manual outlines the emergency procedures to be followed. In general, these procedures are such that they will continue service to multiple-use functions through the period of communications failure at the approximate level prevailing prior to the communications outage, when Garrison inflows continue at previously anticipated levels. These emergency procedures also allow for increased inflows, up to those occurring in maximum possible floods as developed for spillway design purposes.

9-21. Emergency regulation curves included with Exhibit B were developed by the method described in EM 1110-2-3600. The rainfall and plains snowmelt curves assumes a T_s value of five days, with this value selected on the basis of the recession curve of the maximum possible early-spring flood. The relatively steep recession rate is believed to be quite characteristic of rainfall floods and plains snowmelt floods that can be expected to cause high inflows during the March-April flood season.

9-22. During the May-July period, large volumes of inflow to the Garrison project will usually result from mountain snowmelt, augmented at times by general rains over the contributing area. Such floods have a slow recession rate (when compared with floods originating from plains area snowmelt or only from an unusually large rainstorm). Consequently, a T_s value of 15 days, characteristic of mountain snowmelt flood recession, was utilized for the emergency curves applicable during the mountain snowmelt period on the basis that this is the most probable flood type occurring at the time. However, mountain snowmelt runoff could on occasion be augmented by an unusually heavy rainstorm having a much steeper recession than snowmelt along. Since, under emergency conditions, such information probably would not be available to project personnel, release rate increases are restricted in a manner that will compensate for an actual recession rate being steeper than the rate assumed in development of the regulation curves.

9-23. When unprecedented flood inflows occur, or if reservoir levels exceed or are expected to exceed elevation 1855, the regulation curves given with the emergency instructions, Exhibit B, should be used as a guide for release scheduling. These regulation curves relate reservoir levels and inflows to suggested releases, with the suggested release being based on typical hydrograph recession rates for the season, similar to the exclusive flood control regulation curves previously described.

9-23. Responsibility for Application of Regulation Techniques. As described in Section VI of the Master Manual, the Missouri River Division Reservoir Control Center is responsible for and directs all regulation, including flood control regulation, of Garrison and the other main stem reservoirs. Instructions to assure continuation of Garrison regulation during periods of communication failure between the project and the Reservoir Control Center are given in Exhibit B of this, the Garrison Manual.

SECTION X - EXAMPLES OF GARRISON REGULATION

X-A. Historical Regulation

10-1. Garrison Storage Accumulation. Closure of Garrison Dam was made in April 1953, beginning the accumulation of storage in the associated reservoir. However, it was not until 1955 that an appreciable volume of water was stored in preparation for the first power unit coming on line in 1956. Runoff originating above Garrison Dam was generally well below normal during the 1954-1961 period and continuing initial fill of the carry over multiple-use space proceeded quite slowly. Since 1961 runoff from this drainage area has ranged from near normal to well above normal and, following that year, initial fill of the reservoir proceeded at a more rapid rate. Plates 26 and 27 illustrate the levels of Garrison Reservoir that have occurred since initial fill of the minimum pool (elevation 1775 ft msl) occurred in late 1955. From this plate it is evident that the carry-over multiple use zone of the reservoir (elevation 1837.5 ft msl) was first filled in 1965. Exclusive flood control storage space was utilized in both 1969 (maximum reservoir level at elevation 1850.8) and 1975 (maximum reservoir level at elevation 1854.8). The year 1975 was the only occasion when accumulated storage exceeded that allocated for flood control and other beneficial uses.

10-2. Plate 26 and 27 also illustrate the annual variation in the levels of the Garrison Reservoir since 1954. A minimum level usually occurs in late winter. Throughout most of the March-July flood season, storage accumulates in the lake provided upstream runoff is not extremely deficient. From late July, extending through most of the winter season, storage is evacuated to serve multiple-purpose needs and to provide space for the control of runoff that can be expected during the succeeding flood season.

10-3. Garrison Releases. Experienced mean monthly releases from the Garrison project are shown on plates 26 and 27. It is evident that, with one exception, mean monthly project outflows have been less than 40,000 cfs. The exception occurred in 1975 when June, July and August releases averaged 40,100 cfs, 61,800 cfs, and 54,100 cfs respectively. These record high outflows were coincident with the maximum observed levels of the reservoir. Respective maximum mean daily outflows during these three months of 1975 were 50,000 cfs, 65,200 cfs, and 65,100 cfs. Since the first Garrison power unit became operational in 1956, mean daily releases in excess of the full power plant capacity of about 38,000 cfs occurred only during the three months of 1975 discussed above. Mean daily releases as low as 5,000 cfs have been recorded. However, since early 1956 when Garrison power production began, mean daily releases less than 6,000 cfs have not occurred, except on one occasion in 1962 when the daily outflow was 5,800 cfs.

10-4. Diuranal fluctuations of Garrison releases have been very wide except during those periods when mean daily releases approached or exceeded the discharge capability of the power plant. Hourly releases during one day varying from zero, in the morning hours of light power demand, up to the full power plant capability of 38,000 cfs later in the day, when power demands are high, occur frequently in all seasons of the year.

10-5. Regulation Effects. The historical effects of Garrison regulation, as well as regulation provided by upstream reservoirs, upon mean monthly flows at the Garrison damsite are illustrated on plates 26 and 27. Mean monthly unregulated flows shown on these plates are the developed estimates of flows at the damsite if none of the upstream projects, including Garrison, had been in operation. Mean daily maximum and minimum flows for each year of the 1954-1976 period for regulated (observed) and unregulated conditions are given on Table 10. Further discussion of the regulation provided at the Garrison damsite during particular years is contained in succeeding paragraphs and in the discussion of system regulation given in the Master Manual.

10-6. 1961 Regulation. Runoff originating from the drainage area above Garrison Dam during 1961 totaled about 9 million acre-feet (1949 water resources development level), less than one-half of the long-term average. Less annual runoff has been recorded only in 1931 since records began in 1898. Therefore, the regulation provided in 1961 is an example of flow supplementation resulting from the operation of Garrison and other upstream projects. Actual mean daily flows (releases) and the corresponding unregulated flows at Garrison dam site are shown on Plate 28. From this plate it is evident that, during the late summer season, flows at this location would have been extremely low except for storage released from upstream reservoirs. Development of water resources has continued since 1961 and, if the runoff experienced in 1961 were to

TABLE 10

Annual Extreme Mean Daily Flows

Missouri River at Garrison Dam, North Dakota

Year	Mean Daily Flow, 1,000 cfs: Regulated Maximum	Regulated Minimum	Unregulated Maximum	Unregulated Minimum
1954	38.4	6.0	96	2
1955	45.4	4.9	76	3
1956	36.7	5.4	113	7
1957	25.7	8.0	109	4
1958	30.8	6.0	72	2
1959	21.1	8.8	118	4
1960	20.9	6.1	171	3
1961	28.9	6.1	57	0
1962	31.8	5.8	110	5
1963	30.9	6.0	120	2
1964	31.0	6.0	214	3
1965	38.4	9.6	135	6
1966	31.1	8.0	48	2
1967	37.9	7.5	170	3
1968	36.4	7.9	122	3
1969	39.1	11.6	110	5
1970	36.9	12.0	121	1
1971	39.3	17.1	120	5
1972	38.8	11.4	182	6
1973	30.7	13.9	65	3
1974	30.6	6.0	145	2
1975	65.2	14.8	176	5
1976	39.1	13.4	99	3

occur at the present time, an extended period of negligible unregulated flows would result. This indicates that water resource development has proceeded to the extent that storage is required to supply resource development requirements as well as maintaining a live stream below Garrison Dam. The levels of Garrison Reservoir during 1961 are shown on Plate 26. From this plate it is evident that a withdrawal of about ten feet of storage from this project occurred during the year. Storage from other upstream projects was also required for maintenance of the regulated flows, with the upstream Fort Peck Reservoir lowered about 17 feet during the year.

10-7. 1964 Regulation. Unregulated mean daily flows at the Garrison damsite during 1964 crested at 214,500 cfs, the greatest unregulated crest that has occurred at this location since regulation of the Garrison project began. Were it not for the regulation provided by upstream reservoirs, a Bismarck stage approaching 23 feet, 10 feet higher than the non-damaging target stage now utilized for regulation purposes, could have been expected to occur, with corresponding severe flood damages. Actual mean daily Garrison outflows at the time of this unregulated crest were about 25,000 cfs, as illustrated on Plate 29, representing a crest flow reduction of 190,000 cfs and a Bismarck stage reduction of over 14 feet. Garrison levels during this flood period are shown on Plate 26. It is evident that this flood presented no regulation problems at the Garrison project. In fact, throughout 1964 Garrison regulation was based on maintaining only minimum releases necessary for downstream water requirements. The 1964 regulation is illustrative of that usually occurring with total contributary flood season runoff volumes not appreciably above the long-term average, even though unusually large crest runoff amounts may occur.

10-8. 1967 Regulation. Flood season runoff occurring from the Fort Peck to Garrison drainage area during the June-July period of 1967 was the largest since initiation of the comprehensive stream gaging program in about 1930, as described in Section II of this manual. Combined with large amounts of runoff from this reach of the river was well above normal runoff throughout the remainder of the main stem drainage area and severe flood inflows to the Missouri River below the system of reservoirs. Damages prevented by the Garrison project and the other main stem reservoirs during this flood period approached 250 million dollars. As indicated on Plate 26, the maximum Garrison Reservoir level was below elevation 1850, or within the annual flood control zone. The effects of regulation during this flood at the Garrison damsite, as illustrated by unregulated flows and actual Garrison releases are shown on Plate 30. Garrison releases through the flood period were within the power plant capacity and eliminated all damage through the immediate downstream area.

10-9. 1972 Regulation. As discussed in Section II, an unusually large amount of plains snowmelt runoff originated from the Fort Peck-Garrison drainage area during March 1972. By the end of March the level of Garrison Reservoir had risen to elevation 1848, within two feet of the exclusive flood control zone as shown on Plate 27. In anticipation of above-normal runoff from above Garrison Dam during succeeding months, Garrison releases were increased to about full power plant capacity near the end of March, after a marked reduction in releases in mid-March to compensate for the large Knife River flows centering the Missouri River below Garrison Dam. Maintenance of near full power plant output through most of June resulted in a crest reservoir level of elevation 1849, within the annual flood control zone. Effects of reservoir regulation upon unregulated flows at the Garrison damsite during 1972 are shown on Plate 31.

10-10. 1975 Regulation. Flood season runoff (March-July) originating in the drainage area above the Garrison Dam during 1975 was the greatest experienced since runoff records began in 1898, as described in Section II of this manual. While the unregulated crest flow or 175,000 cfs at the Garrison damsite was relatively small in relation to the total volume of runoff that occurred, the unusual aspect was the sustained high unregulated flows extending from late April through July. Also unusual was that most of the well above-normal precipitation contributing to the record runoff occurred after early April. As a consequence, Garrison releases were not increased above normal levels until May. By mid-June it became evident that releases greater than ever previously experienced from the Garrison project would be necessary. Through late June and July regulation was geared to providing what was considered to be the minimizing of total adverse effects resulting from high Garrison Reservoir levels, high flows through the Missouri River each between Garrison Dam and the Oahe Reservoir, high levels of downstream reservoirs that reregulated Garrison releases and high main stem system outflows. The resultant maximum release from Garrison was 65,000 cfs and the crest Garrison elevation was 1854.8. Reservoir levels through the year are shown on Plate 27 while mean daily unregulated flows and releases are shown on Plate 32. A maximum stage near 14 feet was observed at Bismarck; without the control afforded by Garrison and other upstream projects a crest stage of about 21 feet would have occurred. For further information relating to this flood and regulation offered by the reservoir projects in operation, reference is made to the Master Manual as well as the Reservoir Control Center Technical Report describing the 1975 regulation.

10-11. Regulation During Downstream Channel Freezeup. On a continuing basis, perhaps the most critical time for scheduling Garrison releases is in the early winter period when an ice-cover is forming on the Missouri River channel from the headwaters of the Oahe Reservoir upstream to above Bismarck, North Dakota. At this time the power demand is for high Garrison outflows; however, ice formation near Bismarck reduces the downstream channel capacity to about one-half of the Garrison power plant capability. An illustration of the detailed analyses required at the time is beyond the scope of this manual. Reference is made to the MRD-RCC Technical Report F-73, "Freezing of the Missouri River Below Garrison Dam," where the daily analyses made during the December 1972 ice formation period are described for illustrative purposes.

10-12. Summary of Historical Regulation. Historical regulation of the Garrison project has proceeded for only a relatively short period of time, and a substantial portion of this historical period was consumed in the initial fill of Garrison and other downstream reservoirs. However, annual upstream runoff during this period has ranged from near minimum to the maximum recorded since 1898. Therefore, regulation during this historical period is believed to be quite representative of conditions that are likely to be prevalent through the life of the project. Based on this experience, supplemented by analyses of the entire period of hydrologic record, it is believed that regulation criteria developed for the Garrison project are reasonable and represent a near-optimum utilization and control of the water supply that may be available. Of course, studies will continue through the life of the project in an effort to improve procedures. In general, it may be stated that unless very unusual conditions occur, Garrison releases will be maintained at a level within the power plant capacity while reservoir level will not exceed elevation 1854 ft msl, the base of surcharge storage. Minimum daily outflows will not be less than the 6,000 cfs range necessary for functioning of downstream water intakes while the level of the Garrison Reservoir should be maintained well above the established minimum level at elevation 1775 ft msl.

X-B. Long-Term Regulation Analyses

10-13. Long-Term Studies. Simulated regulation of the Garrison Project as a component of the main stem reservoir system through the entire period of available hydrologic record is a technique utilized by the Reservoir Control Center for the development of regulation criteria through the analyses of effects of criteria modifications upon service to authorized functions. Current regulation criteria are the result of many involved and detailed studies, augmented by actual regulation experience. Accomplishment of the long-term studies is described in Chapter V and IX of the Master Manual and in the detailed reports that have been published describing specific studies. From the studies that incorporate current regulation criteria, long-term examples of Garrison regulation are available.

10-14. Garrison Elevation. Long-term analyses indicate that Garrison Reservoir levels will fluctuate from the minimum pool (elevation 1775 ft msl) upward through the levels provided for control of the most severe floods (elevation 1854 ft msl or above). However, with the present level of water resource development, the reservoir can be expected to be above the base of annual flood control (elevation 1837.5) for a majority of the time. Extreme drawdown (below elevation 1800) will occur only in the event of a severe drought extending over several years, such as experienced in the Missouri Basin during the 1930s. A graph of probable Garrison Reservoir elevations that would be experienced with repetition of the entire available hydrologic record is given in the Master Manual.

10-15. On the basis of studies conducted with the 1975 level of Missouri Basin water resource development, the Garrison elevation-duration curve shown on Plate 33 was developed. This curve indicates that a reservoir level at or above elevation 1837.5, the base of the annual flood control storage zone, can be expected about 55 percent of the time. A frequency curve of maximum annual Garrison reservoir elevations is shown on Plate 34. This curve was developed from the long-range studies, tempered by actual regulation experience to date. From this curve it is evident that a maximum annual reservoir level at or above elevation 1837.5 can be expected during 73 years out of every 100 years of experience. Average reservoir levels and the normal variations in these levels at the 1975 water resource development level are shown on Plate 35. This illustrates an average rise in lake levels of eleven feet occurring in the four month period, mid-March to mid-July, followed by a corresponding gradual decrease in levels through the remaining eight months of the year.

10-16. Garrison Releases. Long-term regulation studies indicate that Garrison releases in excess of the power plant capacity of 38,000 cfs will seldom be required. From duration curves shown on Plate 33, an average monthly release rate of 38,000 cfs or less can be expected over 98 percent of the time. This percentage is also believed appropriate for instantaneous release rates at or less than the power plant capacity. The frequency curve of annual maximum releases shown on Plate 34 was developed from long-range study results augmented by data experienced during historical regulation. This curve reflects instantaneous releases at full power plant capacity during all years to supply peak generation requirements. Average monthly releases, based on long-term studies, are shown on Plate 35. It may be noted that except for the winter period of January, February and early March, average releases are relatively uniform through the year. The higher winter releases from Garrison reflect the transfer of power generation to Garrison during this season when lower system releases preclude as much power generation from downstream projects assuring the open water navigation season.

X-C. Emergency Regulation

10-17. Maximum Possible Early Spring Flood. As discussed in Section IX, regulation curves are included with the emergency regulation procedures, Exhibit B of this manual. Inclosure 1 of this exhibit is the set of curves applicable to the early spring season when substantial inflows to the project result primarily from plains area snow melt. An example of using emergency procedures as the only criteria for regulation of the Garrison project is shown on Plate 36. The flood examined is the maximum possible early spring flood developed for spillway design purposes, with a crest inflow of over one million cfs. An initial pool level at elevation 1840 ft msl was assumed. Respective crest reservoir levels and project releases are elevation 1858.8 ft msl and 830,000 cfs, very close to the values determined at the time of the design of the Garrison project about 30 years ago.

10-18. Maximum Possible Late Spring Flood. The effects of using the late spring emergency regulation procedures as given by Inclosure 2 of Exhibit B during the maximum possible late spring flood are shown on Plate 37. The flood inflows were as developed during spillway design studies about 30 years ago and reflect a combination of mountain snowmelt and heavy rainfall runoff. A crest inflow of 960,000 cfs can be controlled to a maximum outflow of 750,000 cfs with a maximum late level at elevation 1857.6 ft msl.

EXHIBIT A

OMAHA DISTRICT
PROCEDURE FOR FORECASTING SEASONAL RUNOFF AT SIDNEY, MONTANA

The basic forecast equation for the unregulated runoff at Sidney for the period May through July is:

$$X_1 = 0.31\ X_2 + 30.6\ X_3 + 23.78\ X_4 + 45.5\ X_5 - 133$$

where X_1 = Unregulated May-July runoff at Sidney in 10,000 AF

X_2 = Unregulated October-November runoff at Sidney in 10,000 AF

X_3 = The sum of October-November precipitation, averaged for twenty selected stations in inches. (Stations are Casper, Cody, Crandall Creek, Diversion Dam, Dubois, Lander, Metz Ranch, Midwest, Recluse, Sheridan, Sunshine, Worland, Yellowstone Park, Big Timber, Billings, Crow Agency, Red Lodge, Livingston, Miles City and Glendive.)

X_4 = The average snow water content on 1 April of nine selected snow courses. (Snow courses are Devils Slide, Lodgepole, Brooks Lake No. 3, Camp Senia, Sourdough, Ranger Creek, Sylvan Pass, Crevice Mountain and Lake Camp.)

X_5 = The sum of April-June precipitation, averaged for twenty stations in inches. (Same stations as used in X_3.)

Average water content of the nine selected snow courses in inches:

1 February	7.4	
1 March	9.5	(2.1 = average gain during February)
1 April	12.3	(2.8 = average gain during March)

Average monthly precipitation of the twenty selected precipitation stations in inches:

April	1.60
May	2.10
June	2.30
Total	6.00

Average values of variables used in basic equation:

$X_1 = 511$, $X_2 = 82.3$, $X_3 = 1.72$, $X_4 = 12.3$, $X_5 = 6.00$

Forecasts of unregulated flow at Sidney on 1 February, 1 March and 1 April are as follows:

1 February Forecast

X_1, X_2 and X_3 are the same as in basic equation.

X_4 = average snow water content of the nine selected snow courses on 1 February, plus the average gain of 4.9 inches

X_5 = 6.00 inches

1 March Forecast

X_1, X_2 and X_3 are the same as in basic equation.

X_4 = average snow water content of the nine selected snow courses on 1 March, plus the average gain of 2.8 inches during March.

1 April Forecast

X_1, X_2, X_3 and X_4 are the same as in basic equation.

X_5 = 6.00 inches.

Actual flow at Sidney is estimated as unregulated flow (X_1) plus or minus storage change in Bull Lake, Boysen, Buffalo Bill and Yellowtail Reservoirs.

EXHIBIT B

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EMERGENCY REGULATION PROCEDURES

FOR THE

GARRISON PROJECT

(LAKE SAKAKAWEA)

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
P. O. BOX 103, DOWNTOWN STATION
OMAHA, NEBRASKA 68101

MRDED-R

SUBJECT: Reservoir Regulation Order, Emergency Regulation Procedure for the Garrison Reservoir (Lake Sakakawea)

TO: Power Plant Superintendent
Garrison Power Plant

FROM: Missouri River Division
Reservoir Control Center

1. Procedures applicable to the regulation of the Garrison Reservoir during any period that communication with the Missouri River Division Reservoir Control Center or the Omaha District Reservoir Regulation Section is not possible are outlined in the following paragraphs. These instructions supersede all previously furnished emergency reservoir regulation criteria.

2. Normally, reservoir regulation orders specifying project releases and power production will be furnished your office by the Reservoir Control Center and your office will report daily to the Reservoir Control Center and the Omaha District pertinent data relating to regulation of the Garrison project. These data will include reservoir elevations, releases, power generation and related hydrologic data. The MRD teletype network will normally be used for transmission of orders and reports. However, if this network is inoperative, alternate means of communication are to be utilized. These include direct telephone, the MRD radio network, relay of data by other main stem project offices and utilization of WAPA communication facilities.

3. When daily communication, as outlined in paragraph 2 above, cannot be established, the following will apply:

a. Every reasonable effort will be made by the Power Plant Superintendent to re-establish communication with the Reservoir Control Center or the Omaha District Reservoir Regulation Section, including use of any Federal, commercial or private means of communication.

b. Following a communication failure, the provision of the latest regulation order will be extended. Hourly power plant loading will follow the WAPA loading schedule, if available. If the hourly schedule has not been received from the WAPA, power plant releases will be made to provide the daily energy schedule specified in the order and will be patterned similar to recent experience. If requested by the WAPA Power Systems Operations Office and if power emergency conditions have been declared, energy generation may be increased to the maximum allowable limit shown on the latest regulation order. These procedures will continue to be utilized until communications are re-established as long as the level of the Garrison Reservoir remains below elevation 1837.5 feet msl.

c. If the reservoir level is above elevation 1837.5, procedures given in paragraph b will be applicable during the first day of communication failure after which conditions will be reviewed to determine if the release rate should be changed. Procedures are as follows:

(1) Minimum release will be the release specified in the most recent available regulation order.

(2) The mean inflow for the preceding 24 hours will be estimated by computing the storage change during the 24-hour period on the basis of pool elevations observed at the damsite. Normally, the pool elevation will follow a relatively smooth curve. Therefore, any sudden fluctuations in the pool level recorder trace from a smooth curve (probably due to wind effects on the reservoir gage) should be disregarded and the storage change based on an extrapolation of the smoothed pool level curve through the 24-hour period. The approximate mean inflow in cfs is equivalent to the mean outflow in cfs for the 24-hour period plus one-half the storage change in acre-feet.

(3) Utilizing the inflow as developed above and the current pool elevation (as indicated by the smoothed pool level curve), determine the rule curve release by use of the emergency curves shown on the attached Inclosure 1 or 2, as appropriate for the season.

(4) If the rule curve release developed by (3) is greater than the release given by (1), make release specified by the appropriate rule curve. However, increases in release rates will be limited as specified on the curves.

(5) With a reservoir level below elevation 1850, any release adjustments made necessary by use of the rule curve in accordance with (4) should be made once daily. With a reservoir level above elevation 1850, the analysis and necessary adjustments should be at intervals of 12 hours or less.

(6) If the release is less than full power plant capability, power plant loading will be patterned similar to recent experience or as prescribed by the WAPA if communication with their Systems Operations Office is possible.

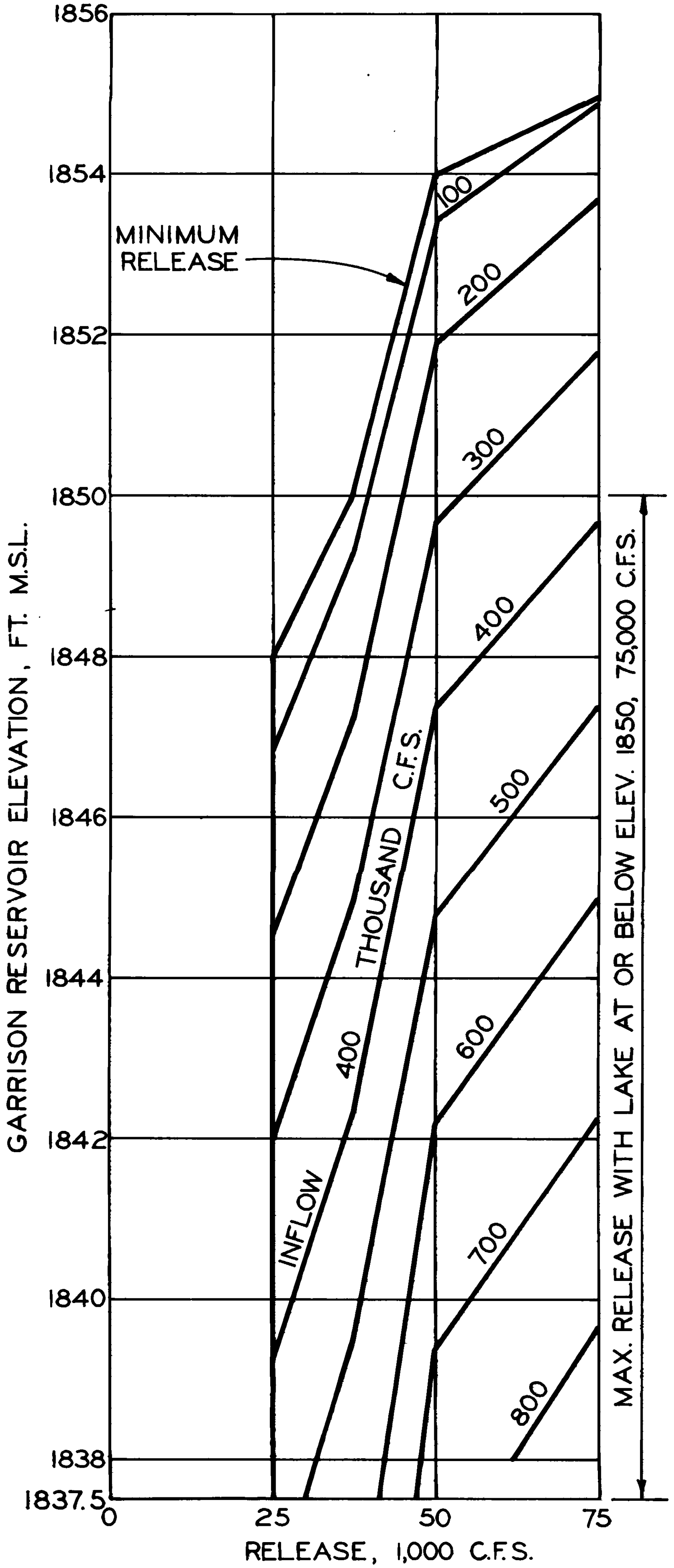
(7) Releases from the project shall be made through the powerhouse to the degree feasible.

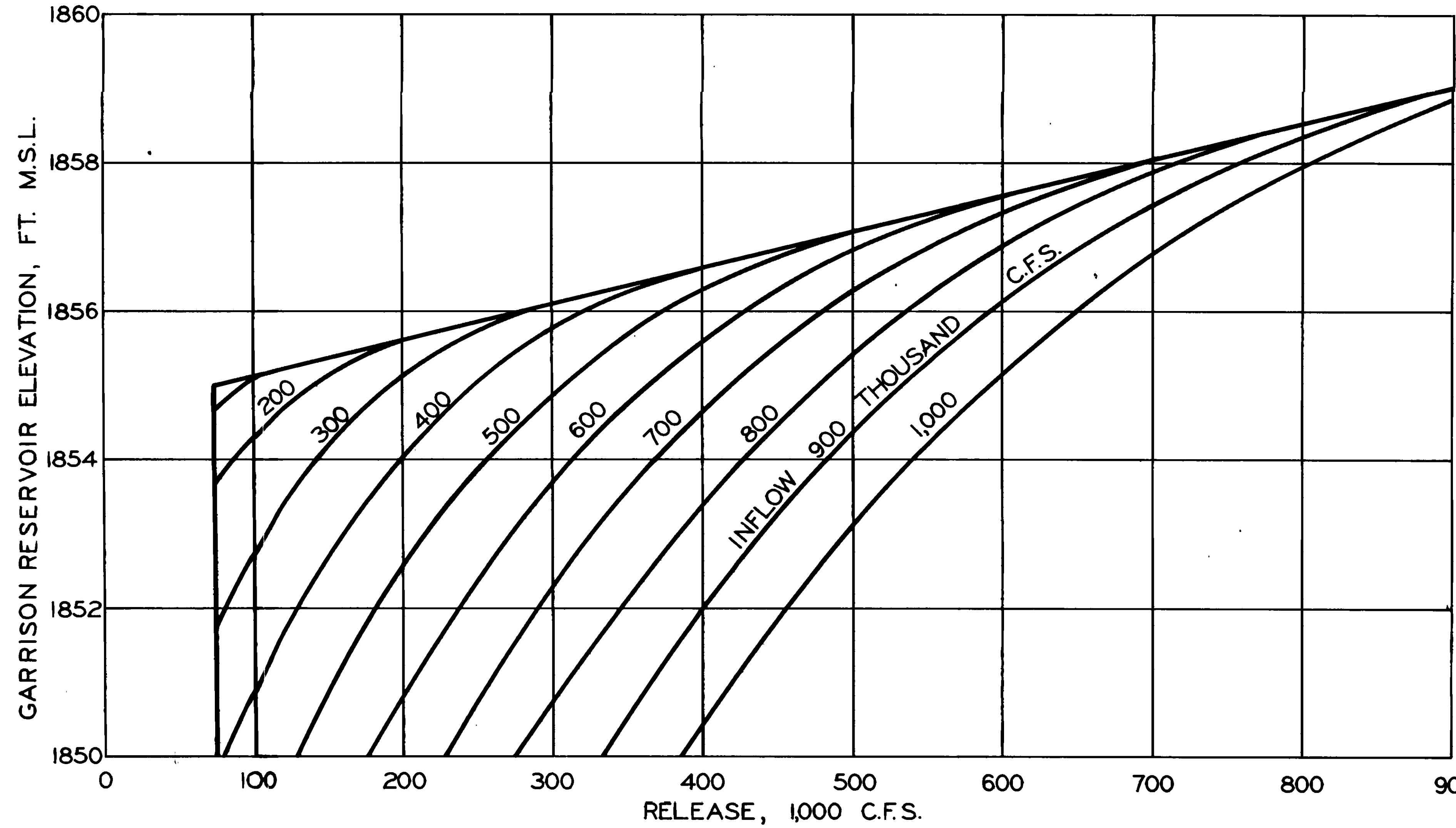
4. In the event of downstream flooding, as reported to or anticipated by the Power Plant Superintendent, releases will be reduced as deemed necessary to alleviate these conditions. However, with a reservoir level above elevation 1837.5 releases will not be reduced below those levels defined by the emergency curves, Inclosure 1 and 2.

5. The foregoing procedures are not intended to relieve the Power Plant Superintendent of taking such additional measures believed necessary to assure the safety of the project.

2 Incl
1. Emergency Regulation Curves (Rainfall and Plains Snowmelt)
2. Emergency Regulation Curves (Mountain Snowmelt Season)

ELMO W. McCLENDON
Chief, Reservoir Control Center

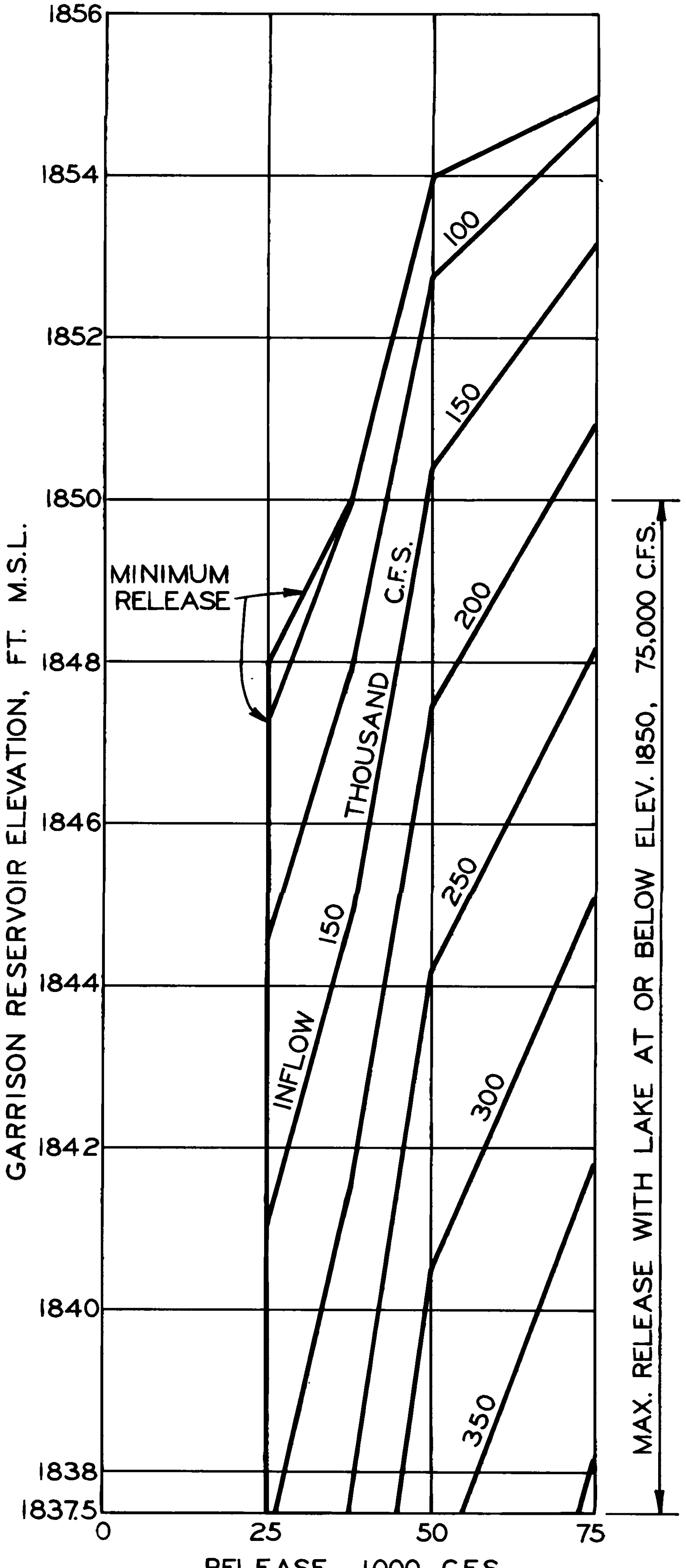


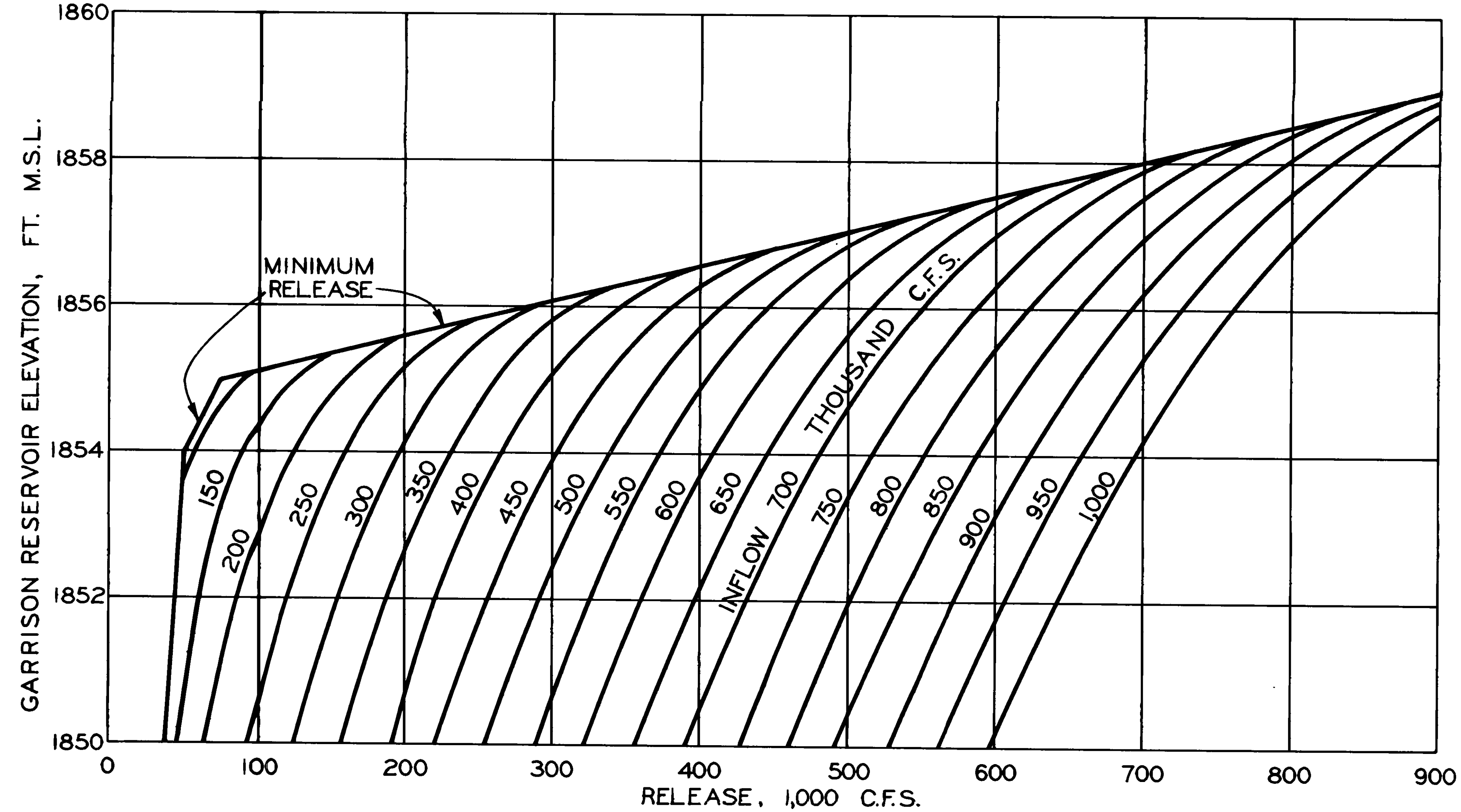


NOTES:

1. Curves are applicable for period 1 August to 30 April.
2. Numbered curves represent inflow in thousand C.F.S.
3. Emergency procedures will consist of:
   a. Enter curves with current pool elevation.
   b. Proceed to curve which equals inflow as determined for preceding 24 hours.
   c. Maintain release as indicated by point of intersection.
   d. No release shall exceed a rate greater than twice the average release rate for the preceding 24 hours.

EMERGENCY REGULATION CURVES
RAINFALL AND PLAINS SNOWMELT





NOTES:

1. Curves are applicable for period 1 May to 31 July.

2. Numbered curves represent inflow in thousand C.F.S.

3. Emergency procedures will consist of:

   a. Enter curves with current pool elevation.

   b. Proceed to curve which equals inflow as determined for preceding 24 hours.

   c. Maintain release as indicated by point of intersection.

   d. No release shall exceed a rate greater than one and one-half times the average release rate for the preceding 24 hours

EMERGENCY REGULATION CURVES
MOUNTAIN SNOWMELT PERIOD

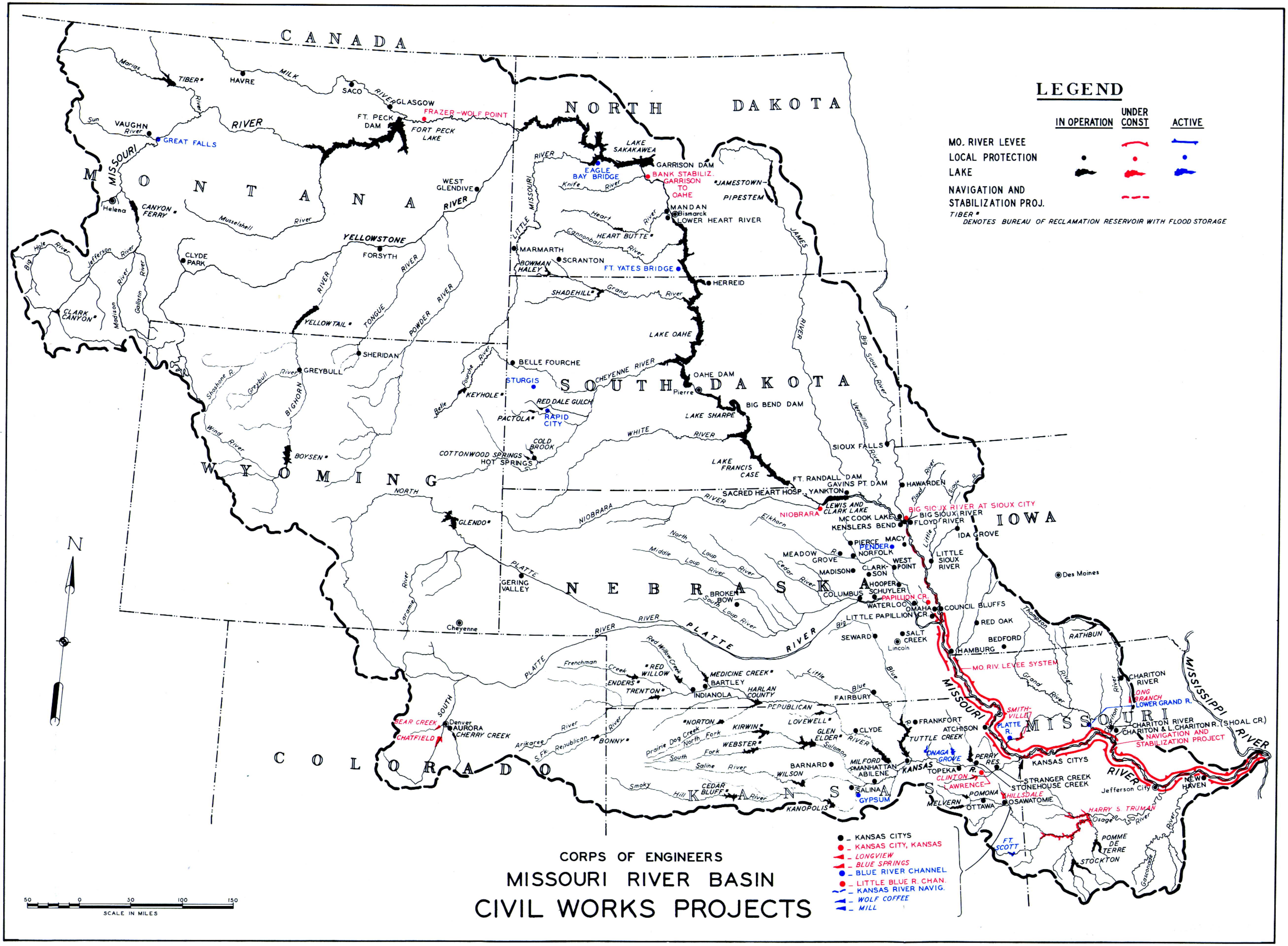
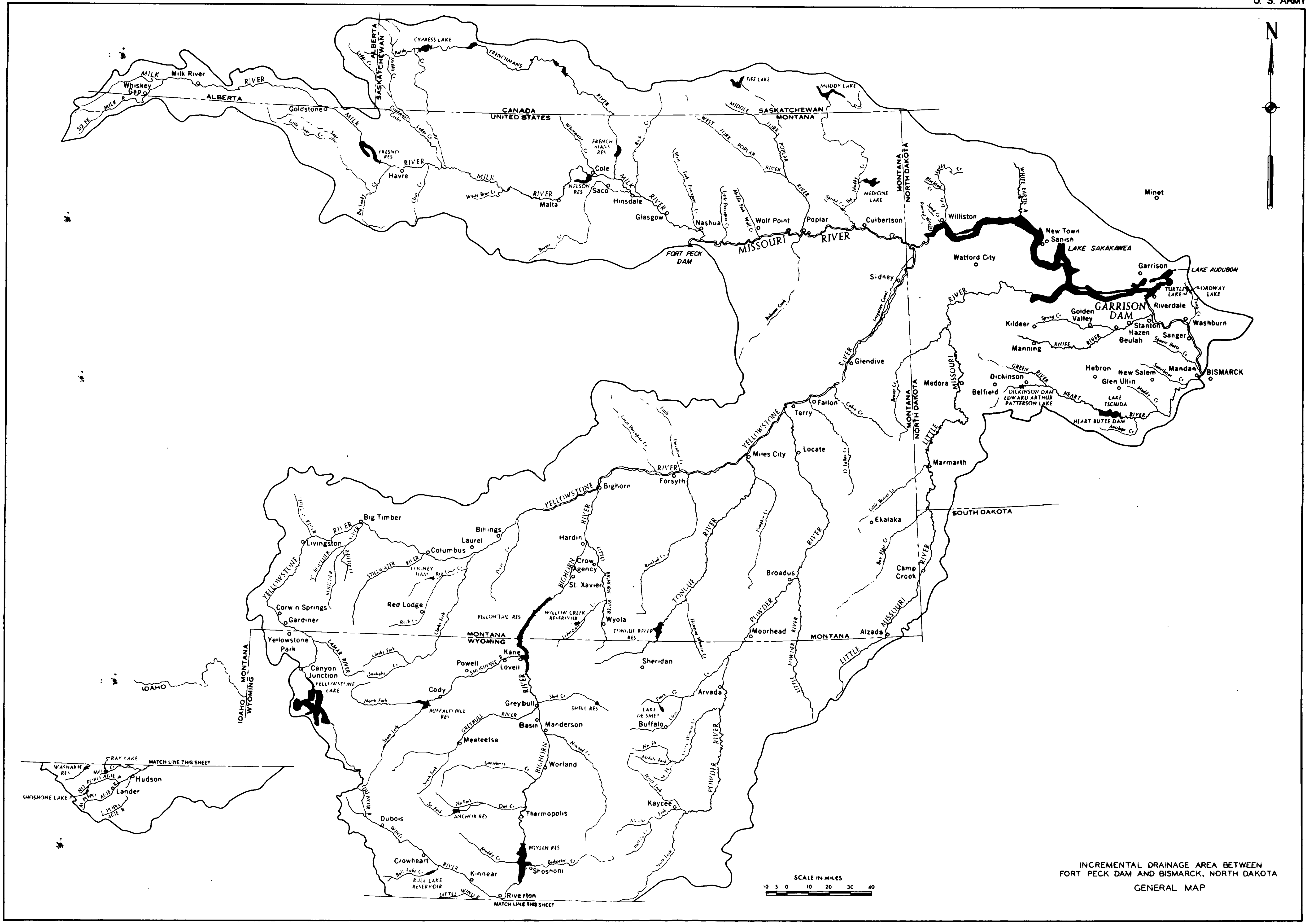
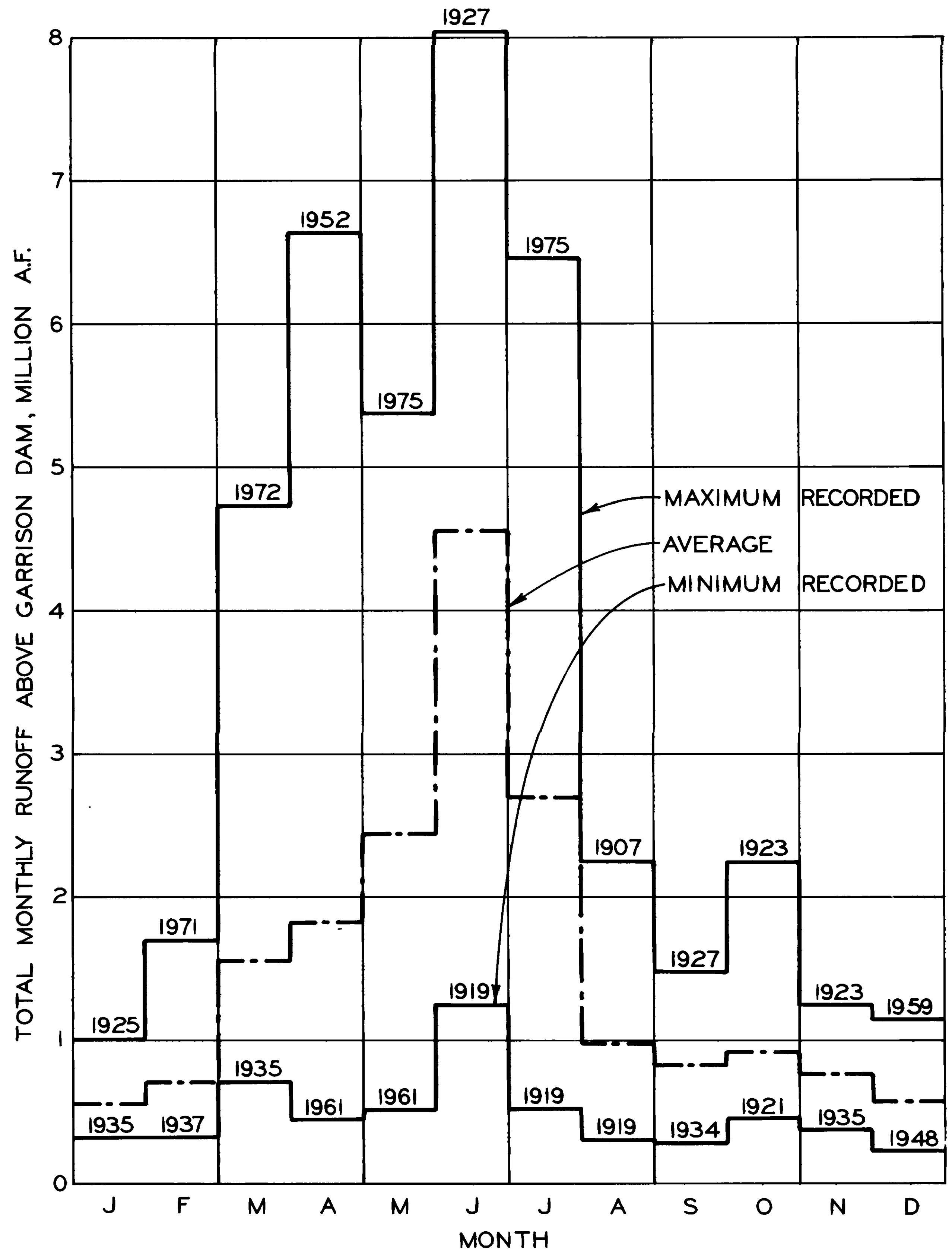

CORPS OF ENGINEERS
MISSOURI RIVER BASIN
CIVIL WORKS PROJECTS
LEGEND
IN OPERATION
UNDER CONST
ACTIVE
MO. RIVER LEVEE
LOCAL PROTECTION
LAKE
NAVIGATION AND STABILIZATION PROJ.
TIBER • DENOTES BUREAU OF RECLAMATION RESERVOIR WITH FLOOD STORAGE
CANADA
NORTH DAKOTA
SOUTH DAKOTA
MONTANA
WYOMING
NEBRASKA
IOWA
KANSAS
COLORADO
MISSOURI RIVER
MISSISSIPPI RIVER
YELLOWSTONE RIVER
PLATTE RIVER
TIBER
HAVRE
SACO
GLASGOW
FRAZER-WOLF POINT
FT. PECK DAM
FORT PECK LAKE
VAUGHN
GREAT FALLS
Helena
CANYON FERRY
WEST GLENDIVE
CLYDE PARK
CLARK CANYON
FORSYTH
YELLOWTAIL
SHERIDAN
GREYBULL
BOYSEN
GLENDO
Cheyenne
GERING VALLEY
LAKE SAKAKAWEA
GARRISON DAM
BANK STABILIZ. GARRISON TO OAHE
EAGLE BAY BRIDGE
JAMESTOWN
PIPESTEM
MANDAN
Bismarck
LOWER HEART RIVER
HEART BUTTE
MARMARTH
BOWMAN HALEY
SCRANTON
FT. YATES BRIDGE
HERREID
SHADEHILL
LAKE OAHE
OAHE DAM
Pierre
BELLE FOURCHE
STURGIS
KEYHOLE
RED DALE GULCH
PACTOLA
RAPID CITY
COLD BROOK
COTTONWOOD SPRINGS
HOT SPRINGS
BIG BEND DAM
LAKE SHARPE
LAKE FRANCIS CASE
FT. RANDALL DAM
GAVINS PT. DAM
SACRED HEART HOSP.
YANKTON
LEWIS AND CLARK LAKE
NIOBRARA
SIOUX FALLS
HAWARDEN
BIG SIOUX RIVER AT SIOUX CITY
BIG SIOUX RIVER
FLOYD RIVER
MC COOK LAKE
KENSLERS BEND
IDA GROVE
PIERCE
MACY
PENDER
NORFOLK
MEADOW GROVE
WEST POINT
LITTLE SIOUX RIVER
CLARKSON
MADISON
HOOPER
SCHUYLER
COLUMBUS
BROKEN BOW
PAPILLION CR.
WATERLOO
OMAHA
COUNCIL BLUFFS
LITTLE PAPILLION CR.
Des Moines
RED OAK
SEWARD
SALT CREEK
Lincoln
BEDFORD
HAMBURG
RATHBUN
MO. RIV. LEVEE SYSTEM
CHARITON RIVER
LONG BRANCH
LOWER GRAND R.
CHARITON RIVER
CHARITON & L. CHARITON R. (SHOAL CR.)
NAVIGATION AND STABILIZATION PROJECT
MEDICINE CREEK
BARTLEY
RED WILLOW
ENDERS
TRENTON
INDIANOLA
HARLAN COUNTY
FAIRBURY
BEAR CREEK
CHATFIELD
Denver
AURORA
CHERRY CREEK
BONNY
NORTON
KIRWIN
WEBSTER
LOVEWELL
GLEN ELDER
CLYDE
FRANKFORT
ATCHISON
TUTTLE CREEK
SMITHVILLE
PLATTE R.
ONAGA GROVE
PERRY RES.
KANSAS CITYS
MILFORD
MANHATTAN
ABILENE
BARNARD
WILSON
KANSAS
TOPEKA
CLINTON
LAWRENCE
STRANGER CREEK
STONEHOUSE CREEK
CEDAR BLUFF
SALINA
GYPSUM
KANOPOLIS
MELVERN
POMONA
OTTAWA
HILLSDALE
OSAWATOMIE
HARRY S. TRUMAN
Jefferson City
NEW HAVEN
FT. SCOTT
POMME DE TERRE
STOCKTON
KANSAS CITYS
KANSAS CITY, KANSAS
LONGVIEW
BLUE SPRINGS
BLUE RIVER CHANNEL
LITTLE BLUE R. CHAN.
KANSAS RIVER NAVIG.
WOLF COFFEE
MILL
SCALE IN MILES
50 0 50 100 150
N

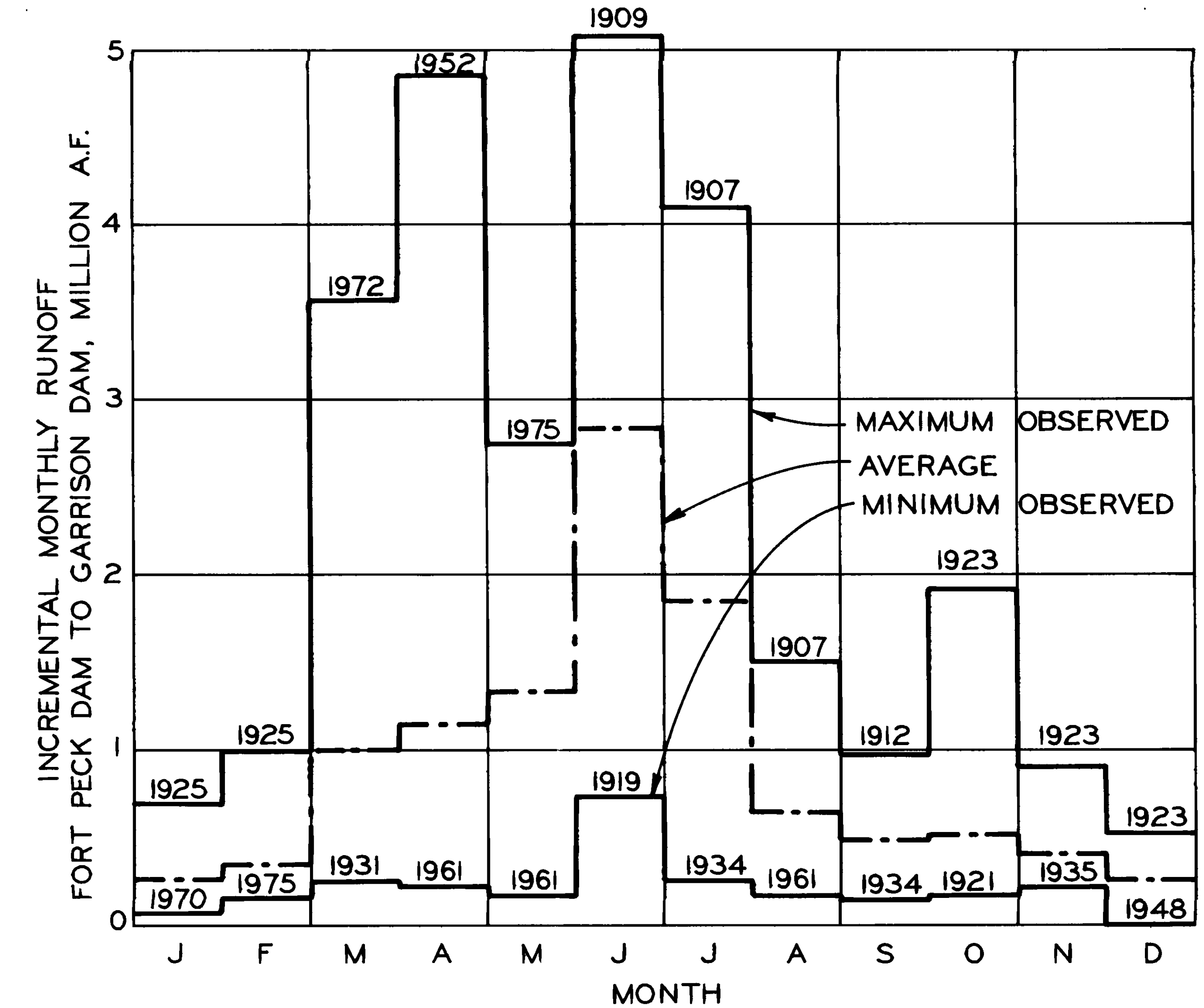
PLATE I



INCREMENTAL DRAINAGE AREA BETWEEN
FORT PECK DAM AND BISMARCK, NORTH DAKOTA

GENERAL MAP

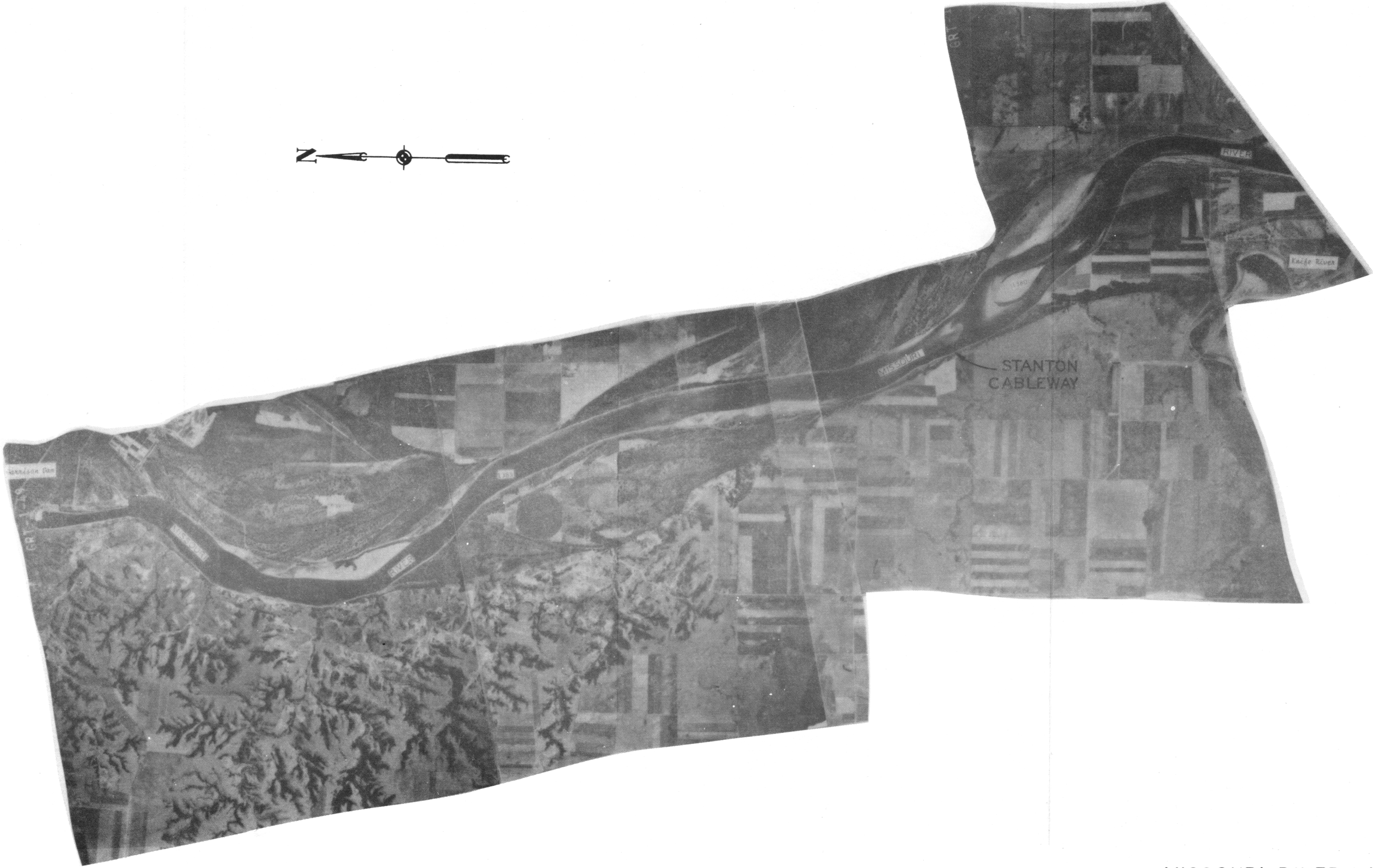




NOTES: 1. Record period extends from 1898 to 1976

2. Runoff adjusted to the 1949 level of water resource development.

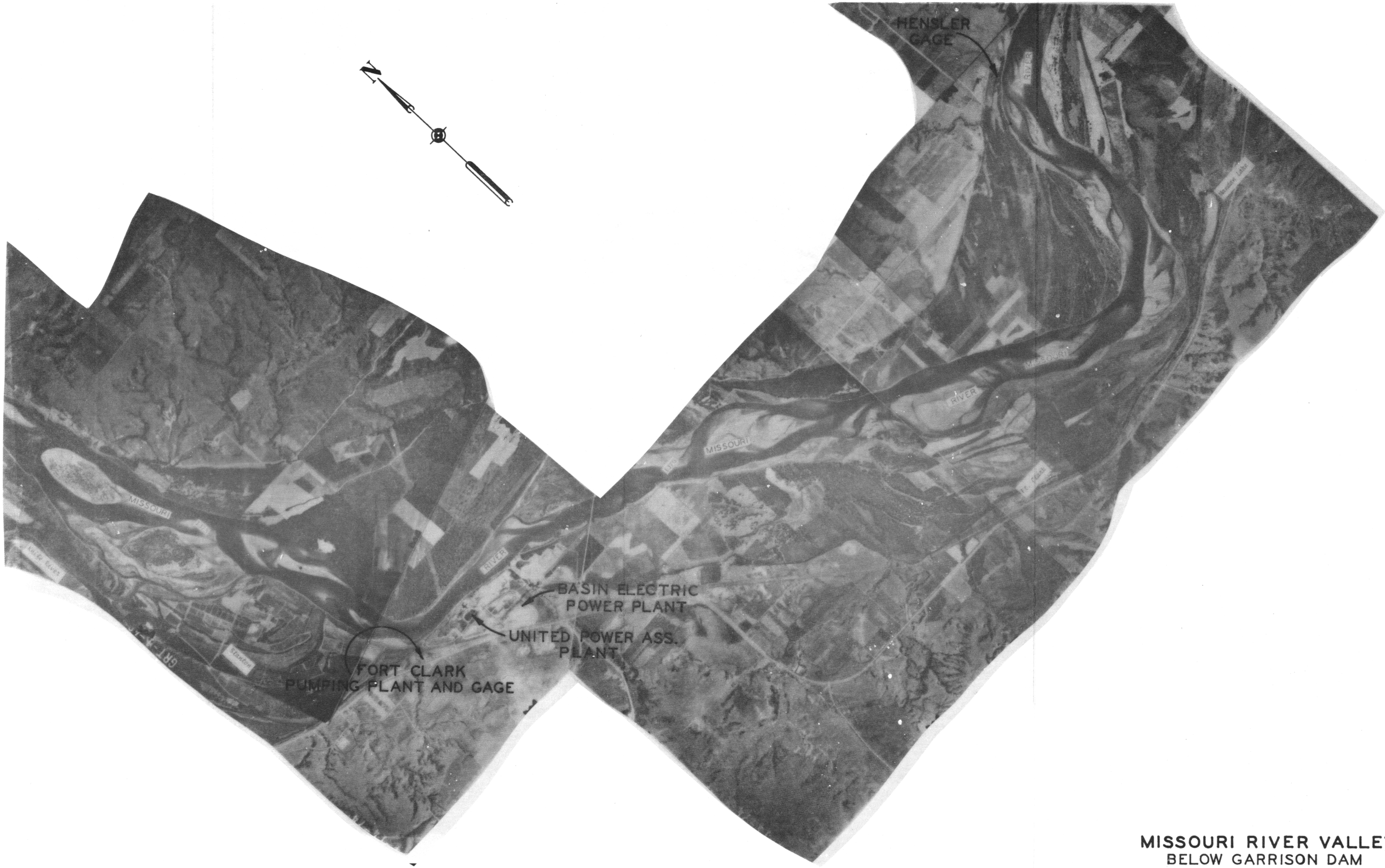
MONTHLY RUNOFF DISTRIBUTION ABOVE GARRISON DAM



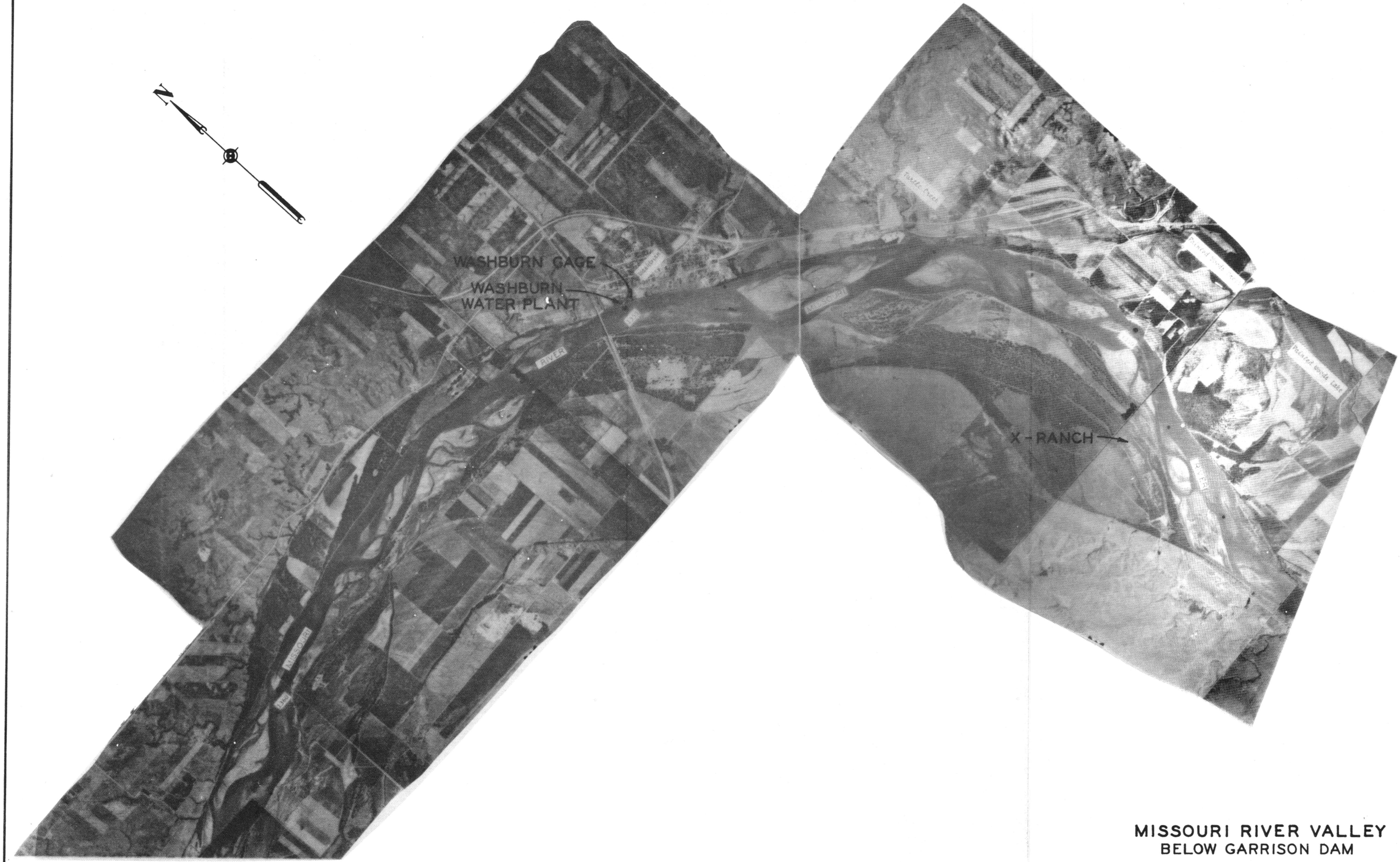
MISSOURI RIVER VALLEY
BELOW GARRISON DAM

PLATE 4

★ U.S. GOVERNMENT PRINTING OFFICE: 1973

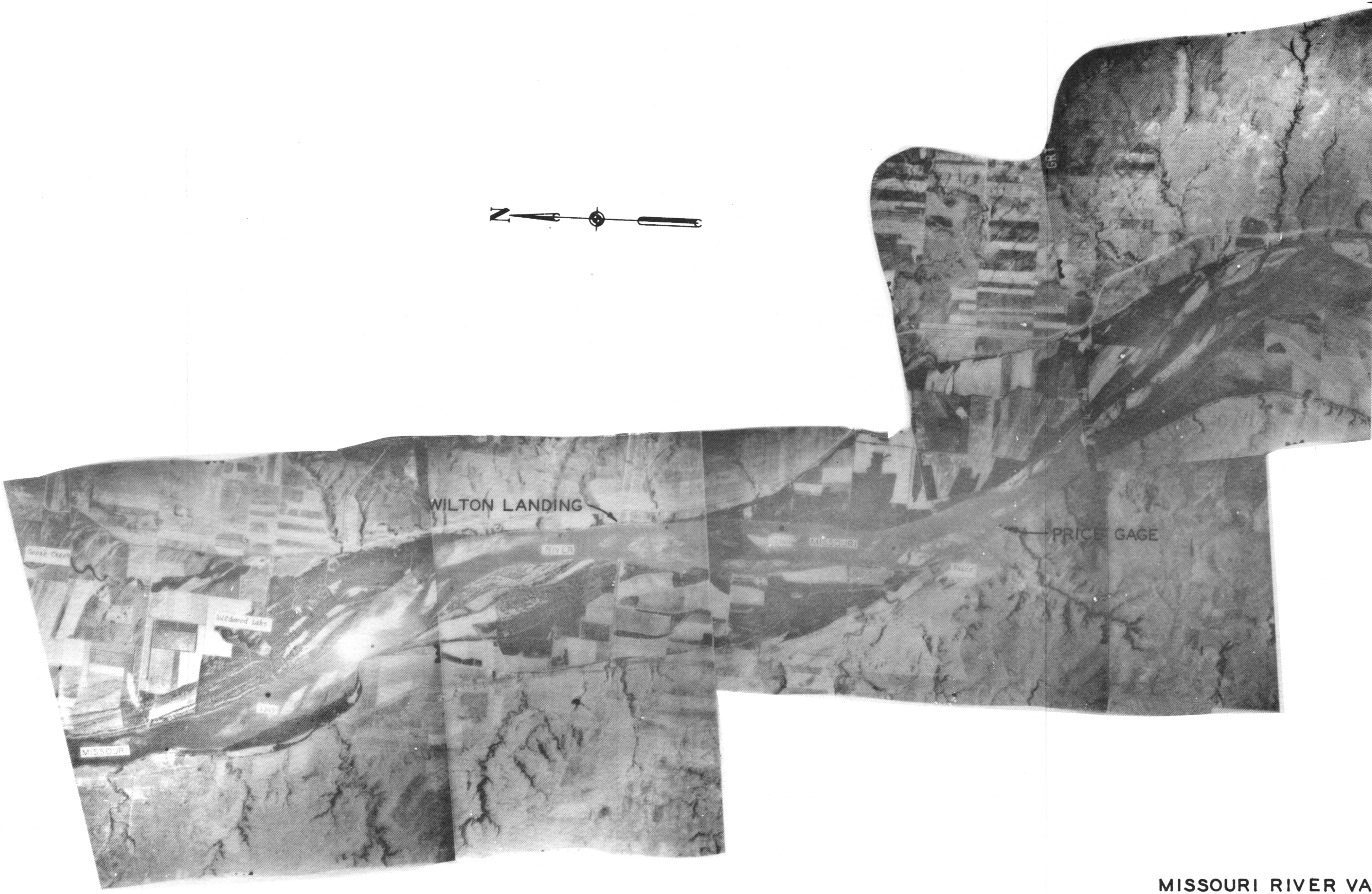


MISSOURI RIVER VALLEY
BELOW GARRISON DAM

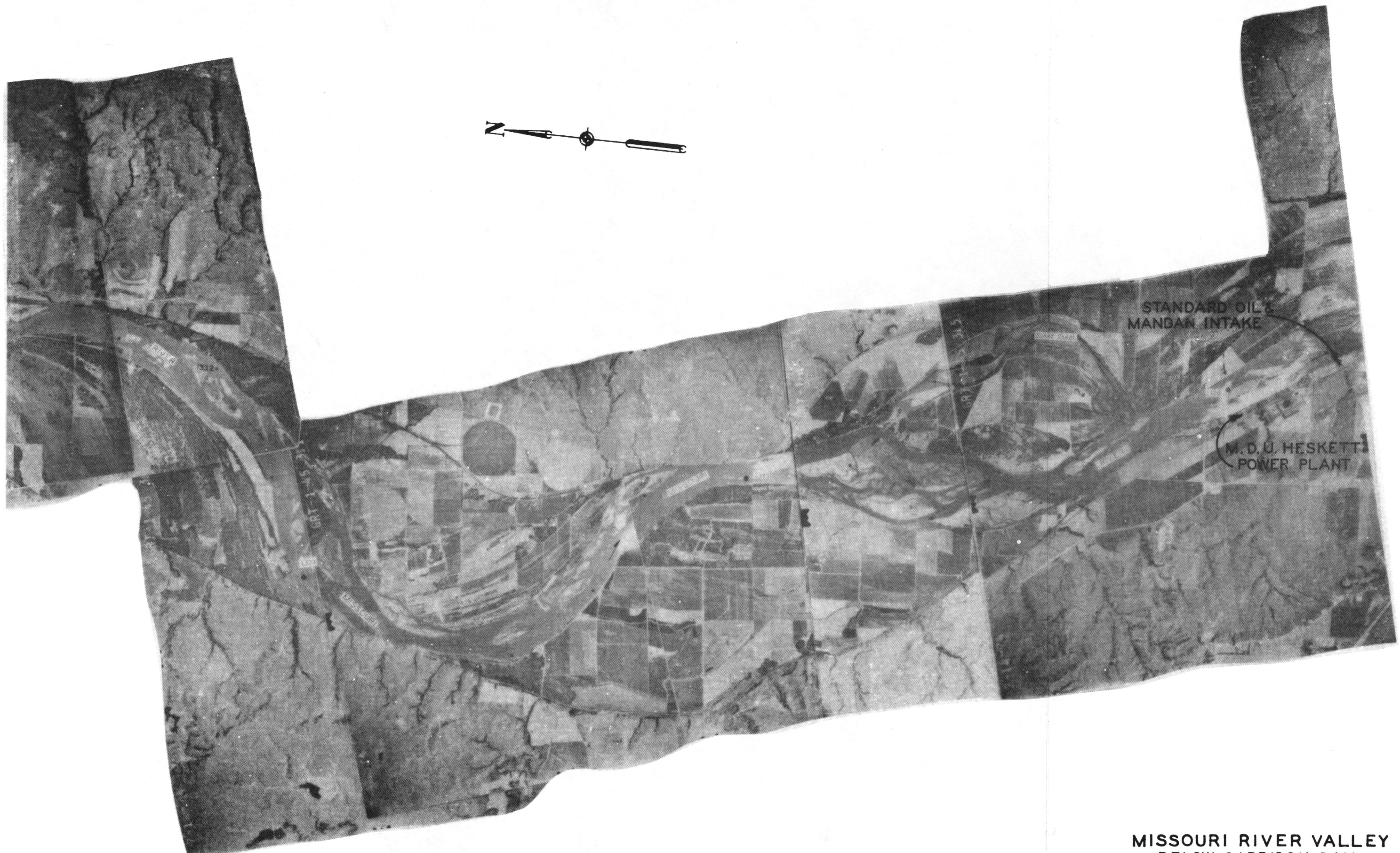


MISSOURI RIVER VALLEY
BELOW GARRISON DAM

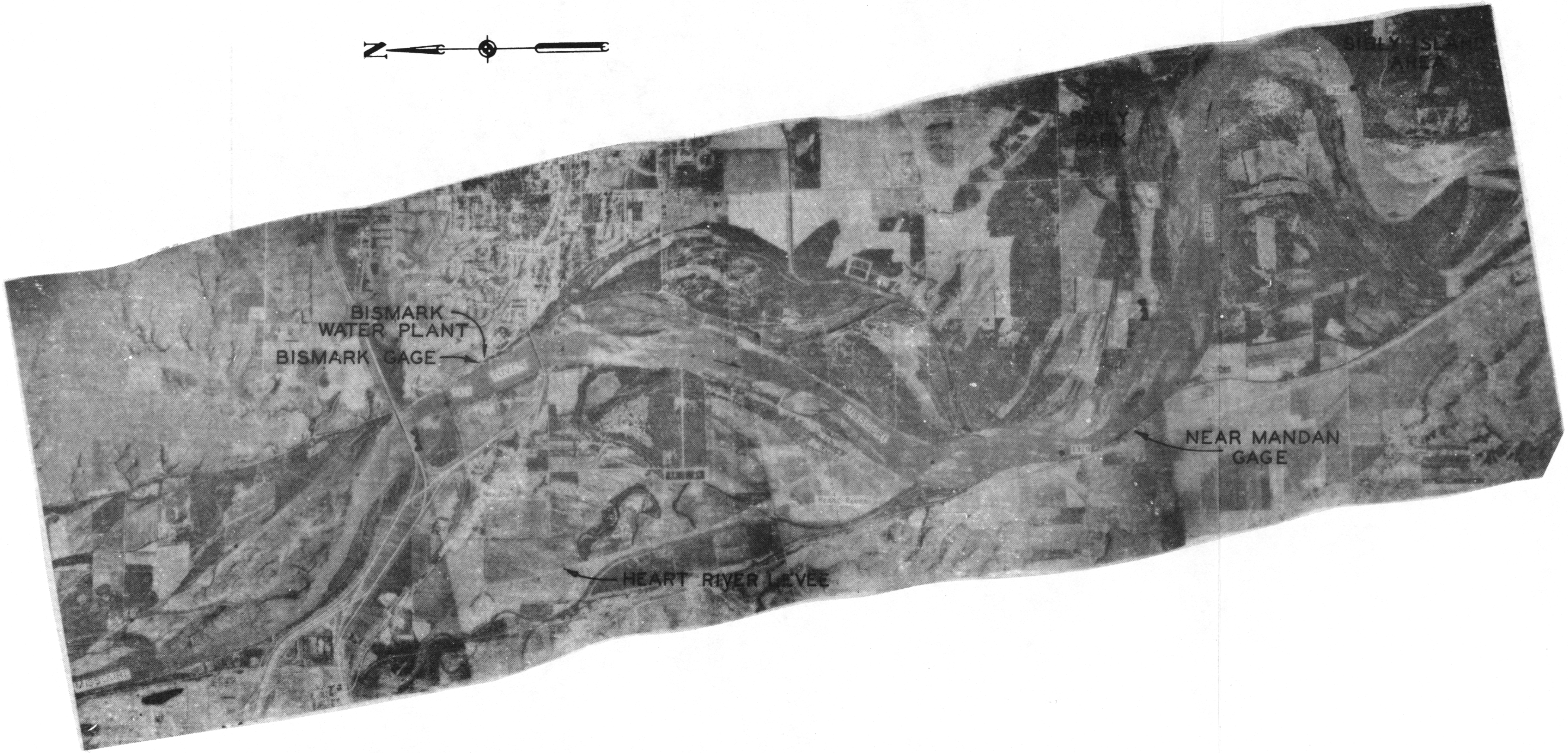
★ U.S. GOVERNMENT PRINTING OFFICE: 1972-



MISSOURI RIVER VALLEY
BELOW GARRISON DAM



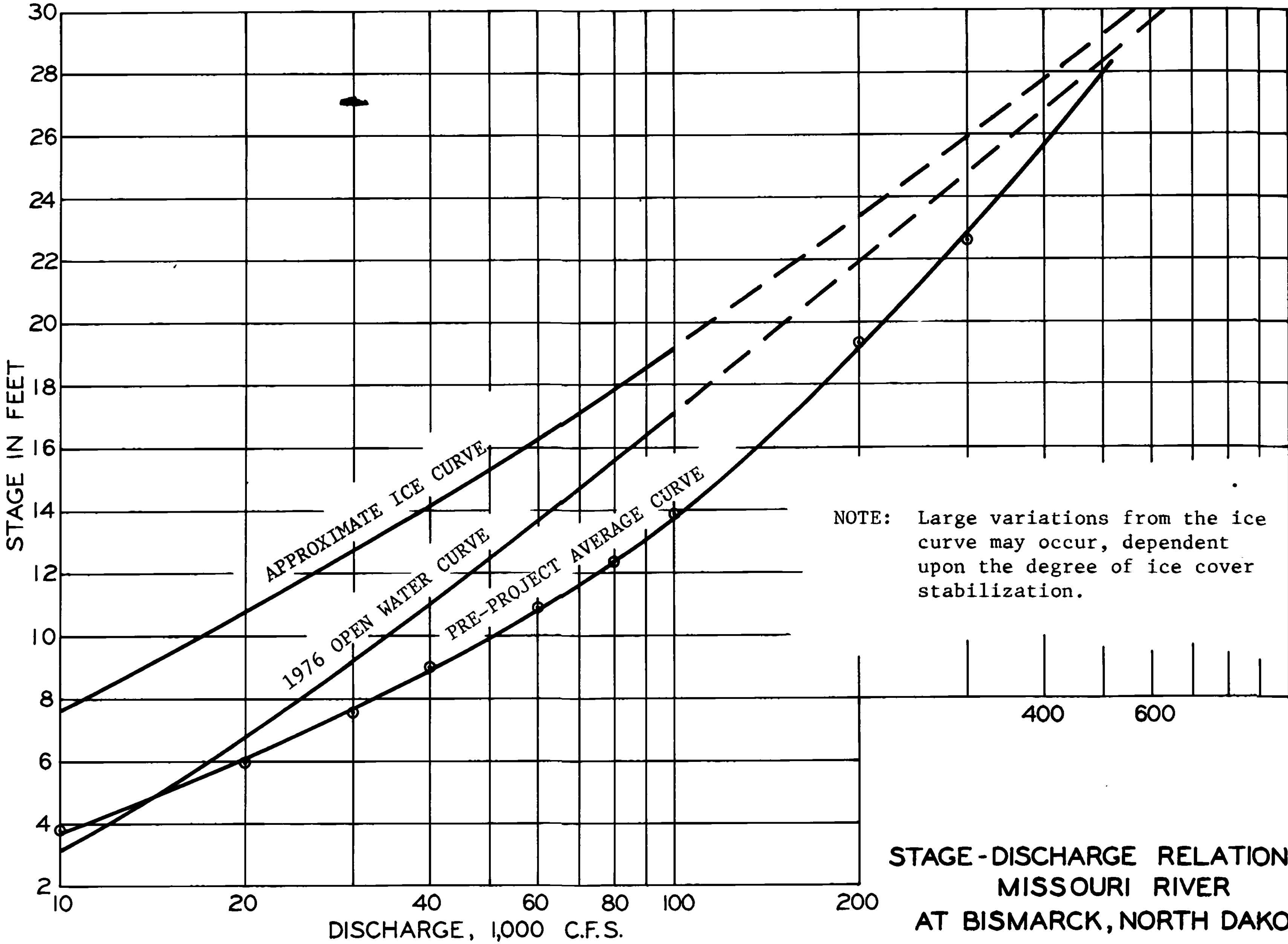
MISSOURI RIVER VALLEY
BELOW GARRISON DAM



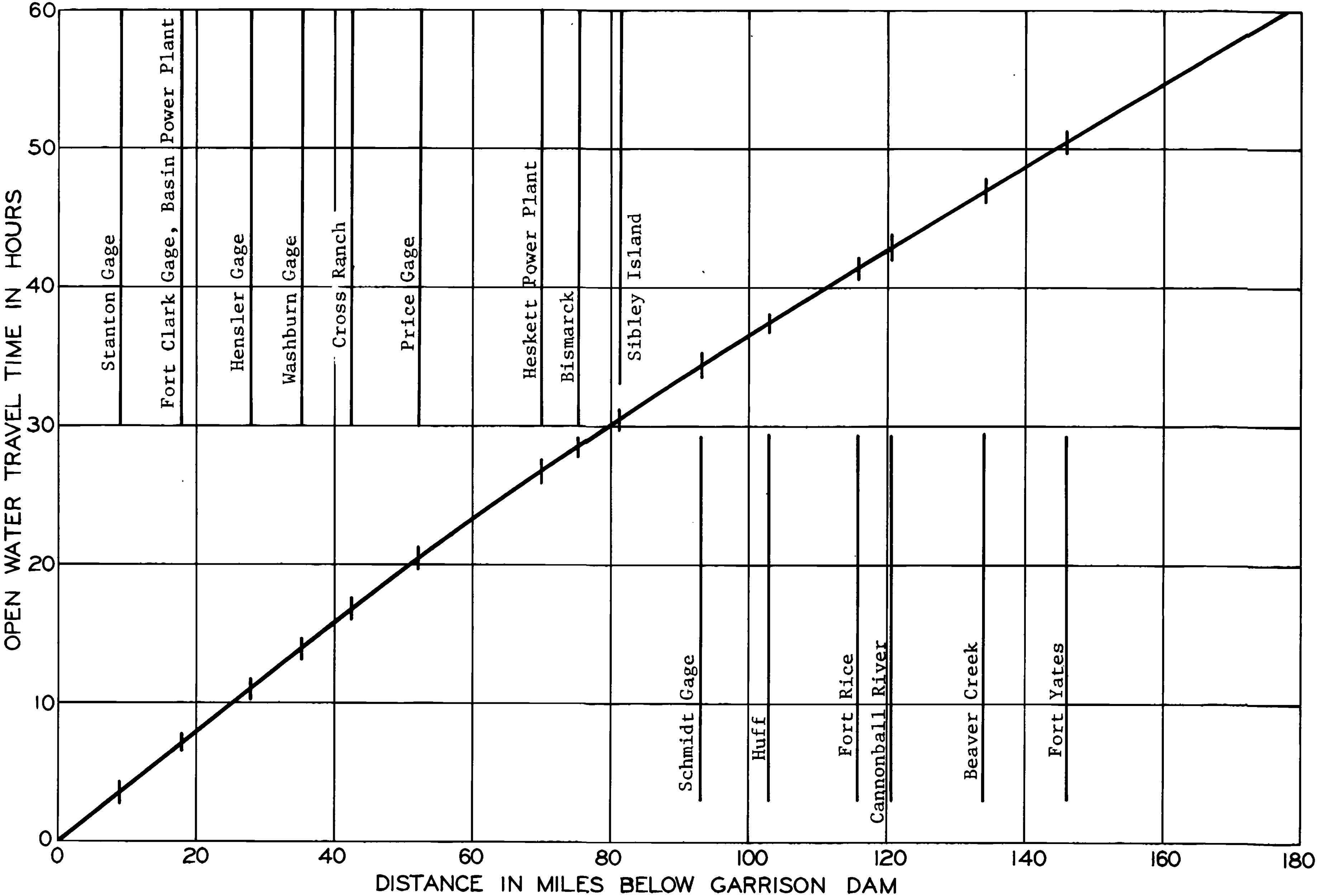
MISSOURI RIVER VALLEY
BELOW GARRISON DAM

PLATE 9

PLATE 10

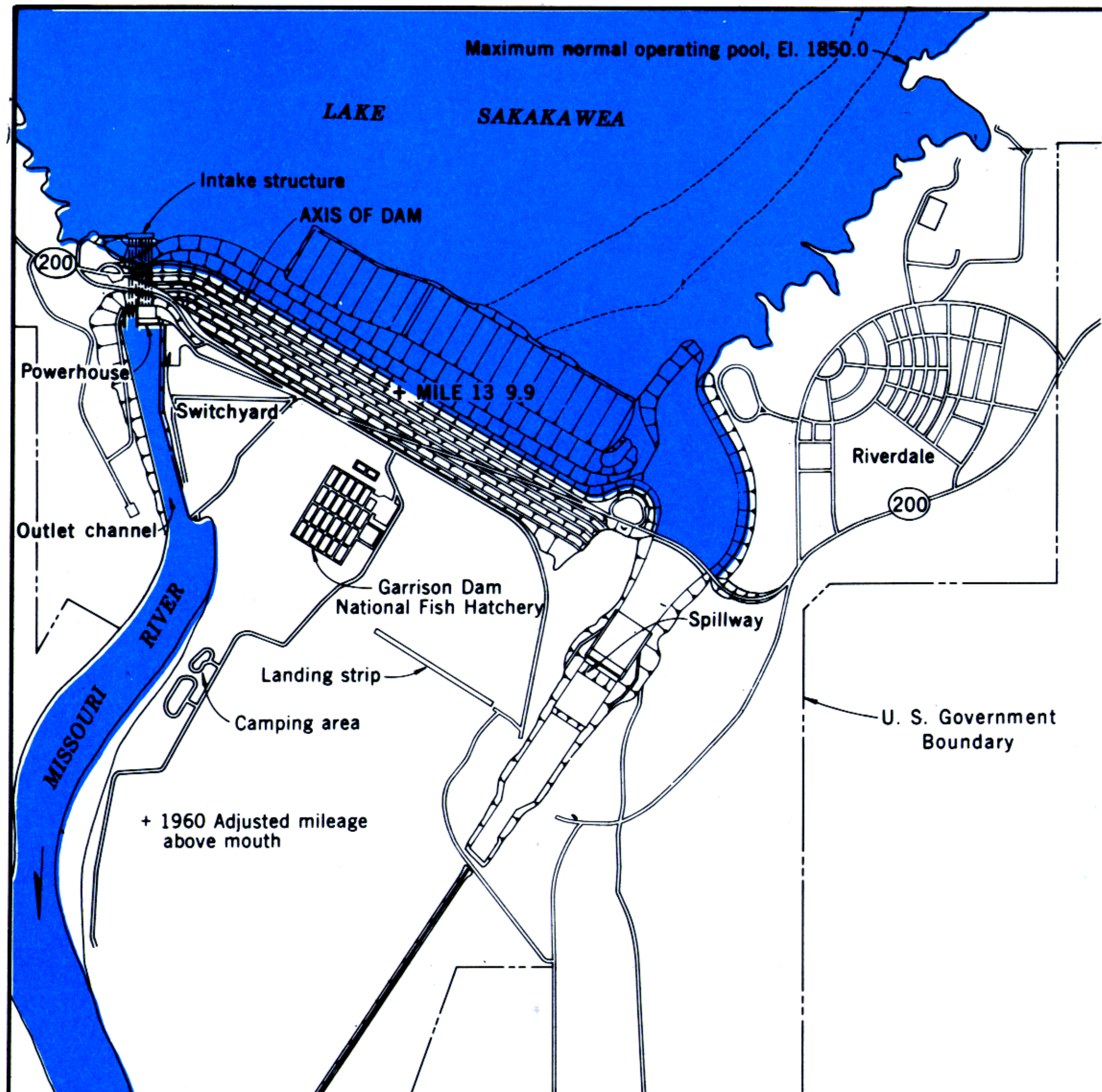


STAGE-DISCHARGE RELATIONSHIPS
MISSOURI RIVER
AT BISMARCK, NORTH DAKOTA

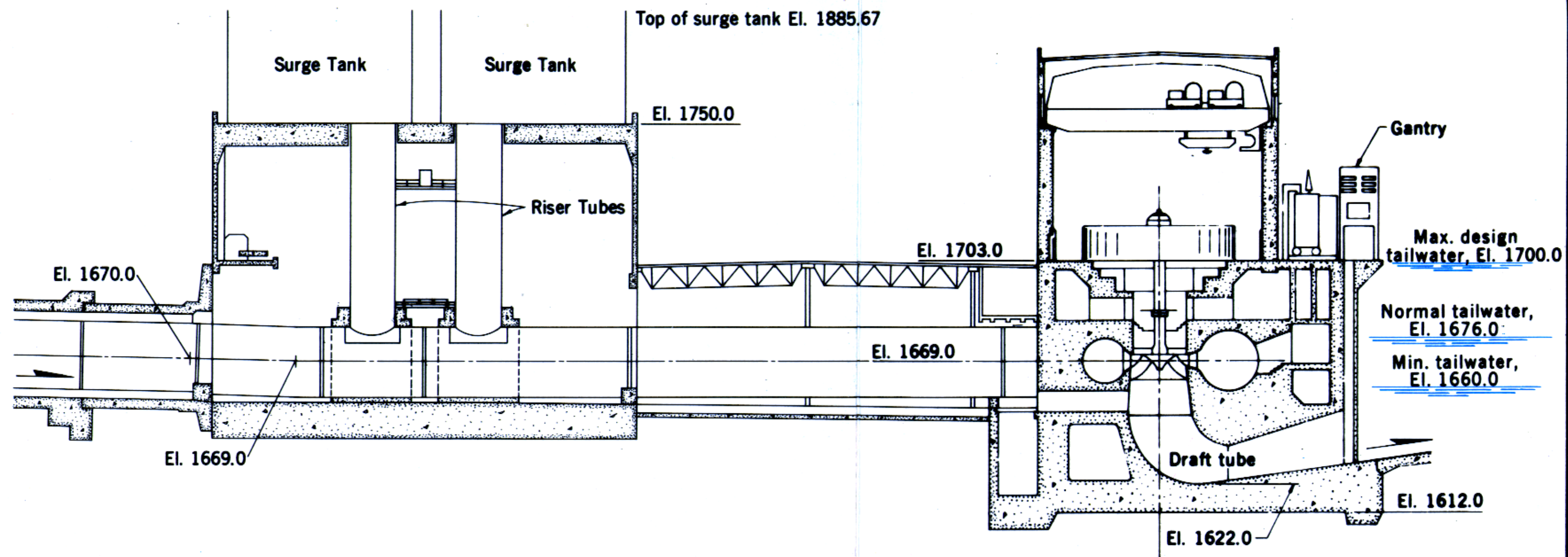


OPEN WATER TRAVEL TIME
BELOW GARRISON DAM

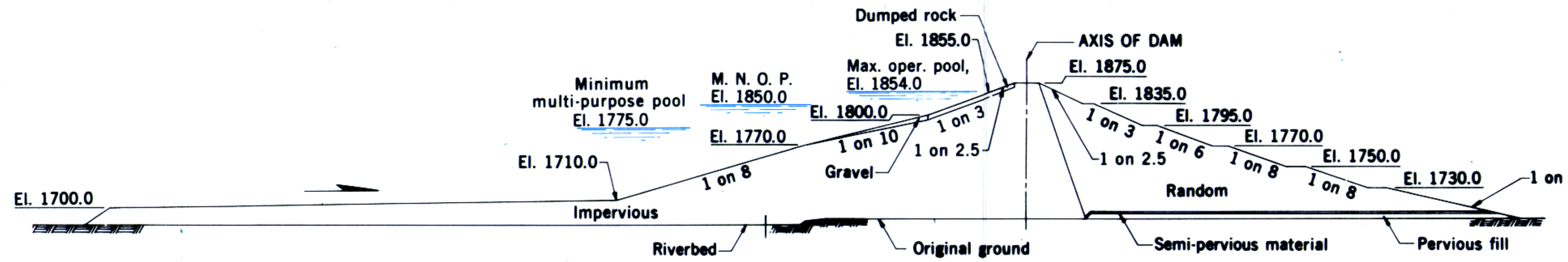
PLATE 11



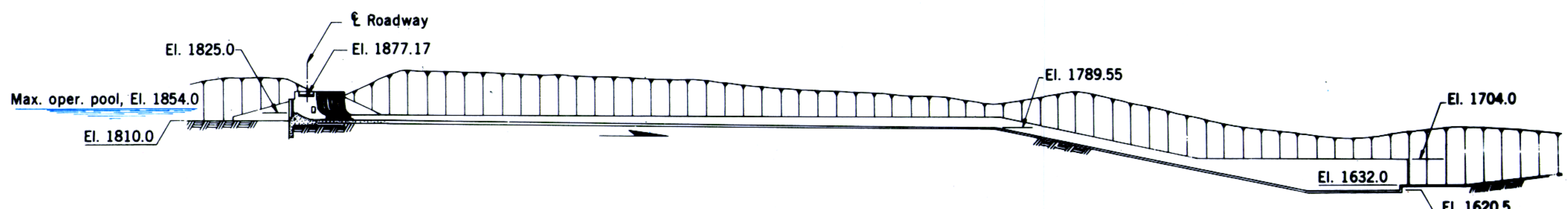
PLAN



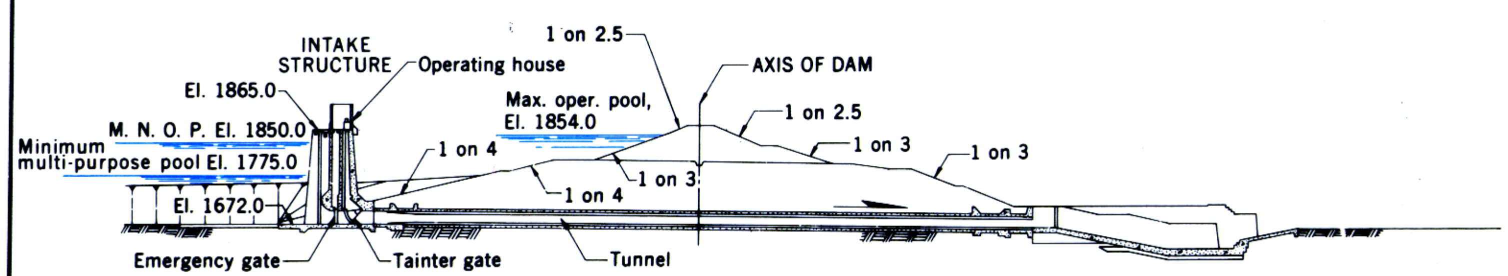
POWERHOUSE SECTION



EMBANKMENT SECTION

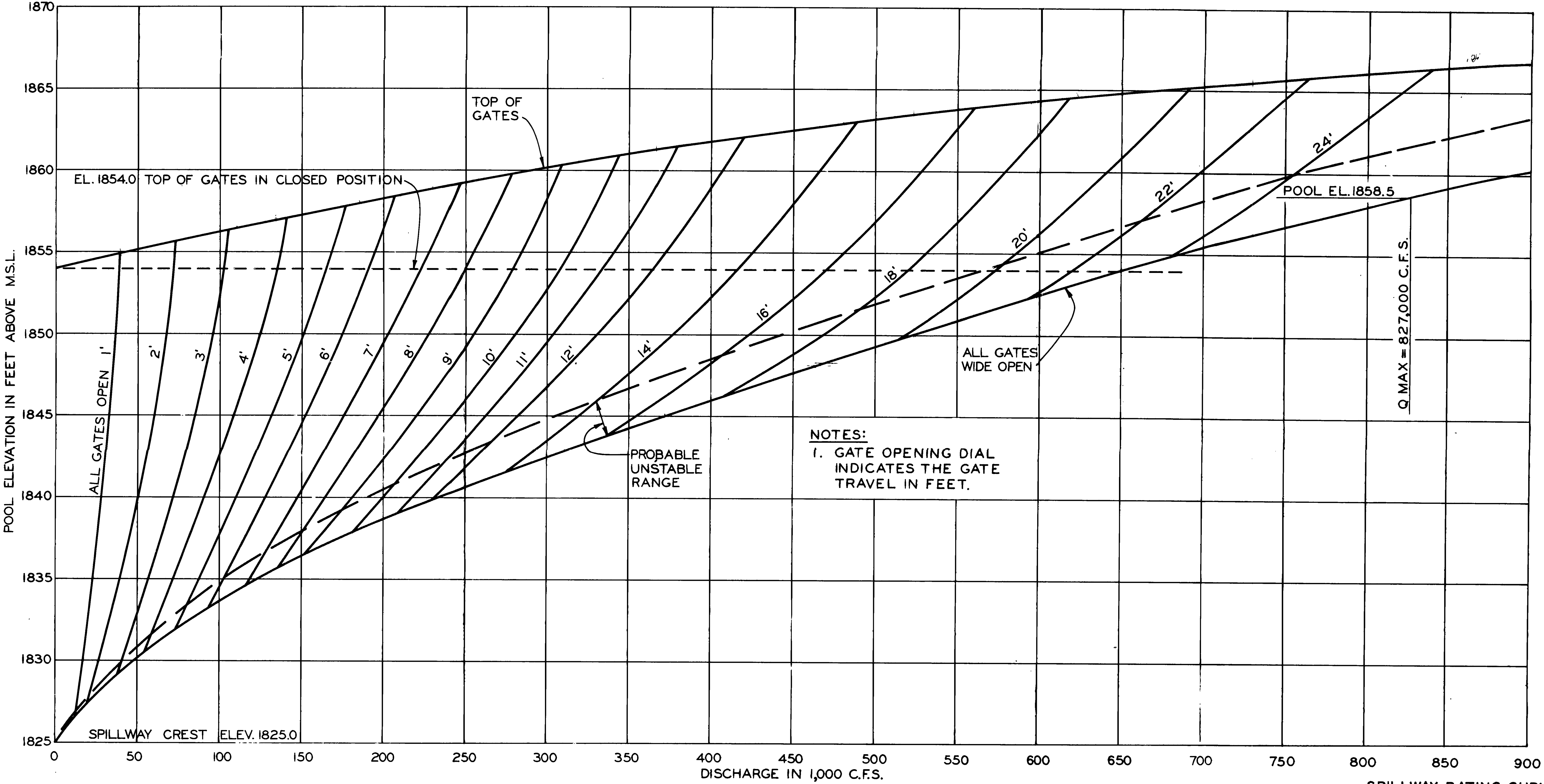


SPILLWAY PROFILE

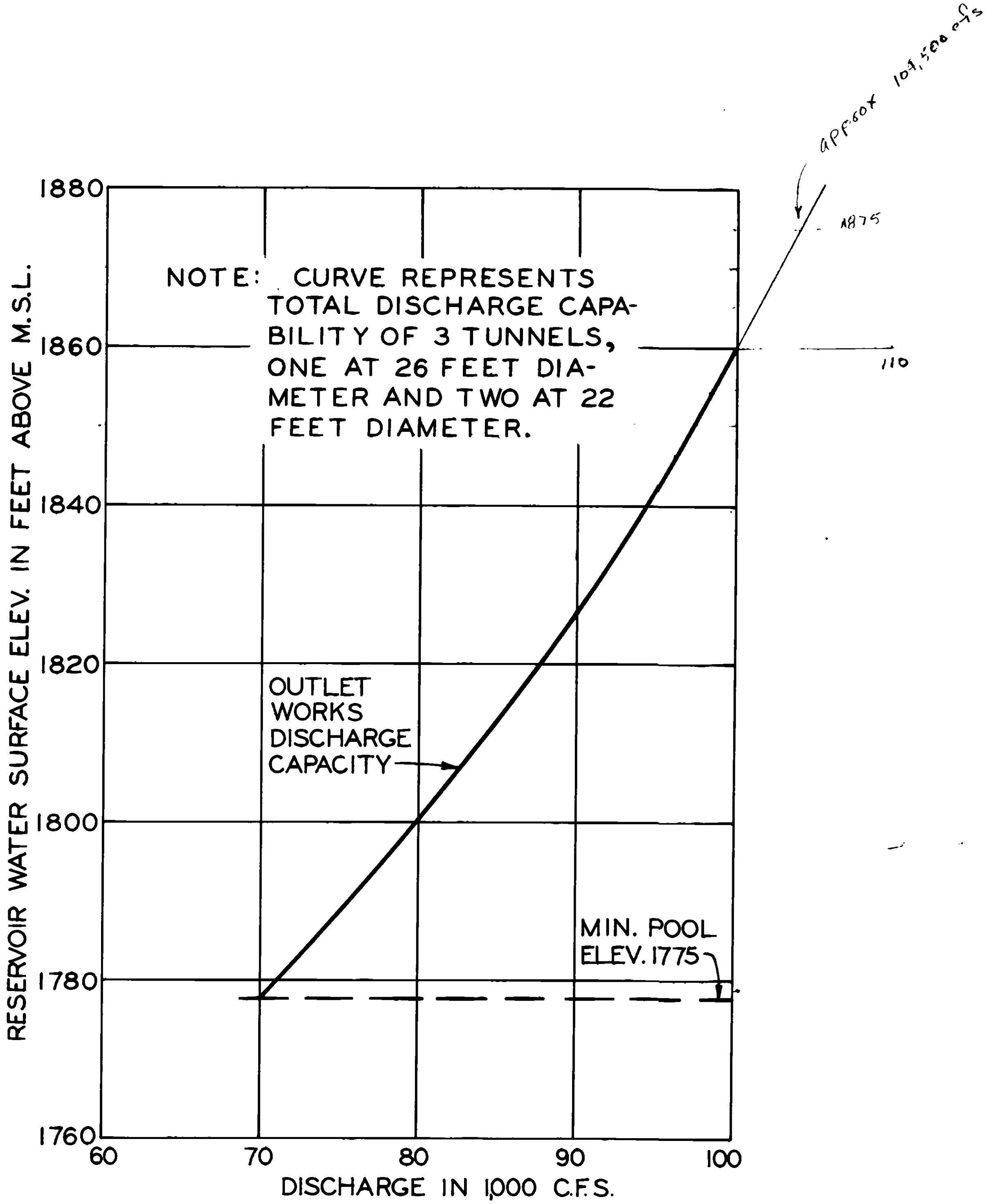


OUTLET WORKS PROFILE

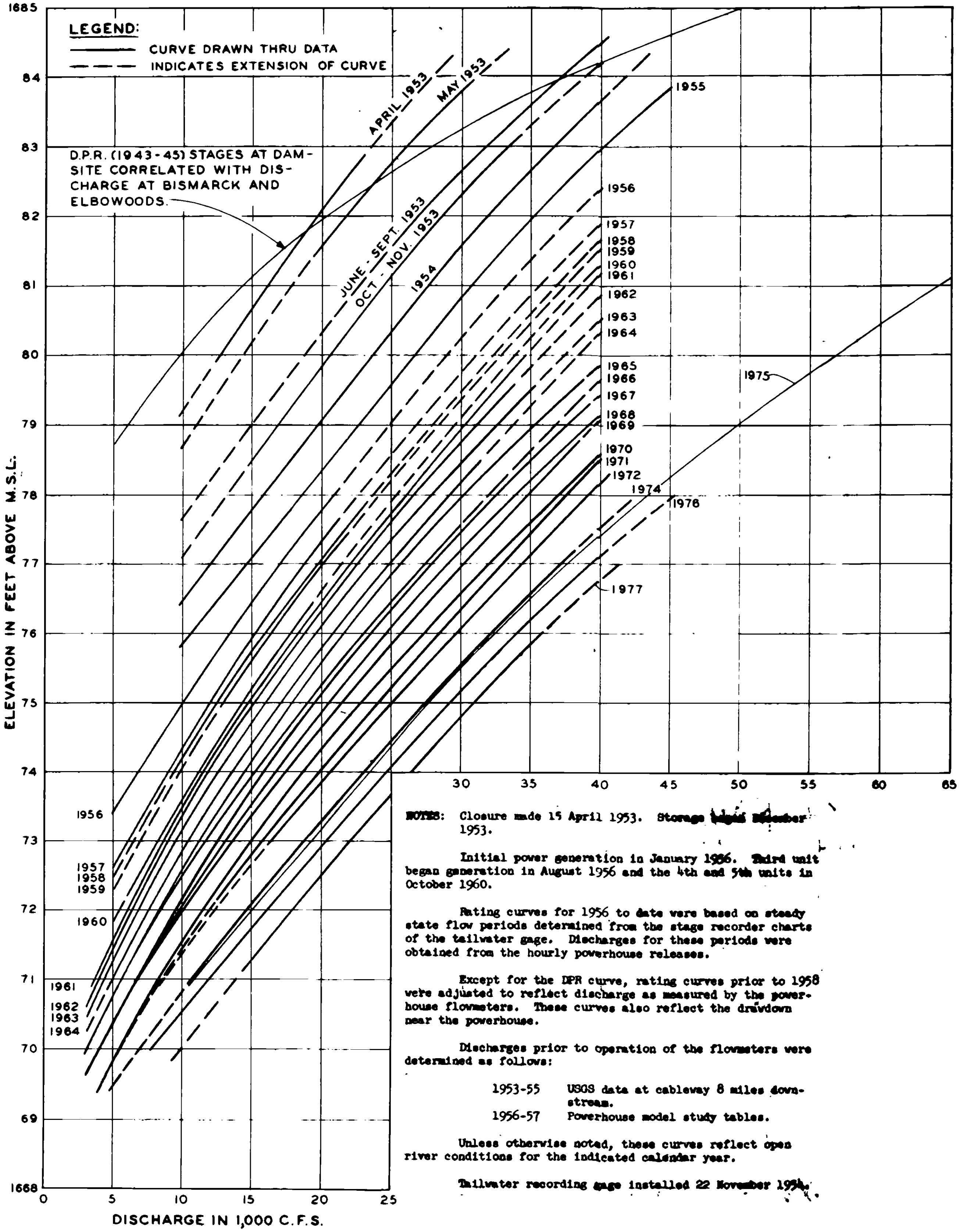
PROJECT LAYOUT
GARRISON PROJECT



SPILLWAY RATING CURVES
GARRISON PROJECT



DISCHARGE RATING CURVE
FOR
FLOOD CONTROL TUNNELS



NOTES: Closure made 15 April 1953. Storage [illegible] [illegible] 1953.

Initial power generation in January 1956. Third unit began generation in August 1956 and the 4th and 5th units in October 1960.

Rating curves for 1956 to date were based on steady state flow periods determined from the stage recorder charts of the tailwater gage. Discharges for these periods were obtained from the hourly powerhouse releases.

Except for the DPR curve, rating curves prior to 1958 were adjusted to reflect discharge as measured by the powerhouse flowmeters. These curves also reflect the drawdown near the powerhouse.

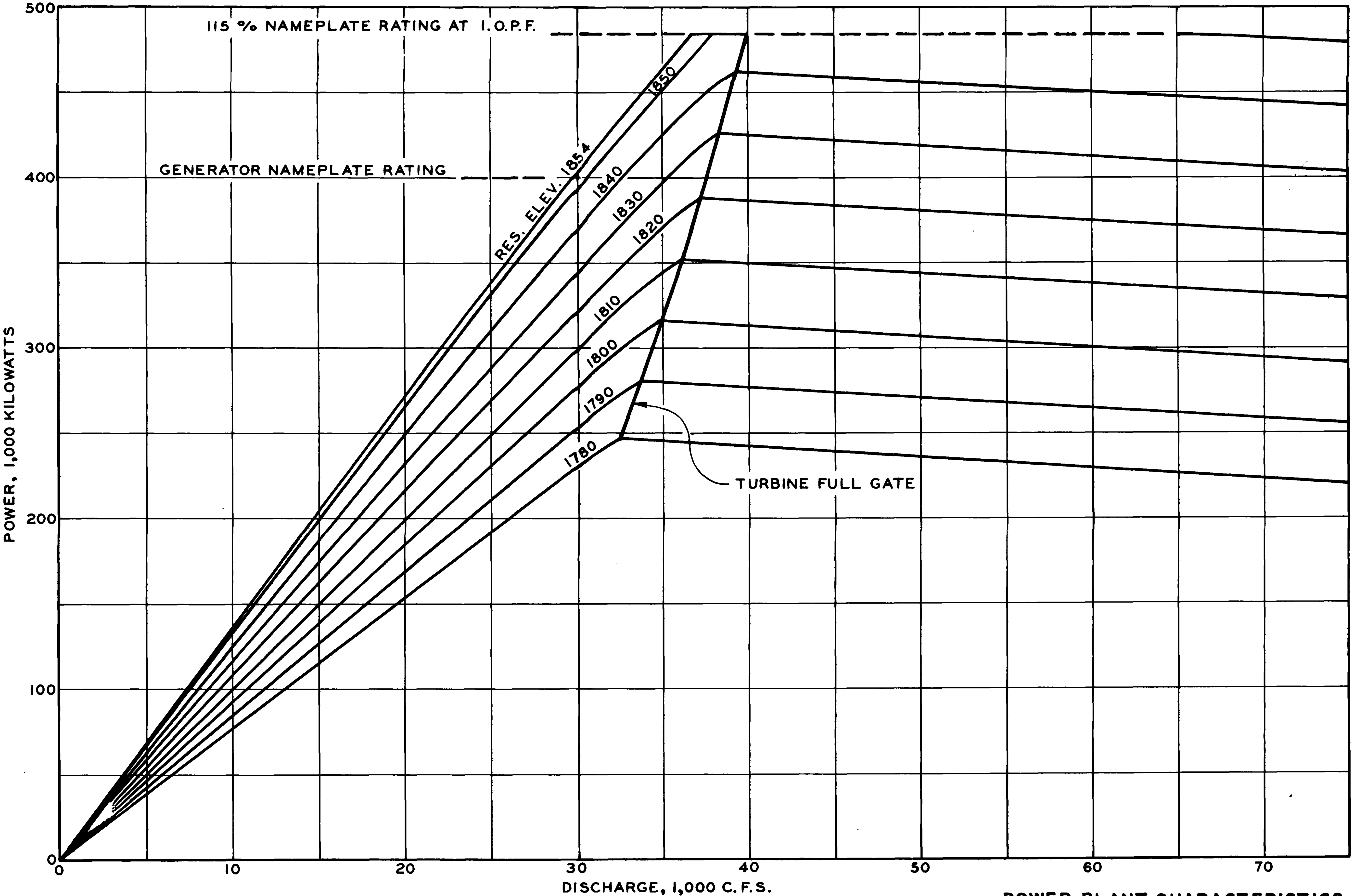
Discharges prior to operation of the flowmeters were determined as follows:

1953-55	USGS data at cableway 8 miles downstream.
1956-57	Powerhouse model study tables.

Unless otherwise noted, these curves reflect open river conditions for the indicated calendar year.

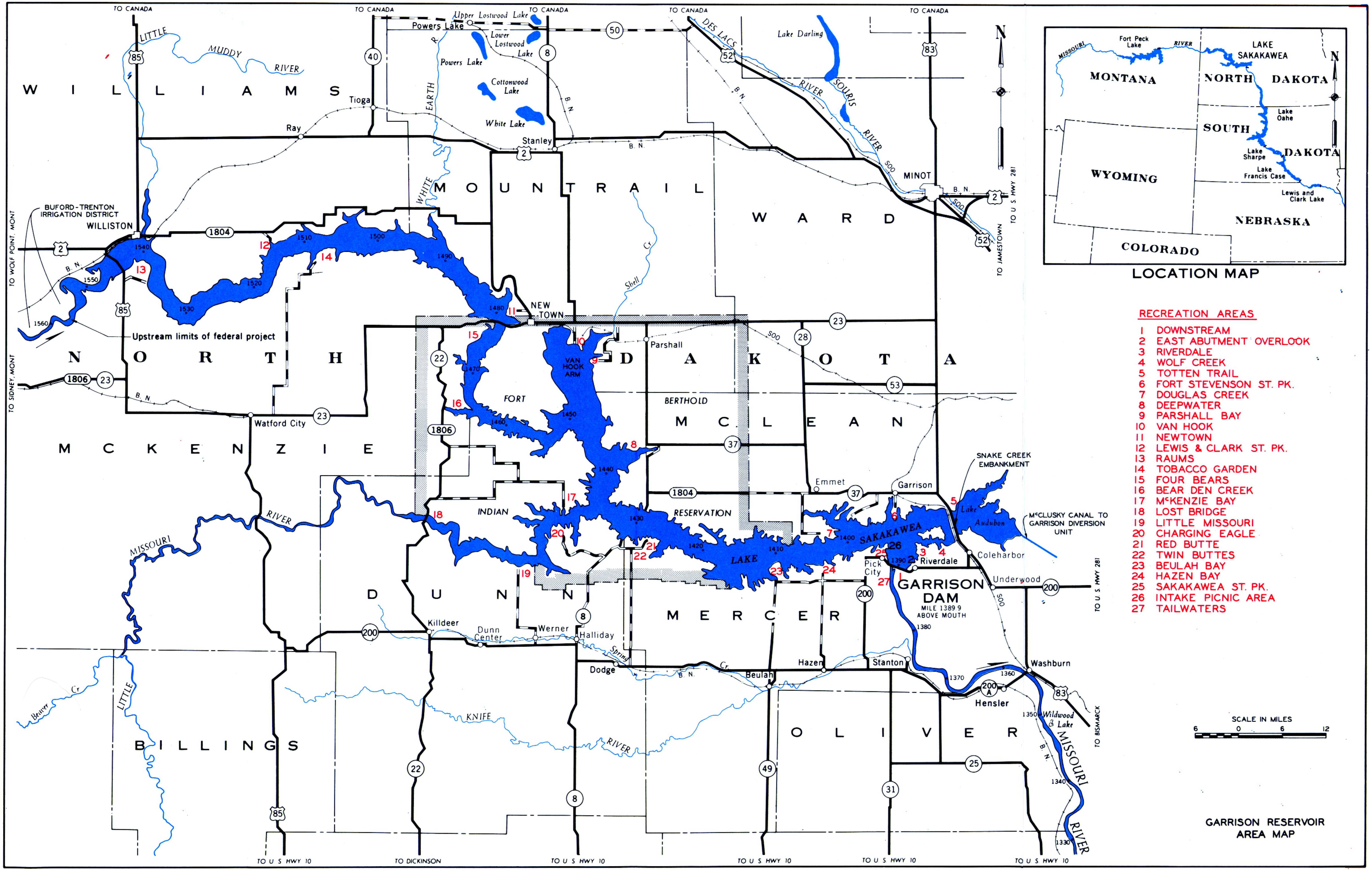
Tailwater recording gage installed 22 November 1954.

GARRISON PROJECT
TAILWATER RATING CURVES
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA



POWER PLANT CHARACTERISTICS
GARRISON PROJECT

PLATE 16



GARRISON RESERVOIR
AREA MAP
LOCATION MAP
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
NEBRASKA
COLORADO
LAKE SAKAKAWEA
Fort Peck Lake
Lake Oahe
Lake Sharpe
Lake Francis Case
Lewis and Clark Lake
RECREATION AREAS
1 DOWNSTREAM
2 EAST ABUTMENT OVERLOOK
3 RIVERDALE
4 WOLF CREEK
5 TOTTEN TRAIL
6 FORT STEVENSON ST. PK.
7 DOUGLAS CREEK
8 DEEPWATER
9 PARSHALL BAY
10 VAN HOOK
11 NEWTOWN
12 LEWIS & CLARK ST. PK.
13 RAUMS
14 TOBACCO GARDEN
15 FOUR BEARS
16 BEAR DEN CREEK
17 McKENZIE BAY
18 LOST BRIDGE
19 LITTLE MISSOURI
20 CHARGING EAGLE
21 RED BUTTE
22 TWIN BUTTES
23 BEULAH BAY
24 HAZEN BAY
25 SAKAKAWEA ST. PK.
26 INTAKE PICNIC AREA
27 TAILWATERS
SCALE IN MILES
6 0 6 12
GARRISON DAM
MILE 1389.9 ABOVE MOUTH
LAKE SAKAKAWEA
WILLIAMS
MOUNTRAIL
WARD
NORTH DAKOTA
McKENZIE
McLEAN
DUNN
MERCER
OLIVER
BILLINGS
FORT BERTHOLD INDIAN RESERVATION
VAN HOOK ARM
Lake Audubon
SNAKE CREEK EMBANKMENT
McCLUSKY CANAL TO GARRISON DIVERSION UNIT
BUFORD-TRENTON IRRIGATION DISTRICT
Upstream limits of federal project
WILLISTON
NEW TOWN
Parshall
Garrison
Emmet
Coleharbor
Riverdale
Pick City
Underwood
Washburn
Hensler
Stanton
Hazen
Beulah
Dodge
Halliday
Werner
Dunn Center
Killdeer
Watford City
Stanley
Tioga
Ray
Powers Lake
MINOT
Lake Darling
Upper Lostwood Lake
Lower Lostwood Lake
Cottonwood Lake
White Lake
Wildwood Lake
MISSOURI RIVER
LITTLE MISSOURI
LITTLE MUDDY RIVER
KNIFE RIVER
SOURIS RIVER
DES LACS
WHITE EARTH
Shell Cr.
Spring Cr.
Beaver Cr.
TO CANADA
TO U S HWY 10
TO DICKINSON
TO BISMARCK
TO JAMESTOWN
TO WOLF POINT, MONT
TO SIDNEY, MONT

PLATE 17

GARRISON PROJECT

AREA IN ACRES EFFECTIVE 1 JUL 1971

(1969 SURVEY)

ELEV	0	1	2	3	4	5	6	7	8	9
1660	0	0	0	0	0	0	0	0	0	23
1670	50	85	114	136	164	209	252	301	338	345
1680	390	445	483	563	701	913	1216	1530	1832	2360
1690	2943	3344	3781	4358	5078	5813	6447	7115	7947	8942
1700	10006	11002	11963	12964	14003	15042	16049	17072	18153	19292
1710	20424	21501	22612	23830	25154	26507	27799	29093	30463	31909
1720	33343	34701	36109	37668	39377	41086	42671	44318	46187	48278
1730	50527	52749	54827	56764	58560	60309	62129	63961	65721	67409
1740	69057	70724	72422	74134	75861	77602	79346	81073	82779	84463
1750	86123	87778	89459	91178	92934	94692	96419	98160	99955	101804
1760	103703	105607	107459	109240	110951	112670	114453	116197	117815	119307
1770	120663	121986	123462	125160	127078	129061	130925	132784	134781	136916
1780	139081	141158	143250	145465	147801	150169	152467	154769	157159	159639
1790	162084	164420	166845	169508	172410	175332	178075	180887	183997	187403
1800	190988	194502	197874	201158	204354	207501	210671	213881	217105	220344
1810	223593	226840	230077	233304	236521	239742	242977	246201	249393	252557
1820	255681	258790	261946	265175	268478	271842	275204	278506	281738	284901
1830	287896	290779	293887	297396	301304	305247	308890	312649	316907	321664
1840	326791	331874	336608	340978	344983	348881	352974	357078	360959	364616
1850	368139	371710	375393	379150	382981	386849	390693	394512	398332	402150
1860	405966									

GARRISON PROJECT

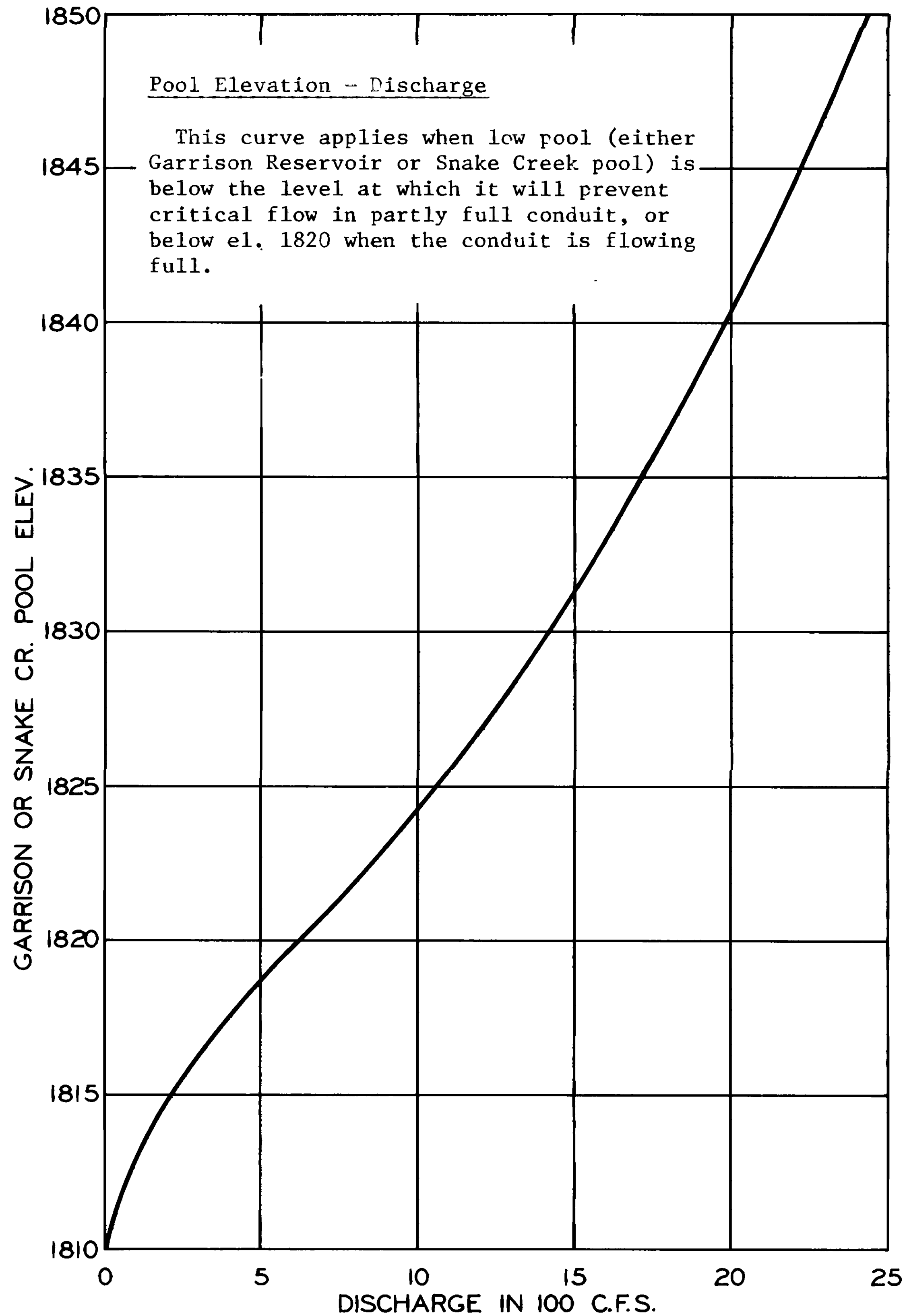
CAPACITY IN ACRE-FEET EFFECTIVE 1 JUL 1971

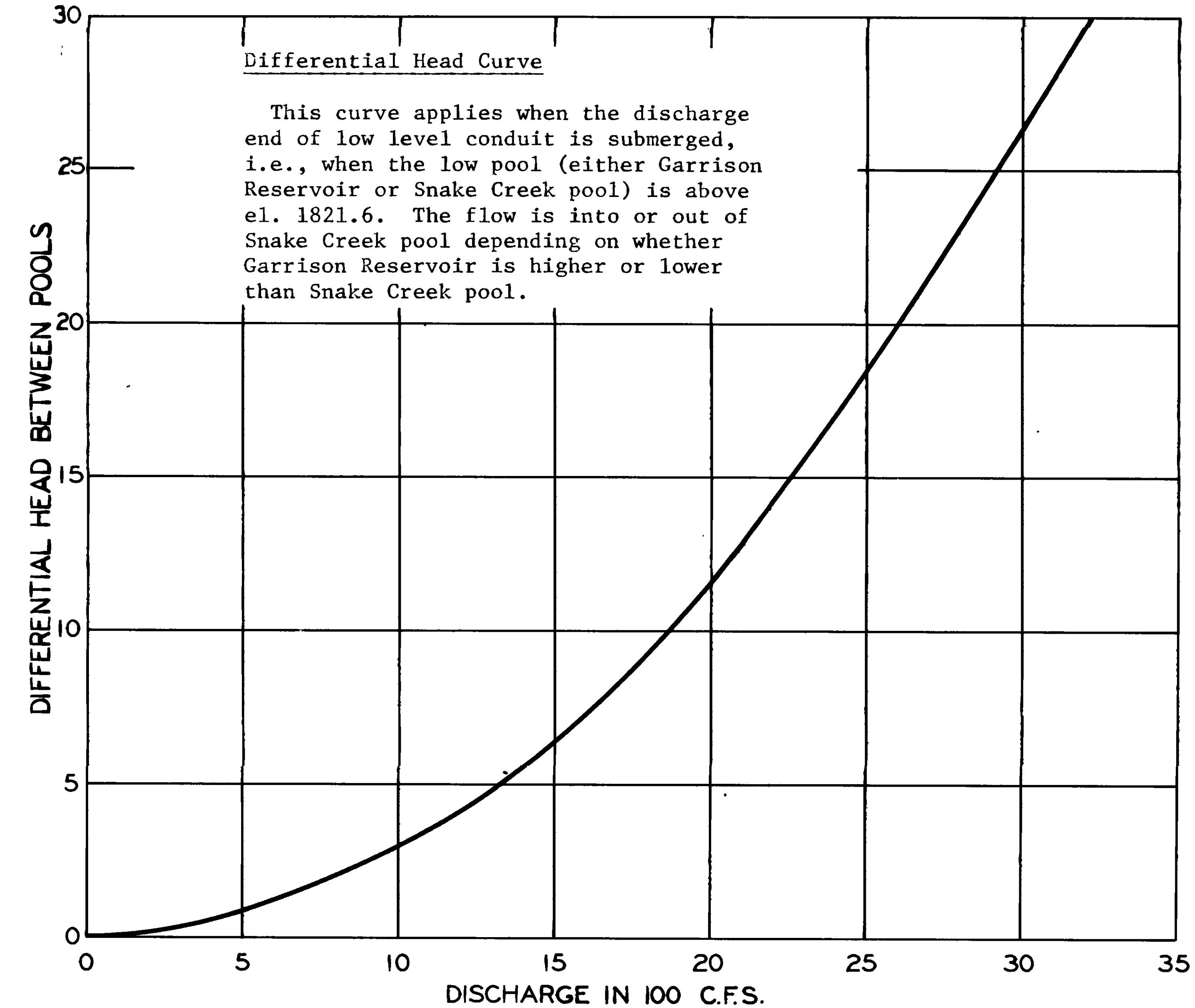
(1969 SURVEY)

ELEV	0	1	2	3	4	5	6	7	8	9
1660	0	0	0	0	0	0	0	0	0	11
1670	45	111	215	340	487	669	905	1174	1507	1850
1680	2198	2630	3089	3597	4216	5000	6043	7433	9103	11098
1690	13823	16984	20512	24546	29229	34702	40856	47596	55087	63490
1700	72971	83502	94975	107429	120903	135435	150987	167534	185132	203840
1710	223716	244698	266718	289913	314378	340222	367393	395820	425580	456747
1720	489398	523433	558801	595652	634137	674406	716310	759749	804947	852124
1730	901503	953179	1007002	1062833	1120530	1179953	1241149	1304212	1369071	1435654
1740	1503890	1573769	1645339	1718614	1793608	1870336	1948813	2029028	2110960	2194587
1750	2279887	2366834	2455443	2545752	2637799	2731621	2827183	2924459	3023503	3124369
1760	3227111	3331775	3438326	3546693	3656806	3768596	3882146	3997503	4114540	4233133
1770	4353155	4474459	4597128	4721384	4847448	4975541	5105571	5237391	5371139	5506953
1780	5644972	5785115	5927288	6071615	6218218	6367218	6518557	6672153	6828095	6986472
1790	7147374	7310641	7476215	7644332	7815232	7989153	8165896	8345303	8527671	8713297
1800	8902478	9095273	9291483	9491021	9693799	9899729	10108802	10321076	10536565	10755286
1810	10977253	11202472	11430933	11662626	11897542	12135669	12377027	12621624	12869429	13120411
1820	13374543	13631773	13892123	14155665	14422473	14692622	14966157	15243030	15523170	15806507
1830	16092973	16382299	16674532	16970074	17269324	17572683	17879819	18190464	18505118	18824279
1840	19148446	19477862	19812194	20151078	20494150	20841045	21191912	21546994	21906069	22268912
1850	22635302	23005190	23378723	23755976	24137023	24521938	24910722	25303324	25699747	26099988
1860	26504047									

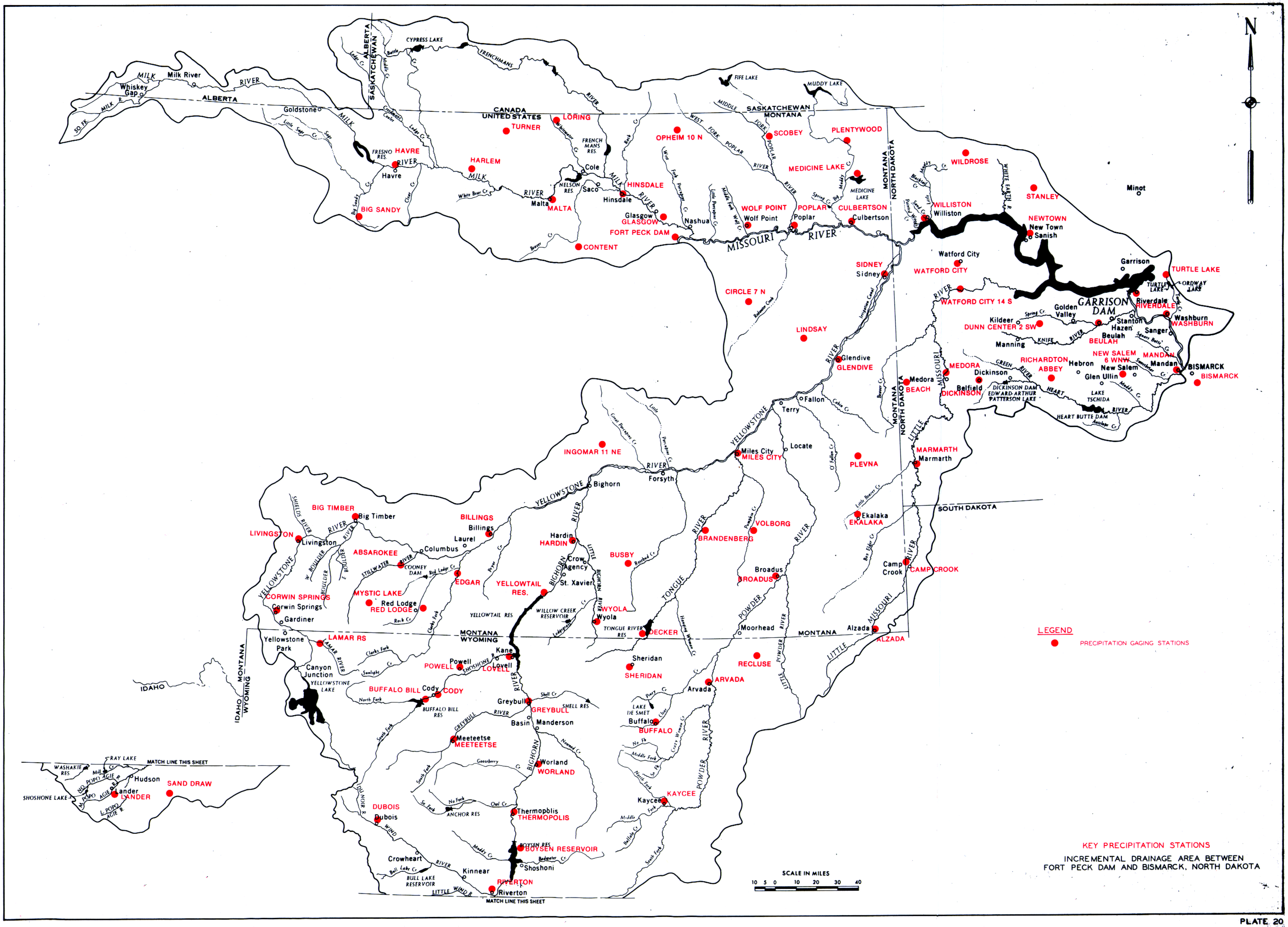
24521538
24137023
484915

AREA AND CAPACITY DATA
GARRISON RESERVOIR



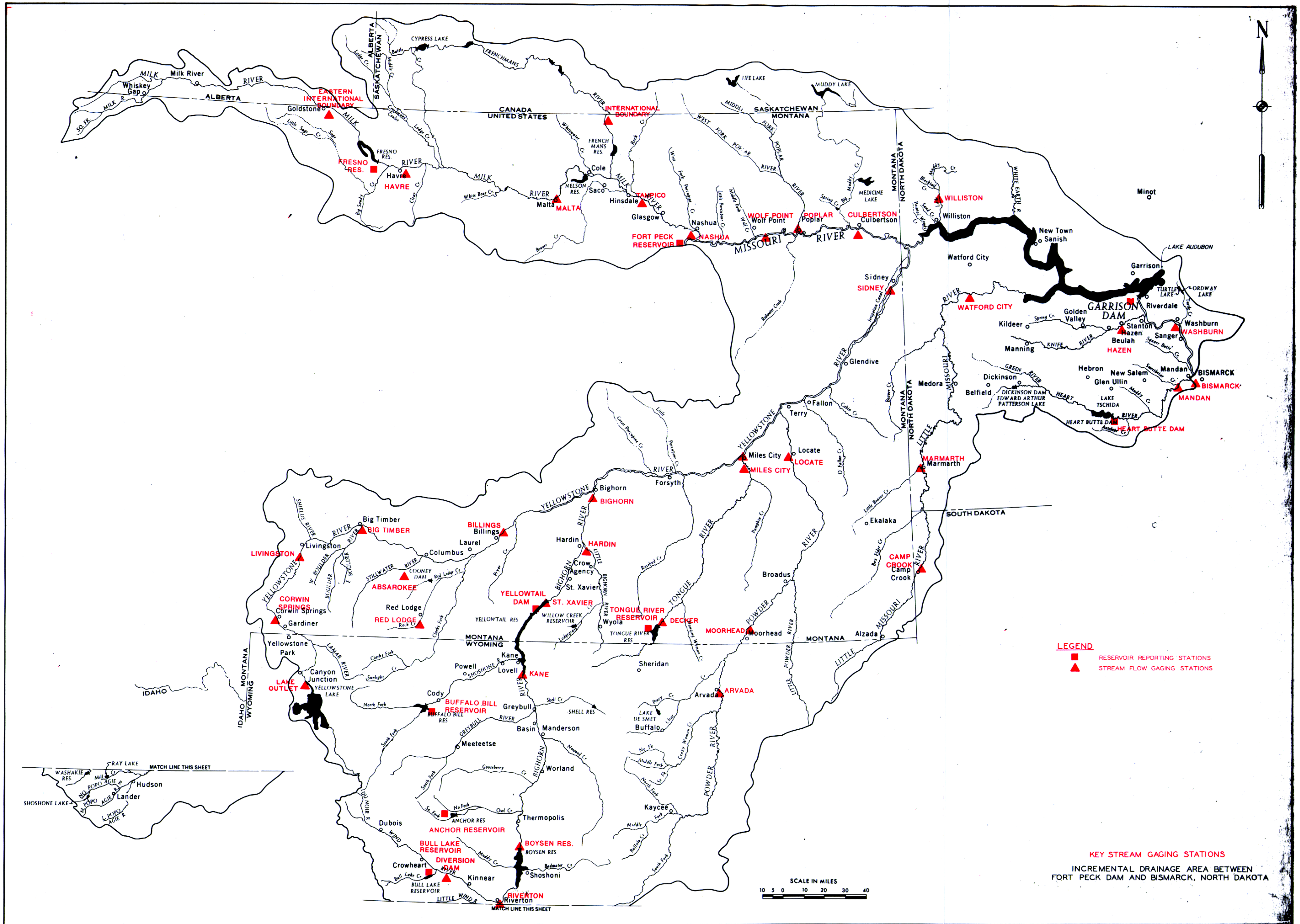


CONDUIT RATING CURVES
FOR
SNAKE CREEK EMBANKMENT



KEY PRECIPITATION STATIONS
INCREMENTAL DRAINAGE AREA BETWEEN
FORT PECK DAM AND BISMARCK, NORTH DAKOTA

PLATE 20


KEY STREAM GAGING STATIONS
INCREMENTAL DRAINAGE AREA BETWEEN
FORT PECK DAM AND BISMARCK, NORTH DAKOTA
LEGEND
RESERVOIR REPORTING STATIONS
STREAM FLOW GAGING STATIONS
SCALE IN MILES
10 5 0 10 20 30 40
N
CANADA
UNITED STATES
ALBERTA
SASKATCHEWAN
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
IDAHO
EASTERN INTERNATIONAL BOUNDARY
INTERNATIONAL BOUNDARY
FRESNO RES.
HAVRE
MALTA
TAMPICO
FORT PECK RESERVOIR
NASHUA
WOLF POINT
POPLAR
CULBERTSON
WILLISTON
SIDNEY
WATFORD CITY
GARRISON DAM
WASHBURN
HAZEN
BISMARCK
MANDAN
HEART BUTTE DAM
MARMARTH
LOCATE
MILES CITY
BIGHORN
BILLINGS
BIG TIMBER
LIVINGSTON
HARDIN
ABSAROKEE
CORWIN SPRINGS
RED LODGE
YELLOWTAIL DAM
ST. XAVIER
TONGUE RIVER RESERVOIR
DECKER
MOORHEAD
CAMP CROOK
LAKE OUTLET
KANE
BUFFALO BILL RESERVOIR
ARVADA
ANCHOR RESERVOIR
BOYSEN RES.
BULL LAKE RESERVOIR
DIVERSION DAM
RIVERTON
MILK RIVER
MISSOURI RIVER
YELLOWSTONE RIVER
BIGHORN RIVER
TONGUE RIVER
POWDER RIVER
LITTLE MISSOURI RIVER
WIND R.
MATCH LINE THIS SHEET
PLATE

STAGE-DISCHARGE TABLE FOR SELECTED KEY GAGING STATIONS BETWEEN FORT PECK DAM AND BISMARCK, NORTH DAKOTA

Gage Height (Feet)	Milk River at Tampico, Montana Gage Datum 2110 msl (CFS)	Milk River at Nashua, Montana Gage Datum 2027.75 msl (CFS)	Missouri R. Near Wolf Point, Montana Gage Datum 1958.57 msl (CFS)	Missouri R. Near Culbertson, Montana Gage Datum 1883.4 msl (CFS)	Yellowstone River at Corwin Spgs, Montana Gage Datum 5079.09 msl (CFS)	Yellowstone River at Livingston, Montana Gage Datum 4542.49 msl (CFS)	Yellowstone River at Billings, Montana Gage Datum 3081.4 msl (CFS)	Yellowstone River at Miles City, Montana Gage Datum 2330.2 msl (CFS)	Yellowstone River at Sidney, Montana Gage Datum 1881.3 msl (CFS)	Little Mo. River at Marmarth, N. Dakota Gage Datum 2686.32 msl (CFS)	Little Mo. River at Watford C. N. Dakota Gage Datum 1929.03 msl (CFS)	Knife River at Hazen, N. Dakota Gage Datum 1712.35 msl (CFS)	Missouri River at Bismarck, N. Dakota Gage Datum 1618.38 msl (CFS)	Heart River Near Mandan, N. Dakota Gage Datum 1638.70 msl (CFS)
0	0	0	1,500	0	0	0	0	0	0	0	0	0	0	0
2	50	50	4,800	2,300	1,750	1,950	2,130	3,700	0	50	800	0	5,600	0
4	590	1,000	9,100	4,700	4,860	6,590	6,860	8,800	3,000	1,000	4,100	200	10,200	400
6	1,350	1,900	14,500	8,400	10,600	14,700	14,500	17,400	8,100	3,000	9,000	500	18,200	1,200
8	1,990	2,900	21,700	14,100	18,600	26,200	24,800	28,500	15,500	5,500	16,000	900	26,800	2,200
10	2,650	3,900	31,400	22,000	27,600	43,600	37,400	41,400	25,800	8,500	25,000	1,300	36,500	3,500
12	3,340	4,900	45,000	33,600	35,800		52,400	56,900	38,300	12,000	35,000	1,900	49,000	5,300
14	4,040	5,900		50,000	46,400			75,000	53,900	17,000	47,000	2,600	66,500	7,600
16	4,760	7,000		78,000					72,000	22,000	54,000	3,400	80,500	10,400
18	5,490	8,000							97,000	28,000		4,300	100,500	13,700
20	6,230	9,100							135,000	34,000		5,400	140,000	17,600
22	7,290	10,600								39,000		6,600	180,000	22,400
24	9,060	12,700								46,000		8,100	240,000	37,600
26		14,200										22,600	350,000	68,200
28		16,500											500,000	
30		21,500												

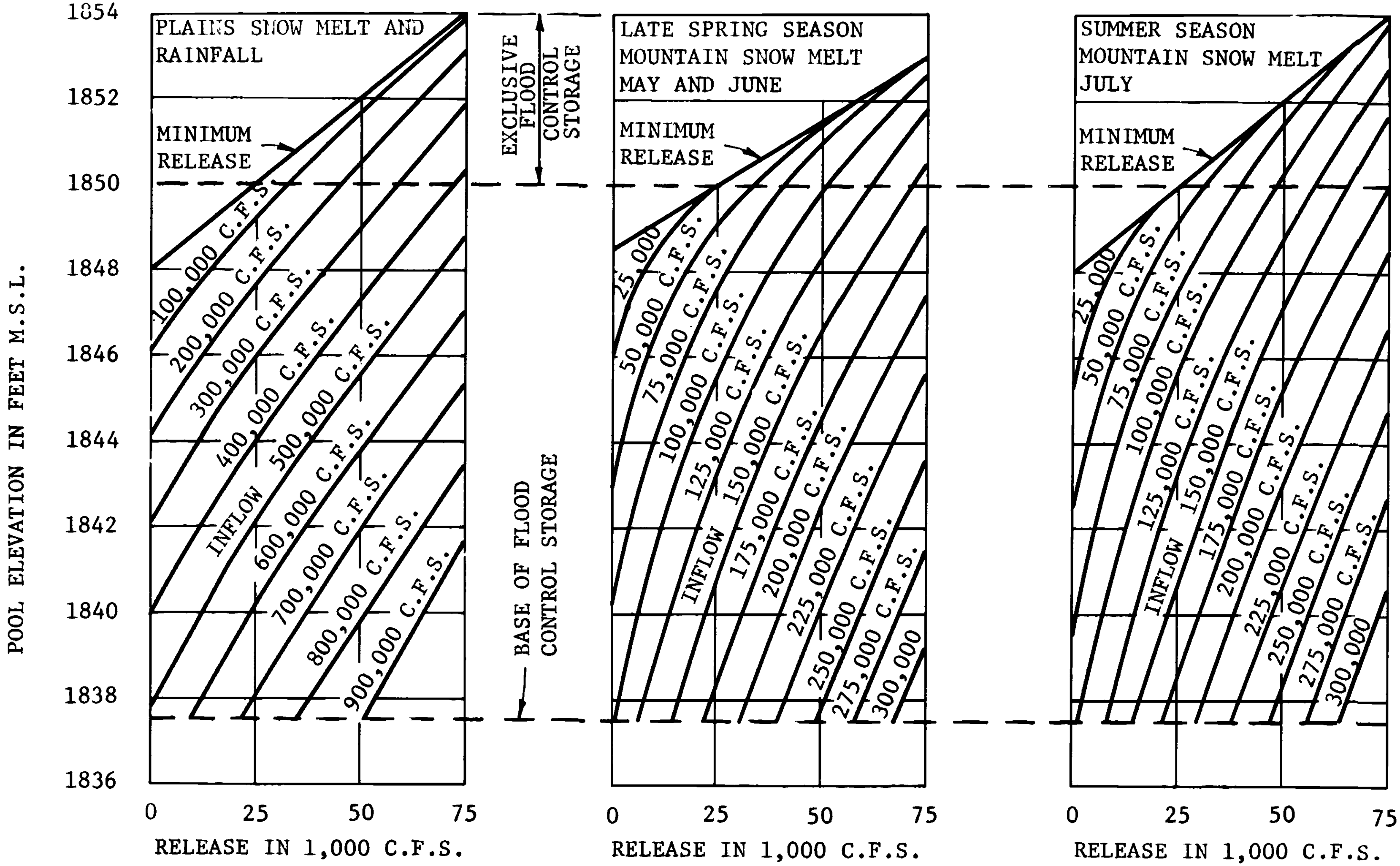
RESERVOIR ELEVATION CORRECTIONS AT THE GARRISON DAM

TO ALLOW FOR WIND TIDE EFFECTS

ELEVATION 1850 M. S. L.

(TRUE ELEVATION = REPORTED POOL ELEVATION + CORRECTION)

WIND DIR.	WIND SPEED - MILES PER HOUR														
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.4	-0.6	-0.7	-0.9
10	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.4
20	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
30	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.4	+0.4	+0.6	+0.7	+0.8	+0.9
40	+0.0	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.1	+1.4	+1.5	+1.9
50	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.9	+1.1	+1.4	+1.6	+2.0	+2.4	+2.7
60	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.1	+1.4	+1.7	+2.1	+2.5	+3.0	+3.4
70	+0.0	+0.0	+0.0	+0.1	+0.3	+0.5	+0.7	+1.0	+1.4	+1.7	+2.1	+2.5	+3.0	+3.5	+4.0
80	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.8	+1.2	+1.5	+1.9	+2.4	+2.9	+3.4	+3.9	+4.5
90	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.1	+2.6	+3.2	+3.7	+4.2	+4.8
100	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.3	+1.7	+2.2	+2.7	+3.3	+3.8	+4.4	+5.1
110	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.7	+2.2	+2.8	+3.3	+3.9	+4.5	+5.1
120	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.3	+1.7	+2.2	+2.7	+3.3	+3.8	+4.4	+5.1
130	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.1	+2.6	+3.2	+3.7	+4.2	+4.8
140	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.8	+1.2	+1.5	+1.9	+2.4	+2.9	+3.4	+3.9	+4.5
150	+0.0	+0.0	+0.0	+0.1	+0.3	+0.5	+0.7	+1.0	+1.4	+1.7	+2.1	+2.5	+3.0	+3.5	+4.0
160	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.1	+1.4	+1.7	+2.1	+2.5	+3.0	+3.4
170	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.9	+1.1	+1.4	+1.6	+2.0	+2.4	+2.7
180	+0.0	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.1	+1.4	+1.5	+1.9
190	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.4	+0.4	+0.6	+0.7	+0.8	+0.9
200	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
210	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.4
220	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.4	-0.6	-0.7	-0.9
230	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.6	-0.7	-1.1	-1.4	-1.7
240	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.8	-1.2	-1.5	-2.0	-2.4
250	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.8	-1.1	-1.5	-2.0	-2.5	-3.1
260	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-1.9	-2.4	-3.0	-3.6
270	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.7	-1.1	-1.5	-2.1	-2.7	-3.3	-4.0
280	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.8	-1.2	-1.7	-2.2	-2.8	-3.5	-4.3
290	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.6	-0.8	-1.2	-1.7	-2.3	-2.9	-3.6	-4.3
300	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.8	-1.2	-1.7	-2.2	-2.8	-3.5	-4.3
310	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.7	-1.1	-1.5	-2.1	-2.7	-3.3	-4.0
320	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-1.9	-2.4	-3.0	-3.6
330	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.8	-1.1	-1.5	-2.0	-2.5	-3.1
340	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.8	-1.2	-1.5	-2.0	-2.4
350	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.6	-0.7	-1.1	-1.4	-1.7

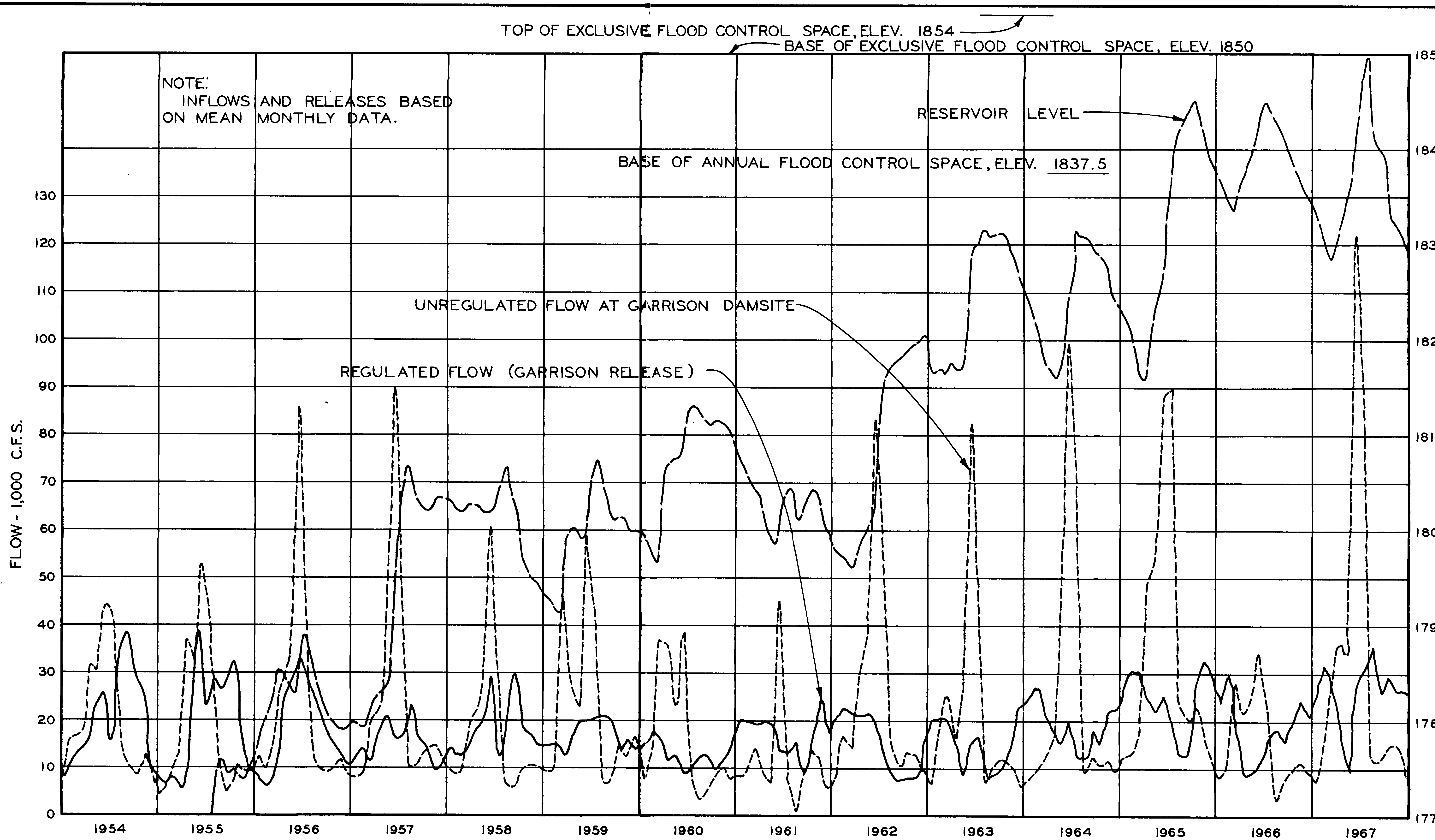


NOTES:

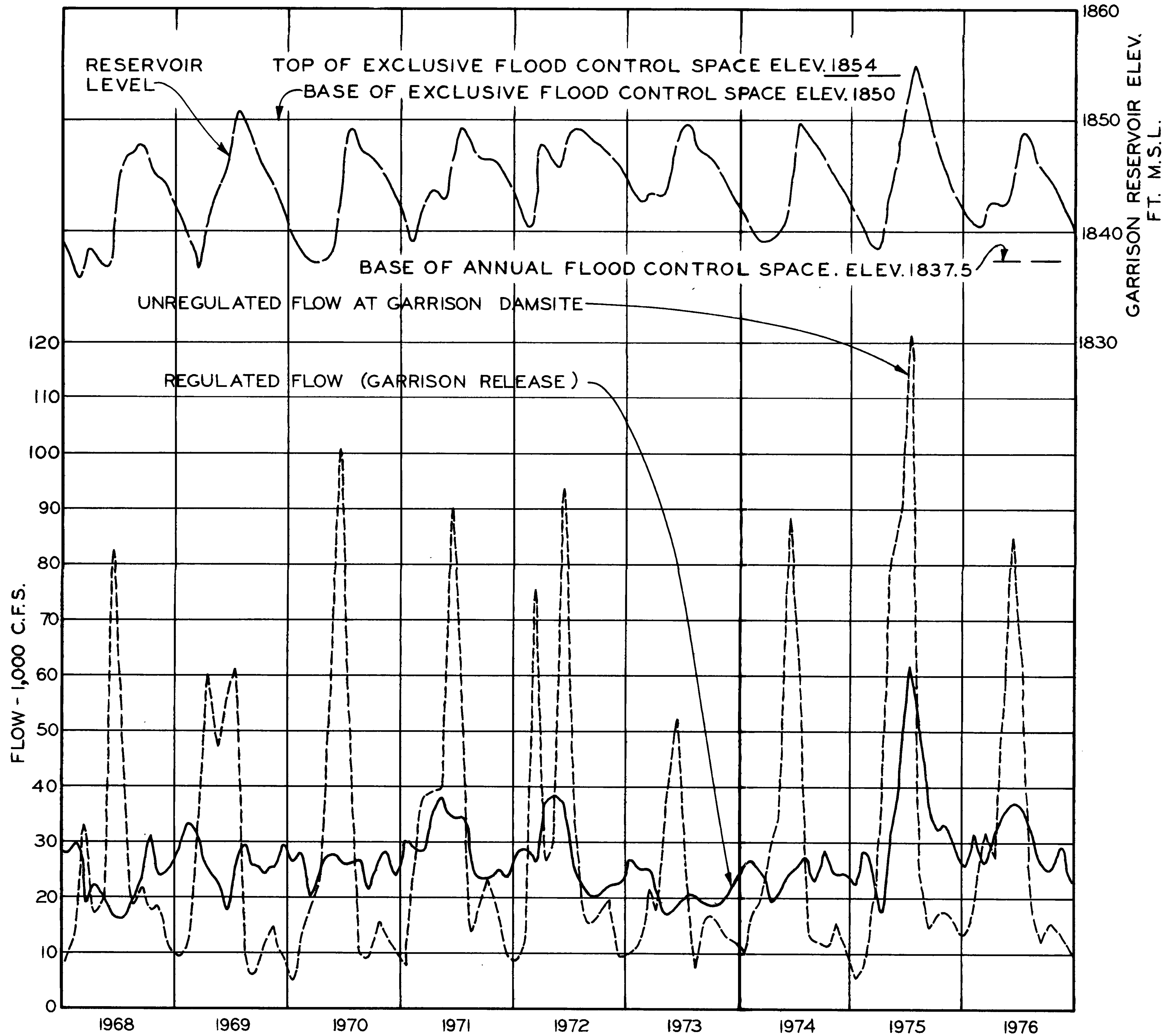
1. RELEASES ARE DETERMINED FROM POOL ELEVATION AND MEAN DAILY INFLOW.

2. CURVES ARE APPLICABLE FOR THE REGULATION OF MODERATE FLOODS SIMILAR TO THOSE OF PAST RECORD. FOR LARGER FLOODS, THE RULE CURVES INCLUDED IN THE EMERGENCY REGULATION PROCEDURES MAY BE USED AS REGULATION GUIDES.

EXCLUSIVE FLOOD CONTROL REGULATION CURVES

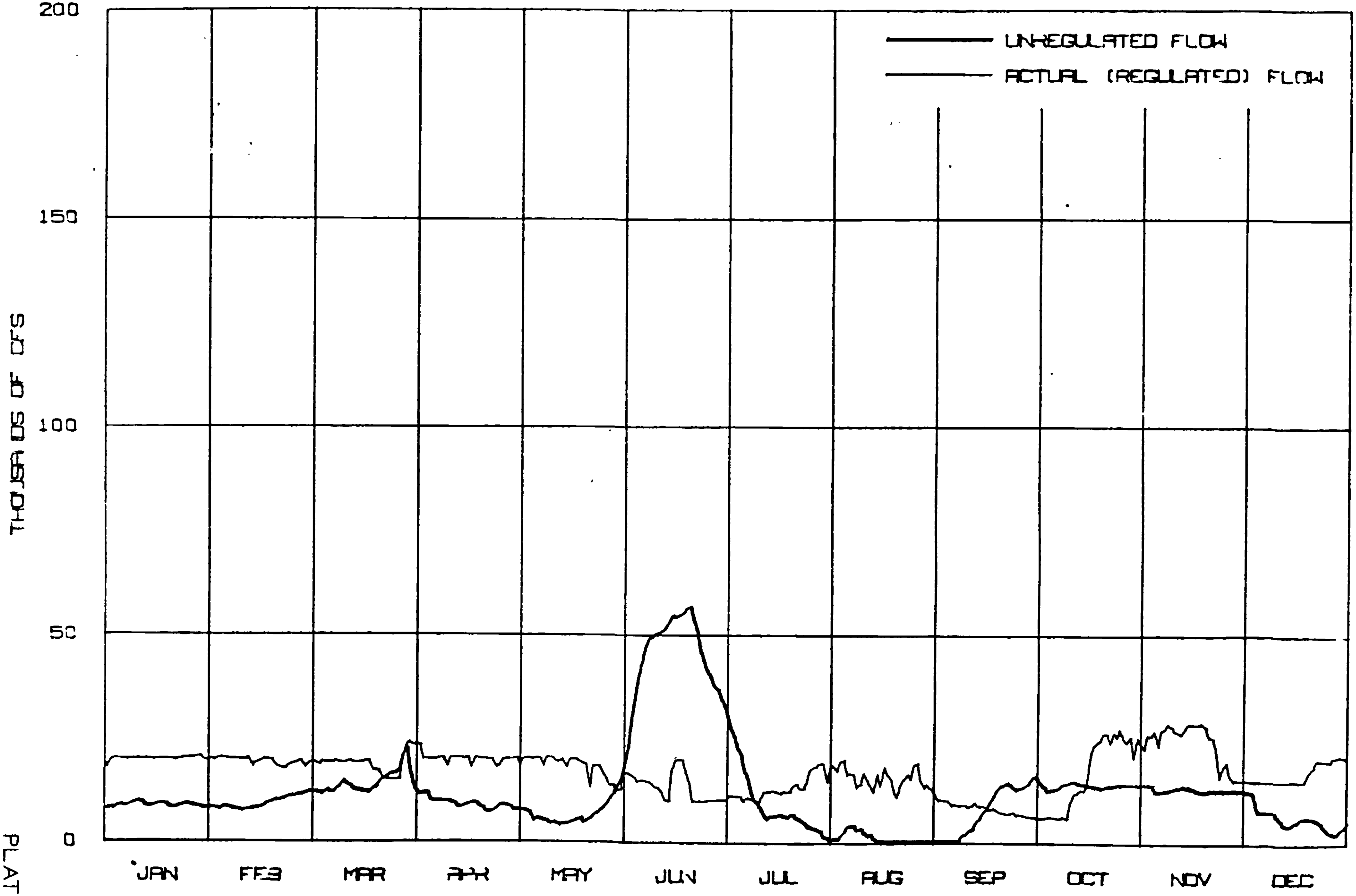


GARRISON REGULATION
1954 - 1967



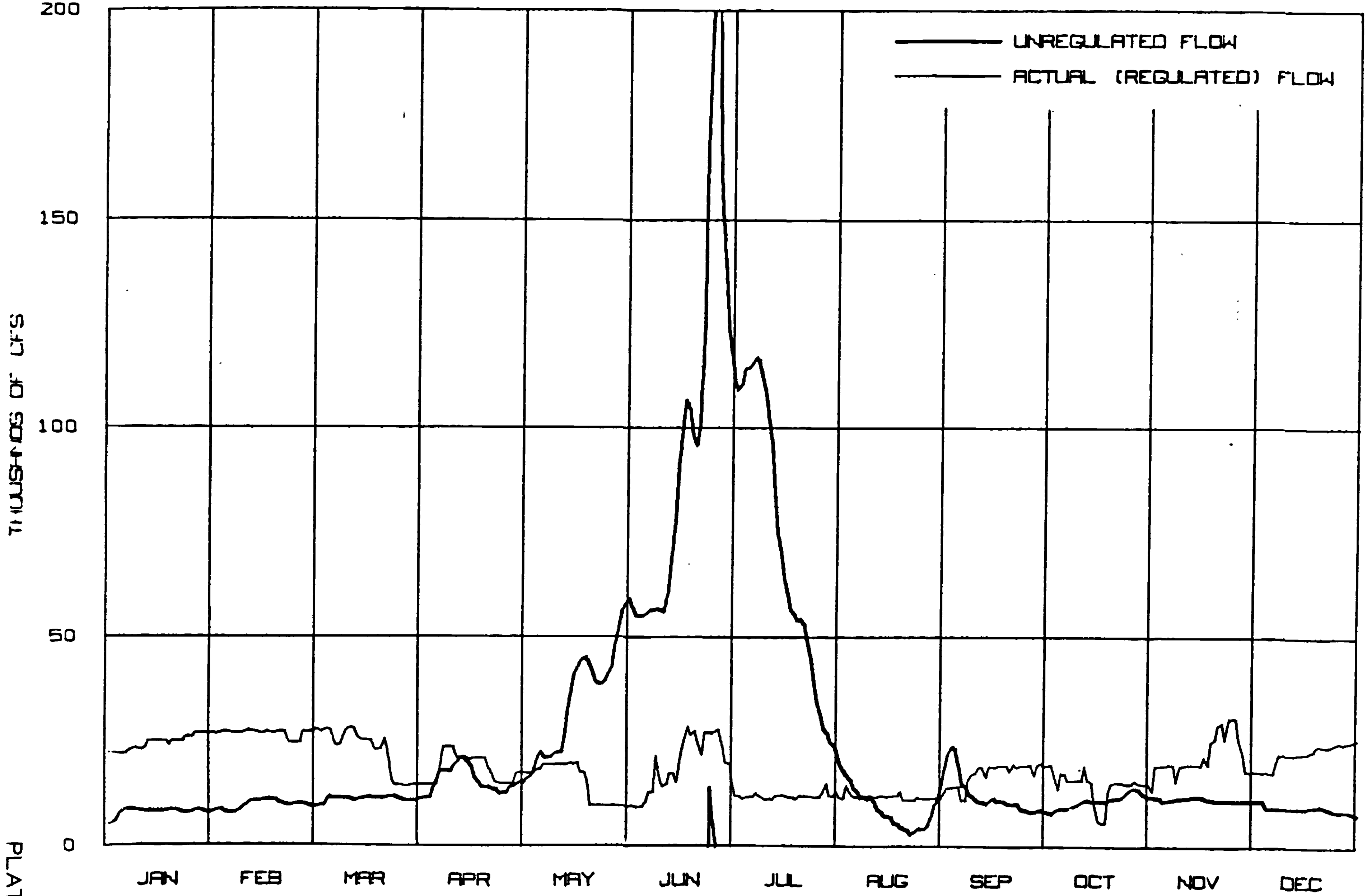
NOTE:
INFLOWS AND RELEASES BASED ON MEAN MONTHLY DATA.

GARRISON REGULATION
1968 - 1976

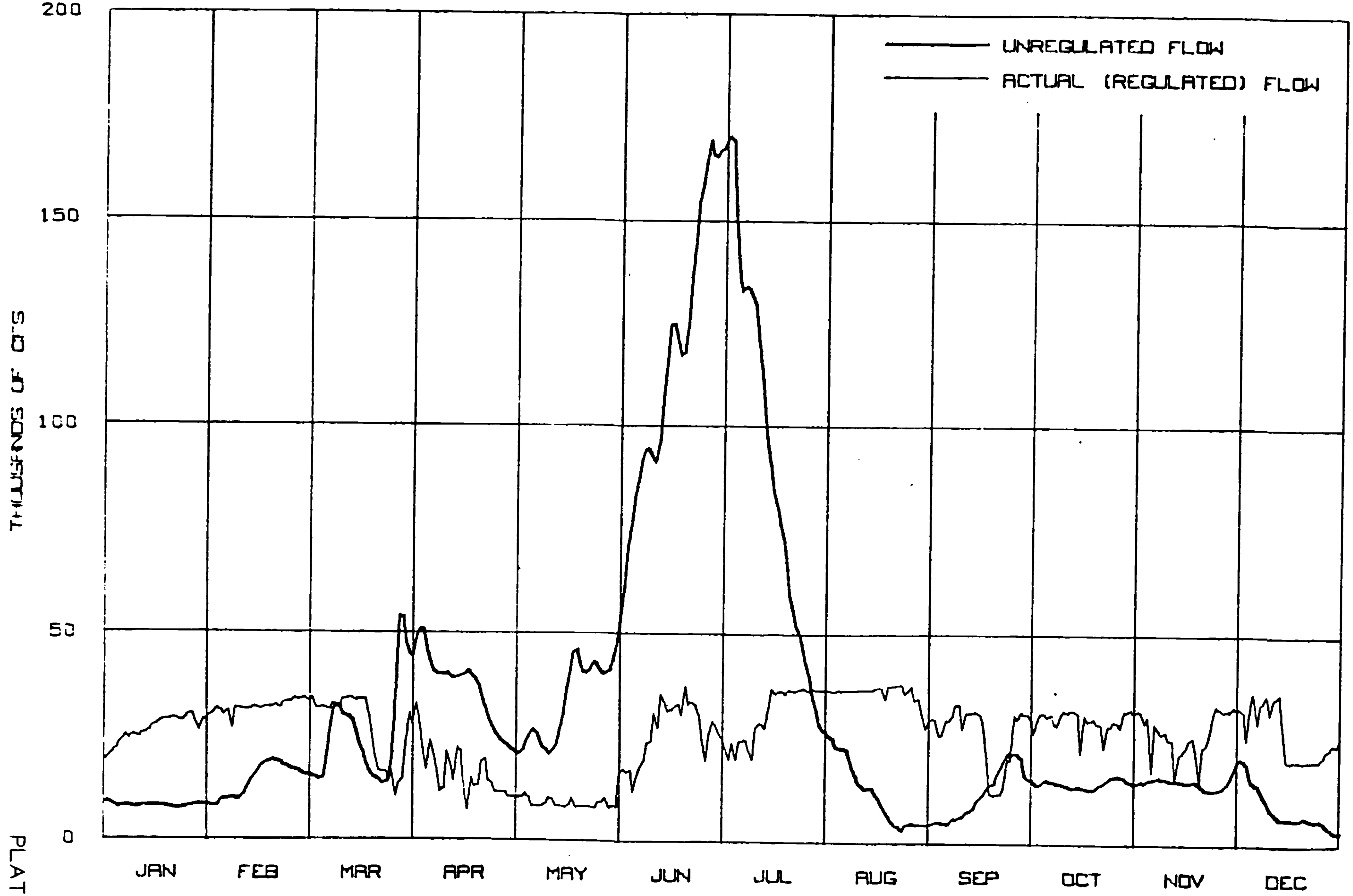


1961
ACTUAL AND UNREGULATED FLOWS
MISSOURI RIVER AT GARRISON DAM

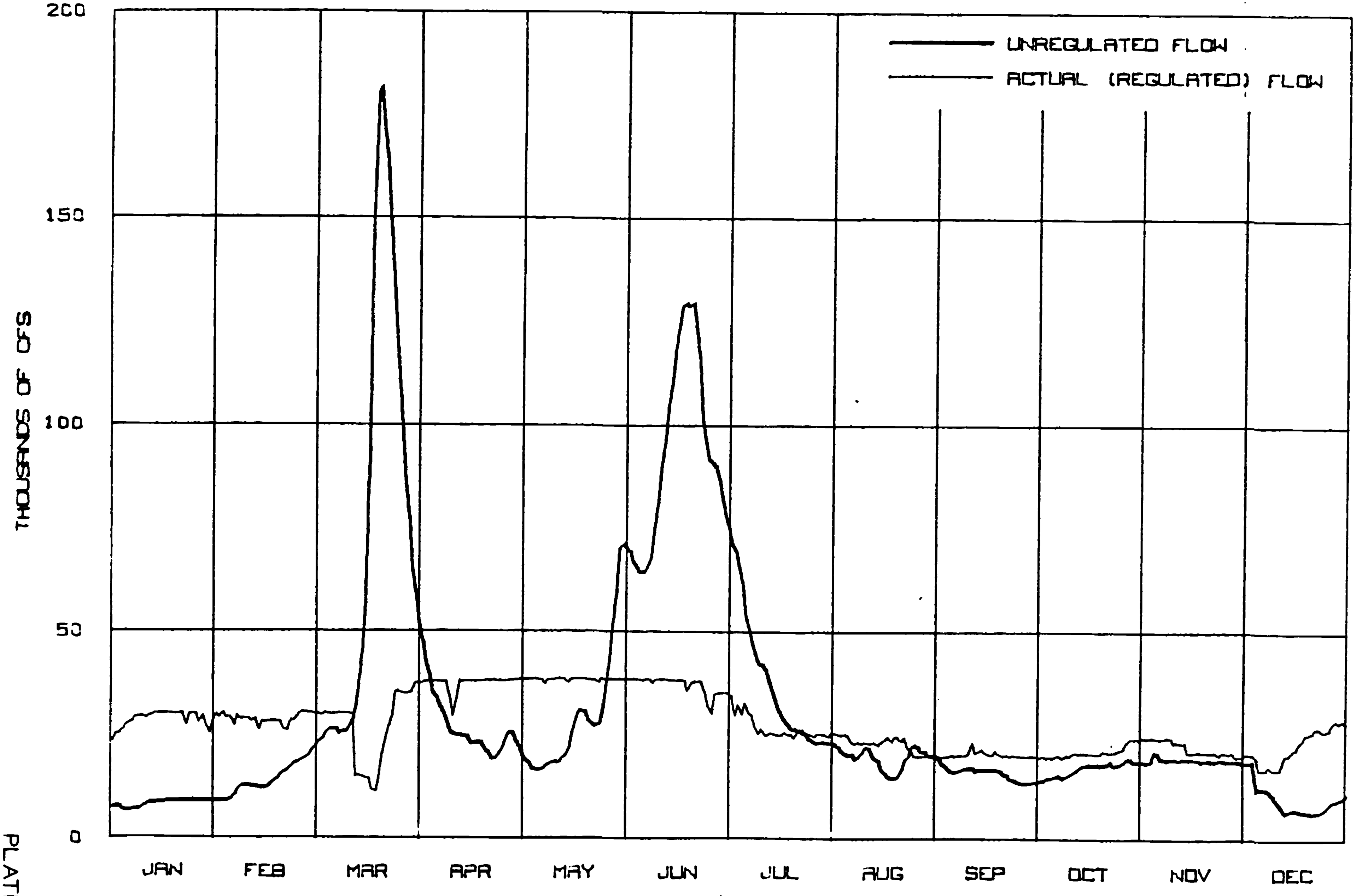
PLATE 27



1964
ACTUAL AND UNREGULATED FLOWS
MISSOURI RIVER AT GARRISON DAM

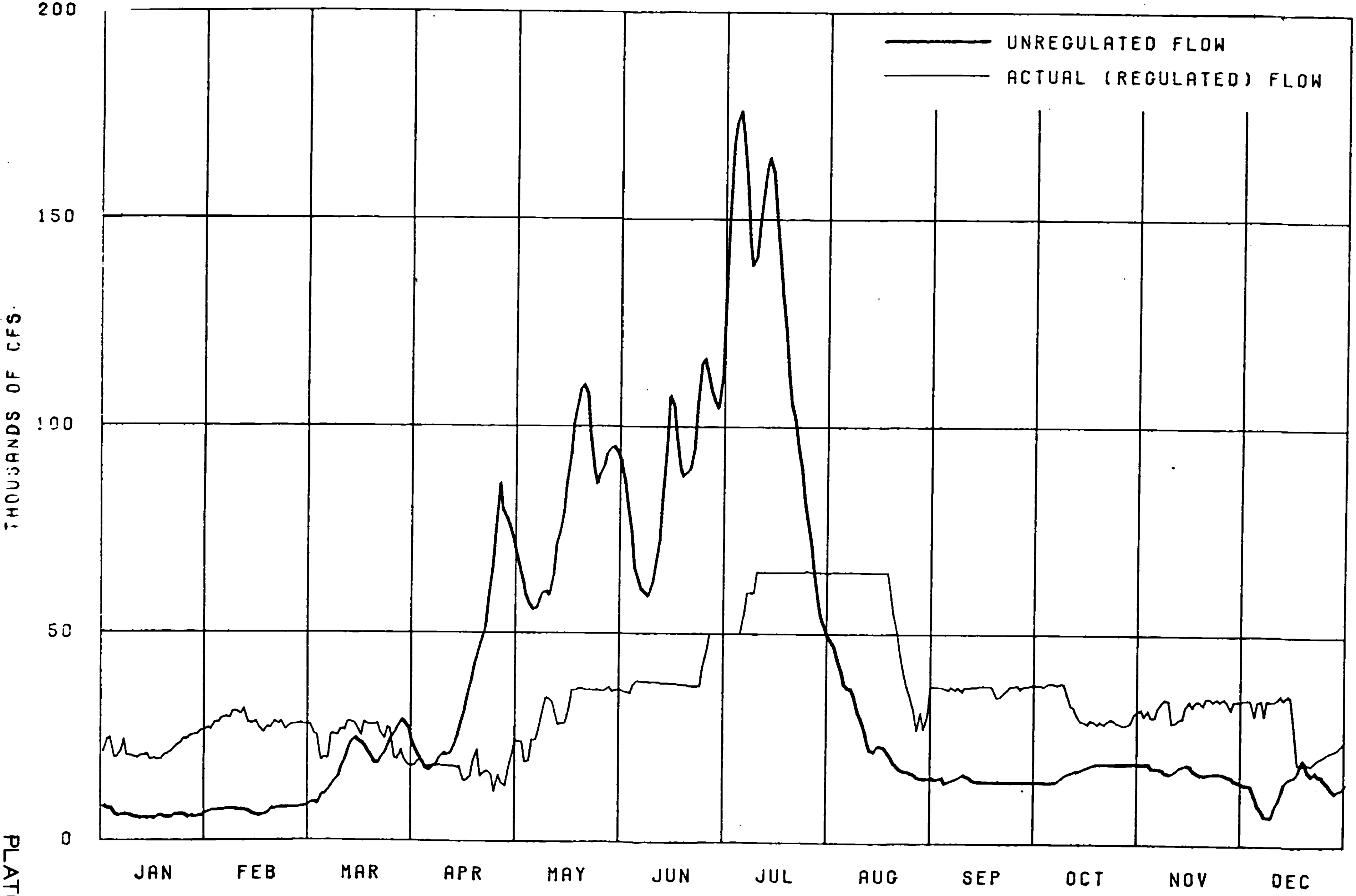


1967
ACTUAL AND UNREGULATED FLOWS
MISSOURI RIVER AT GARRISON DAM



1972
ACTUAL AND UNREGULATED FLOWS
MISSOURI RIVER AT GARRISON DAM

PLATE 30

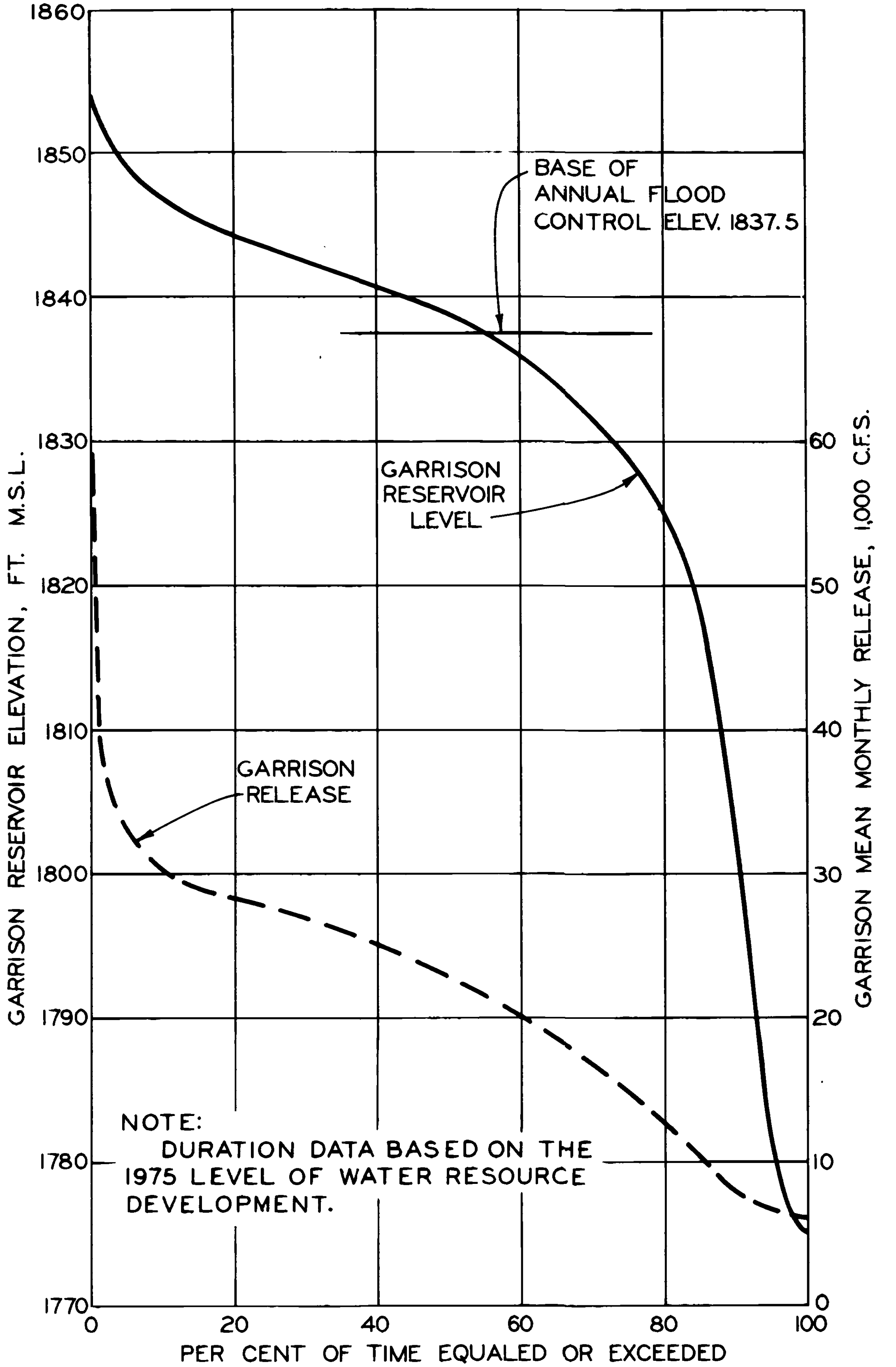


1975

ACTUAL AND UNREGULATED FLOWS

MISSOURI RIVER AT GARRISON DAM

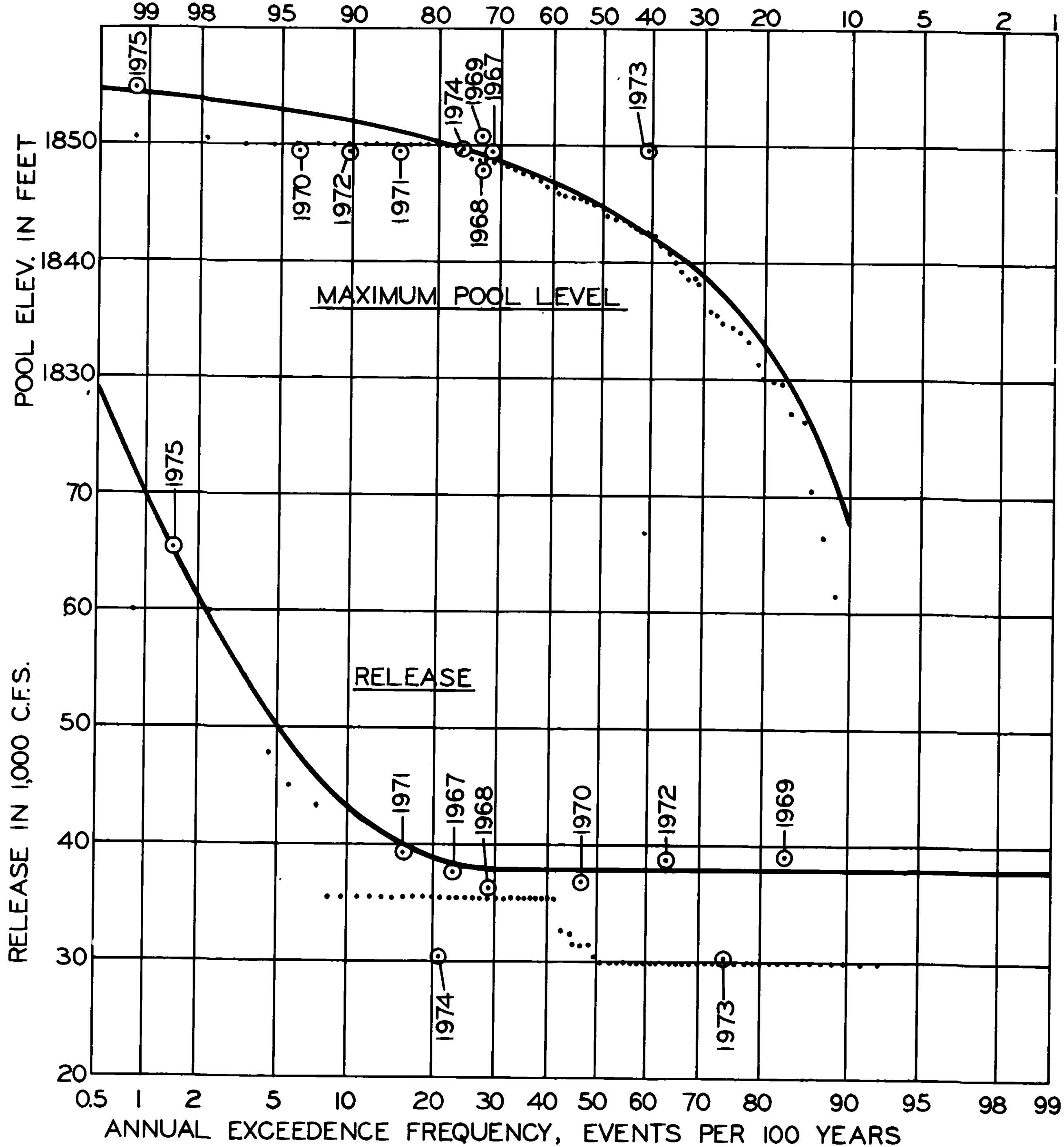
PLATE 31



DURATION CURVES FOR
POOL LEVELS AND RELEASES
GARRISON PROJECT

PLATE 32

ANNUAL EXCEEDENCE FREQUENCY CURVES
FOR
MAXIMUM POOL LEVELS AND RELEASES
GARRISON PROJECT

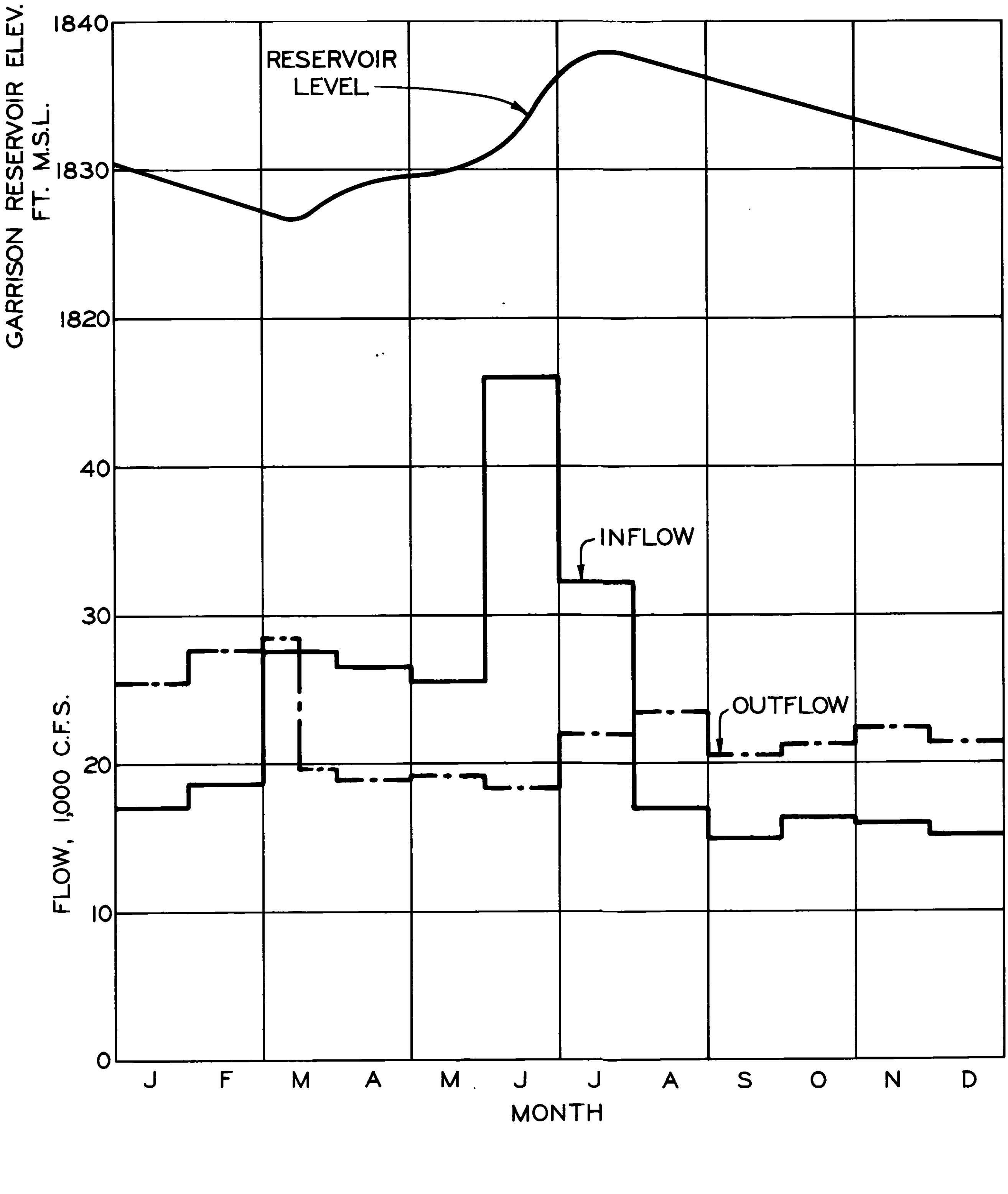


NOTES:

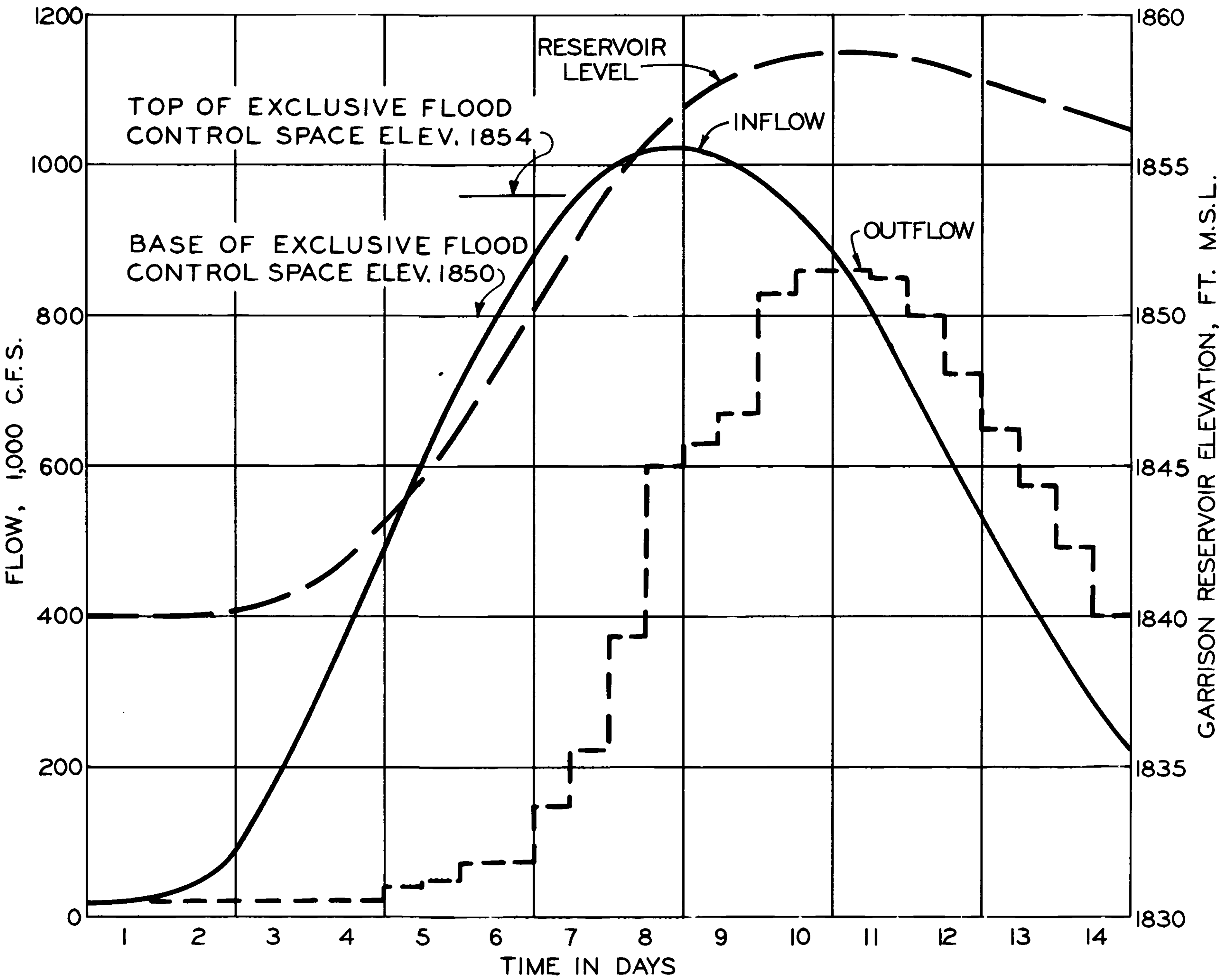
1. Small points are based on Computer Study 2-76-1975, using mean monthly release and end-of month elevations.

2. Large circles are based on actual daily data for listed year.

NOTE: Based on 1975 Level of Water Resource Development and Record Period Extending From 1898 Through 1975.

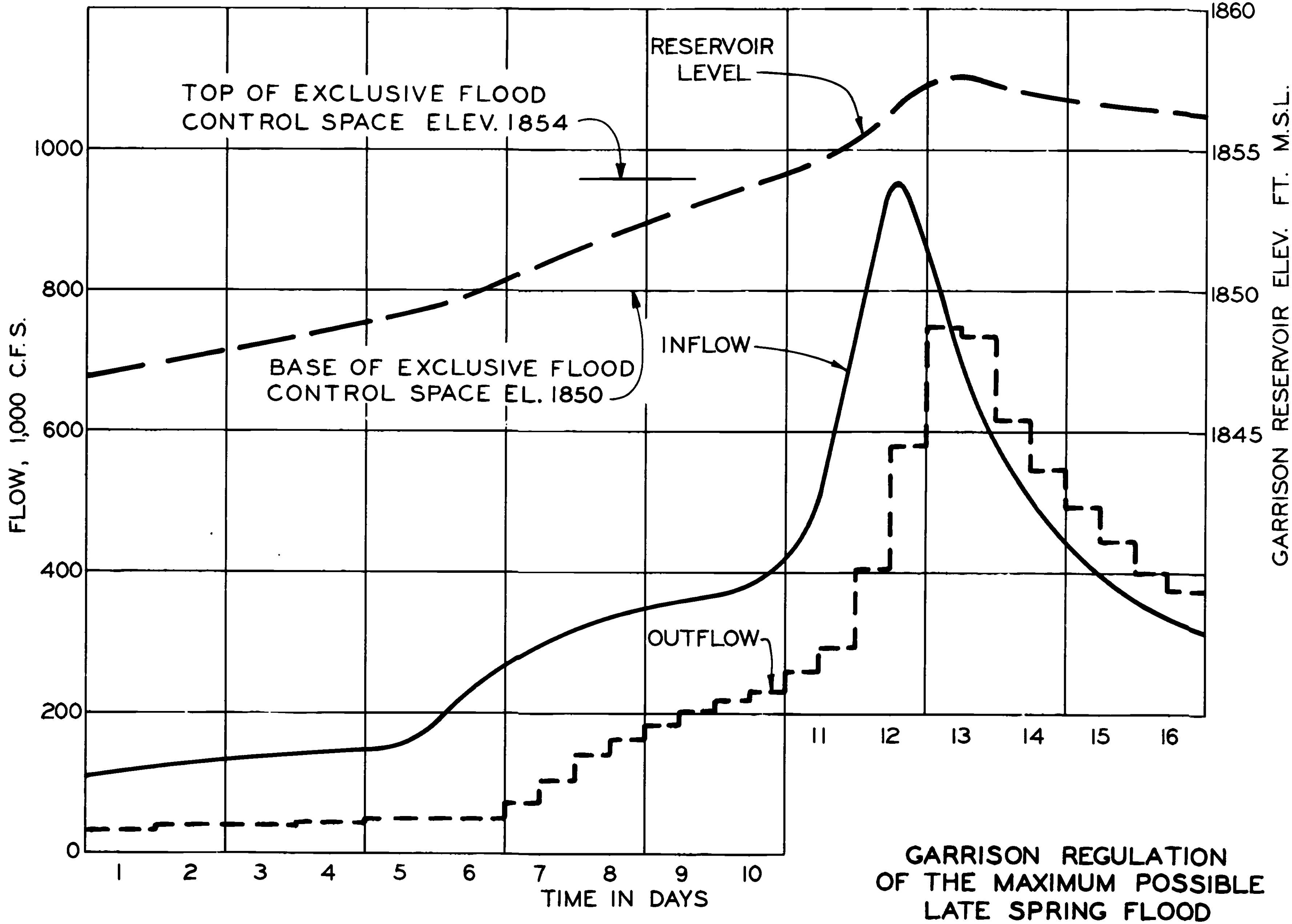


MONTHLY AVERAGE INFLOWS, OUTFLOWS AND RESERVOIR LEVELS GARRISON PROJECT



GARRISON REGULATION
OF THE MAXIMUM POSSIBLE
EARLY SPRING FLOOD

PLATE 35



GARRISON REGULATION
OF THE MAXIMUM POSSIBLE
LATE SPRING FLOOD

PLATE 36